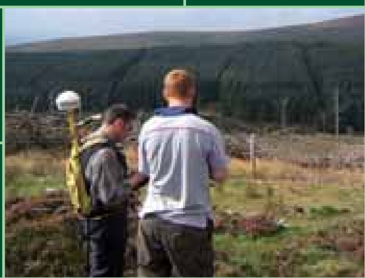
National Forest Inventory

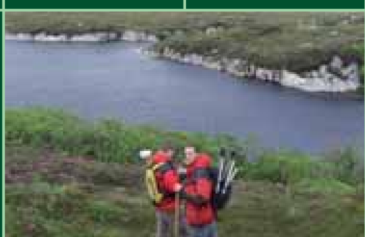
Republic of Ireland

Forest Service

THE DEPARTMENT OF
AGRICULTURE, FISHERIES & FOOD
AN ROINN TALMHAÍOCHTA, IASCAIGH AGUS BIA

Methodology





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National Forest Inventory

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Methodology

Covering the National Forest Inventory, 2004 to 2006.

The Forest Service of the Department of Agriculture, Fisheries and Food is Ireland's national forest authority. It is responsible for the forestry sector, the administration of forestry grant schemes, forest protection, the control of felling and the promotion and support of forest research. The Forest Service promotes Sustainable Forest Management as a central principle of Irish forest policy, whereby forests are managed to provide economic, social and environmental benefits on a sustainable basis for both current and future generations.

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Introduction

1.1 Background

At the end of the 19th century, the area of forest cover in Ireland was estimated to be approximately 69,000 hectares (ha), or circa 1% of the national land area. During the first 75 years of the 20th century, forestry in Ireland was almost exclusively the responsibility of the State, and by 1985 forest cover had increased to approximately 420,000 ha. The mid 1980s saw a significant increase in private forest development, with the introduction of EU-funded grant schemes aimed at encouraging private land owners, mainly farmers, to become involved in forestry. As a result, the area of the national forest estate in Ireland has now increased to approximately 700,000 ha. Of these, approximately 57% are in public ownership and 43% in private ownership.

Despite this increase in the amount of forest cover in Ireland, the State did not have inventory information for the entire national forest estate. Coillte Teoranta (The Irish Forestry Board) own 56% of the forest estate and maintain a detailed inventory of its forests, while private estate managers also maintain inventories. However, a comprehensive and standardised inventory of the entire private forest estate has not been available. This lack of information on the composition of our forests, in relation to species, timber volumes, increment and biodiversity, has been an impediment to the sustainable management and utilisation of the national forest resource.

1.2 Information needs

The goal of the National Forest Inventory (NFI) of Ireland is to assess the current composition of Ireland's forest resource in a representative and reproducible manner. The undertaking of a NFI arose from a strategic action in the 1996 'Growing for the future' (Anon, 1996) policy document for the development of the forest industry in Ireland. Data from the NFI will be used to estimate carbon stocks through the calculation of forest biomass figures in Irish forests and greenhouse gas emissions associated with land-use change. The NFI was also initiated in response to demands for multi-resource information about Ireland's forests from international and national bodies such as the Food and Agricultural Organisation/Economic Commission for Europe (FAO/ECE) and Council of Forest Research and Development (COFORD). Appendix 1 outlines a selection of these information needs.

1.3 Objectives

The purpose of the NFI was to record and assess the current extent, state and composition of Ireland's forest resource, both public and private, in a timely, accurate and reproducible manner. The NFI is the first, purely statistical approach to forest inventory undertaken in Ireland to provide an assessment of growing stock volume in both the public and private national forest estates. The NFI will also provide information to monitor Sustainable Forest Management (SFM) (Anon., 1998a) and data to support forest policy, specifically in relation to:

- Volume, including deadwood;
- Biomass/carbon;
- Forest area;
- Species composition and forest structure;
- Forest biodiversity;
- Forest health and vitality.

1.4 NFI Overview

In 2007 the Forest Service of the Department of Agriculture, Fisheries and Food completed the first statistical NFI in Ireland. This inventory involved a detailed field survey of Ireland's forests. Ireland's NFI is based on a randomised systematic grid sample design. As a result of a pilot study in Co. Wexford, a grid density of 2 km x 2 km (Figure 1) was estimated to provide the frequency of plots needed to achieve a national estimate of volume with a precision of ±5%, at the 95% confidence level. This grid density equated to 17,423 points nationally, each representing approximately 400 ha.

Each circular NFI permanent sample plot measures 25.24 metres (m) in diameter and comprises 500 m^2. Within each plot a variety of primary attributes were assessed, from the tree top to the soil underneath. For example, information is being collected on: tree growth and development, the diversity of plant species and soil type.

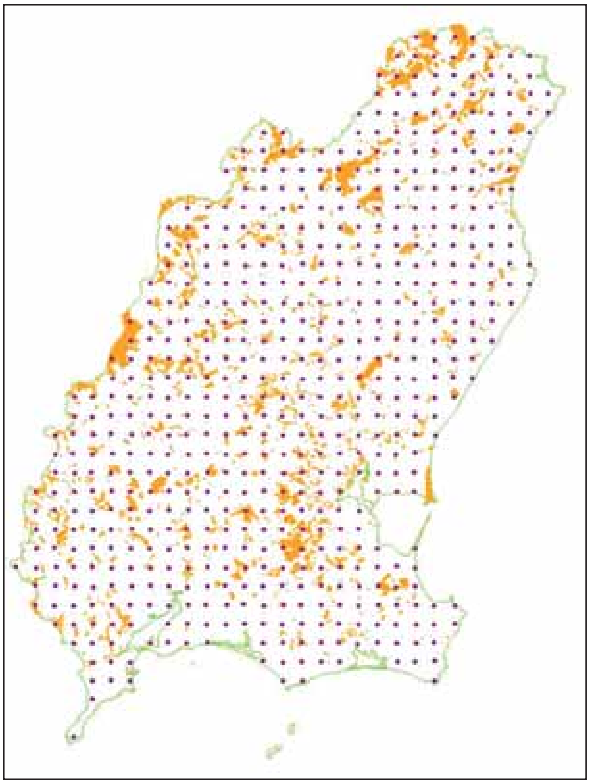


Figure 1. Primary sample grid for Co. Wexford.
© Ordnance Survey Ireland, 2007[1].

The underlying technology used in the NFI consisted of an integrated system of hardware and software developed by the Institute of Forest Ecosystem Research Ltd. (IFER), Czech Republic. It allowed for the preparation of a NFI database, background maps, and plot generation. This in turn allowed for the creation of projects for field teams, which facilitated the field data collection process.

To carry out the data collection work, the Forest Service recruited professional foresters, with six foresters working in the field at any one time. Due to staff turnover, twelve field staff were employed during the course of the project. The field data collection began in November 2004 and was completed in November 2006. In total, 1,742 NFI plots have been established throughout the country, with the number of plots in each county relative to the size of the county and the level of forest cover. Training, field team support, validation and other quality control procedures were undertaken by two staff to ensure data quality and the smooth running of field operations.

Following the completion of field data collection work, primary data pre-processing and data analysis were completed. During data pre-processing the validity of the data was checked and data values were amended where necessary. Secondary variables, such as volume, were also calculated. Data analysis involved the production of statistics which describe components of the national forest estate, e.g. volume of standing deadwood per hectare. Data analysis and results generation were undertaken by the Forest Service, in close collaboration with the IFER, and completed in June 2007.

[1] Inlcudes Ordnance Survey Ireland (OSi) data reproduced under OSi Licence number 6155. Unauthorised reproduction infringes OSi and Government of Ireland copyright.

1.5 Layout of Methodology

The primary purpose of this methodology publication is to give the background to the NFI, outline the plot location and field data collection procedures and describe the data analysis techniques used. The range of attributes that were included in the inventory are described in detail, as well as data collection methodologies for these attributes. An appreciation of the contents of this manual will aid in the interpretation of the results and in understanding how the NFI differs from conventional, stand level inventories.

This publication is divided into four sections. Section A, chapters 2-4, describe the sample point selection and the fieldwork preparation processes. The navigation to and establishment of the plot centre is explained in Section B, chapter 5. Field data attributes and collection techniques are detailed in Section C, chapters 6-12. In section D, a summary of the field-work validation and data analysis procedures are presented in chapter 13 and 14.

Section A

Selecting and Locating the Sample Points

CHAPTER 2
OVERVIEW OF NFI LAND-USE CLASSIFICATION

There are three stages of land-use classification undertaken in the NFI. These stages are land-use type, land-use category and land-use class (Figure 2). They form the basis of the NFI, as the classification process dictates whether the sample points are included in the NFI or not, and the range of attributes to be collected at the individual sample points.

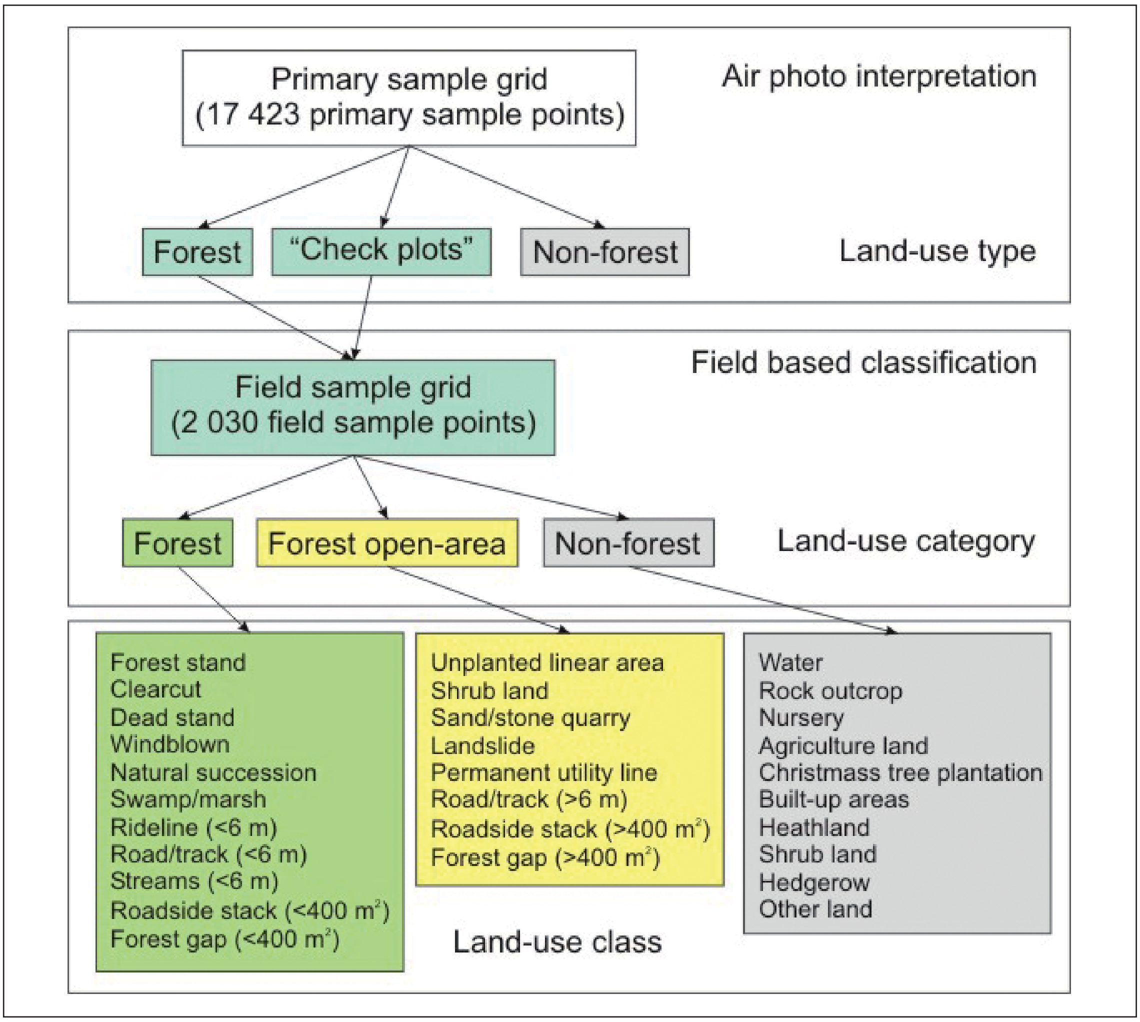


Figure 2. Overview of the NFI land-use classification.

The initial stage classifies the 2 km x 2 km grid (17,423 sample points) into Forest and Non-Forest **land-use types** using air photo interpretation. This desk based exercise is detailed fully in Chapter 3.

In the second stage, the first attribute to be assessed after locating the plot centre is **land-use category**, which includes; Forest, Forest Open Area and Non-Forest (Chapter 5). Plots classified as Forest and Forest Open Area were established as permanent sample points and became the focus of the NFI.

The final stage of classification involved the assignment of a **land-use class**, which gave a more detailed description of the sample point (Chapter 5). This information was also used to update the air photo interpretation results.

Chapter 3
Selection of Sample Points

A 2 km x 2 km grid was overlaid on the total land base of the Republic of Ireland, to facilitate land-use type (LUT) interpretation using colour air photos. The primary focus of the interpretation is to identify forest land. In tandem with this, other land-use types are identified for reporting purposes.

Each plot was randomly located within a radius of 100 m from the grid intersection, by adding randomly generated numbers (-100 to +100) to the six digit Irish national grid co-ordinates (Figure 3). As the grid is permanent, it allows for the re-assessment of primary sample points at future dates, to monitor forest land-use change (i.e. afforestation and deforestation). The location of primary sample plots is given by x and y grid co-ordinates, available as six digit Irish national grid co-ordinates.

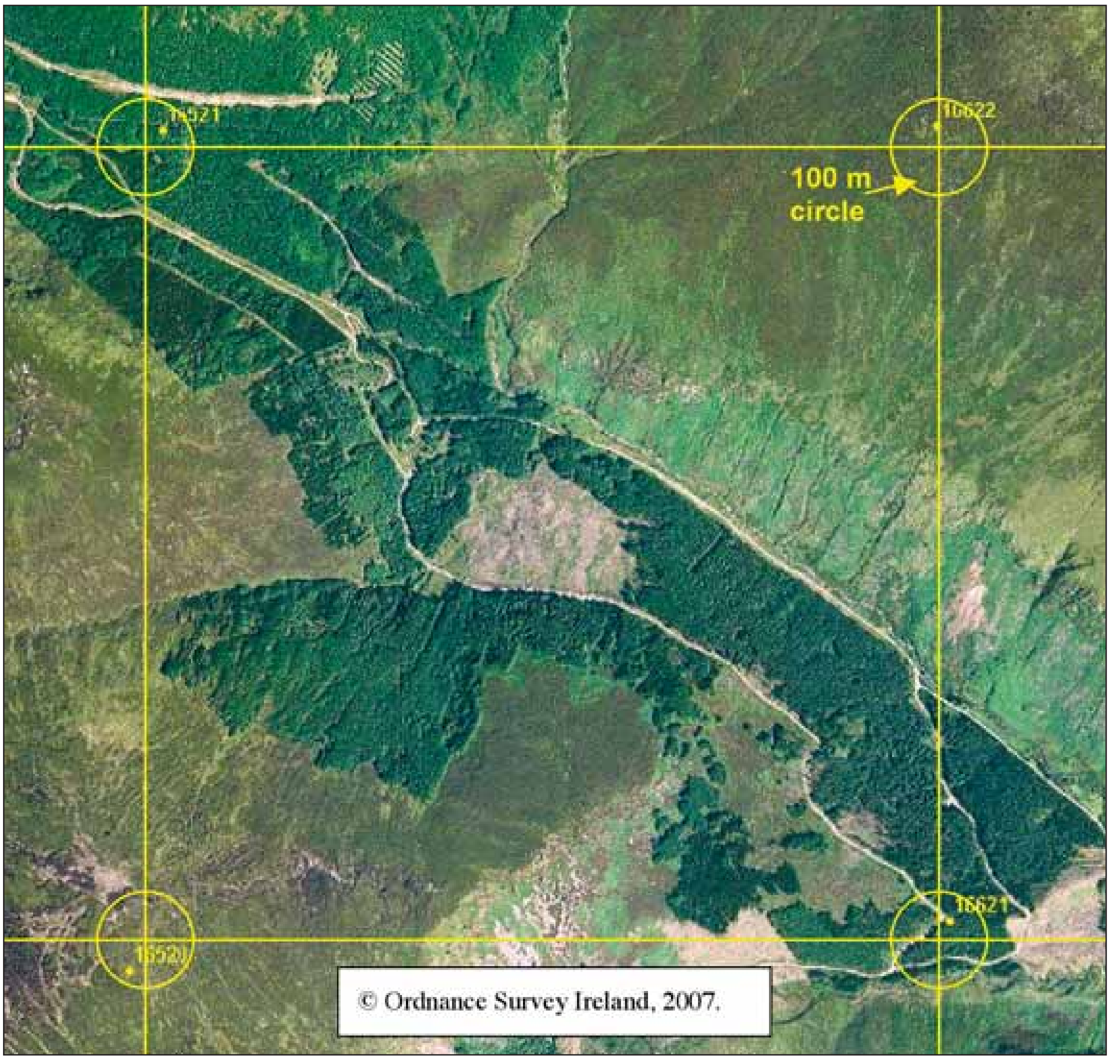


Figure 3. Schematic representation of the location of sample plots based on the randomised systematic grid design.

3.1 Data Sources

In this section the datasets used in the air photo interpretation exercise are outlined.

3.1.1 Primary dataset

The primary dataset used in the NFI was air photography obtained from OSi. Technical information on the air photos used is available in Table 1. The first photo interpretation exercise was carried out in early 2005 using air photos made during 2000. This was reviewed in late 2006 using air photos made during 2004. Complete coverage was available for the 2000 air photos and 35% coverage for the 2004 air photos.

Table 1. Details of the air photos used in the NFI.

Details	Description
Scale	1:40,000
Data format	Tiff
Pixel size	1 m x 1 m
Year of flight	2000 + 2004
Specifications	2 km x 1.5 km
Number of photos	26,500 approximately
Individual file size	8 MB approximately

3.1.2 Secondary datasets

In order to capture forests that may not be apparent on the air photographs, e.g. recently planted forests (planted 2000-2006), three forest datasets were used to aid in the identification of Forest and Non-Forest areas. These forest maps were draped over the sample points in 'wire-frame' format and used as an indicative guide as to where forests were located. These secondary datasets are listed as follows:

- A map containing all **Forest Service** grant and premium aided plantations, 1990-2006.
- Forest maps from the **Forest Inventory and Planning System (FIPS)** survey, identifying the distribution of the national forest estate in Ireland in 1998.
- **Coillte Teoranta** provided its comprehensive forest inventory dataset for all the forest land they manage. This database provides crop information such as age and species.

3.2 Land-Use Types

The LUTs used in the air photo interpretation exercise are shown in Table 2, while the definitions of the LUTs are presented in Section 5.2.1. Land-use types have been based on land cover maps developed by Teagasc (Irish Agriculture and Food Development Authority) (Fealy *et al.*, 2006). The LUTs also have sufficient scope to enable re-classification into broader land-use categories, such as those which are consistent with IPCC guidelines and with the requirements of LULUCF, as specified under article 3.4 of the Kyoto protocol (IPCC, 2001).

Table 2. Land-use types used in the NFI.

Land-use type	Land-use type
Forest	Green space (urban)
Bareland within forest ownership boundary	Green space (rural)
Check plots	Coastal complex
Other woodland	Cropland
Individual tree	Grassland/forage/pasture
Hedgerow	Water bodies
Stonewall	Sea
Bare rock	Quarry
Bare soil	Paved road
Bog and heath	Sand
Cutover peat (industrial)	Shrub
Cutover peat (domestic)	Deforestation
Built land (urban)	Other
Built land (rural)	

3.2.1 Definitions of land-use types used in the NFI

1. Forest

Land with a minimum area of 0.1 hectare, a minimum width of 20 m, trees higher than 5 m and a canopy cover of more than 20% within the forest boundary, or trees able to reach these thresholds *in situ*.

Explanatory notes

1. A tree is a woody perennial of a species forming a single main stem or several stems, and having a definitive crown.
2. It includes windbreaks, shelterbelts and corridors of trees with an area of more than 0.1 ha and minimum width of 20 m.
3. Forest is determined both by the presence of trees/stumps and the absence of other predominant land-uses. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 20% and a minimum tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to be restocked.
4. The forest area is determined by the forest boundary. The term forest boundary is defined by any man-made boundary enclosing the forest area or, in the absence of such boundary feature, the boundary of the forest is determined by extending out 1 m from the position of the pith-line[2] of the outermost trees.
5. The forest area includes forest roads, firebreaks and other small open areas on forest land; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest.
6. The forest area excludes tree stands in agricultural production systems, for example in fruit plantations and Christmas tree plantations.
7. The term also includes trees in urban parks and gardens, provided these areas satisfy the forest definition.

[2] Pith-line is a notional line connecting the ground-level tree piths/centres of the outermost trees. Where the trees have been planted this is commonly referred to as the planting line.

2. Bareland within forest ownership boundaries

Bare-areas within the forest ownership boundary which are **not** integral to the forest. These areas have to be greater than 2 ha if they are surrounded by trees on all sides, otherwise they are classified as a Forest, if they are integral to the forest. Again all available digital information is consulted in the decision-making process, to assess the possibility of recently planted or stunted trees being present but not visible in the air photos.

3. Check plots

These are areas, which are difficult to interpret as Forest or Non-Forest. They are visited on the ground by survey teams for land-use allocation. An example of this would be an area of *Ulex spp.* or *rhododendron ponticum*, which could be mistaken for forest in the air photo interpretation exercise.

4. Other woodland

These are groups of trees that do not meet the criteria specified in the forest definition. This category covers areas of trees less than 0.1 ha, or less than 20 m in width, and/or with a canopy cover of less than 20%.

5. Individual tree

An individual tree with a crown that has no contact with any other tree e.g. a tree in parkland.

6. Hedgerow

Linear features (<20 m wide) that have tree and/or shrub species present.

7. Stonewall

Linear features without tree or shrub species present.

8. Bare rock

Exposed rock with little or no vegetation present. This can occur at low or high elevations and include scree slopes, mountain-tops, karst landscapes or rocky outcrops.

9. Bare soil

Land where soil is exposed or land that has had the surface vegetation removed. It does not describe land-used for agricultural crop production or forest fire breaks.

10. Bog and heath

This is land dominated by bog and heath vegetation (*Calluna, Erica, Molinia, Eriophorum* spp.). These areas occur in upland and lowland areas throughout Ireland. This class occurs mostly on unenclosed land.

11. Cutover peat (industrial)

Land where the original peat bog has been cutover for industrial peat use. These are generally large areas situated in the midlands and west of Ireland. They are easily distinguished by the systematic harvesting bays, which are separated by large drains.

12. Cutover peat (domestic)

Land where the original peat bog has been cutover for domestic peat use. These are generally small areas situated in the midlands and west of Ireland. They are characterised by the turf cutting 'plot' divisions of the bog.

13. Built land (urban)

Land occupied by buildings, within towns and cities.

14. Built land (rural)

Land occupied by houses, farm buildings and other buildings in rural areas.

15. Green space (urban)

Green spaces located in urban areas such as parks, gardens and sports fields.

16. Green space (rural)

Green spaces located in rural areas such as parks, gardens and sports fields.

17. Coastal complex

Occurs in coastal areas and is usually a mixture of grass, shrub and rock.

18. Beach

A strip of land adjacent to the coast containing sand.

19. Cropland

Land currently under agricultural crops or temporarily unplanted land, excluding grassland.

20. Grassland/forage/pasture

Land predominantly under grass species, excluding bog and heath.

21. Water bodies

Any inland river, stream, canal, lake, pond or resevoir.

22. Sea

Coastal water.

23. Quarry

Man made sand, gravel or stone quarries.

24. Road

Any public paved road.

25. Shrub

It refers to vegetation types where the dominant woody elements are shrubs i.e. woody perennial plants, reaching a height of more than 0.5 m and less than 5 m in height at maturity and without a definite stem and crown.

26. Deforestation

The conversion of forest to another land-use, implying the longterm or permanent loss of forest cover.

27. Other

Land not described by any other category.

3.2.2 Land-use type interpretation procedure

Classification of land-use type was carried out, using a GIS, by five foresters who had considerable field experience in collecting NFI data, including the use of air photos during the navigation to plots.

In order to classify the sample points, it is necessary to view the air photos, using a GIS, at a scale of at least 1:15,000. In some cases it is necessary to zoom, to a scale of 1:5,000, into each individual sample point, in order to clearly identify the LUT. The provision of additional vector detail in the GIS, also aids the identification process (Figure 4)

Interpretation was based on the criteria established in the forest definition. If it was unclear whether a sample point should be classified as Forest or another land-use type, the sample point was classified as a check plot. Sample points classified as either forest or check plot became the focus of the ground survey.

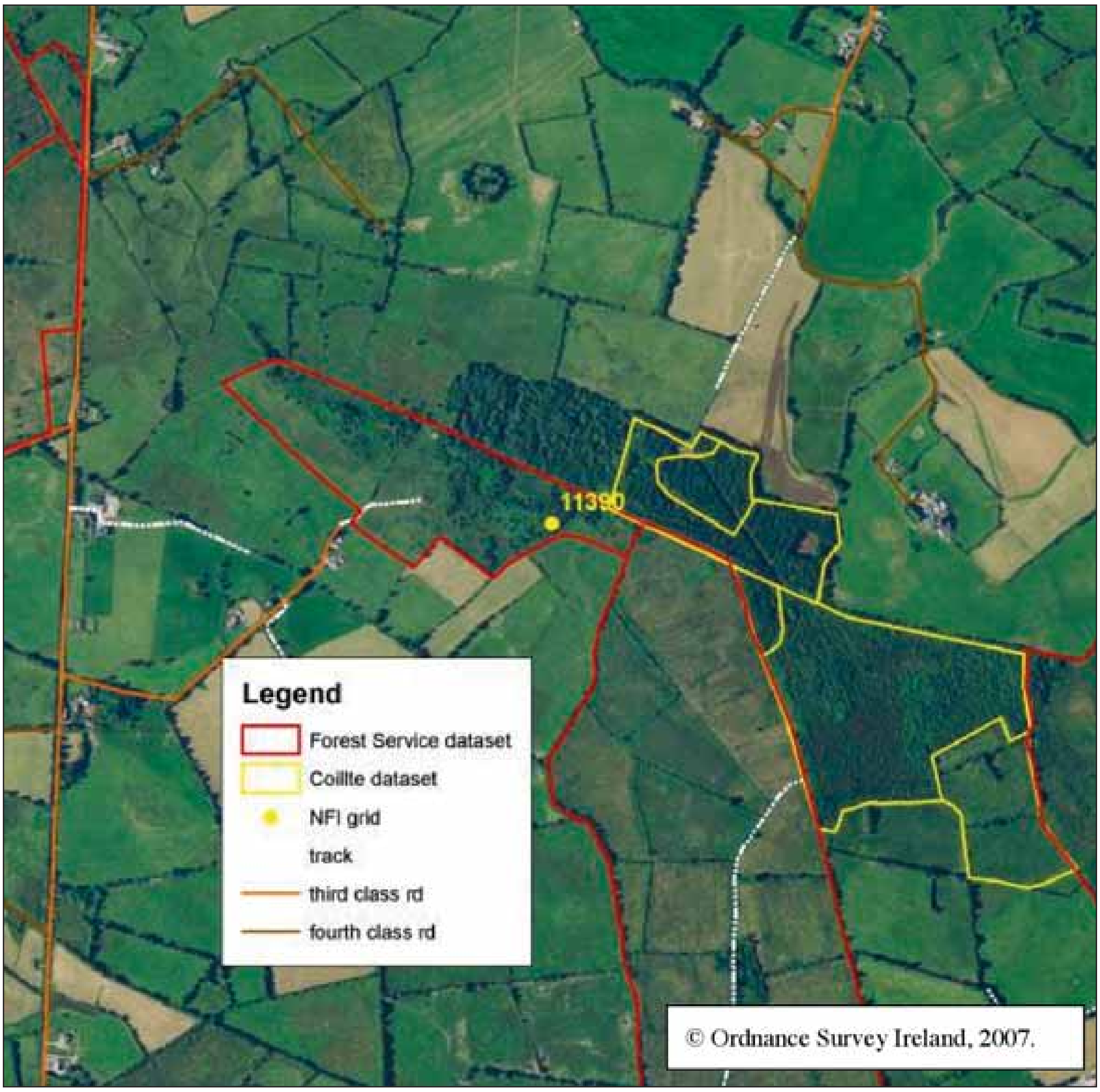


Figure 4. Air photo interpretation datasets.

Chapter 4
Preparation for Ground Survey

Plots classified as 'Forest' or 'Check' in the primary sample are referred to as the 'ground survey plots'. These ground survey plots became permanent sample plots if they were classed as 'Forest' or 'Forest Open Area ' when visited in the field.

4.1 Preparation of Background Maps and Information

The preparation phase for the NFI field assessment includes the collation of background information and the preparation of maps. The preparation of background information, such as stand age and species on each of the ground survey plots aided in locating the plot and provided background details for the plot prior to a field visit such. Crop details were provided by Coillte and internal Forest Service datasets. Where possible, ownership details were used to contact private owners whose land contains ground survey plots. Private landowners were notified by letter of the impending visit of field teams to their area. In order to aid efficient navigation to plot centres and efficient work planning, field teams used the following:

1. 1:50,000 OSi Discovery Series map to aid general plot location and work planning (Figure 5).
2. Colour air photos at 1:10,000 scale also aids this process (Figure 6).
3. Digital maps, such of forest and stand boundaries and road infrastructure, are pre-loaded into the field-computer and this helps to complete the navigation to the plot centre (Figure 7).

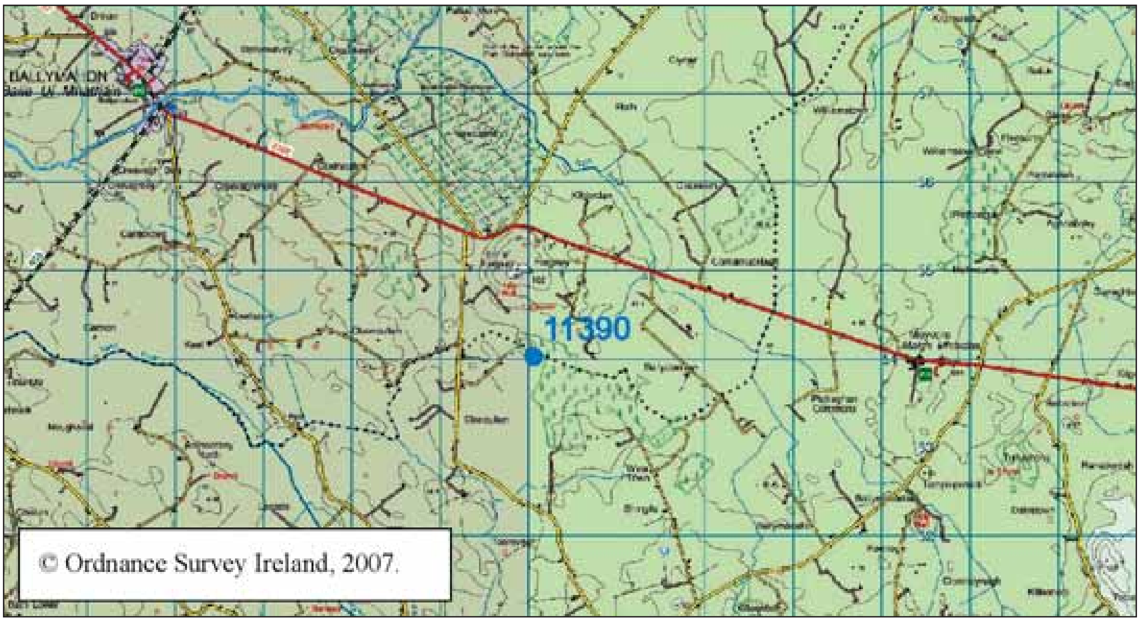


Figure 5. Example of general plot location on OSi discovery series map.

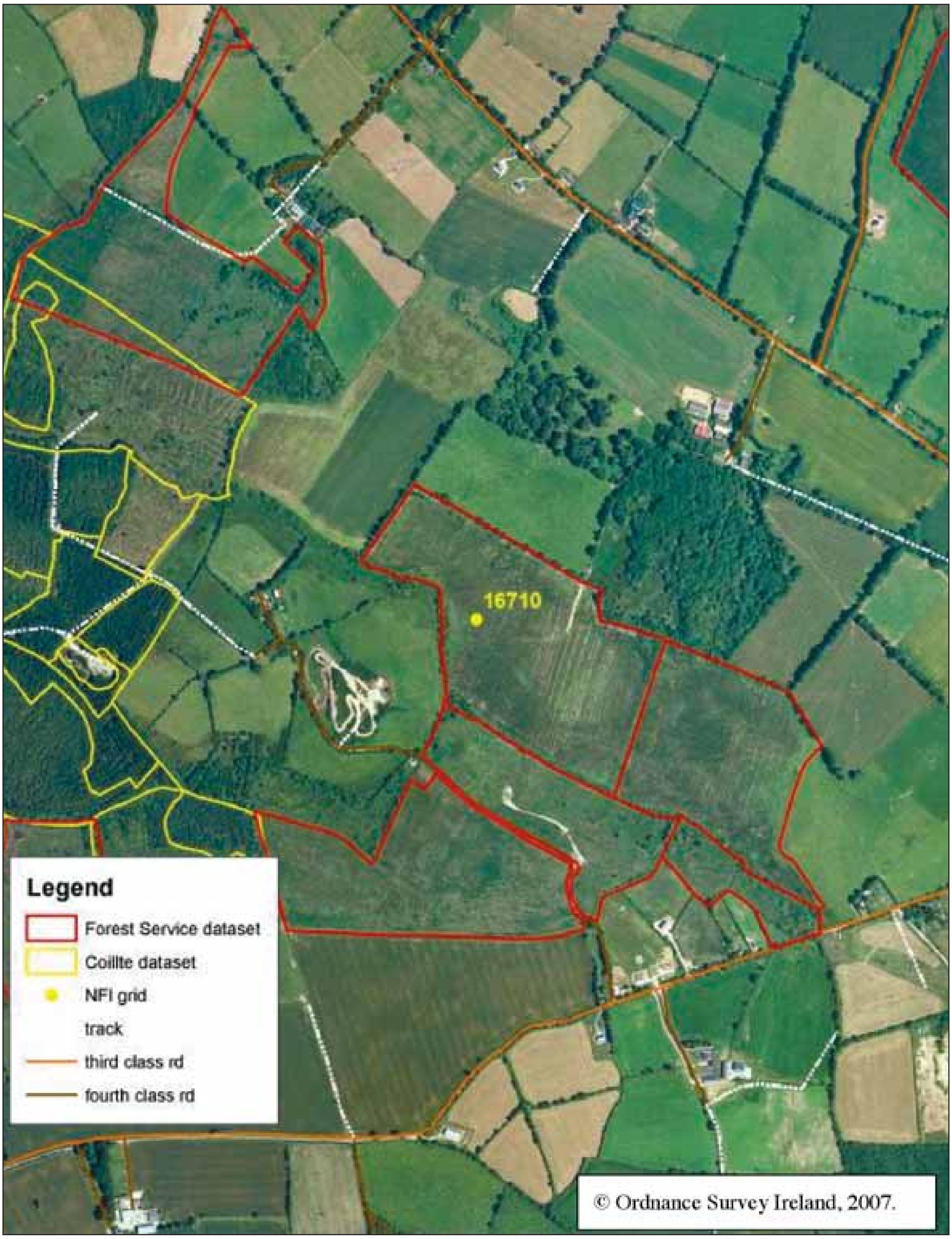


Figure 6. Example of plot location on air photo.

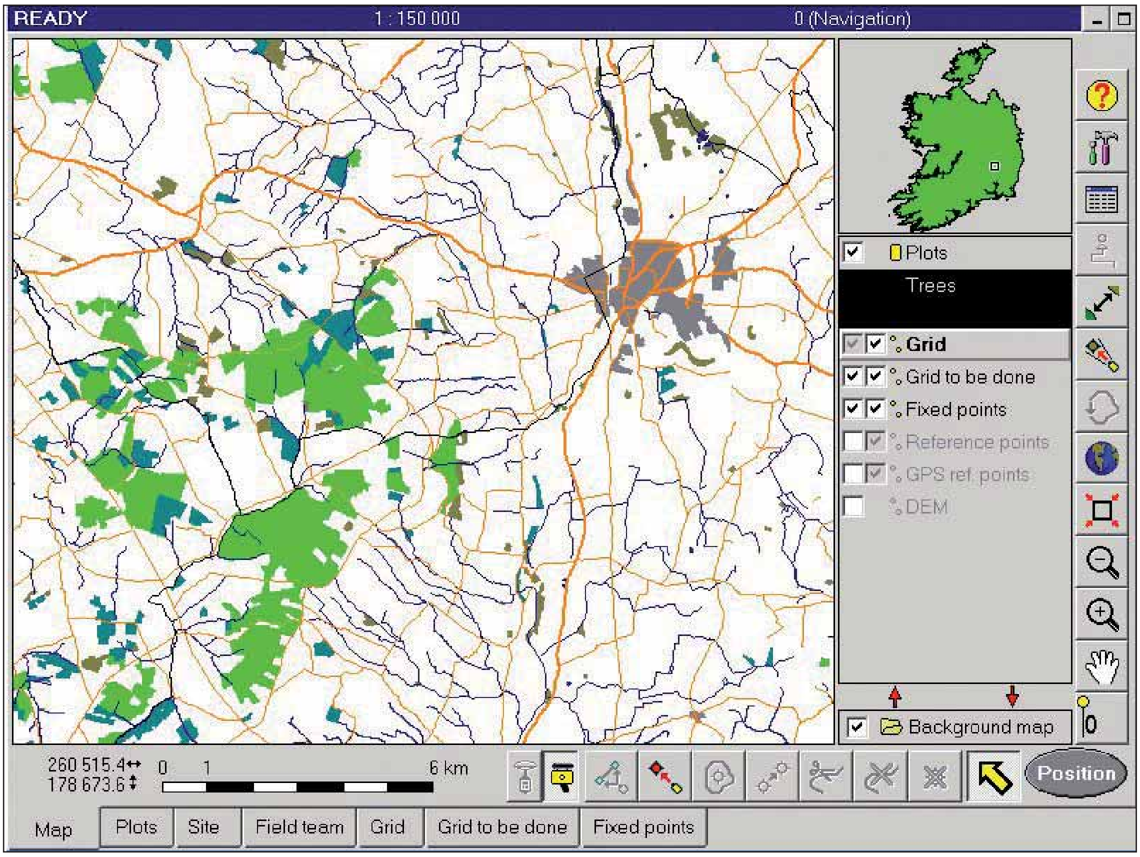


Figure 7. Example of digital map on the field computer.

Section B

Field Navigation and the Establishment of the Plot Centre

Chapter 5
Establishment of the Plot Centre

Being able to precisely locate the plot centre is essential in the assignment of a definitive land-use class.

5.1 Navigation to Ground Survey Plots

The exact location or centre of ground survey plots in the field is found by navigating to a six figure national grid co-ordinate using a combination of a GPS and compass/laser technology.

Field teams navigate as close as possible to the plot centre using a GPS and mark the position on the ground. Due to the variation in the individual GPS readings around the true position, navigation to the plot centre is completed with the compass/laser. The use of the compass/laser to complete navigation also overcomes any issues with dense canopy cover, which restricts GPS use.

The laser provides range-finding functionality (i.e. distance), while the electronic compass indicates the direction of travel (i.e. azimuth). Magnetic declination (i.e. angular offset of the magnetic north from true north) is calculated prior to navigation in the area where measurements will take place. This declination is incorporated into the electronic compass prior to locating the plot centre. An azimuth precision test is performed to ensure that no local magnetic field is affecting compass readings. Precision of plot centre location is between one and five metres, and is dependent on achieved precision of GPS position measurement and distance of navigation with the compass/laser.

The plot centre is marked with a pole and referred to as the Generated Origin (GO). High specification GPS and compass/laser equipment enables highly accurate plot location, which ultimately determines the land-use class. The plot centre becomes the permanent origin of the local Cartesian[3] coordinate system to which all the measured entities (e.g. trees) are referenced. If the plot centre does not provide an ideal location for measurement, due to obstruction of sight line(s), then an out-of-centre measurement procedure is used enabling measurement to take place from any point inside or outside of the plot, which has been referenced to the plot centre.

5.2 Land-Use Categories

Once the plot centre has been located, the point on the ground where the plot centre is located is classified into one of three land-use categories: Forest, Forest Open Area, or Non-Forest. The total forest area includes both Forest and Forest Open Area.

5.2.1 Forest

See Section 3.2.1

[3] A cartesian coordinate system is used to determine each point uniquely in a plane through two numbers, usually called the x-coordinate and the y-coordinate of the point.

5.2.2 Forest Open Area

Definition: Forest Open Area is a non-stocked area (>400 m^2 and <2 ha) enclosed within the forest boundary.

Forest Open Area is an integral component of Irish forests (Figure 8). No other land-use should predominate on the site, such as grazing or peat harvesting.

The 2 ha upper limit was adopted as open areas larger than this are deemed not to be integral to the forest. Areas greater than 2 ha and surrounded by trees are classified as Non-Forest. These large areas occur mainly in the public estate and are usually deemed unplantable owing to climatic, fertility or legal constraints.

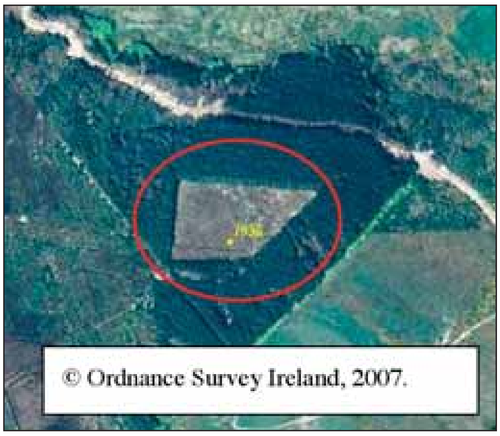


Figure 8. Forest Open Area, 1.8 ha gap.

5.2.3 Non-Forest

Definition: Areas that do not conform to the Forest or Forest Open Area definitions.

> **Note**
> **A land-use category can be assigned when there is >90% of one land-use category occurring on the plot.**
>
> **Where two land-use categories occur in a plot, a plot shift may be undertaken (Section 5.5). However before this is undertaken, the boundary between the land-use categories must be clearly identified.**

5.3 Forest Boundary

Definition: The forest area is determined by the forest boundary. The term forest boundary is defined as any man-made boundary enclosing the forest area or, in the absence of such boundary feature, the boundary of the forest is determined by extending 1 m from the position of the pith-line of the outermost tree.

Application: Being clearly able to identify the boundary between the land-use categories is essential for the correct assignment of land-use category to the ground survey plot. In section 5.3.1 examples of identifying the forest boundary are presented.

Measurement and Description:

Explanatory notes:

1. The presence of man-made boundaries delineating parcels of land is a well defined feature on the Irish landscape, i.e. hedgerow, sod-bank, stream, river, stonewall, drain, road centre and wire fence. The centres of boundary features and/or their positions relative to the pith-line of outermost trees will identify the Forest or Forest Open Area boundary.
2. In the absence of any boundary features, the edge of the Forest is determined by extending out 1 m from the position of the pith-line of the outermost trees (Figure 9).
3. All areas where the boundary feature is >5 m and <20 m from the pith-line are classified as Forest Open Area.

4. All areas where the boundary feature is <5 m from the pith-line are classified as Forest.
5. Outlier trees more than 20 m from the nearest tree in the main body of trees will not be included in the forest (Figure 10). Examples of this usually occur in natural succession land.

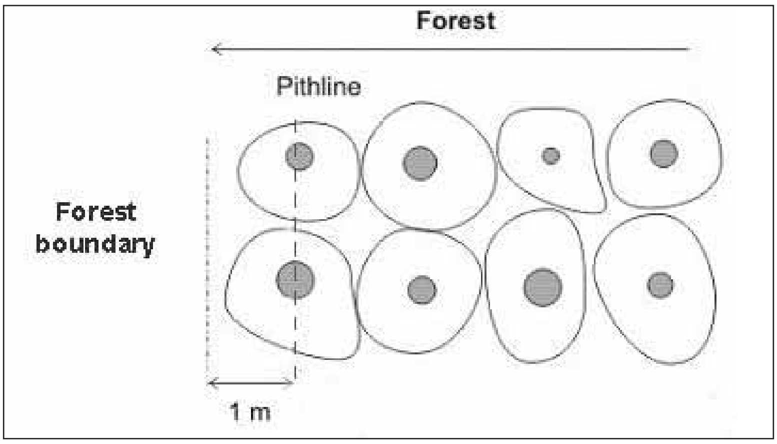


Figure 9. Establishing the Forest boundary where there is no boundary feature.

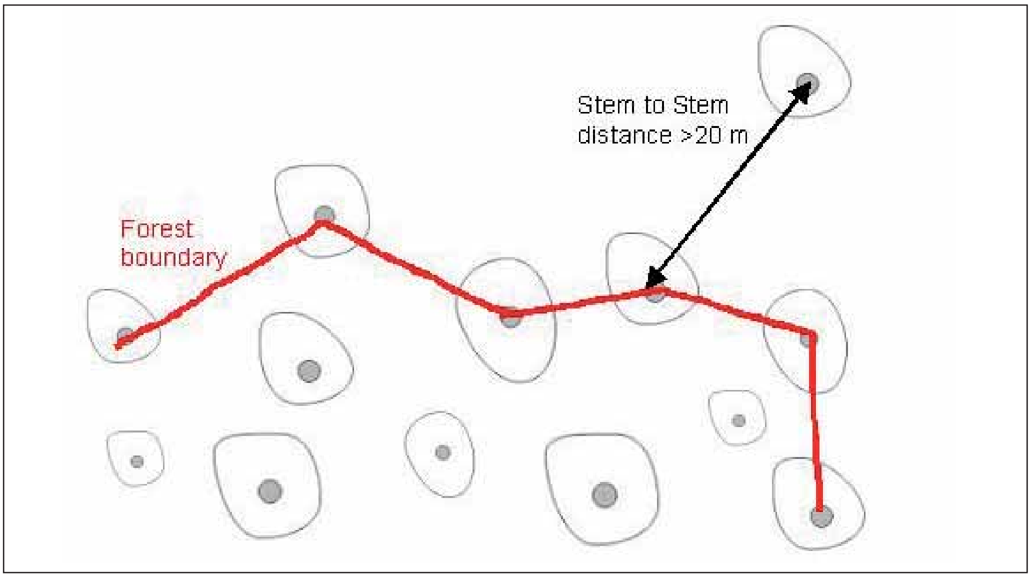


Figure 10. Identifying outlier trees.

It is important to restate that Forest is defined both by the presence of trees/stumps and by the **absence of other predominant land-uses**. For example, a canopy of trees may be considered continuous from air photo interpretation. However, a feature on the ground (such as a fence) may dictate a change to another predominant land-use. Two examples of this are illustrated in Figure 11. In the first photo, the canopy cover was continuous but the timber fence delineated the Forest boundary, excluding the trees in grassland. In the second example, the wire fence defines the Forest boundary.

Figure 11. Forest boundary examples, survey pole marks the plot centre in grassland.

5.3.1 Identifying the Forest and Forest Open Area boundary

In this subsection four examples describing the identification of the Forest and Forest Open Area boundary are presented.

Example 1

In this example the man-made boundary (hedgerow) is a more permanent feature than the fence line (Figure 12). The set-back to the hedgerow is wider than 4 m and narrower than 19 m, thereby conforming to the Forest Open Area classification. If the set-back was wider than 19 m it would be lassified as Non-Forest.

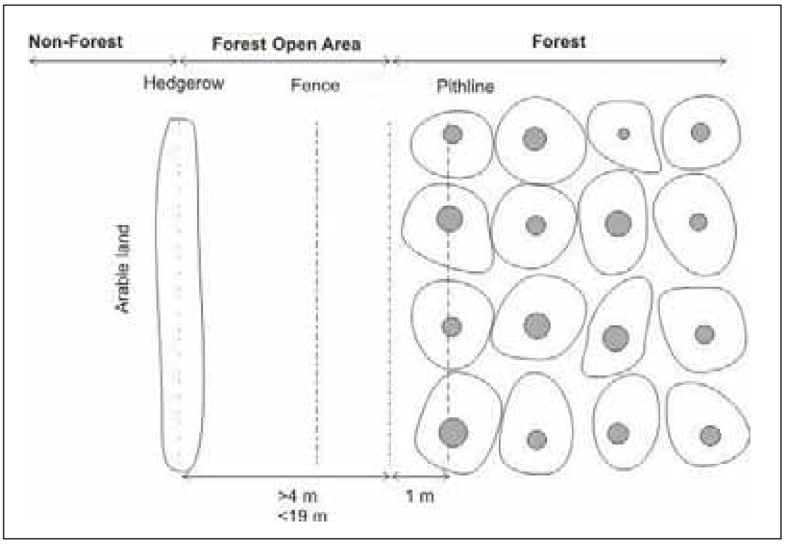


Figure 12. Identifying the land-use category boundary, example 1.

Example 2

A farmer decides to plant a wet area in a field, a fence is erected to stock proof the plantation (Figure 13). There is no definitive boundary such as a hedgerow or stonewall. The fence-line is then the boundary between Forest and Non-Forest. As in the previous example, the distance between the pith-line and fence would need to be wider than 5 m in order to constitute Forest Open Area.

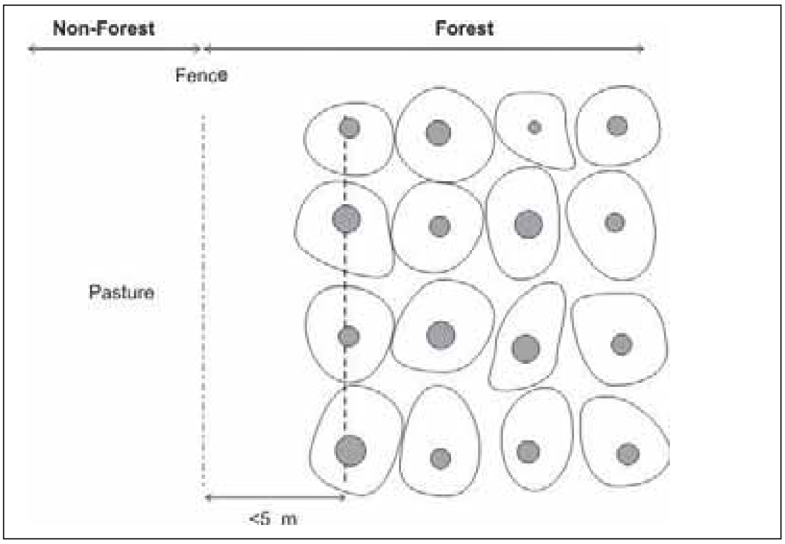


Figure 13. Identifying the land-use category boundary, example 2.

Example 3

In the absence of any stone wall, hedgerow or fence, the outer row of trees should be used to determine the boundary. This boundary occurs 1 m from the pith-line (Figure 14). Where there is a firebreak present, it will be classified as Forest Open Area. This could occur on an unenclosed heathland site. If the firebreak was wider than 19 m it would be classified as Non-Forest.

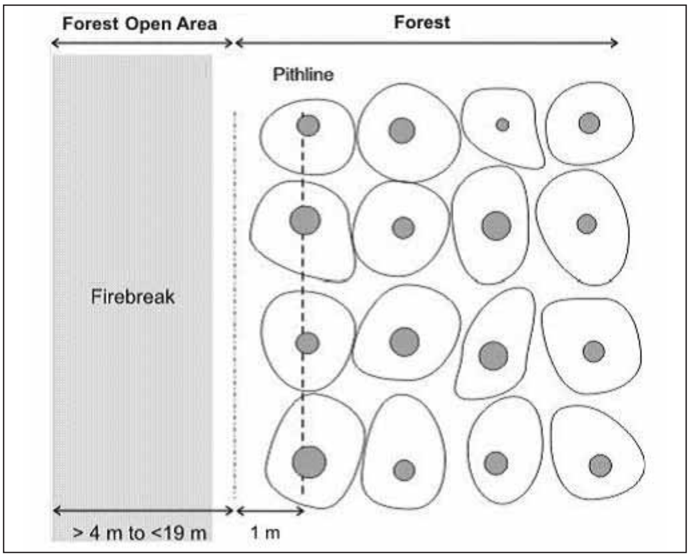


Figure 14. Identifying the land-use category boundary, example 3.

Example 4

The road in this example (Figure 15) may be classified as Non-Forest as it is a paved public road. In the case of a bog road/mountain track/right of way, the NFI field team will have to decide whether or not the road is integral to forest management, and classify accordingly. The fence is not the forest boundary, as the road is a more permanent feature. If it was a forest road, the area would be classified as Forest Open Area, where the road was at least 6m wide form pith-line to pith-line.

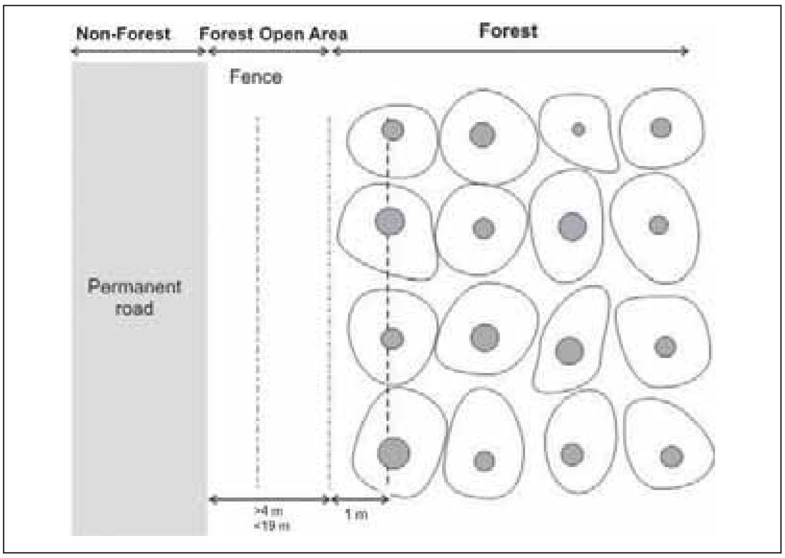


Figure 15. Identifying the land-use category boundary, example 4.

5.4 Land-Use Class

The land-use class classification gives a more detailed description of the land-use class in which the plot centre occurs.

5.4.1 Forest

1. Forest

   This is an area that complies with the forest definition and does not meet any of the other sub-category definitions listed below.

2. Clear-cut

   The trees in this area have recently been felled with no-evidence of replanting, though the potential to replant exists. As there is generally a requirement by law to replant these areas, they are temporarily unstocked.

3. Dead

   This is an area that contains dead trees; this may be due to biotic (animal) or abiotic (climatic, nutritional) factors. At least 80% of the trees have to be dead at the time of assessment.

4. Windblown

   This is an area where the trees have been windblown. At least 80% of the trees have to be windblown at the time of assessment.

5. Natural succession

   This is an area where the trees have colonised previously unforested land. These lands must conform to the forest definition.

6. Swamp/marsh

   These areas can have a high water table all year round (e.g. edge of lake) or can be seasonally flooded. They must conform to the forest definition.

7. Ride line

   This is an unplanted area within the forest boundary that is >3 m and <6 m wide, from pith-line to pith-line.

8. Road/Track

   This is a forest road/track within the forest boundary that is >3 m and <6 m wide, from pith-line to pith-line.

9. Water

   A water body that is located within the forest boundary and that is <400 m^2 in size. This sub-category also includes streams that are <6 m wide, from pith-line to pith-line.

10. Roadside stack

    This area is <400 m^2 in size and is used for the purpose of stacking timber. It must either have timber present or evidence of previous timber stacking.

11. Gap with shrubs (<400 m^2)

    A gap in the canopy that is <400 m^2 in size and contains shrub species.

12. Gap without shrubs (<400 m^2)
A gap in the canopy that is <400 m^2 in size and does not contain shrub species. The gap can be due to a number of biotic or abiotic factors or to the area having been left unplanted.

5.4.2 Forest Open Area

1. Unplanted linear area
This is an unplanted linear area within the forest boundary. It can include the following:
   - A **Rideline** is an unplanted strip used to sub-divide large forest areas and facilitate access for forest management. It must be >6 m wide from pith-line to pith-line.
   - **Road setback** that is >5 m and <20 m wide from pith-line to road edge.
   - **Building setback** that is >5 m and <20 m wide from pith-line to boundary feature.
   - **Hedgerow setback** that is >5 m and <20 m wide from pith-line to hedgerow.
   - **Forest edge setback** that is >5 m and <20 m wide from pith-line to boundary feature.
   - **Pipeline setback** that is >5 m and <40 m wide from pith line to pith-line or boundary feature.
   - **Firebreak** is an unplanted area for the purpose of forest protection, that is >5 m and <20 m wide from the pith-line to the boundary.
   - **Riparian zone** is an area left unplanted due to the presence of a water body, that is >6 m and <40 m wide from pith-line to pith-line when situated within the forest. At the forest edge, it should be >5 m and <20 m wide from pith-line to the centre of the stream.

2. Utility line
This is an area that occurs under a power line. The unplanted area beneath the power line must be <40 m from pith-line to pith-line when situated within the forest stand. When situated at the forest edge, the unplanted area should be <20 m. If there is another predominant land-use (e.g. agricultural or Christmas trees) occurring in the exclusion area then the area becomes Non-Forest regardless of width.

3. Road/track
This is an unpaved forest road within the forest boundary that is >6 m wide from pith-line to pith-line.

4. Roadside stack
These areas must be >400 m^2 and used for the purpose of stacking timber. They must either have timber present or evidence of previous timber stacking present.

5. Bare land (>400 m^2)
These are gaps in the canopy that are >400 m^2 and less than 2 ha in size. The gaps can be due to a number of biotic or abiotic factors or to the area having been left unplanted. No other land use should predominate on the site.

6. Shrub land
This is an area within the forest boundary that has shrub species present on >80% of the plot.

7. Stone, sand and/or gravel quarry
This is an active or a disused quarry, which conforms to the Forest Open Area definition.

8. Landslide
The movement of soil, peat or rock down slope, that has a minimum width of 20 m.

9. Water
   Water body that is <0.1 ha in size or consisting of a stream/river <6 m wide from pith-line to pith-line.

10. Walkway
    This is an unpaved forest track used for the purposes of recreation within the forest boundary that is >6 m wide from pith-line to pith-line.

5.4.3 Non-Forest

1. Water
   Water body that is >0.1 ha in size or consisting of a stream/river >6 m wide from pith-line to pith-line.

2. Utility line
   This is an area that occurs under a utility line. The unplanted area must be wider than 40 m from pith-line to pith-line, when situated within a forest. When situated at a forest edge, the setback distance must be greater than 20 m.

3. Rock outcrop (including scree and limestone pavement)
   An area of outcropping rock that is situated outside the forest boundary.

4. Nursery
   An area used for the production of tree seedlings.

5. Agricultural land
   An area used for the purpose of agriculture.

6. Christmas tree plantation
   An area used for the production of Christmas trees.

7. Built-up areas
   An area >400 m^2 in size that has buildings present.

8. Heathland
   An area of bog and heath that is located outside the forest boundary.

9. Shrub land
   This is an area outside the forest boundary where shrub species are the dominating vegetation.

10. Hedgerows
    A row of woody plants used to demarcate spaces and property boundaries. The hedgerow may contain a mixture of trees and shrubs.

11. Other land
    An area that is not readily conforming to any of the Non-Forest sub-categories defined in this section.

5.5 Plot Shift and Mirage

5.5.1 Introduction

If two land-use classes occur in the plot, i.e. the plot centre lands in Forest but a portion of the plot is assigned to Forest Open Area or to Non-Forest, a plot shift should be considered. Plot shifting is where the original plot centre (generated origin (GO)) is moved to a new location (new origin (NO)), to ensure that >90% of the plot area is assigned to one land-use class. The flowchart detailed in Figure 16 aids in the decision making process.

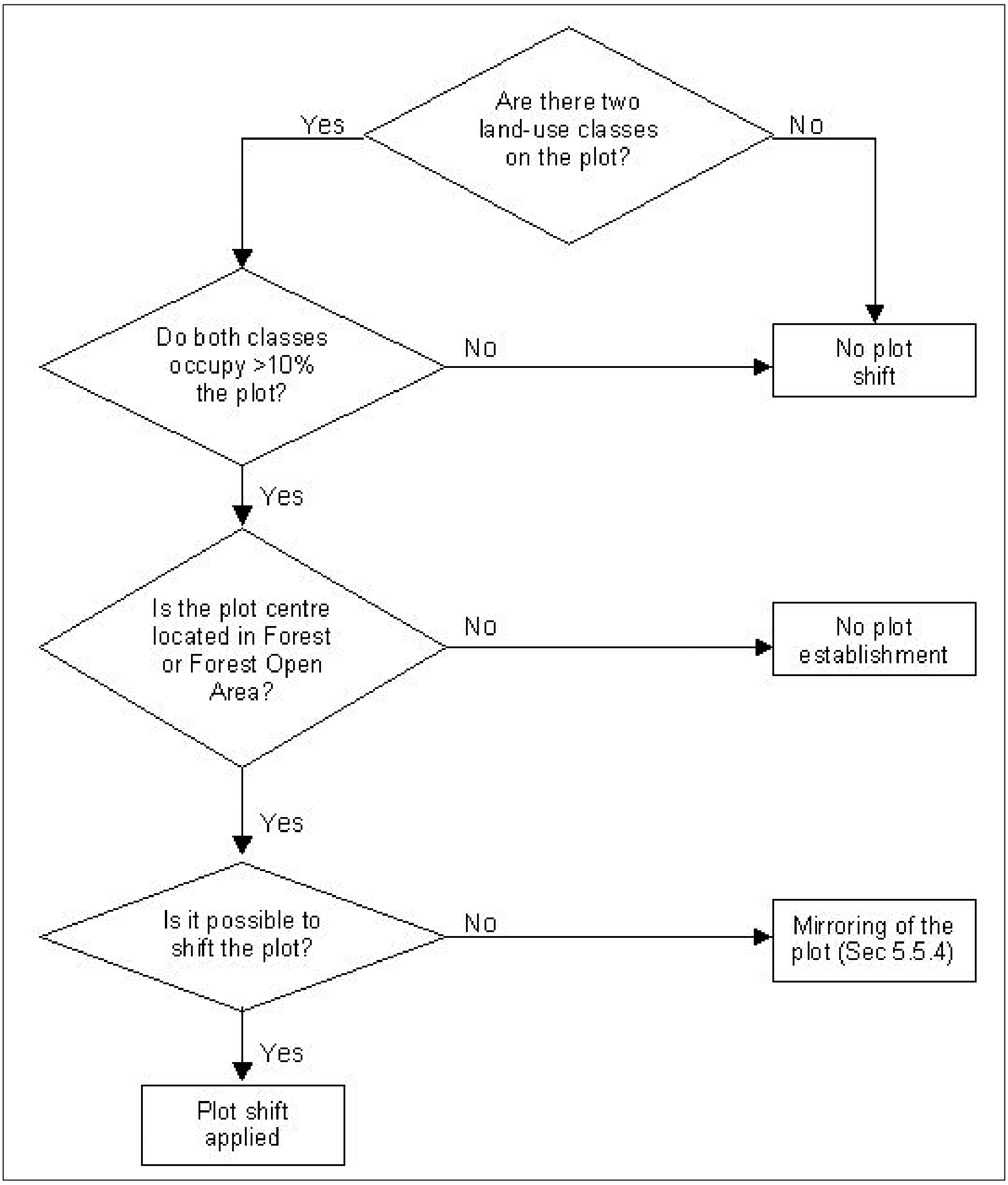


Figure 16. Plot shift decision diagram.

5.5.2 Plot shifting procedure

Where plot shifting is necessary, the new plot centre is moved 12.62 m from the original position perpendicular to the boundary between the two land-use classes. The positions of the generated and new origin are recorded, which may be checked later during validation. For examples see Figures 17 and 18 (next page).

In certain circumstances a plot that has been shifted may still have two landuse categories on the plot. Shifting a plot more than once is described in the next section.

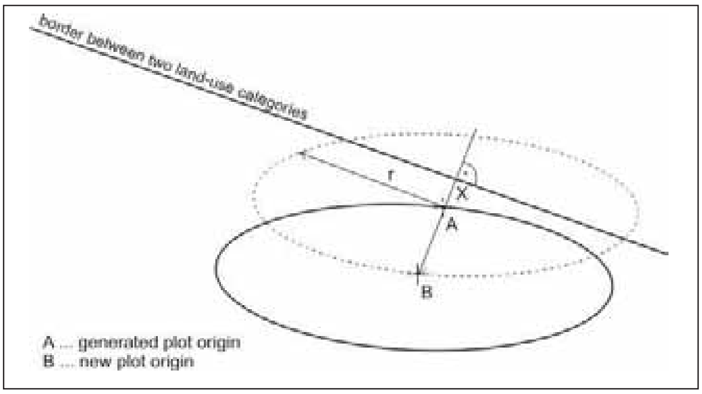


Figure 17. Plot shift procedure.

5.5.3 More than one plot shift

In certain circumstances it is not possible to attain >90% of the plot area assigned to one of the land-use classes in one plot shift. In this situation a plot needs to be shifted more than once, but cannot be shifted across a different land-use class. As in the previous section, the new plot centre is moved 12.62 m from the original position perpendicular to the boundary between the two land-use classes.

In Figure 19 the first move is perpendicular to the forest road. Moving the plot centre across the forest road is not permitted. As there is still >10% Forest Open Area occurring within the plot after the first move, the plot is shifted for a second time perpendicular to the Forest boundary. If the original plot centre had landed on the road, no shift would have been required, see section 5.5.4 on plot mirage.

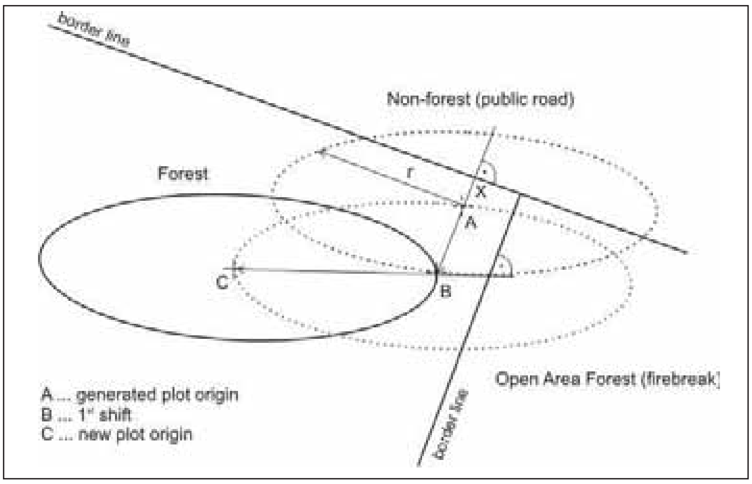


Figure 19. More than one plot shift.

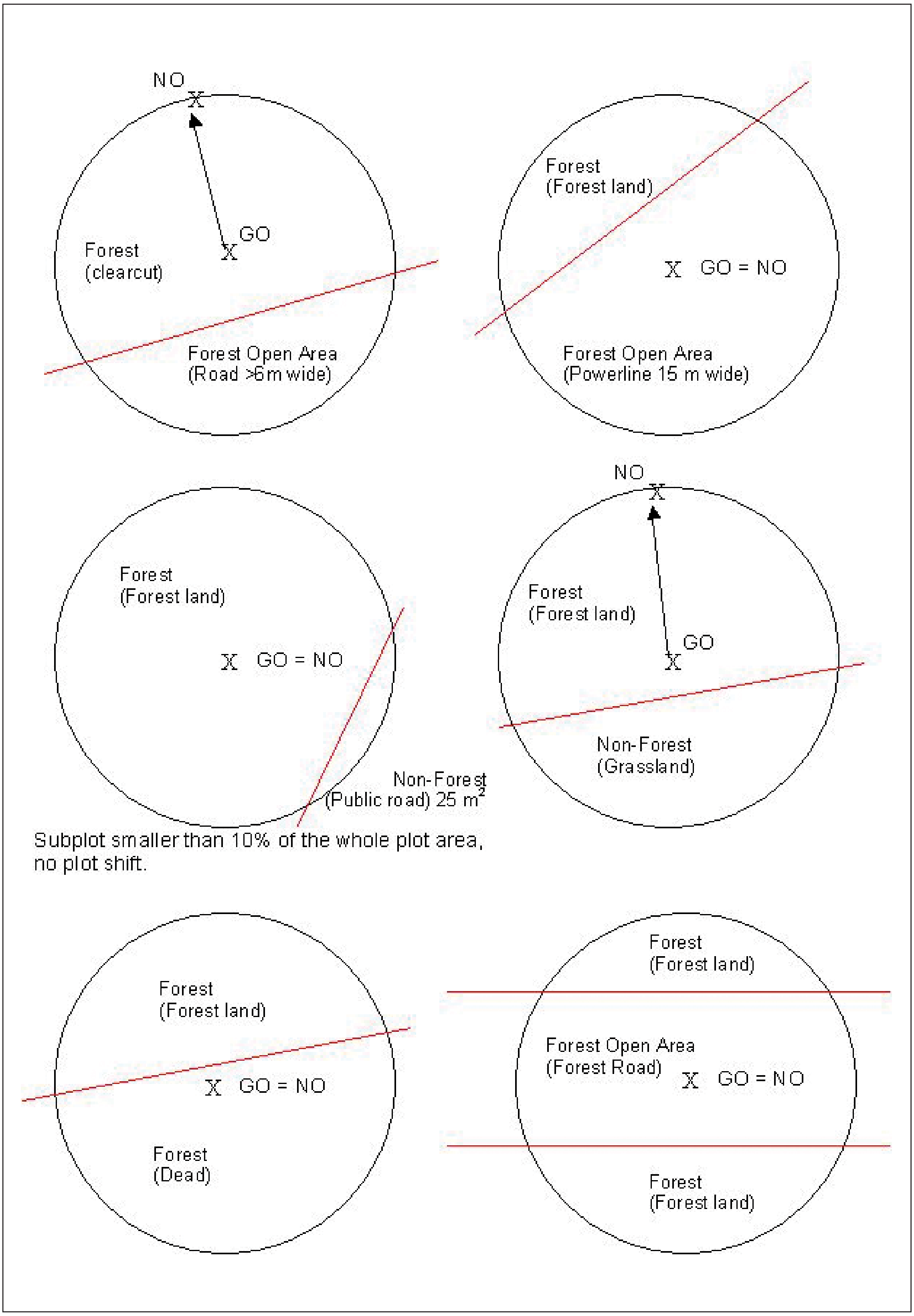


Figure 18. Plot shift examples.

5.5.4 Plot mirage

Plot mirage only occurs in the Forest Open Area land-use class, where a plot lands on a linear feature such as a rideline or forest road. In plot mirage, the data collection is confined to the land-use category where the plot centre is located. Other land-use categories occurring on the plot are excluded.

In the example in Figure 20, data are only recorded for attributes occurring on the rideline. Any attributes occurring on the striped areas are excluded. Attributes are assessed on the basis that the whole plot occurs on the rideline. For the purpose of data collection, the attributes occurring on the rideline are mirrored onto the striped area.

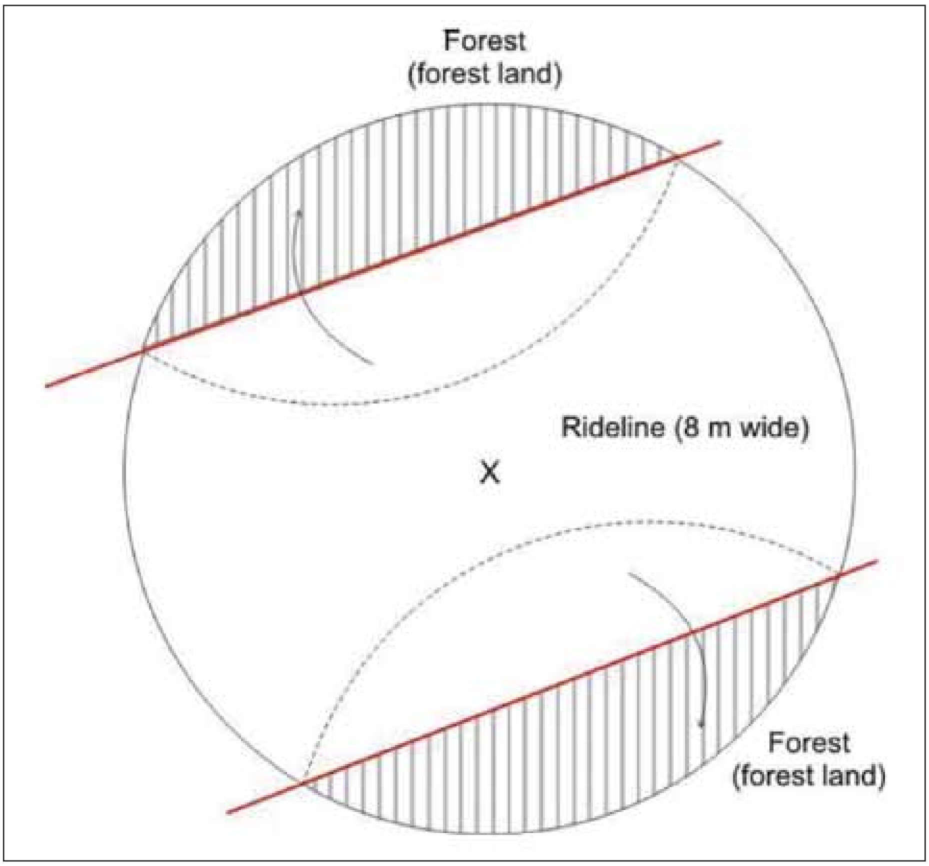


Figure 20. Plot mirage example.

Section C

Field Data Collection

CHAPTER 6
DATA COLLECTION OVERVIEW

6.1 HARDWARE AND SOFTWARE OVERVIEW

The NFI used computer-aided field data collection techniques. These techniques comprised field computers, specialised measurement equipment and system software. A full list of NFI equipment is included in Appendix 2, while the specifications of some hardware components are presented in Appendix 3.

The underlying technology used in the NFI is an integrated system of hardware and software developed by IFER. The software Field-Map™, is a specialised inventory software that allows for the preparation of a NFI database, background maps and plot generation. This in turn provides for the creation of projects for field teams, which facilitates the field data collection process. Inventory data is uploaded to a central database via USB memory sticks.

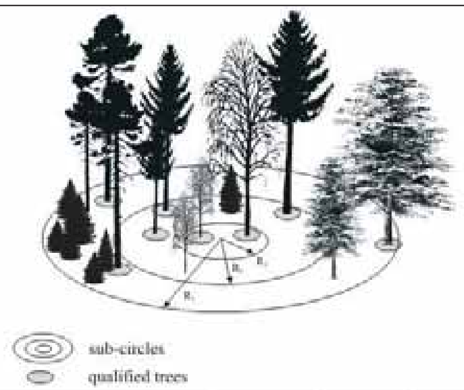
The NFI database is a full relational database containing 127 tables. The database also features a spatial map component, which is a layer containing the locations of field plots and ancillary background map data used for navigation to field plots. Selected layers (e.g. trees) have a spatial reference (i.e. position relative to the plot centre). Each of the data layers and attributes will be described in more detail in subsequent chapters.

6.2 PLOT DESIGN

In this section the individual ground survey plot design is described and some of the information collected on site is summarised.

The exact location of the centre of ground survey plots is identified in the field by navigating to a six digit Irish national grid co-ordinate using both GPS and electronic compass/laser technology. The total size of the circular sample plot is 500 m^2 (i.e. 25.24 m in diameter). All stated dimensions relate to horizontal distances. Adjustments for slope are automatically made by the laser/range-finding equipment.

The concentric circle approach, comprising three concentric circles with different radii is used for tree assessment. Trees of different dimensions are mapped and described on each particular plot (Figure 21). The decision about which tree is considered to be qualified is based on its position on the plot and its dbh (see section 10.4 for dbh definition).



	R_1	R_2	R_3
Sub-circle radius (m)	3	7	12,62
Sub-circle area (m^2)	28,3	153,9	500
Treshold diameter (mm)	70	120	200

Figure 21. Concentric plot design with threshold diameters.

6.3 Overview of Attributes Included

Ireland's NFI assesses the current state and development of the forest estate in relation to standing trees, forest structure, forest regeneration, deadwood and other site characteristics.

Tree positions are mapped using a combination of electronic compass and laser. The dbh of each tree is recorded, along with other descriptive parameters such as species, age, social status, timber quality, branchiness and damage. A sub-sample of seven trees per species, the 'height trees', were selected for height measurement, based on the distribution of dbh of the measured trees (Figure 22). An upper stem and base diameter were also measured for a maximum of five trees (dbh $\geq$ 200 mm) for the primary species and three trees for each other species present. The upper diameter is measured using a remote diameter scope. For all 'height trees' regardless of dbh, horizontal crown projection is measured. Vitality is assessed for all 'height trees' of *spruce, pine, oak* and *beech* species which are dominant or co-dominant (crown is in the upper level).

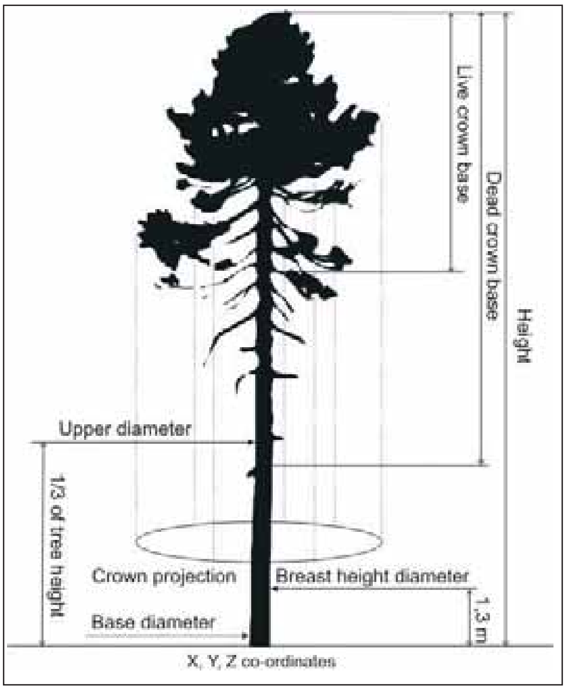


Figure 22. Visual representation of tree data collected.

Small trees that are planted and have a maximum dbh of 69 mm are assessed on the 3 m plot. Naturally regenerated small trees with a maximum dbh of 69 mm and minimum height of 20 cm are also included.

A description of the forest stand in the 12.62 m plot is undertaken using attributes similar to those collected in stand level inventories, such as forest type, growth stage and thin status. The total number of all trees with a minimum height of 20 cm is recorded on the 7 m plot.

Site characteristics with reference to the entire plot are described in detail, such as soil type and terrain. Ground vegetation over the whole plot is identified and quantified as a percentage cover on the plot. The dimensions and quantities of deadwood are also assessed; this includes stumps, lying and standing deadwood.

A summary of the main NFI attributes collected is presented in Table 3.

Table 3. Main NFI attributes.

Plot	**Deadwood**
Plot id	Branch cover
Plot area	Stumps presence
Land-use category	Stump diameter, height and decay status
Geographic coordinates	Dead logs presence
Forest structure	Dead logs distribution
Stand layer type, canopy closure and composition	Dead log mid-diameter, length and decay status
Social status	Valuable site identification
Fork	Game accessibility and food
Dead tree	**Site**
Forest diversity	Altitude
Species composition	Relief form
Species composure	Aspect
Diameter and height diversity	Slope
Production	Erosion
Dbh	Anthropogenic factor
Upper diameter	Humus form
Upper diameter height	Soil condition
Tree height	Group soil
Live crown base	Parent material
Dead crown base	Principal soil
Stem quality (straightness, branchiness)	Peat texture
Damage	Soil texture
Negative factor limiting regeneration	Drainage
Type, intensity and age of regeneration tree damage	Moisture
Tree mechanical damage type, intensity and age	Soil depth
Peeling intensity and age	Peat depth
Stem rot	Litter description
Tree break	**Regeneration**
Tree root damage type, intensity and age	Presence
Other tree damage type	Origin
Defoliation	Protection
Defoliation of tree top	Regeneration distribution
Type and intensity of discoloration	Species mixture
Broadleaf damage	Species and age composition
Ecosystem	Height class
Lichens presence and type	Regeneration tree number
Plants species and cover	**Forest management**
Shrub species and cover	Ownership
Grass cover	Forest type
Herb cover	Forest subtype
Moss cover	Forest naturalness
Fern cover	Cultivation type
Brush cover	Growth stage
Shrub cover	Thin status
	Rotation type
	Stocking

Chapter 7
Site

This chapter details the type of information that is recorded to describe the environment in which the plot occurs.

7.1 County

Definition: The county in Ireland in which the plot is located.

7.2 Ownership

Definition: Ownership specifies both land and timber ownership.

Application: Forest ownership type is important as it has the potential to impact on forest management and timber supply.

Measurement and Description: Forest Service and external datasets are used to specify ownership type. Assessment is based on the location of the plot centre.

Attribute **Ownership**

1. **Coillte**: Forest land owned by Coillte.
2. **Private grant aided**: Private afforested land which was or is in receipt of grant and/or premium over the period 1980 to present.
3. **Private**: Private forest land which was not in receipt of grant and premium since 1980. This category includes estate planting and natural succession land.
4. **National Parks and Wildlife Service (NPWS)**: Forest land owned by the NPWS.
5. **Farm partnership**: Grant aided forest that is privately owned, but is being managed by Coillte.
6. **NPWS/Coillte**: Forest land owned by NPWS, but Coillte retain ownership of the timber.
7. **Other**: Not belonging to any of the above, e.g. Bord na Móna, Electricity Supply Board, Department of Defence or any local authority

7.3 Accessibility

Definition: All plots are recorded as either accessible or inaccessible.

Application: Inaccessible plots are excluded from the data analysis.

Measurement and Description: If it was physically impossible to walk to the plot, due to difficult terrain such as marshy ground, the plot was classified as inaccessible.

7.4 Magnetic Declination

Definition: Magnetic declination is the angular offset of magnetic north from true north.

Application: As the magnetic fields around the earth are continually changing, so too will the magnetic declination. As the positions of trees on the plot are recorded using an electronic compass it is important to be able to relocate these trees for validation or future measurements. When a sample plot is revisited in the future, the magnetic declination will have changed but when the azimuth is readjusted for the new declination the trees can be relocated.

Measurement and Description: The magnetic declination is recorded in degrees.

7.5 Photograph

Definition: An image recorded by a digital camera.

Application: Plot photographs provide a desk check facility for ambiguous or difficult plots requiring verification. They also provide pictorial evidence in making land-use allocation decisions.

Measurement and Description: After plot cleaning[4], to provide a clearer view of the plot, photographs are taken from the plot centre Four photographs are taken at the centre of the plot, with the first photograph facing north and then in the three other cardinal directions, east, south and west.

7.6 Management Access

Definition: Distance from the nearest road/track suitable for timber transport is recorded as an indication of plot accessibility.

Application: From a forest management viewpoint, access will indicate the distance to the nearest timber stacking area. This information will also be of use to the validation team and future inventory teams.

Measurement and Description: Distance from the nearest road/track is measured from the plot centre.

Attribute **Management Access**

1. Plot is within 100 m from the nearest road/track.
2. Plot is further than 100 m from the nearest road/track.

7.7 Slope

Definition: The measurement of the steepness of terrain, the ratio of vertical rise to horizontal distance expressed in degrees.

Application: From a forest management viewpoint, the slope will indicate the traversability of the site where the plot is located.

Measurement and Description: The slope of the plot is measured in degrees using the clinometer across the extent of the plot, i.e. from plot edge to plot edge.

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[4] Plot cleaning is the clearance of ground vegetation or removal of side branches, which facilitates movement and measurement in the plot.

7.8 Physiographic Divisions

Definition: Physiographic divisions are significant divisions for soil formation in Ireland.

Application: The classes give an indication of the type of landscape in the area where the plot is located. Assessment is based on the plot altitude, soil group and appearance of the landscape.

Measurement and Description: Five major physiographic divisions are used in this classification (Gardiner and Radford, 1980).

Attribute **Physiographic Division**

1. **Mountain and hill**: Mountain and hill soils occurring at elevations of 365-500 m, with steep slopes common. These soils are mainly peaty podsols, peaty gleys, blanket peat and lithosols. Outcropping rock is common. The majority of these areas occur on the higher mountain slopes.
2. **Hill**: Hill soils are predominantly acidic and occur between 150-365 m. The largest of these areas is the old red sandstone uplands of Munster. The principal soils in these areas are brown podzolics but other soils included in this division are rendzinas and outcropping rock of the Burren area.
3. **Rolling lowland**: Rolling lowland soils occur at elevations below 150 m. Acid brown earths and brown podzolics make up the majority of the soils. Extensive areas of gleyed soils are also included, such as those formed on the Castlecomer plateau.
4. **Drumlins**: Drumlins consist of a thick cover of boulder clay deposited in the form of small hills. As these hills were formed beneath moving ice, the ridges tend to be parallel to the direction of ice flow. Drumlins occur mainly in the north-west, west and some midland areas, and the landscape is characterised by the 'eggs in the basket' similarity. Gley soils dominate in these areas.
5. **Flat to undulating lowland**: Flat to undulating lowland generally occur at elevations below 100 m. Brown earths and grey brown podzolic soils dominate this area. It stretches from the Golden Vale across the central plain to the east coast, as well as occupying large areas of east Galway and Roscommon.

7.9 Surface Topography

Definition: The general land surface shape in which the plot occurs.

Application: The classes give an indication of the topography of the area where the plot is located.

Measurement and Description: The surface topography is categorised into three classes (Anon, 1998b). Assessment is based on the area in the vicinity of the plot.

Attribute **Surface Topography**

1. **Concave**: Surface profile is mainly 'hollow' in one or several directions.
2. **Convex**: Surface profile is mainly 'rounded' like the exterior of a sphere.
3. **Straight**: Surface profile is linear, either flat or sloping in one direction.

7.10 Relief Form

Definition: Classification of different relative elevations of the earth's surface (Anon, 1998b).

Application: The classes give an indication of the position of the plot in the landscape (Figure 23).

Measurement and Description: The relief form is categorised into seven classes (Anon, 1998b). Assessment is based on the area in the vicinity of the plot.

Attribute **Relief Form**

1. **Crest**: The generally convex uppermost portion of a hill, usually convex in all directions with no distinct aspect.
2. **Upper slope**: The upper portion of the slope immediately below the crest of the hill; it has a specific aspect.
3. **Middle slope**: Area between the upper and lower slope; the surface profile is generally neither distinctly concave nor convex and will have a straight surface profile with a specific aspect.
4. **Lower slope**: The area toward the base of a slope; generally has a concave surface profile with a specific aspect.
5. **Toe slope**: The area demarcated from the lower slope by a decrease in slope gradient.
6. **Depression**: Any area concave in all directions; it may be at the base of a slope or in a generally level area.
7. **Flat/Level**: Any flat area (i.e. slope $<5^{o}$) where the surface profile is generally horizontal and straight with no significant aspect.

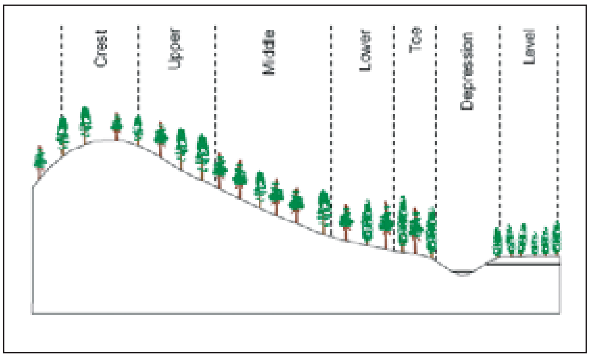


Figure 23. Relief form (Anon, 1998b).

7.11 Altitude

Definition: Altitude is the height of the plot above sea level.

Application: Altitude is an important factor in tree growth, with productivity generally reduced at higher elevations. Exposure and more impoverished soil types are the main limiting factors at higher elevations.

Measurement and Description: The altitude (m) of the plot centre is determined using GPS.

7.12 Aspect

Definition: Aspect describes the orientation of the slope.

Application: Aspect indicates how exposed the plot is to factors such as wind, e.g. a site with a SW aspect will be exposed to the prevailing winds.

Measurement and Description: It is measured by electronic compass and categorised by the cardinal points of a compass.

Attribute **Aspect**

1. Flat: For plots with a slope of <5^{o}, a 'flat' aspect is entered.
2. North.
3. North east.
4. East.
5. South east.
6. South.
7. South west.
8. West.
9. North west.

7.13 Vegetation Cover

Definition: The structure, cover and species composition of plants within the plot.

Application: Quantifying the percentage vegetation cover on the plot allows for the assessment of plant diversity. Tree species are excluded in the vegetation cover assessment. All plant species present, including grass, herb, moss, fern, shrub and brush cover, are recorded.

Forest managers have used plant diversity for a considerable time to indicate site/ground conditions, in particular nutrient availability (Anderson, 1950). The assessment of plant diversity is an important indicator which can be used in the monitoring of SFM. The structure/range of the vegetation present will also be indicative of the insect diversity.

Measurement and Description: The total vegetation type and vegetation cover on the entire plot is quantified into percentage classes, based on an adjusted Braun-Blanquet scale (Braun-Blanquet, 1983). This scale is also used to classify individual plant species, which are named. Appendix 4 and 5 detail the list of plant and shrub species recorded.

Attribute **Vegetation Type**

1. Grass
2. Herb
3. Moss
4. Fern
5. Brush
6. Shrub.

Attribute **Vegetation Cover**

1. **No presence**: No vegetation cover present on the plot.
2. **Rare (0-0.2%)**: Total vegetation cover present on the plot is less than 0.2% of the plot area.
3. **Sporadic (0.2 to 1%)**: Total vegetation cover present on the plot is between 0.2 and 1% of the plot area.
4. **Infrequent (1-5%)**: Total vegetation cover present on the plot is between 1 and 5% of the plot area.
5. **Frequent (6-25%)**: Total vegetation cover present on the plot is between 5 and 25% of the plot area.

6. **Common (26-50%)**: Total vegetation cover present on the plot is between 26 and 50% of the plot area.
7. **Very common (51-75%)**: Total vegetation cover present on the plot is between 51 and 75% of the plot area.
8. **Abundant (76-100%)**: Total vegetation cover present on the plot is between 76 and 100% of the plot area.

7.14 TREE LICHENS

Definition: A lichen is an organism consisting of an outer fungal body enclosing photosynthetic algae.

Application: Lichens are unique, as they consist of two totally unrelated life forms, an alga and a fungus, living together in a complex but balanced state of mutual interdependence.

Measurement and Description: For the purpose of the NFI, lichens have been classified into three growth forms (Broad, 1989) (Figure 24). The type of trees on which the lichens occur and lichen coverage on the plot are recorded.

Attribute **Lichen Type**

1. **Crustose**: Encrusting forms that spread over and into the surface substrate on which they grow.
2. **Foliose**: Leafy forms that spread horizontally over the substrate. Attached by root-like threads called rhizinae.
3. **Fruticose**: Shrubby or beard-like forms that may be erect or pendulous.

Crustose

Folicose

Fruiticose

Figure 24. Illustrations of crustose, folicose and fruiticose lichens.

Attribute **Tree Type**

1. **Conifers**: Lichens present on coniferous tree species.
2. **Broadleaf with smooth bark**: Lichens present on broadleaf tree species with smooth bark.
3. **Broadleaf with rough bark**: Lichens present on broadleaf tree species with rough bark.

Attribute **Coverage**

1. **Rare (0.1-5%)**: Lichens are present on trees occupying between 0.1 and 5% of the plot area.
2. **Sporadic (6-25%)**: Lichens are present on trees occupying between 6 and 25% of the plot area.
3. **Frequent (51-75%)**: Lichens are present on trees occupying between 51 and 75% of the plot area.
4. **Abundant (76-100%)**: Lichens are present on trees occupying between 76 and 100% of the plot area.

7.15 Anthropogenic Factors

Definition: These are human induced factors that may have changed the original nature of the plot area.

Application: This classification is important, as these factors may constrain forest management.

Measurement and Description: Assessment is based on the presence of an anthropogenic factor within the 12.62 m plot.

Attribute **Anthropogenic Factors**

1. **None**: There are no human induced factors influencing forest management on the site.
2. **Archaeological features**: A site or monument that is part of our national heritage.
3. **Recreation**: A site or feature that is used for the purpose of recreation is located within the vicinity of the plot.
4. **Mine areas and quarry**: Site is being actively mined or quarried.
5. **Mine dump and spoils**: Residue from mining operations are present on the site.
6. **Landfill**: The disposal of refuse is taking place on the site.
7. **Other**: Other human induced factors influencing forest management on the site

7.16 Management Constraints

Definition: Factors influencing forest management in the plot.

Application: Constraints that potentially have a bearing on management operations and timber supply.

Measurement and Description: Assessment is based on presence of a management constraint within the 12.62 m plot.

Attribute **Management Constraint**

1. **No constraints**: There are no factors influencing forest management to the extent that normal forest management practices will be affected.
2. **Boulders present**: The presence of large boulders in the plot will impact on forest management, particularly in relation to harvesting access.
3. **Utility line present**: Forest management in the plot will be influenced by the presence of an overhead utility line.
4. **Amenity/recreation**: The plot is located in an area where recreation is a primary management constraint.
5. **Landscape sensitivity**: The plot is located in an area of high landscape value. Any forest operations undertaken in these areas will need to take cognisance of this fact.
6. **Designated areas of special protection**: The plot has landed in an area which is protected by Irish and/or EU law, as the area is of scientific or public interest. Forest management in these areas will be influenced by the type of designation. Consultation with relevant bodies and modified forest operations are carried out on these sites. Designations include: Special Protection Area (SPA), National Heritage Area (NHA), Special Area of Conservation (SAC), Nature Reserves, National Park, Acid Sensitive and Fisheries Sensitive areas.
7. **Limestone pavement**: Forest plots located on limestone pavement, karst features, e.g. the Burren in Co. Clare.
8. **Other**: A management constraint not mentioned in the above list.

Chapter 8
Soil

The description of the soil is a significant feature in the NFI as soil is one of the primary factors determining a tree's growing conditions. Soil acts as a medium for growth, by providing root anchorage and regulating water and nutrient availability. The composition of the soil can also have consequences for other parts of the ecosystem, such as water quality.

Descriptive attributes relating to soils are detailed in this chapter. The litter and humus layers are described first, followed by sections detailing the composition of the soil type, parent material and soil structure. Two soil related factors, cultivation and site roughness, are covered in the final sections.

8.1 Litter and Humus

The litter layer and humus are described in this section.

8.1.1 Litter layer

Definition: The non-living, slightly decomposed organic material on the surface of the forest floor is defined as the litter layer.

Application: Even in an undecomposed state, litter is an important component of the forest. The partially decayed stem wood, branches and leaves are able to store water, prevent water loss from evaporation, and reduce erosion resulting from surface runoff.

Measurement and Description: The presence of a litter layer in the plot is assessed when the soil pit is dug, which takes place within the 12.62 m plot. The composition of the litter layer is categorised, with the depth (mm) of each component recorded. Recently afforested lands, particularly those previously improved for agriculture, may have a grass/herb derived litter layer.

Attribute **Litter Type**

1. Grass
2. Leaves
3. Needles
4. Moss

8.1.2 Humus

Definition: Organic layers at the soil surface, where leaf litter and other organic matter are decomposing and being incorporated into the upper mineral soil.

Application: Humus consists of undecayed to mostly decayed organic matter, usually leaves/needles, which are broken down into soil by decomposers (microorganisms, insects, earthworms) and exposure to light, wind, rain, etc. Humus contains many nutrients that are recycled in the soil when it is broken down into humus.

Measurement and Description: The humus form and thickness of the humus sub-layers are described, including the agents of decomposition (Horgan, *et al.*, 2003).

Attribute **Humus Type**

1. **No humus**: There is no humus development. The litter layer may not have formed yet or could have been removed due to surface runoff or flooding.

2. **Mor humus**: This is raw humus, composed of unincorporated organic material, usually distinct from the mineral soil. It comprises the current litter layer overlying a matted layer of partly decomposed material.
3. **Moder humus**: This is the intermediate between mor and mull. The current litter layer overlies partly decomposed material, which is not matted as in mor.
4. **Mull humus**: This is the humus-rich layer of forested soils consisting of mixed organic and mineral matter. The humus is being incorporated into the soil, i.e. there is no clear differentiation between the soil and humus layer.

8.2 Soil Description

This section describes the soil condition, soil group and principal soil type.

8.2.1 Soil condition

Definition: Broad classification into peat and mineral soil.

Application: Soil condition allows for the broad classification of soil based on the peat and mineral soil depth. The classification is used to distinguish mineral soils and peats.

Measurement and Description: Soil condition is assessed when the soil pit is dug. Peat and soil depth are measured to the nearest cm.

Attribute **Soil Condition**

1. **No peat:** Mineral soil with no peat present.
2. **Less than 30 cm of peat:** Mineral soil overlain with less than 30 cm of peat.
3. **More than 30 cm of peat:** More than 30 cm of peat present.
4. **Mineral soil less 20 cm:** Mineral soil less than 20 cm in depth.

8.2.2 Soil group

Definition: A standardised system of nomenclature was used to classify soils into groups.

Application: Soil group has a bearing on several parts of the ecosystem. The type of soil can affect the growth of trees and other vegetation by influencing moisture and nutrient availability. These same characteristics also affect other parts of the ecosystem, such as water quality.

Measurement and Description: The soil group classification used in the NFI is a modification of the ten great soil groups (Gardiner and Radford, 1980) to include sand, making 11 great soil groups.

Attribute **Soil Group**

1. Brown earth
2. Grey brown podzolic
3. Brown podzolic
4. Podzol
5. Gley
6. Rendzina
7. Basin peat
8. Blanket peat
9. Regosol
10. Sand
11. Lithosol

Each soil group is briefly described in the following section. The photographs labelled ©**Teagasc, 2007** were reproduced with the permission of Teagasc from a presentation to the Forest Service (Radford, 2004). Photographs labelled ©**Coford, 2007** were reproduced with the permission of COFORD from *A Guide to forest Tree Species Selection and Silviculture in Ireland* (Horgan *et al.*, 2003).

Brown earth

Relatively mature, well-drained mineral soils, derived from parent materials of acidic or basic status (Figures 25-27). These soils possess a rather uniform profile with little differentiation in horizons and no removal and deposition of materials such as iron oxides, humus or clay, although constituents such as calcium and magnesium may be leached to some extent. They occupy approximately 13% of the land area of Ireland.

Figure 25. Brown earth.

Figure 26. Acid brown earth.

Figure 27. High base brown earth.

Grey brown podzolic

These well-drained mineral soils are similar in many respects to the brown earths, except that clay has been translocated from the surface to a sub-surface layer (horizon) (Figures 28 and 29). They are usually formed from glacial drift of predominantly limestone composition and have a medium to high base saturation status. They occupy approximately 24% of the land area of the country.

Figure 28. Grey brown podzolic.

Figure 29. Grey brown podzolic.

Brown podzolic

Well-drained, acid mineral soils, derived mainly from acidic parent materials such as shale, granite or sandstone (Figure 30). Located on hills and rolling lowland. They are formed under the influence of the podzolisation process, subject to some leaching. Due to the presence of iron oxides the horizon has a reddish-brown colour. This group occupies approximately 12% of the land area of the country.

Figure 30. Brown podzolic.

Podzol

These soils are subject to intense leaching of minerals, particularly iron and aluminium, and are formed from acidic parent materials (Figures 31 and 32). They have a distinct sequence of horizons, with a subsurface layer of removal, the A2 horizon and subsurface layer of accumulation, B horizon. Due to severe leaching of iron and cementation, some podzols may develop a thin impervious 'iron pan' in the B horizon. They may have a peaty surface layer of less than 30 cm drained or 45 cm undrained and are located on mountain and hill land, where the high rainfall is a major factor in their development. They occupy approximately 8% of the land of the country.

Figure 31. Podzol.

Figure 32. Peaty podzol.

Gley

This group contains soils in which the effects of drainage impedance dominate (Figure 33). They develop under conditions of permanent or intermittent waterlogging. The mineral horizons of Gleys are grey or blue-grey in colour, with distinct rusty mottling frequently evident. Rooting depth is usually limited, aeration is poor and rate of organic matter decomposition is slow. The impeded condition may be due to a high water level, seepage or springs, or it may be due to the impervious nature of the parent material. Gleys occupy approximately 22% of the land area of Ireland.

Figure 33. Gley.

Rendzina

These are well-drained, shallow mineral soils (Figure 34 and 35). They are very dark in colour, with a high lime content. Derived from limestone bedrock, or limestone sands and gravels such as eskers, they are less than 50 cm in depth.

Figure 34. Rendzina.

Figure 35. Rendzina.

Peats

For an area to be classified as peat, the peat depth has to be greater than 30 cm on drained and 45 cm on undrained land. Peats are divided into two groups:

- **Basin peat**
  Basin peat consists of fen peat and raised bog. Fen peat originally formed under the influence of base rich ground water in shallow lakebeds and depressions in the landscape. It is usually alkaline in its lower layers but as it develops, the upper layers become more acidic and the vegetation changes from one dominated by *Phragmites* and *Carex* species to one of *Sphagnum* and *Calluna* species, resulting in raised bog.

- **Blanket peat**
  Blanket peat occurs in wet, cold and acid conditions in elevated areas and at lower elevations along the western seaboard. Blanket peat usually extends over the entire landscape, covering

the hills and valleys. Its vegetation is usually dominated by acid-loving plants, such as *Sphagnum, Calluna, Tricophorum, Eriophorum* and *Molinia* species. When it occurs at elevations greater than 150 m it is described as 'high level'; below this, it is described as 'low level' blanket peat.

Regosol

This group consists of mineral soils, which are immature and show little distinct horizon development (Figure 36). They occur in low-lying flat areas along river courses, lake-beds or at mouths of river estuaries. The texture varies from sands to clays, drainage ranges from excessive to poor. May be acid or alkaline depending on the source of the deposits.

Figure 36. Regosol.

Sand

Soils occurring in this group are found in coastal regions and are characterised by the high percentage (>90%) of sand content (Figure 37). These soils have very little horizon differentiation. Due to the absence of clay and silt particles, these soils have poor nutrient and moisture retention capacity.

Figure 37. Sand.

Lithosol

Very shallow and stony mineral soils, usually overlying solid or shattered bedrock (Figure 38 and 39). Located mainly at higher elevations where they are associated with podzols. These soils are frequently characterised by outcropping rock and may occur on steep slopes.

Figure 38. Lithosol.

Figure 39. Lithosol.

8.2.3 Principal soil

Definition: Principal soil categorises the soil groups into more descriptive classes e.g. gleys are further categorised into gleys and peaty gleys.

Application: In order to further describe soil fertility/management.

Measurement and Description: Principal soil is assessed when the soil pit is dug. In the attribute list below 'flushed' describes peat with a sufficient nutrient content that permits the growth of more demanding species, such as Mollina. 'Unflushed' peat is characterised by the presence of Calluna species.

Attribute **Principal Soil**

1. Basin peat (unmodified)
2. Basin peat (industrial cutover)
3. Basin peat (domestic cutover)
4. Basin peat (cutover and reclaimed)
5. Fen peat (unmodified)
6. Fen peat (man modified)
7. Marl
8. Interdrumlin peat
9. Blanket peat - high level (flushed)
10. Blanket peat - high level (unflushed)
11. Blanket peat - high level (industrial cutover)
12. Blanket peat - high level (domestic cutover)
13. Blanket peat - high level (cutover and reclaimed)
14. Blanket peat - low level (unflushed)
15. Blanket peat - low level (flushed)
16. Blanket peat - low level (industrial cutover)
17. Blanket peat - low level (domestic cutover)
18. Blanket peat-low level (cutover and reclaimed)
19. Acid brown earth
20. Alkaline brown earth
21. Brown podzolic
22. Gley
23. Peaty gley
24. Grey brown podzolic
25. Lithosol
26. Podzol
27. Peaty podzol
28. River alluvial
29. Lake alluvial
30. Esturine alluvial
31. Coastal sand
32. Rendzina
33. Sand

8.3 Parent Material

Definition: Parent material may be either solid rock, which has weathered, or some superficial deposit, such as glacial drift or alluvium, that has been derived from weathered rocks and transported to its current state.

Application: The ability to classify the national forest estate in terms of parent material is important in quantifying the area of the forest estate which is located on sensitive sites. This has implications for forest management, such as the application of fertiliser or the planting of certain species.

Measurement and Description: Glacial drift is the most common parent material of Irish soils and varies considerably in constitution and in geological composition, giving rise to many different soils. The general soil map of Ireland (Gardiner and Radford, 1980) was used as the basis for the identification and classification of parent material.

Attribute **Parent Material**

1. Alluvium
2. Basalt glacial till
3. Glacial muds of Irish Sea origin

4. Granite and sandstone
5. Limestone
6. Limestone and shale glacial till
7. Limestone glacial till
8. Limestone gravelly till
9. Limestone morainic gravels and sands
10. Limestone till, shallow in places
11. Mica schist glacial till
12. Mixed sandstone, limestone glacial till
13. Morainic sands and gravels and blown sands
14. Mostly Silurian shale
15. Mostly Ordovician-Silurian shale glacial till
16. Mostly Ordovician-Silurian shale sandstone
17. Mostly Upper Carboniferous limestone and shale-sandstone glacial till
18. Mostly basalt
19. Mostly granite
20. Mostly granite or rhyolite glacial till
21. Mostly granite-sandstone
22. Mostly limestone and shale
23. Mostly limestone glacial till
24. Mostly mica-shist, gneiss, quartzite and sandstone
25. Mostly sandstone
26. Mostly sandstone, granite, quartzite or mica shist
27. Ordovician-Silurian-Cambrian shale
28. Ordovician-Silurian-Cambrian shale and mica shist
29. Sandstone glacial till
30. Sandstone, Lower Avonian shale
31. Sandstone, granite, mica schist
32. Stony limestone glacial till
33. Till of Irish Sea origin with limestone
34. Upper Carboniferous shale and sandstone
35. Upper Carboniferous shale glacial till
36. Peat

8.4 Structure

Peat and soil texture are described in this section, as well as the assessment of peat and soil depth. Soil moisture, drainage, cultivation and site roughness are also included.

8.4.1 Peat texture

Definition: Peat texture is a measure of the decomposition or humification of peat.

Application: Peat texture is used as a criterion in peat classification.

Measurement and Description: The classification scale is based on the 'von Post scale' (Von Post, 1924), which uses values ranging from 1 to 10, where 1 is the least decomposed. This scale has been simplified and expanded as detailed below.

Attribute **Structure**

1. **Fibric**: Degree of decomposition is from 1 to 3, very light in colour, full of non-decomposed plant remains, primarily *Sphagnum* species. When squeezed the water is a light brown colour.
2. **Hemic**: Degree of decomposition is from 4 to 6 and it is dark brown in colour. Identification of plant residues is difficult.
3. **Sapric**: Degree of decomposition is from 7 to 10. It is black in colour, greasy in texture and identification of plant remains is very difficult.
4. **Peat with mineral materials**: This covers areas where reclamation has taken place or where most of the peat has been removed or incorporated into the mineral layer. The peat has been altered by the addition of mineral materials and fertilisers.

8.4.2 Soil texture

Definition: Soil texture refers to the relative proportions of the various size particles in the mineral fraction of the soil.

Application: The soil texture is a significant soil characteristic to assess, as it is an important indicator of plant growth. For example, sandy soils generally have low organic content and poor moisture retention ability.

Measurement and Description: Classes of texture are based on different proportions of sand, silt and clay (Figure 40). In the field, the percentages of sand, silt and clay particles in a soil are estimated by feel. The soil is rubbed between fingers and thumb and an estimate of the amount of sand, silt and clay present is made.

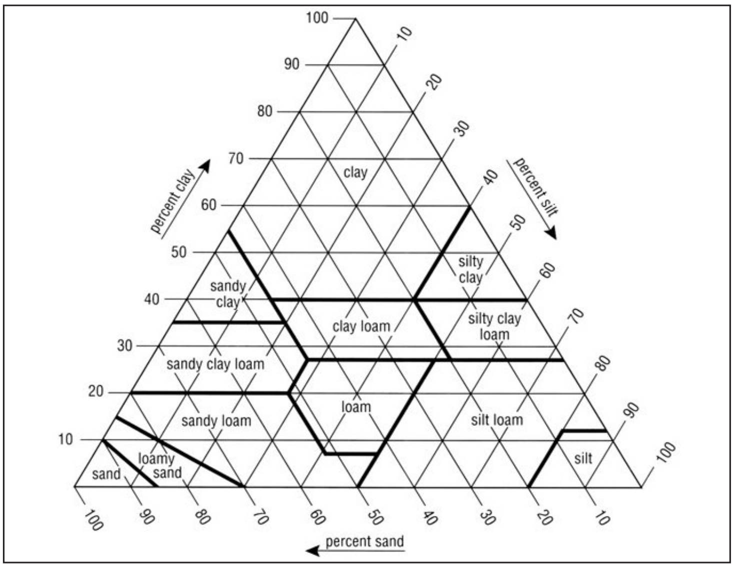


Figure 40. Chart showing the percentages of clay, silt and sand in the basic textural classes (Anon., 1993).

8.4.3 Soil/peat depth

Definition: The depth of peat and soil.

Application: Soil and peat depth are important factors in tree growth. Forest management is also affected, in terms of access and stability.

Measurement and Description: The depth of mineral soil is measured in the soil pit. Peat depth may also be measured using a soil stick. Soil or peat depth (cm) is recorded to a maximum of 100 cm. In the case where both soil and peat are present (e.g. a peaty gley), the maximum combined recording depth is also 1 m.

8.4.4 Soil moisture

Definition: Moisture contained in the soil above the water table.

Application: Soil moisture describes the availability of moisture in forest soils, thereby affecting tree growth.

Measurement and Description: In the field, the soil moisture can be estimated by feel. The time of year and any extremes of weather conditions are taken into account.

Attribute **Soil Moisture**

1. **Dry**: The soil is dry with little or no moisture present, e.g. excessively drained coastal sand.
2. **Moist**: The soil is moist with some moisture present, e.g. most mineral soils or drained peatland.
3. **Wet**: The soil is wet with a lot of moisture present, e.g. gley or undrained peat soil.

8.4.5 Soil drainage

Definition: Soil drainage describes the capacity of the soil to drain water.

Application: This attribute can influence both silvicultural and harvesting practices.

Measurement and Description: Assessment is made on the 12.62 m plot. Soil structure, slope and topography are taken into consideration.

Attribute **Soil Drainage**

1. **Excessive**: Soil has poor moisture retaining ability, e.g. Coastal Sand.
2. **Well drained**: Site is dry and the soil profile shows no sign of water impedance, e.g. Brown Podzolic with shale parent material.
3. **Moderately well drained**: No significant sign of water impedance, e.g. Podzol.
4. **Imperfectly drained**: Drainage is restricted due to the soil texture or presence of an iron pan. When the soil pit has been dug, the hole may partially fill with water, e.g. Surface water gley.
5. **Poorly drained**: Soil has poor capacity to drain excess water. The soil pit will usually fill with water as it is being dug, e.g. Ground water gley.
6. **Very poorly drained**: Site is very wet, i.e. water present at the surface, e.g. Blanket peat – low level.

8.5 Soil Cultivation

Definition: Soil cultivation describes treatments applied to the soil in order to make the soil more suitable for the natural regeneration or establishment of planted trees.

Application: The future development of the stand can be significantly influenced by soil cultivation. For example, mounding will encourage the establishment of trees due to benefits such as the raised planting position, which is free from competing vegetation.

The method of cultivation can impact on the future stand development and management. For example, from the 1950s through to the 1980s a high percentage of forests were established on peatland using double mould board ploughing. In exposed areas these stands became susceptible to windblow and in many cases this resulted in the adoption of a 'no thin' management prescription. The trafficability of the site can also be affected by the method of cultivation.

Measurement and Description: Assessment of the cultivation type present is made on the 12.62 m plot.

Attribute **Cultivation**

1. **Mounding**: Drains are opened at regular intervals with the spoil from the drain being used to create raised planting mounds (Figure 41).
2. **Ripping**: A vertical steel plate, with horizontal tines attached, is pulled through the soil at a depth of 30-60 cm with the purpose of uplifting and shattering any impermeable layers and loosening the soil.
3. **Agricultural ploughing**: An agricultural plough turns over one to two sods into which the trees are planted. The site is only partially ploughed.
4. **Pit/slit planting**. The trees are planted into a pit/slit opened with a spade. No mechanical site preparations are present.
5. **Double mould board ploughing (DMD)**: A plough with two large boards facing in opposite directions is used to turn two sods, leaving a deep drain in between the two plough ribbons (Figure 41).
6. **Single mould board ploughing (SMB)**: A plough with one large board is used to turn a sod leaving a deep drain beside the plough ribbon (Figure 41).
7. **No cultivation**: There was no soil cultivation, the trees regenerated naturally.

8.6 Site Roughness

Definition: Site roughness describes the unevenness of the surface of the terrain.

Application: The roughness of a site will dictate machine accessibility. This will be of importance in carrying out forest operations.

Measurement and Description: Assessment is made on the 12.62 m plot and is based on the occurance of obstacles on the site.

Attribute **Roughness**

1. **Even**: Even terrain, no obstacles e.g. ripping, pit planting, mounding or agricultural ploughing.
2. **Uneven**: Obstacles frequent, but do not restrict normal forest management techniques e.g. SMB or DMB. Some mounded sites may also be included if there is a high frequency of drains.
3. **Rough**: Obstacles occurring with a size and frequently that may restrict or require modifications to normal forest management techniques. e.g. deep drains, boulders, etc.

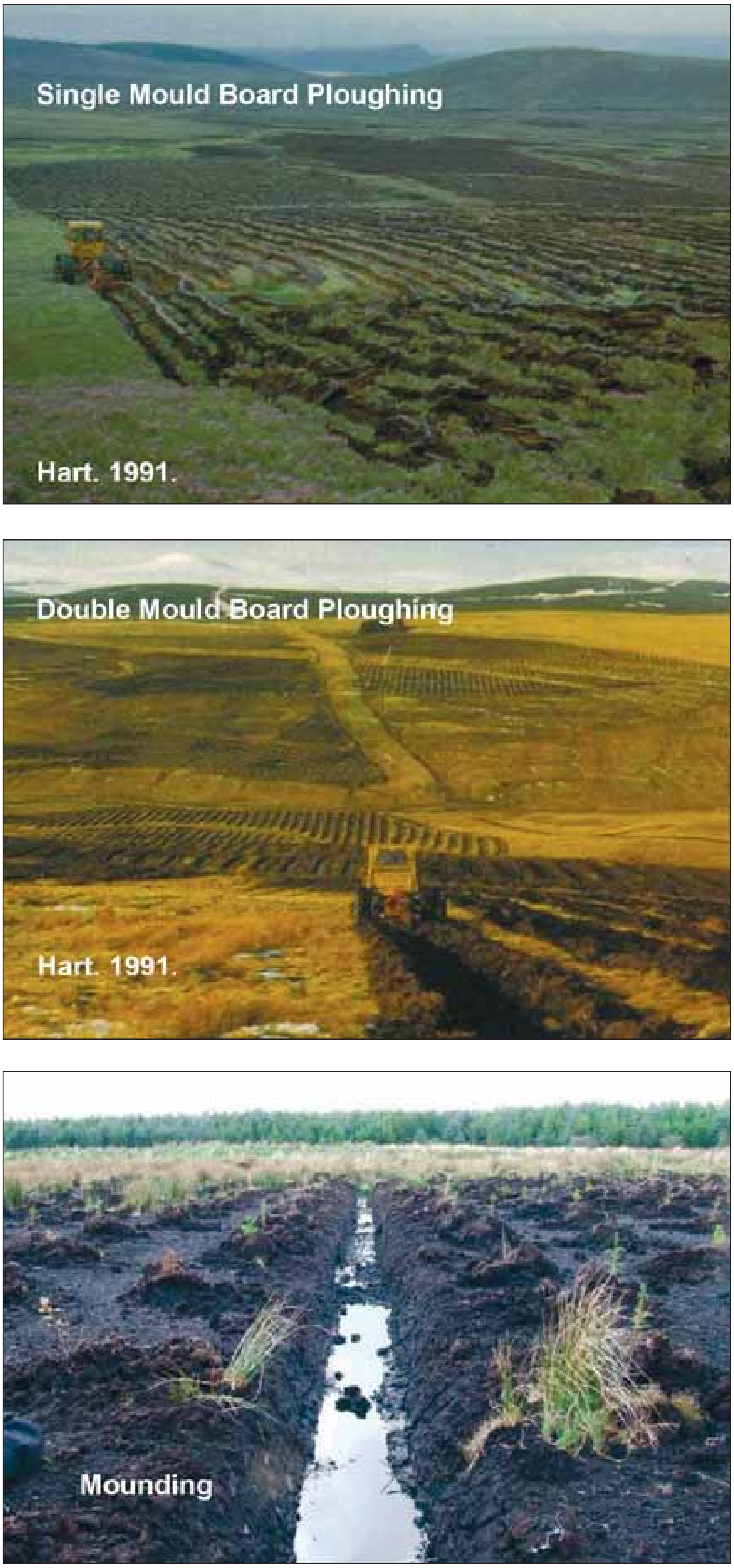


Figure 41. Soil cultivation type: SMB, DMB, mounding.

CHAPTER 9
FOREST STRUCTURE

This chapter describes the structure of the stand within the plot. The data collected are similar to the information which is collected in stand level inventories.

9.1 NATIVENESS

Definition: Nativeness describes the origin of species occurring within the plot.

Application: From an ecological point of view, the quantification of the forest estate in terms of its nativeness is of interest.

Measurement and Description: A number of different native woodland types are found across Ireland, each influenced by soil type, climate and other physical factors. Native tree species for the purpose of the NFI are listed in Table 4. The species list is based on the list of species eligible for inclusion in Ireland's Native Woodland Scheme (Anon. 1998c).

The assessment of nativeness is based on the species canopy cover in the 7 m plot. The number of tree species was used as a guide in canopy cover estimation.

Attribute **Nativeness**

1. **Native**: More than 80% of the canopy is comprised of native species.
2. **Mixed**: Between 20-80% of the canopy is comprised of native species.
3. **Non-native**: More than 80% of the canopy is comprised of exotic species.

Table 4. Native tree species for the National Forest Inventory.

Common Name	Botanical Name
Alder	*Alnus glutinosa*
Silver birch	*Betula pendula*
Downy birch	*Betula pubescens*
Ash	*Fraxinus excelsior*
Sessile Oak	*Quercus petrea*
Pedunculate Oak	*Quercus robur*
Scots pine	*Pinus sylvestris*
Hazel	*Corylus avellana*
Holly	*Ilex aquifolium*
Crab apple	*Malus sylvestris*
Aspen	*Populus tremula*
Wild cherry	*Prunus avium*
Eared willow	*Salix aurita*
Goat willow	*Salix cinerea*
Rusty willow	*Salix cinerea ssp. Oleifolia*
Rowan	*Sorbus aucuparia*
Yew	*Taxus baccata*

9.2 Forest Type

Definition: A standardised system of nomenclature was adopted to classify forests based on the composition of tree canopy cover.

Application: Classification of the forest area into broad forest types provides a useful means of assessing and interpreting the NFI results.

Measurement and Description: The categories were based on those used in the 'Inventory of Private Woodlands – 1973' (Purcell, 1973). Classification is based on the percentage canopy cover on the plot. The assessment of forest type takes place over the 12.62 m plot, but where there are two distinct forest types occurring on the plot, classification is based on the forest type where the plot centre is located.

Attribute **Forest Type**

1. **Conifer high forest**: A forest composed of at least 81% (by canopy cover) coniferous trees (CHF).
2. **Broadleaf high forest**: A forest composed of at least 81% (by canopy cover) broadleaved trees (BHF).
3. **Mixed high forest**: A forest composed of broadleaved and conifer species, the minor category making up at least 20% of the canopy (MHF).
4. **Felled-unplanted**: Forest of which at least 81% of the canopy has been felled and which has not been replanted.
5. **Felled-replanted**: Forest of which at least 81% of the canopy has been felled and which has been replanted within the last two years.
6. **Blown-unplanted**: A forest where at least 81% of the canopy has been blown and which has not been replanted.
7. **Blown-replanted**: A forest where at least 81% of the canopy was blown and which has been replanted.
8. **Burned-unplanted**: A forest where at least 81% of the canopy has been burned and it has not been replanted.
9. **Burned-replanted**: A forest where at least 81% of the canopy has been burned and which has been replanted. Evidence of burnt trees/tall stumps must be present on site.
10. **Undeveloped**: An undeveloped conifer forest is one where at least 81% of the planted trees are unlikely to ever produce a pulpwood or high forest stand.
11. **Scrub**: Broadleaf forest, usually semi-natural broadleaf forest, which is unlikely ever to become a high forest. Depending on management, scrub species may include *Quercus, Salix, Corylus* and *Ilex*.

9.3 Forest Subtype

Definition: Describes if one or more species occur.

Application: Indicates the level of species diversity.

Measurement and Description: The assessment of forest subtype is based on the 12.62 m plot. The classification of forest subtype is based on canopy cover (Table 5).

Table 5. Examples of forest type and associated subtype.

Forest type	Forest subtype	Example species	Mix Ratio
CHF	Pure	Sitka spruce	None
CHF	Mixed	Sitka spruce: hybrid larch	80:20
BHF	Pure	oak	None
BHF	Mixed	oak: beech	80:20
MHF	Mixed	oak: Scots pine	50:50

Attribute **Forest Subtype**

1. **Pure**: The dominant species occupies at least 81% of the canopy.
2. **Mixed**: A forest is rated as 'mixed' when the dominant species has a maximum of 80% canopy cover.

9.4 Even/Uneven Aged

Definition: Describes the uniformity of tree age within the plot.

Application: The even/uneven aged classification is used to assess the diversity of tree age within the national estate, which is used as an indicator for biodiversity and sustainability.

Measurement and Description: The assessment of even/uneven aged was based on the assessment of tree canopy in the 7 m plot.

Attribute **Even/Uneven Aged**

1. **Even aged**: At least 81% of the canopy is made up of trees that have an age difference of 4 years or less.
2. **Uneven aged**: At least 20% of the canopy is made up of trees that have an age difference of 5 years or more.

9.5 Forest Storey

Each storey in the plot is classified and described in relation to: storey type, growth stage, thin status, rotation type, canopy cover and stocking.

9.5.1 Storey type

Definition: Storey type classification describes the differentiation of the trees into distinct storeys.

Application: Storey type describes the vertical structure or diversity of the forest canopy.

Measurement and Description: A storey must make up at least 10% of the canopy and be not more than two-thirds of the height of the main storey before it is recorded as a separate storey. The assessment of storey type takes place on the 12.62 m plot.

Attribute **Storey Type**

1. **Main storey**: The main storey is comprised of trees, which are all largely even-aged and these trees present a regular appearance with one canopy layer.
2. **Secondary storey**: The secondary storey is comprised of trees, which are largely even-aged and these trees present a regular appearance of one canopy layer beneath the main storey.
3. **Reserved storey**: The reserved storey is the main storey in the forest for the purposes of providing amenity and shelter for game and forest management, and for natural regeneration. The numbers of trees are low and the canopy cover may not be uniform.
4. **Multi-storied**: The forest is irregular with no uniform differentiation in vertical structure due to its regeneration from multiple disturbances, such as thinning, windblow or fire. The trees may be irregular in height, age and/or species composition.

9.5.2 Growth stage

Definition: Growth stage describes the development of the storey.

Application: This is used to assess the development stage of the forest estate.

Measurement and Description: The growth stage of a storey is primarily determined based on the mean dbh of the trees in that storey. An ocular assessment of the mean dbh may be used as a guide in the classification of growth stage. The assessment of growth stage takes place for each storey on the 12.62 m plot.

Attribute **Growth Stage**

1. **Post establishment**: A recently established storey up to and including 4 years of age.
2. **Pre-thicket**: This covers storeys where the green branches are not yet touching, where the trees are older than 4 years and have a mean dbh of 30 mm.
3. **Thicket**: This covers storeys where the canopy has closed but the lower branches are mainly green. Mean dbh ranges from 31 to 70 mm.
4. **Small pole**: This covers layers where the canopy has fully closed and the lower branches are dead. It may be unthinned and the mean dbh ranges from 71 to 140 mm.
5. **Pole**: This covers storeys where the mean dbh ranges from 141 to 200 mm.
6. **Incoming high forest**: These storeys may be thinned or unthinned and the mean dbh ranges from 201 to 300 mm.
7. **High forest**: These storeys may be thinned or unthinned and the mean dbh ranges from 301 to 400 mm.
8. **Overmature**: This includes storeys that have reached very large dimensions with trees in excess of 400 mm mean dbh.
9. **Uneven aged**: Multi-storied storeys are classified as uneven aged.

9.5.3 Thin status

Definition: Describes the thinning status of the storey and the frequency of harvesting operations in the storey.

Application: Thin status indicates the intensity of forest management by assessing the number of intermediate fellings.

Measurement and Description: The classification of thin status was based on whether the storey was thinned, i.e. some of the trees were cut or harvested to provide growing space for the remaining trees.

Where no thinning had taken place an ocular assessment of the growth stage of the forest storey determined the thin status.

For example, if a storey has been thinned once then the thin status is recorded as 'First thinning'. A similar storey could also have been recorded as 'No thinning' if it was at a development stage where it could be thinned but was left unthinned.

Where a thinning had occurred, the stocking of the storey and the decomposition of stumps was used as an indicative guide to the number of thinnings. The assessment of thin status stage takes place for each storey on the 12.62 m plot.

Attribute **Thin Status**

1. **Juvenile forest:** This is a storey that has not reached the development stage for first thinning.
2. **Respacing/pre-commercial thinning:** The spacing of the storey has been altered prior to the first thin stage. Mainly associated with naturally regenerated stands.
3. **First thinning:** The storey has received a first thinning, generally identified by the presence of extraction racks, and stumps arising from selective thinning may be present. All stumps have the same state of decomposition.
4. **Second thinning:** The storey has received a second thinning, generally identified by the presence of extraction racks and stumps arising from selective thinning. The stumps are grouped into two different stages of decomposition.
5. **Subsequent thinning:** Any thinning post second thinning. Generally the storey is well opened up and the decomposition of the stumps is grouped into a number of different stages.
6. **No thinning:** No thinning has taken place in the storey, but the storey is at a development stage where thinning could have taken place.

9.5.4 Rotation type

Definition: Rotation type describes the land type on which the storey has been established and how the storey was established (i.e. artificial or naturally).

Application: Rotation type is used to identify new, artificially established plantations. This is required for the purpose of carbon stock reporting under the Kyoto agreement.

Measurement and Description: The assessment of rotation type takes place for each storey on the 12.62 m plot.

Attribute **Rotation Type**

1. **Afforestation**: Establishment of forest plantations on land that, until then, was not classified as forest. Implies a transformation from Non-Forest to Forest.
2. **Reforestation**: Establishment of a forest on temporarily unstocked lands that are considered as forest. Generally identified by the presence of stumps and deadwood on the site.
3. **Semi-natural**: Forest land where greater than 80% of the tree species regenerated naturally. Native and non-native tree species are included. This forest land may not be managed in accordance with a formal or an informal plan applied regularly over a sufficiently long period (5 years or more). It generally indicates natural succession type forests.

9.5.5 Canopy cover

Definition: The percentage of the plot area with canopy cover, by storey.

Application: Canopy cover will indicate the amount of gaps present in the forest canopy. These open areas are an important ecological refuge.

Measurement and Description: The canopy cover of each storey is recorded in 5% intervals. In stands with a young storey the potential canopy cover attainable by that storey should be assessed. In mixtures, stocking is an indicator of canopy cover, but the structure of the mixture will ultimately be the defining factor. For example, a row mixture of oak and Scots pine may have a stocking comprised of 75% oak and 25% Scots pine. However as the mixture is a row mixture the potential canopy cover on the plot will 50% oak and 50% Scots pine (Figure 42). The assessment of canopy cover takes place for each storey on the 12.62 m plot.

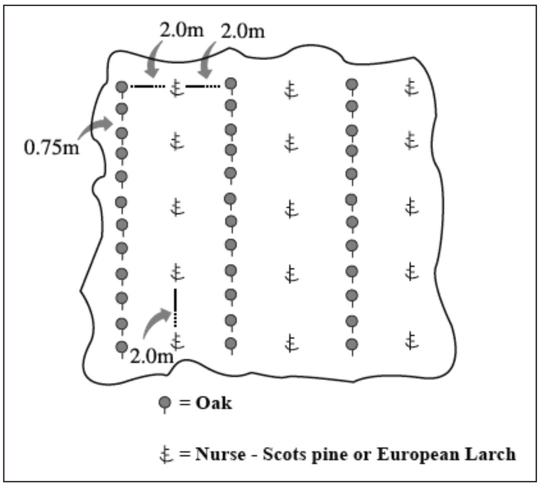


Figure 42. Canopy cover in a mixture (Anon., 2003).

9.5.6 Tree Species

Definition: Name of the tree species.

Application: One of the primary attributes used for the classification of NFI results.

Measurement and Description: All planted tree species on the 12.62 m plot are recorded. The species of naturally regenerated trees that are greater than 20 cm in height are also recorded.

9.5.7 Stocking

Definition: The stocking describes the density of trees per unit area for each species in a storey.

Application: This will indicate the density of trees, which is an important attribute in assessing the productive potential of the estate.

Measurement and Description: For each storey, all planted trees within the 7 m plot are counted. Naturally regenerated trees must be greater than 20 cm in height to be included. All dead trees are excluded from the assessment.

9.5.8 Age

Definition: Tree age is defined as the total number of years the tree has been present in the stand.

Application: Tree age is used to indicate the age structure of the national forest estate, which has implications for sustainable timber supply.

Measurement and Description: In a plantation forest, the date of planting is considered year 0 even though the tree may be 3 years old from seed. In coppiced stands the tree age is defined as the age of the stem above the root stock in years (not the age of the rootstock or the total age from seed). The assessment of tree age takes place on the 12.62 m plot. The means by which the age was determined is also recorded.

Attribute **Age Determination**

1. **Forest database**: Age is available from forest records.
2. **Increment core**: An increment core is taken from a tree outside the plot. A tree of similar dimension to those within the plot is sampled.
3. **Stump**: The rings are counted on one of the freshly cut stumps within the plot.
4. **Whorl counting**: Whorl counting was used to estimate age, primarily in young stands.
5. **Estimation**: The age was estimated based on silvicultural knowledge.

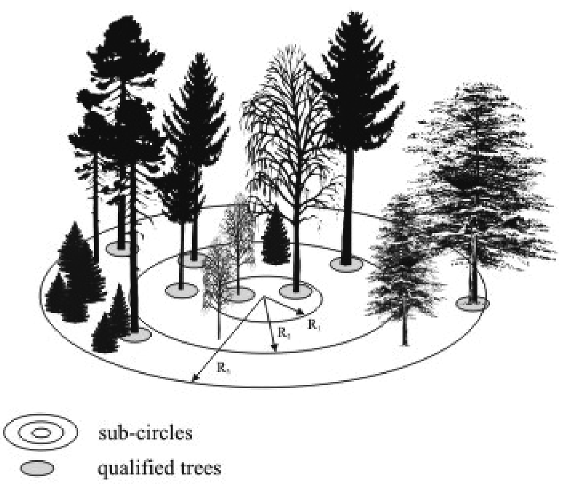
Chapter 10
Individual Trees

This section details the information that is collected on the individually mapped trees within the plot.

Definition: Individual trees are those which satisfy the threshold diameter limits for the concentric plot design.

Application: The description of individual trees depict the national forest estate in terms of tree related attributes, such as dbh and height.

Measurement and Description: Trees that are mapped vary depending on threshold tree diameters at breast height (Figure 43). All attributes defined in this chapter are for those trees that are mapped.



	R_1	R_2	R_3
Sub-circle radius (m)	3	7	12,62
Sub-circle area (m^2)	28,3	153,9	500
Treshold diameter (mm)	70	120	200

Figure 43. Concentric plot design.

10.1 Species

Definition: Tree species is identified.

Application: One of the most defining aspects of any national forest estate is the species composition. It is important for timber production, carbon sequestration and biodiversity.

Measurement and Description: The species of each tree is recorded using a species list which is presented in Appendix 6.

10.2 Tree status

Definition: Tree status indicates whether a tree is dead or alive.

Application: The segregation of standing trees into living and dead trees is used for growing stock and biomass calculation. It is also in the quantification of the standing deadwood.

Measurement and Description: Classification is based on whether or not the tree is photosynthetically active or has a living cambium. The decay status is used to indicate how long the tree has been dead.

Attribute **Tree Status**

1. **Living tree**: Tree that is photosynthetically active and has a living cambium.
2. **Recently dead tree**: Tree has died in current or previous growing season.
3. **Dead tree from the past**: The tree has been dead for more than 2 years.

10.3 Age

Definition: Age of the tree in years.

Application: The structure of the forest estate in terms of age distribution will indicate the sustainable economic, social and environmental future demands that the forest estate can meet.

Measurement and Description: The age of each tree is recorded using the same methodology as outlined in section 9.5.8.

10.4 Diameter at Breast Height

Definition: The diameter at breast height (dbh) of a tree is the stem diameter at 1.3 m from ground level.

Application: Tree dbh is one of the most important attributes in forest management. From a timber production view point, the dbh is used in the quantification of growing stock (i.e. timber volume of living trees) and for the quantification of potential products. The dbh distribution is also an important biodiversity indicator.

Measurement and Description: Trees are girthed using a diameter tape and the diameter is recorded to the nearest mm. The dbh measurement convention detailed below and Figure 45 was adapted from the Forest Mensuration: a handbook for practitioners[5] (Matthews and Mackie, 2006):

1. The dbh of a tree is measured at 1.3 m from ground level. In order to retain consistency, a pole of 1.3 m in length was used to identify the exact height of diameter measurement.

2. The diameter tape must be taut and at right-angles to the stem.

3. The measurement conventions outlined in the following subsections are adhered to when measuring dbh (Figure 44):
   a) On sloping ground, measure the diameter at 1.3 m from ground level on the upper side of the tree.

[5] ©Crown copyright material is reproduced with the permission of the Controller of HMSO and Queens printer for Scotland.

b) On uneven or ploughed ground, measure the diameter at 1.3 m from the ground level at the base of the tree.

c) Where a swelling occurs at 1.3 m above ground level, measure the diameter above and below the swelling at an equal distance from the 1.3 m point. In the case where a mean of two diameters cannot be taken, e.g. stem break, measure the diameter below the swelling at the point where it is smallest.

d&e) On leaning trees, measure the diameter at 1.3 m from ground level on the underside of the tree, at right angles to the axis of the stem.

f) On coppiced trees, measure the diameter at 1.3 m from ground level and not stool level.

g) On trees that fork below 1.3 m, treat each limb as a separate tree and measure the diameter of both trees.

h) On trees that fork at 1.3 m, treat as one tree and measure the diameter below the fork at the point where it is smallest.

i) On trees where the forks have fused up to and above 1.3 m, measure the diameter below 1.3 m where it is smallest.

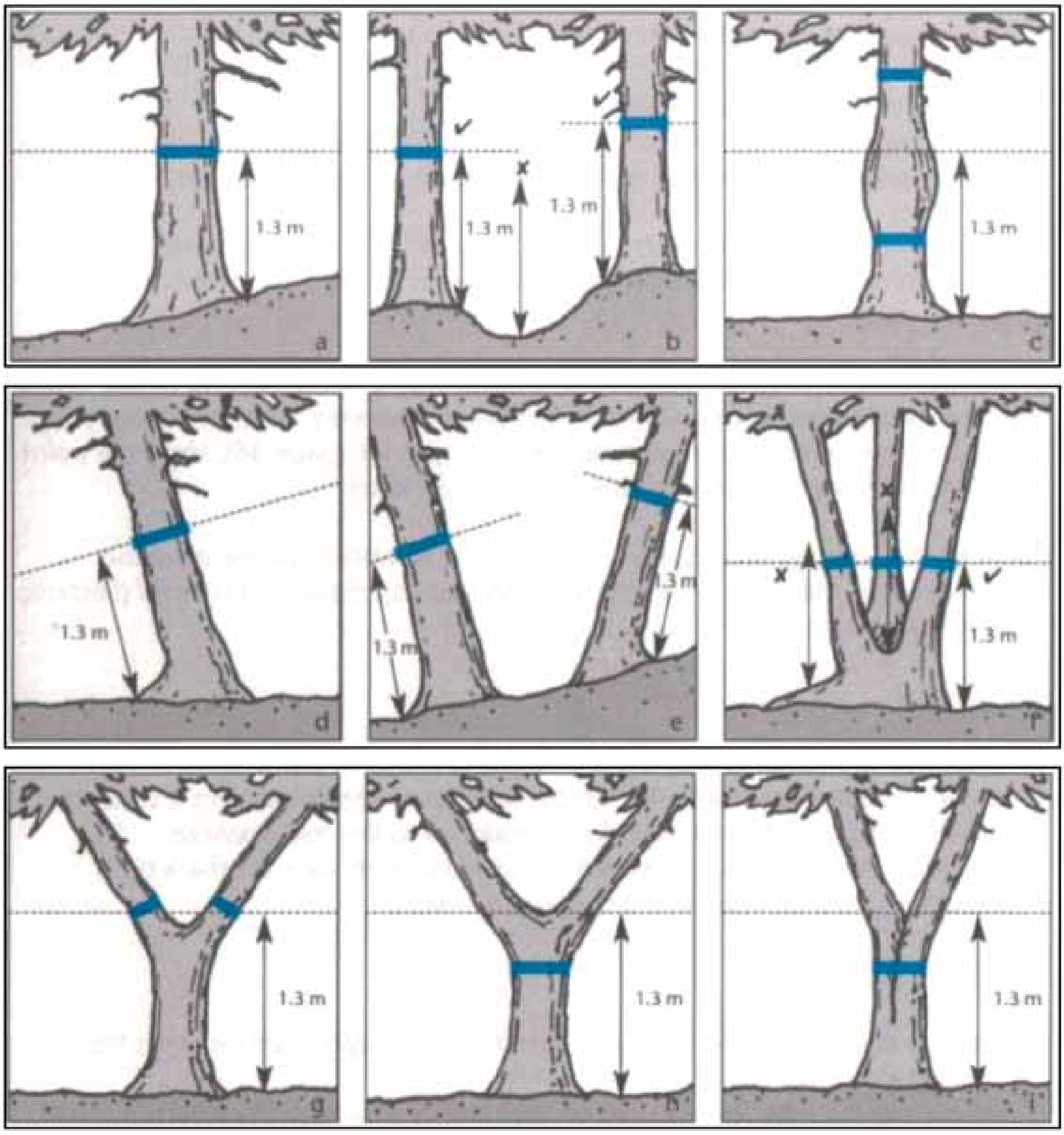


Figure 44. Dbh measurement convention.

10.5 Dbh Height

Definition: The height at which dbh is measured.

Measurement and Description: This is usually recorded at 1.3 m. In some circumstances, as detailed in Figure 44, it is permissible to record the diameter at another height, provided that the height at which the diameter was measured is recorded.

10.6 Tree Height

Definition: The height of a tree is the vertical distance between the base of the tree and its tip (Figure 45).

Application: Tree height is an important variable in forest management, as it allows the quantification of tree growth and volume. The range of tree heights across the plot will indicate the diversity in the canopy structure.

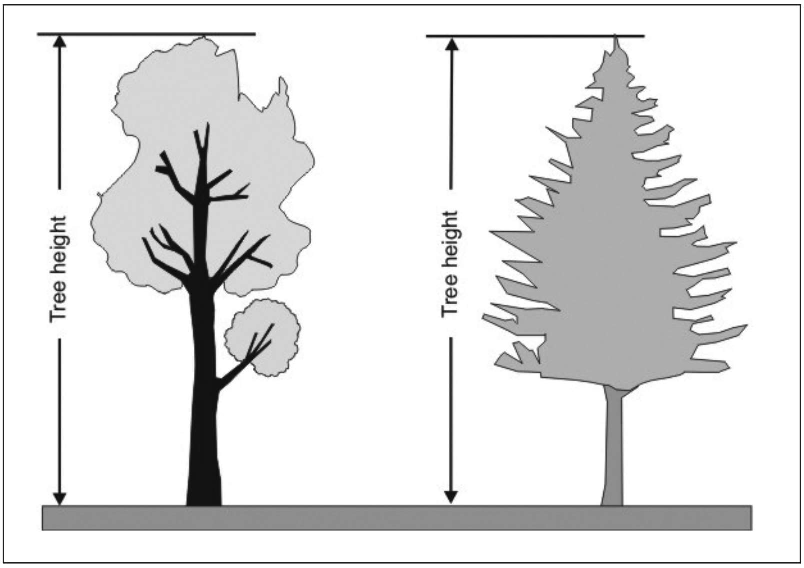


Figure 45. Tree height.

Measurement and Description: Height is measured to the nearest cm using a laser rangefinder equipped with clinometer.

The selection of trees for which to obtain height measurements is based on the assessment of the dbh range for each tree species on the plot. If possible, seven uniform dbh classes per species are created from which height sample trees will be selected, one for each class (Figure 46). Trees with crown/leader damage, or forked below 1.3 m, are excluded from the selection process.

In pure stands, a maximum of seven height measurements are taken across the dbh distribution. In mixed stands, a maximum of seven height measurements are taken for each species occurring on the plot. If there are less than seven trees for any particular species, then all of the trees are sampled for height.

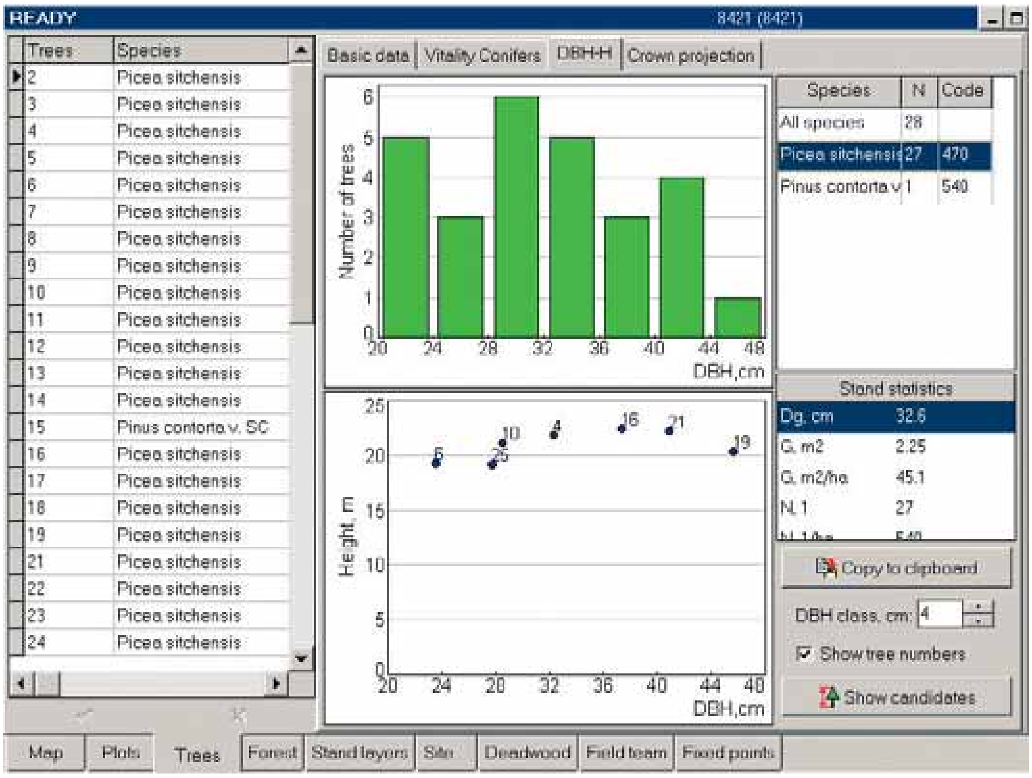


Figure 46. Field-Map™ representation of diameter classes and associated sample height trees.

In order to obtain a precise height measurement, the following conventions should be observed:

1. Measurement taken at a distance of 1.5 times the height of the tree.
2. On leaning trees, height measurement may be prone to error (Figure 47). Measurement takes place perpendicular to the direction of lean or as demonstrated in Figure 48. Trees with excessive lean are unsuitable for height measurement.
3. Height measurement on broadleaf trees should be to the true total height. (Figure 49). The edge of side branches should not be used as the point of sight.
4. On sloping ground, measurements should be taken across the slope. If this is not possible, measurements can take place from a position uphill of the tree.

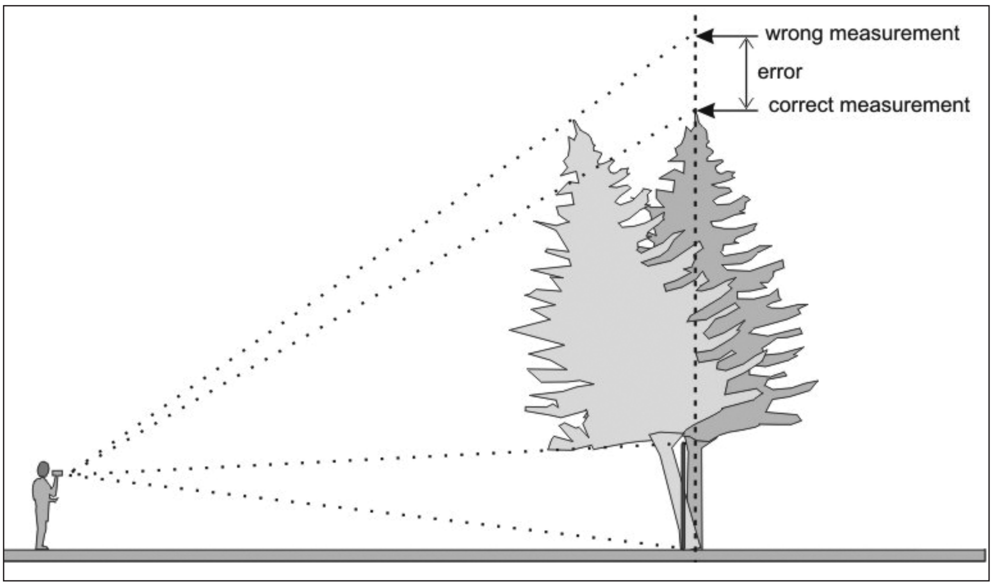


Figure 47. Height measurement error on leaning trees.

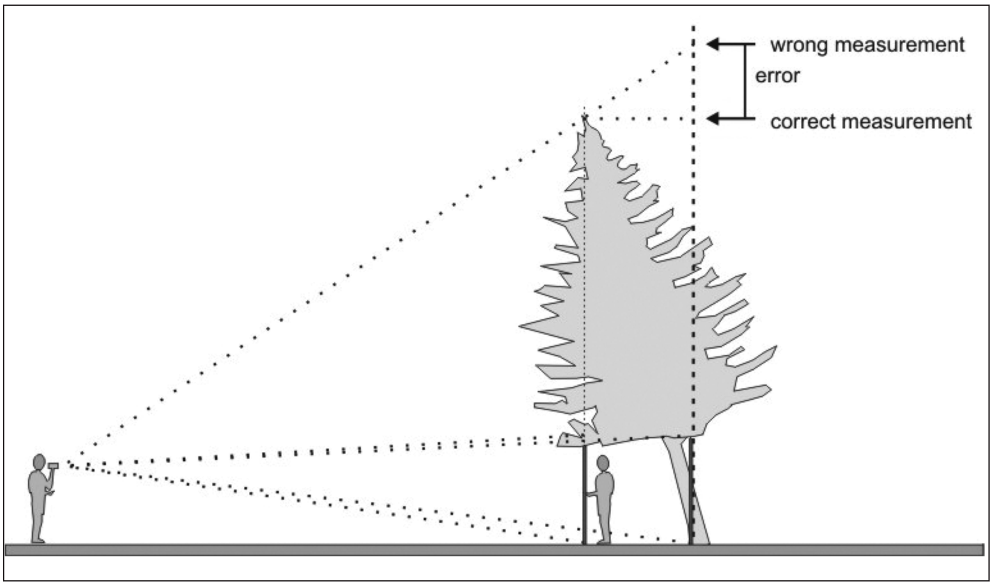


Figure 48. Height measurement on slanted trees.

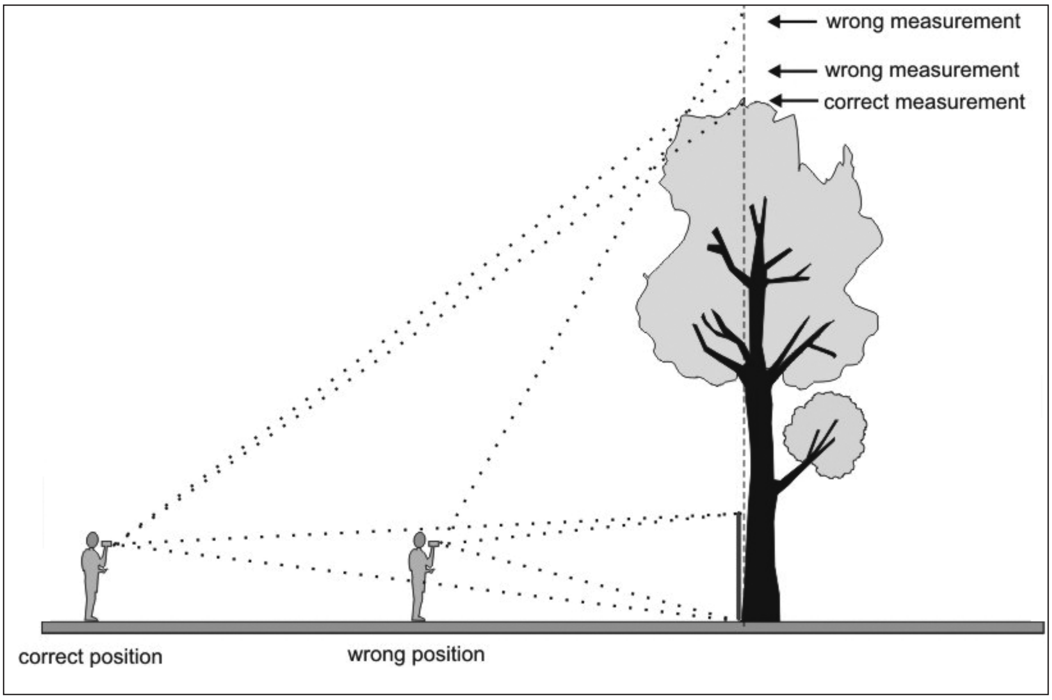


Figure 49. Height measurement on broadleaf trees.

10.7 Crown Measurements

This section details the crown attributes recorded for each tree: position of the living and dead crown base and crown projection.

10.7.1 Position of living and dead crown base

Definition: The vertical distance between the ground level and the bases of the living and dead crowns.

Application: The size of a tree crown is strongly correlated with tree growth. The crown displays the leaves/needles to allow the capture of radiant energy for photosynthesis. Thus, measurements of the tree crown are made to assist in the quantification and understanding of tree growth. These measurements also facilitate the assessment of crown biomass.

Measurement and Description: The living crown base is the lowest whorl of live branches. Epicormic shoots are not considered in regard to the live crown base. Determination of the live crown base on broadleaf trees is detailed in Figure 50. The height of the living crown base on each height sample tree is recorded to the nearest cm. The dead crown base is the lowest whorl of dead branches.

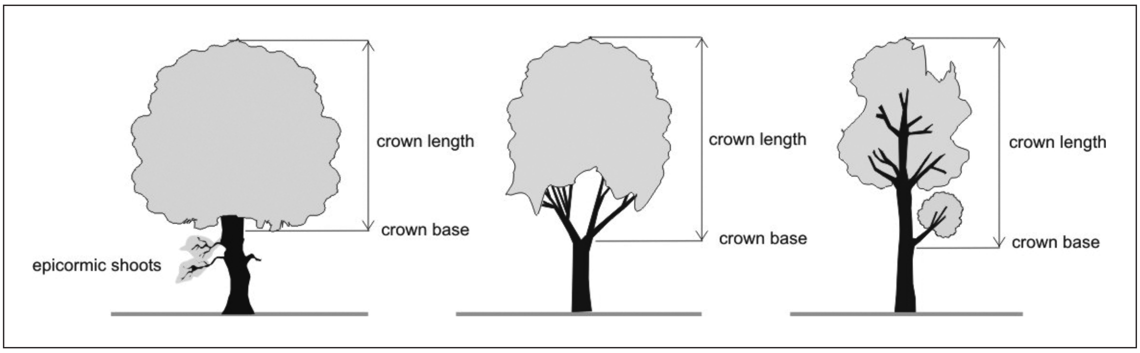


Figure 50. Crown base measurement on broadleaf trees.

10.7.2 Crown projection

Definition: Crown projection is the projection of the crown onto a plane (i.e. horizontal) view.

Application: In the previous section, the measurement of the position of the live and dead crown base was outlined, while in this section the measurement of the distribution of the crown around the stem of the tree is specified. These three measurements allow the biomass of the crown to be estimated.

Measurement and Description: The projection of the crown (m^2) onto a plane (i.e. horizontal) view is measured for each height sample tree. It is determined by indicating on the ground exactly where the edge of the crown is directly over-head. A minimum of four positions are mapped to gain an accurate representation of the crown projection (Figure 51). The position of the points are recorded on the local Cartesian coordinate system using a combination of the laser rangefinder and electronic compass.

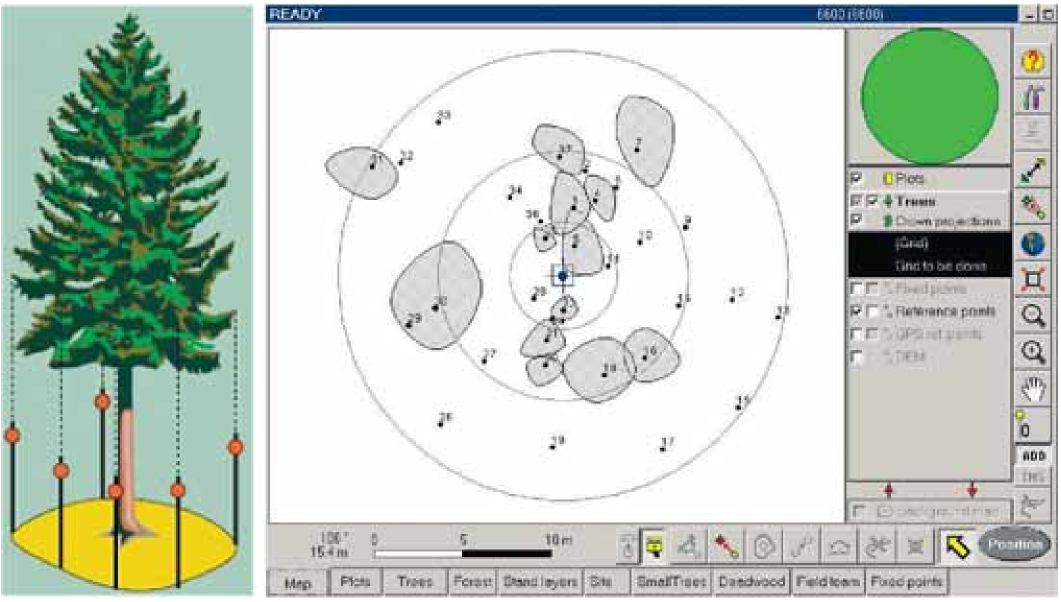


Figure 51. Representation of crown projections taken on a plot.

10.8 OTHER STEM DIAMETER MEASUREMENTS

This section describes the upper stem and base diameter attributes.

10.8.1 Upper stem diameter

Definition: The diameter of a tree stem, recorded at a height equal to 1/3 of the tree height.

Application: Obtaining an upper diameter measurement facilitates a more precise estimation of volume, as it provides additional information on the shape of the stem.

Measurement and Description: Trees included are randomly selected from height sample trees that have a dbh ≥200 mm.

In pure stands, a maximum of five upper stem diameters are measured. In mixed stands, a maximum of five measurements are taken for the primary species, with a maximum of three measurements taken for each subsequent species present. Broken or bent trees are excluded from selection. Also excluded are heavily branched trees, due to poor stem visibility. An upper stem diameter is recorded (mm) at a height equal to 1/3 of the total tree height. This is determined using an electronic range finder and remote diameter scope (Figure 52).

If there is some obstruction on the stem (e.g. whorl of branches) at the measuring height that does not allow the measurement, then the measurement may be taken directly above or below the obstruction.

Attribute **Upper Stem Diameter**

1. **Diameter**: The diameter in mm is recorded.
2. **Height**: The height (cm), at which the upper stem diameter is measured, is recorded.

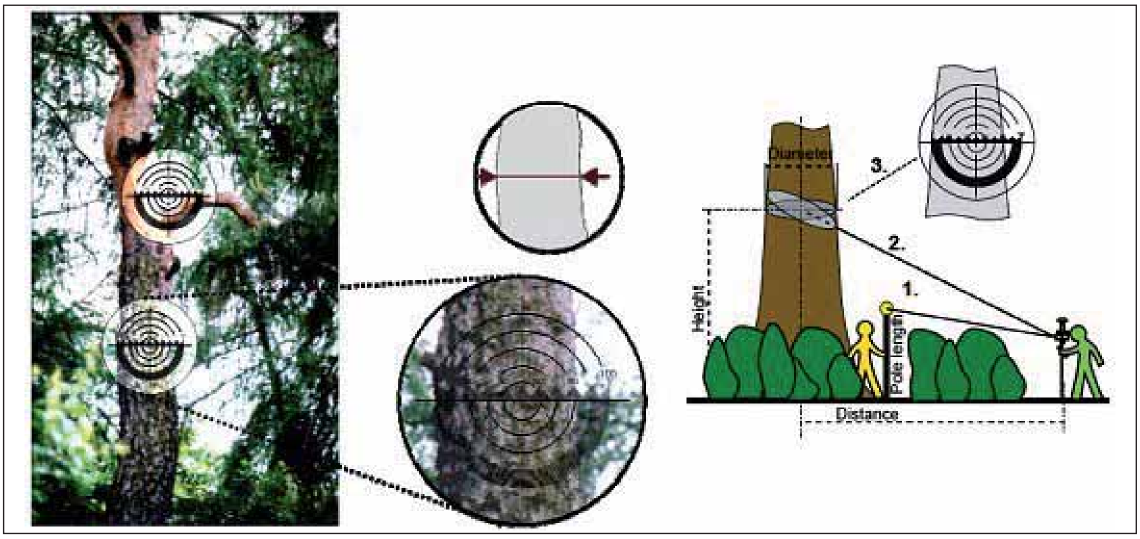


Figure 52. Diameter measurement at one third of the tree height.

10.8.2 Base diameter

Definition: Base diameter is the diameter of the stem measured at a height above ground level equal to one third of the diameter at ground level.

Application: The combination of the base and upper stem diameter measurement facilitates a more precise estimate of volume, as it provides additional information on the shape of the stem.

Measurement and Description: The base diameter is measured on each tree which has been sampled for upper stem diameter. The height above ground level at which diameter is measured is equal to one third of the base diameter at ground level (Figure 53). For example if the diameter at ground level is 66 cm then the base diameter is measured at a height of 22 cm from ground level. Base diameter is measured using a diameter tape and is recorded in mm.

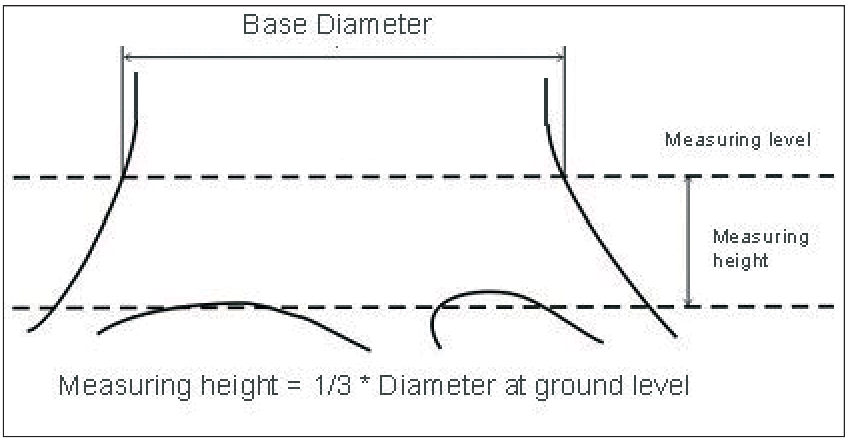


Figure 53. Base diameter.

10.9 Tree Layer Descriptions

Tree layer description attributes define the vertical position of a tree's crown and also describe competition between tree crowns. Tree layer and social status (IUFRO) describe the vertical position, while social status (Kraft) describes the vertical position and crown competition. Crown competition is also described by the attribute crown shape.

10.9.1 Tree layer

Definition: The distinctive layer in which a tree's crown occurs.

Application: Tree layer describes the differentiation of the vertical crown structure into distinctive layers.

Measurement and Description: A tree layer may arise from a natural (e.g. fire) or man-made (e.g. clearfell) disturbance where trees develop as a uniform cohort.

Attribute **Tree layer**

1. **Main layer**: The tree occurs in the main layer.
2. **Secondary layer**: The tree occurs in the secondary layer, beneath the main layer.
3. **Reserved layer**: The tree occurs above the main layer in a reserved tree layer and is retained for the purpose of amenity, forest management, game management or natural regeneration.

10.9.2 Social status (IUFRO)

Definition: Social status (IUFRO) describes the vertical position of the trees within the plot relative to the highest stand layer.

Application: This indicates the vertical position of trees within the stand, thereby indicating the stage of tree development.

Measurement and Description: The position of the tree in relation to the crown position of the highest trees is specified (Figure 54).

Attribute **Social Status (IUFRO)**

1. **Upper**: The height of the tree is at least two-thirds the height of the highest trees.
2. **Middle**: The height of the tree is at least one-third the height of the highest trees.
3. **Bottom**: The height of the tree is lower than one third of the highest trees.

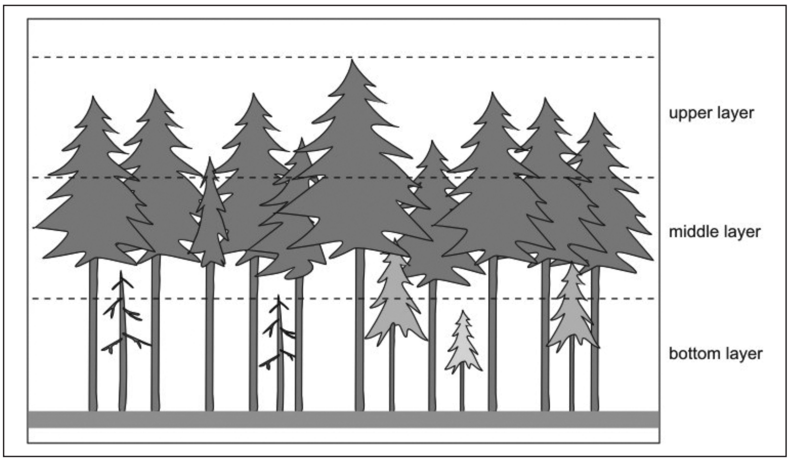


Figure 54. Social status (IUFRO).

10.9.3 Social status (Kraft)

Definition: Social status (Kraft) describes the relative position of the trees in terms of their vertical distribution and their inter-relationships.

Application: This indicates the level of competition within the stand, thereby indicating the stage of trees development.

Measurement and Description: Within each stand, trees can be differentiated into crown classes as competition for light, nutrients and moisture sets in (Figure 55). As the weaker trees are crowded out by their more vigorous associates, their crowns become increasingly misshapen and restricted in size. Unless freed by random events or deliberate thinnings, such trees gradually become overtopped and die. This differentiation is described by assigning a social status to individual trees (Smith, *et al.*, 1997). The social status of the individual trees are recorded.

Attribute **Social Status (Kraft)**

1. **Dominant trees**: Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the sides; larger than the average trees in the stand and with well developed crowns.
2. **Main co-dominant**: Trees with crowns present in the general level of the crown cover and receiving full light from above and partly from the sides; larger than the average trees in the stand and with crowns well developed but possibly somewhat crowded on the sides.
3. **Co-dominant trees**: Trees with crowns forming the general level of the crown cover and receiving full light from above but comparatively little from the sides; usually with medium-sized crowns more or less crowded on the sides.
4. **Sub-dominant trees**: Trees shorter than those in the three proceeding classes but with crowns extending into the crown cover formed by co-dominant and main co-dominant trees; receiving a little direct light from above but none from the sides; usually with small crowns considerably crowded on the sides.
5. **Suppressed trees**: Trees with crowns entirely below the general level of the crown cover, receiving no direct light either from above or from the sides.

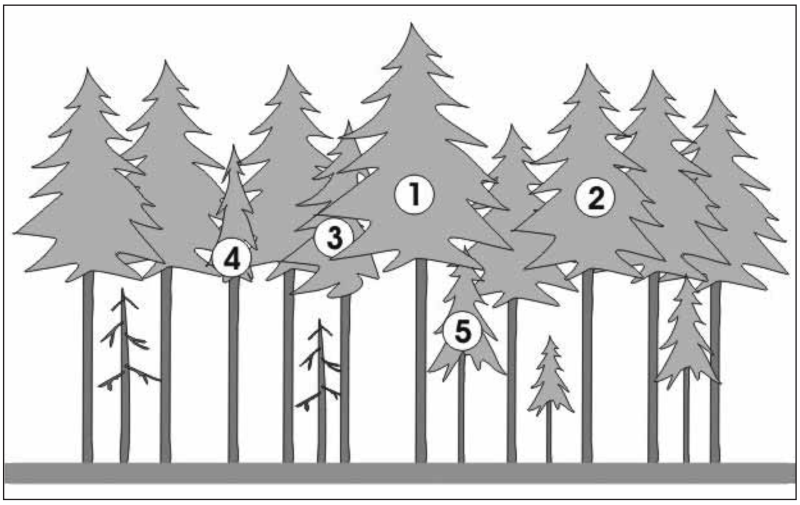


Figure 55. Social status (Kraft).

10.9.4 Crown shape

Definition: The distribution of the crown around the axis of the stem.

Application: This indicates the level of competition encountered by the tree, thereby indicating the stage of stand development.

Measurement and Description: The internal competition between neighbouring trees affects the shape of the crown, potentially resulting in an irregular crown which could be offset to one or more sides. In a symmetrical crown, the branches and foliage are distributed evenly around the stem. Assessment is based on quantifying the distribution of the crown around the axis of the main stem. Apportioning the area surrounding the stem into four parts will aid in the classification process (Figure 56).

Attribute **Crown Shape**

1. **Regular**: The distribution of the crown around the axis of the main stem is symmetrical.
2. **Slightly one-sided**: The distribution of the crown around the axis of the main stem is slightly one-sided.
3. **Strongly one-sided**: The distribution of the crown around the axis of the main stem is strongly one-sided.

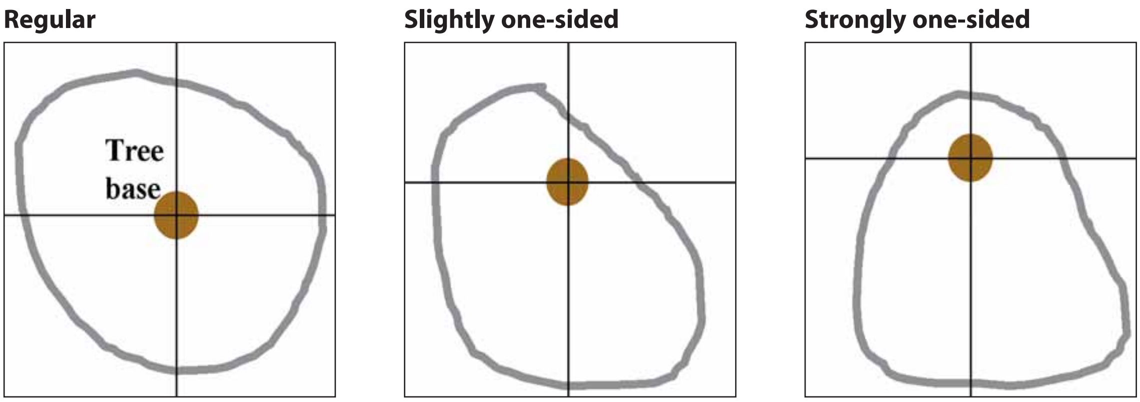


Figure 56. Crown projection illustrating crown symmetry around the stem.

10.10 Branching

In this section, two attributes related to tree branching; branchiness and pruning, are described.

10.10.1 Branchiness

Branchiness: Describes the relative size and number of branches present on a tree.

Application: The size and number of branches impact on timber quality. This classification describes the level of branching on the individual trees.

Measurement and Description: Branchiness is defined in relation to the position, number and size of living and dead branches and is assessed on the first 6 m of the stem. Pruned trees are not assessed for branchiness. Classification of branchiness is based on three factors:

- **Branch frequency**: Branch frequency relates to the quantity of branches along the stem.
- **Branch diameter in relation to stem diameter**: The branch diameter at the point of branch entry is assessed relative to the stem diameter.

- **Species**: The classification should be species specific, as what may be considered medium branching in one species may be considered light branching in another, e.g. medium branching in *Picea sitchensis* will more than likely be considered light branching in *Pinus contorta*.

Attribute **Branchiness**

1. **Light**: Small diameter branches or medium sized branches which occur infrequently. This may occur on trees that are growing at high densities or in stands where an understorey is present.
2. **Medium**: Branches are present in a quantity and size that is deemed not to be either light or heavy.
3. **Heavy**: Large diameter branches which occur frequently. Common where a tree has had an unrestricted growing space e.g. an edge tree.

10.10.2 Pruning

Definition: Pruning is the artificial removal of branches from the stem of a tree.

Application: A problem with branches is that they form knots, which are a common defect of wood. Branches do not necessarily fall off when they cease to function. Some may fall off and act as access routes for infection by rotting fungi. The presence of a dead knot is more serious than a live knot, as the wood elements laid down around dead branch wood have no connection with the dead material (Smith *et al.*, 1997). Dead knots are a serious defect in sawn timber as they are liable to fall out when dried. Artificial pruning removes branches from the lower, more valuable portion of the stem.

Measurement and Description: The presence or absence of pruning is classified for each tree.

Attribute **Pruning**

1. **Low pruned (up to 3m)**: Branches have been artificially removed up to a height of 3m.
2. **High pruned (more than 3m)**: Branches have been artificially removed up to a height greater than 3 metres
3. **No pruning**: No pruning has been carried out.
4. **Undeterminable**: Difficult to determine if pruning has been carried out.
5. **Brashed**: Tree has been brashed to provide access. Normally occurs on one side of the trees in straight lines through the forest.

10.11 Stem Form

The stem form is described in terms of: tree fork, stem straightness and shaping.

10.11.1 Tree fork

Definition: Division of the main stem into two or more stems.

Application: The presence or absence of a fork starting below 5 m from ground level is noted, as this will impact on the merchantable assortment volumes recovered after harvesting.

Measurement and Description: Trees classified as being forked must have at least two main stems occurring below 5 m, where the diameter of one stem is at least half the diameter of the other (Figure 57). If more than one fork is present, the lowest occurring fork is noted.

Attribute **Stem Fork**

1. **No fork**: There is no fork present on the tree below 5 m.
2. **Fork below 1.3 m**: There is forking present on the tree below 1.3 m in height.
3. **Fork 1.3-3 m**: There is a fork present 1.3 m and 3 m.
4. **Fork 3-5 m**: There is a fork present between 3 m and 5 m.

Figure 57. Forked tree.

10.11.2 Stem straightness

Definition: Stem straightness describes a tree's stem in terms of straight log lengths.

Application: The assessment of stem straightness is carried out in order to provide an indication of potential end products, which could be produced from the stem. For example, a large diameter log, if straight, has multiple end uses, but if crooked the end uses are limited. Stem straightness assessment will allow the degree of down grading to be quantified, thereby giving a reliable estimate of potential end products and value.

Measurement and Description: A prototype method of assessing stem quality in standing Sitka spruce trees was developed in the early 1990s and is described by Methley (1998). Stem straightness was identified as the most important single factor affecting log quality in Sitka spruce. Although knots were acknowledged to have a significant impact on log and sawn timber quality, they were not considered the primary cause of downgrade in spruce logs. An assessment method based on a visual estimate of straight log lengths in the first 6 m of the stem was devised. The assessment of straightness is categorised into one of seven categories for all tree species. These categories are illustrated in Figure 58, which is an adaptation of a figure presented in MacDonald *et al*. (2001).

Attribute **Stem Straightness**

1. **Greater than or equal to 5 m**: A log with a minimum length of 5 m.
2. **One 4-5 m log**: A log with a minimum length of 4m and maximum length of 4.9 m.
3. **One 3 m and one 2 m log**: One log 3 m in length and one log 2 m in length.
4. **One 2-3 m log**: A log with a minimum length of 2 m and maximum length of 2.9 m.
5. **Two 2 m logs**: Two logs with a minimum length of 2 m.
6. **One 2 m log**: A log with a minimum length of 2 m.
7. **No straight logs**: There are no straight logs present.

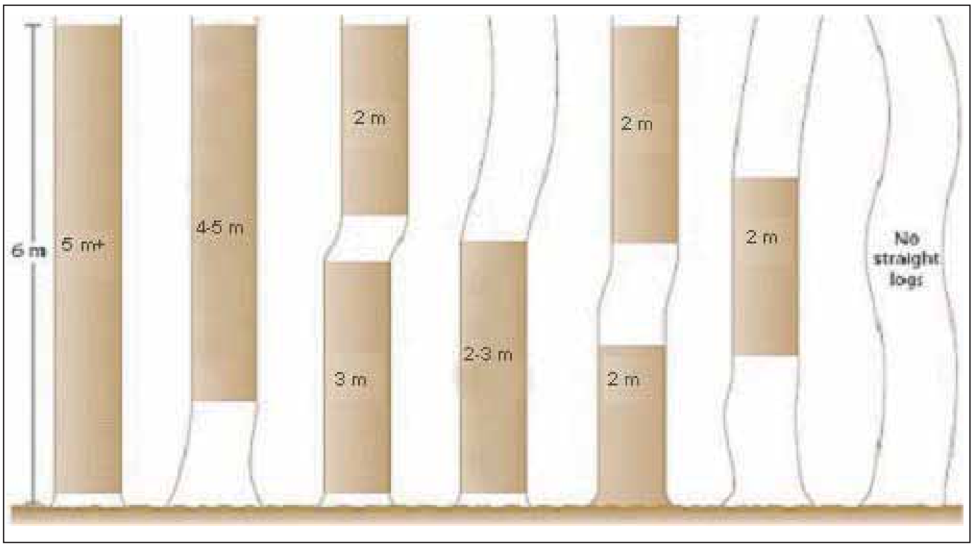


Figure 58. Assessment of stem straightness.

10.11.3 Shaping

Definition: Shaping is the removal of competing tree leaders and side branches in order to improve the quality of broadleaf tree form.

Application: The classification will identify broadleaf tree species which are intensively managed for timber production.

Measurement and Description: The occurrence of shaping, where visible, is recorded.

10.12 Stem Rot

Definition: Stem rot is the discoloration softening, and often disintegration of plant tissue as a result of fungal or bacterial infection.

Application: The presence or absence of rot will impact on the health and vitality of a forest. This can impact on harvesting returns and also indicate the level of biodiversity. Some indicators of rottening are illustrated in Figure 59.

Measurement and Description: The occurence and type of stem rot are recorded.

Attribute **Stem Rot**

1. **No rot**: There are no signs of rot on the tree.
2. **Inner rot**: An inner section of the tree has suffered rot, which may be identified by butt-swelling and resin exudation.
3. **Stem surface rot**: Rot is present at the stem surface.
4. **Stem cavity**: The rot has created a stem cavity.

Figure 59. Signs of tree rot: stem cavity, bracket fungus and mushrooms.

10.13 Stem and Peeling Damage

Definition: Damage to stems caused by biotic (e.g. deer), abiotic (e.g. wind) or by mechanical factors (e.g. harvesting or extraction machines) (Figures 60 and 61).

Application: Provides information on the health and vitality of the forest estate. There are also economic consequences due to downgrade.

Measurement and Description: Abrasion of the bark resulting in a loss of bark/vascular cambium/wood from the stem surface. In the case of more than one instance of damage, it is the cumulative effect that is assessed. The degree and age of damage present on the stem is recorded.

Attribute **Stem and Peeling Damage**

1. **No damage**: Damage is not present.
2. **Damage up to 1/8 of circumference**: Up to 1/8 of the stem circumference has been damaged.
3. **Damage to more than 1/8 of circumference**: More than 1/8 of the stem circumference of the tree has been damaged.

Attribute **Age of damage**

1. **New damage**: Damage took place within the current or the last growing season and is still relatively fresh.
2. **Old damage**: The damage took place 2 or more growing seasons ago.
3. **Repeated damage**: There is a mixture of old and new damage.

Figure 60. Stem damage.

Figure 61. Peeling damage.

10.14 Root Damage

Definition: Damage to a tree's roots can be caused by biotic (e.g. deer), abiotic (e.g. wind) or by mechanical (e.g. harvesting or extraction machines) factors.

Application: These injuries may cause instability, can act as a route for infectious diseases and can cause a reduction in timber quality.

Measurement and Description: Root damage is assessed where visible on all individual trees.

Attribute **Root damage**

1. **No root damage**: There is no visible root damage present.
2. **Roots damaged**: There is root damage present.

10.15 Tree Break

Definition: Tree break details the presence or absence of defects along the bole or in the crown of the tree.

Application: These injuries may cause a reduction in the quality and quantity of timber recovered at harvest.

Measurement and Description: Wind is the primary cause of these tree break damage. All categories of damage affect the quality, quantity and future value of timber. See Figure 62 for examples of the categories.

Attribute **Tree Break**

1. **No break**: There are no signs of the breakage or damage listed below.
2. **Tree top break**: Less than two year's leader growth has been broken.
3. **Crown break**: The crown of the tree is broken, more severe than tree top break, but still occurring in the live crown.
4. **Stem break**: The stem below the live crown has broken or snapped. Note, that remaining stem must be greater than 1.3 m in height to be a tree, otherwise it is a stump.
5. **Bent, curved or slanted tree**: The tree is bent or slanted, e.g. basal sweep or partially windblown tree. The tree is not lying on the ground.
6. **Substitute tree top**: The tree top has been broken but has been replaced by a new leader. This results in a kink in the stem otherwise described as a 'bayonet' feature.
7. **Lying living tree**: This is where the tree is lying on the ground and is still living, i.e. windblown tree. Trees that are obviously supported by another tree are also included in this category.

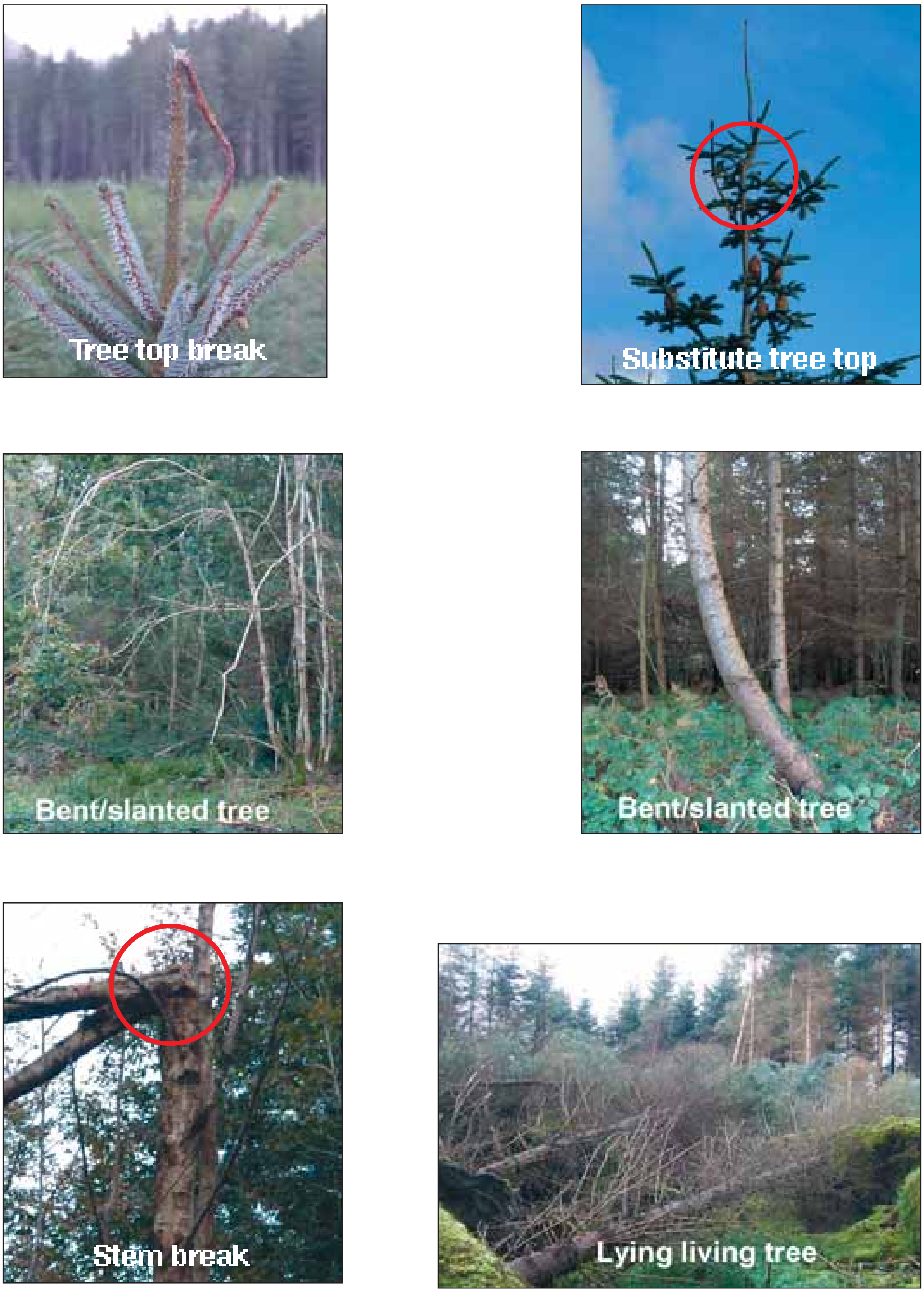


Figure 62. Tree break categories.

10.16 Other Damage

Definition: This includes any other factors which cause damage to trees.

Application: Other damage which impacts on tree growth and which has not been defined in other sections in this chapter.

Measurement and Description: If there is damage to individual trees present in the plot, determine the primary cause and classify accordingly.

Attribute **Other Damage**

1. Insect
2. Fungus
3. Deer
4. Squirrel
5. Vole
6. Rabbit, hare
7. Poor drainage
8. Poor planting stock
9. Exposure
10. Elevation
11. Storm, windbreak
12. Crown competition
13. Fire
14. Frost
15. Drought
16. Salt
17. Air pollution
18. Herbicide
19. Poor nutrition
20. pH extreme
21. Unsuitable site
22. Other damage

10.17 Tree Vitality

Tree vitality is described using the following five attributes: vitality, growth tendency, defoliation, discolouration and broadleaf vitality.

10.17.1 Vitality (IUFRO)

Definition: Tree vitality describes the capacity of a tree to survive and grow.

Application: The assessment of tree vitality is an important indicator of forest health.

Measurement and Description: Vitality is assessed for all individual trees.

Attribute **Vitality**

1. **Very Biotic**: Vigorous growth with little or no defoliation.
2. **Normal**: Regular tree with no serious defoliation or damage present in the crown.
3. **Slimsy**: Poorly performing tree. Serious defoliation damage to the crown.

10.17.2 Growth tendency

Definition: Growth tendency describes the annual height increment in the 2 years preceding the date of assessment.

Application: This is used to describe the rate of height growth in the forest estate.

Measurement and Description: Growth tendency is assessed for all trees.

Attribute **Growth Tendency**

1. **Increasing**: Annual height increment is increasing.
2. **Constant**: No differentiation in annual height growth for the two preceding years.
3. **Decreasing**: Annual height increment is decreasing or there is no height increment.

10.17.3 Tree defoliation

Definition: Tree defoliation is the abnormal loss of tree foliage.

Application: This is an important indicator of forest health and vitality.

Measurement and Description: Defoliation may occur as a result of environmental or man-made causes, such as wind, heat, drought, early frost, chemicals, insects or diseases (Figure 63).

Defoliation is assessed on the spruce and pine trees for which height measurements were recorded. A percentage defoliation is recorded. Defoliation is assessed twice, first for the whole tree and then for the upper one third of the tree. The assessed tree is compared to how a healthy tree would appear in the same growing conditions.

Figure 63. Defoliation on Sitka spruce.

10.17.4 Tree discolouration

Definition: Deviation from the usual colour of the living foliage for that species; dead or dying needles/leaves are excluded.

Application: Discolouration of a tree's foliage signifies that the tree is under stress, which could be due to factors such as nutrient deficiency or water-logging (Figure 64). This is an important indicator of the health and vitality of the forest estate.

Measurement and Description: Assessment is only made on spruce and pine trees that have been sampled for height. The colour change and the trend of discolouration are recorded.

Figure 64. Discolouration in Sitka spruce.

Attribute **Discolouration Type**

1. **Yellowing**: The foliage has a yellow appearance.
2. **Browning**: The foliage has a brown appearance.

Attribute **Discolouration Trend**

1. **From old to young**: The intensity of discolouration is more extreme in the older foliage, with a more limited occurrence in the newer foliage.
2. **From young to old**: The intensity of discolouration is more extreme in the young foliage, with a more limited occurrence in the older foliage.
3. **Evenly young and old**: Foliage age has no impact on the discolouration trend.

10.17.5 Broadleaf vitality

Definition: Broadleaf vitality describes the capacity of a broadleaf tree to continue to grow in a healthy condition.

Application: This in an important indicator of vitality in the broadleaf forest estate.

Measurement and Description: Assessment is made on oak and beech trees that have been sampled for height.

Attribute **Broadleaf Vitality**

1. **Undamaged**: Tree is growing healthily.
2. **Weakened**: Tree growth is slightly affected due to minor stress, such as minimal stem damage.
3. **Moderately damaged**: Tree growth is moderately affected due to considerable stress, such as prolonged periods of drought or defoliation caused by insect infestation.
4. **Strongly damaged**: Tree is under severe stress, significantly affecting tree growth/survival. High levels of defoliation and/or dieback. Serious crown damage may also be present.

Chapter 11
Small Trees

Definition: Trees classified as small trees, include all planted trees less than 7 cm dbh, and naturally regenerated trees greater than 20 cm in height and less than 7 cm dbh.

11.1 Presence of an Overstorey

Definition: An overstorey is a storey of trees that occurs above a regenerating secondary storey of small trees.

Application: This attribute identifies the portion of the forest estate regenerating beneath an overstorey (Figure 65).

Measurement and Description: Assessment is carried out on the 12.62 m plot.

Attribute **Presence of an Overstorey**

1. **Absent**: There is no overstorey present, i.e. afforestation, or reforestation after a clearfell.
2. **Present**: There is an over storey present, i.e. trees from a previous rotation were retained. An example of this is the continuous cover, shelterwood system.

Figure 65. Regeneration below forest stand and free area occurrence of regeneration.

11.2 Origin of Regeneration

Definition: Origin of regeneration describes whether the tree was artificially introduced or else regenerated naturally.

Application: This is used in the assessment of natural regeneration in the forest estate.

Measurement and Description: Assessment is carried out on the 7 m plot.

Attribute **Origin of Regeneration**

1. **Natural regeneration, planting <20%**: Most of the canopy, i.e. ≥80%, is the result of natural regeneration. Planted trees make up <20%.
2. **Natural regeneration, planting 20-50%**: The majority of small tree canopy, 50-80%, is a result of natural regeneration. Planted trees make up a minority, 19-49%.
3. **Planting, Natural regeneration 20-50%**: The majority of small tree canopy, 50-80%, is a result of planting. Natural regeneration makes up a minority, 19-49%.

4. **Planting, natural regeneration <20%**: Most of the tree canopy, i.e. ≥80%, is the result of planting. Natural regeneration makes up <20%.

11.3 Distribution of Regeneration

Definition: The distribution of small trees in terms of spatial arrangement.

Application: The spatial arrangement is of interest due to site access and management considerations during operations such as thinning (Figure 66).

Measurement and Description: Assessment is carried out on the 12.62 m plot.

Figure 66. Distribution of regeneration.

Attribute **Distribution of regeneration**

1. **Regular**: The trees are distributed uniformly, e.g. 2 m x 2 m square spacing.
2. **Group**: The trees are distributed in groups.
3. **Random**: The trees are distributed randomly with no particular pattern.

11.4 Species Structure

Definition: Species structure describes the species distribution of small trees. If there is more than one species present, the plant distribution may follow a predefined structure e.g. planting in groups.

Application: The planting of trees in groups is a common feature in plantations recently established in Ireland (Figure 67). Assessment is carried out on the 12.62 m plot.

Measurement and Description: Assessment is carried out on the 12.62 m plot.

Attribute **Species Structure**

1. **Homogenous**: The structure is uniform throughout the plot where one tree species is present.
2. **Individually mixed**: There is more than one species present, with the species mixture occurring in a random manner.
3. **Group-mixed**: The structure is based on groups of trees of each species. Line mixtures are included in this category.

Figure 67. Individually mixed stand (Sitka spruce and Japanese larch) and a group mixed stand, line mixture (beech and Scots pine).

11.5 Silvicultural Treatment

Definition: Silvicultural treatment describes the operations that have taken place during the stand establishment stage.

Application: This is used to assess the intensity of management that the young trees are receiving.

Measurement and Description: Assessment is carried out on the 12.62 m plot.

Attribute **Silvicultural Treatment**

1. **No management**: No management has been provided, which is common with naturally regenerated small trees.
2. **Site preparation**: Site preparation has been provided, e.g. mounding.
3. **Respacing**: Release cutting or opening up of the forest stand has taken place.
4. **Fencing**: The area has been fenced to exclude deer, rabbit or hare.
5. **Extraction of logging residues**: Harvest residues have been removed.
6. **Leaving residues**: Residues resulting from harvesting operations are left on site, e.g. windrowing.

11.6 Dominant Negative Factor

Definition: Dominant negative factors impacting on the survival, growth and development of the small trees.

Application: This is used to identify factors impacting on the growth and development of the small trees.

Measurement and Description: Assessment is carried out on the 12.62 m plot for all small trees.

Attribute **Dominant Negative Factor**

1. **No negative factor**: Tree has no dominant negative factor.
2. **Light deficiency**: Due to the presence of an overstorey the tree being assessed is not growing optimally.
3. **Vegetation competition**: The tree is competing with other vegetation for resources in its growing space, such as water.
4. **Grazing/Browsing**: Damage by animals feeding on the shoots and foliage of the tree.
5. **Current erosion**: Erosion is affecting tree growth, such as stream erosion following heavy rainfall.
6. **Unkind weather conditions**: Extremes of weather conditions, such as drought or high winds, do not provide ideal conditions for tree growth.
7. **Swamped soil**: Saturated soil/peat providing inadequate growing conditions.
8. **Frost**: Frost may damage the photosynthetic tissue of a tree's growing parts, thereby reducing tree growth and impacting on tree form.
9. **Herbicides**: Inaccurate application of herbicides may have an adverse affect on tree growth and health.
10. **Nutrition deficiency**: Elements required for healthy tree growth are absent, which can be manifested by chlorotic foliage and a poor growth rate.
11. **Insects**: Damage by insects, which reduce a tree's vitality. Examples include: defoliation by aphids or pine shoot moth.
12. **Other factors**

11.7 Small Tree Attributes

This section details the small tree measurements recorded and the small tree damage.

11.7.1 Small tree measurements

Definition: Attributes measured on individual small trees: age, height dbh and origin.

Application: Individual small tree measurements are used to assess the current growth and productive potential of young forest stands. All small trees occurring within the 3 m plot are assessed.

Measurement and Description: The age, height and dbh (if tree is above 1.3 m in height) of each small tree is recorded. The origin of small trees, i.e. planted or naturally regenerated, is also recorded. The same age, dbh and height measurement conventions used in the previous chapter are used for the small tree measurements.

11.7.2 Small tree damage

Definition: Biotic or abiotic damage present on individual trees.

Application: This is used to identify the most common types of damage present on small trees.

Measurement and Description: A description of the damage is made for all small trees that had measurements recorded.

Attribute **Small Tree Damage**

1. **No damage**: There is no damage present on the tree.
2. **Terminal damage**: Terminal shoot damage exists on the tree, such as dieback, forking, or grazing.
3. **Fraying**: Fraying by deer, leading to stem and shoot damage.
4. **Peeling up to 1/8 of the circumference**: Peeling of the stem by animals where less than 1/8 of the bark of the circumference has been removed.
5. **Peeling more than 1/8 of the circumference**: Peeling of the stem by animals where more than 1/8 of the bark of the circumference has been removed.

Chapter 12
Deadwood

Definition: Sound and rotting logs, stumps, and branches.

Application: All living organisms have finite life spans after which they become part of the decaying portion of the ecosystem. Soft-bodied organisms and small plant structures generally decay rapidly and provide a quick turnover of nutrients, an addition to the forest floor, and/or food for forest wildlife. Large woody material contain very significant stores of carbon and energy and is the foundation of an important forest food web. This large material usually decays more slowly and therefore provides a more steady input of energy and longer-lasting structures (Stevens, 1997). Deadwood also provides habitat for plants, animals and insects and a source of nutrients for soil development.

Measurement and Description: Deadwood is assessed on the whole plot (i.e. 12.62m) and categorised into three components: branch, log and stump. Standing dead trees are assessed as individual trees (see Chapter 10.2)

12.1 Branch

Definition: Non-living branch residue on the forest floor.

Application: Calculation of biomass in harvesting residue.

Measurement and description: Branches must be less than 7 cm top diameter. Branch cover is assessed on the whole plot. Where the branch residue is present in piles (e.g. windrows), then the total coverage is estimated based on the amount of wood in the piles.

Attribute **Branch Coverage**

1. **No presence**: No branch or harvesting residue present on the plot.
2. **Rare (0-0.2%)**: Total coverage of branch or harvesting residue present on the plot is less than 0.2% of the plot area.
3. **Sporadic (0.2 to 1%)**: Total coverage of branch or harvesting residue present on the plot is between 0.2 and 1% of the plot area.
4. **Infrequent (1-5%)**: Total coverage of branch or harvesting residue present on the plot is between 1 and 5% of the plot area.
5. **Frequent (6-25%)**: Total coverage of branch or harvesting residue present on the plot is between 6 and 25% of the plot area.
6. **Common (26-50%)**: Total coverage of branch or harvesting residue present on the plot is between 26 and 50% of the plot area.
7. **Very common (51-75%)**: Total coverage of branch or harvesting residue present on the plot is between 51 and 75% of the plot area.
8. **Abundant (76-100%)**: Total coverage of branch or harvesting residue present on the plot is between 76 and 100% of the plot area.

12.2 Dead Log

Definition: Lying dead logs or its parts.

Application: Calculation of biomass in lying dead logs and used as a biodiversity indicator.

Measurement and Description: Logs present with a minimum mid diameter of 7 cm and a minimum length of 1 m. Only the portion of the log occurring within the plot is included. Assessment of the log length stops at 7 cm top diameter (Figure 68). The mid diameter and length of the log is recorded in cm.

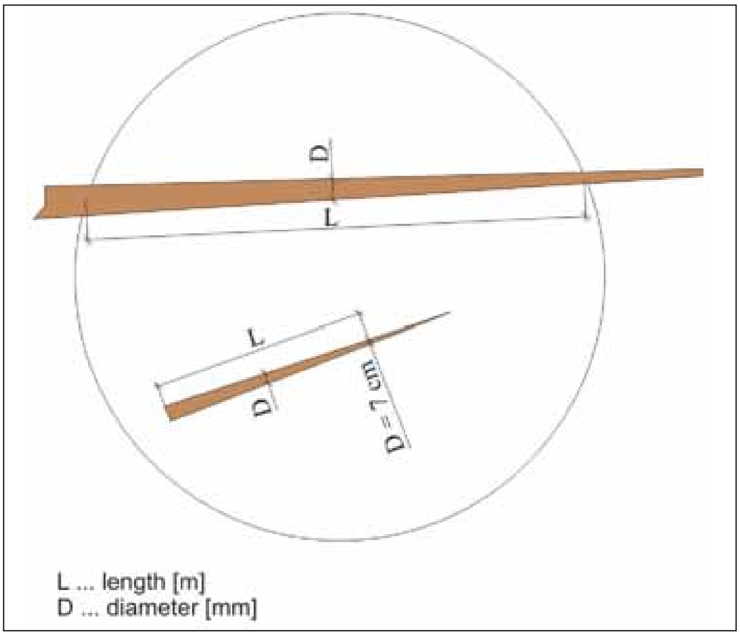


Figure 68. Dead log measurement.

12.2.1 Dead log category

Definition: Categorisation of dead logs based on a threshold diameter and length.

Application: This attribute is used to describe the size of dead logs present.

Measurement and Description: The assessment of dead logs is on the 12.62 m plot. Recently harvested logs are excluded, as these will be removed from the forest. Where the logs have not been collected and are showing signs of decomposition, they are included as dead logs.

Attribute **Dead Log Category**

1. **No dead logs**: There are no dead logs present.
2. **Only dead logs under threshold diameter**: Logs are present, but they have a mid-diameter of less than 7 cm and/or they are less than 1 m in length.
3. **Dead logs present**: Logs are present with a minimum mid diameter of 7 cm and a minimum length of 1 m.

12.2.2 Dead log distribution

Definition: The spatial distribution of dead logs on the plot.

Application: The distribution of dead logs impacts on the decomposition of the deadwood and also on its habitat value (Figure 69).

Measurement and description: The assessment of dead log distribution is on the 12.62 m plot.

Attribute **Dead log distribution**

1. **Deadwood distributed randomly**: Random distribution of dead logs within the plot.
2. **Deadwood islands**: The dead logs are located in isolated piles.
3. **Piles of deadwood**: Deadwood is located in linear piles, i.e. windrows.

Figure 69. Dead logs randomly distributed and dead logs in piles.

12.3 Stump

Definition: The base of a tree remaining in the ground after most of the stem has been harvested.

Application: Calculation of biomass in stump deadwood (Figure 70).

Measurement and description: Stumps occurring on the 12.62 m plot are included in the assessment. A stump must have a minimum top diameter of 20 cm and height of less than 130 cm. A stump with a height of greater than 130 cm is considered a standing dead tree (sec 10.2). The top diameter and height of the stump is recorded in cm.

Figure 70. Stump deadwood.

12.3.1 Stump category

Definition: Categorisation of stumps based on a threshold top diameter.

Application: This attribute is used to describe the size of stumps present on the site.

Measurement and description: Assessment is based on the 12.62 m plot.

Attribute **Stump Category**

1. **No stumps present**: There are no stumps present.
2. **Stumps under threshold diameter**: Stumps are present, but they have a top diameter of less than 20 cm.
3. **Stumps present**: Stumps are present with a minimum top diameter of 20 cm.

12.4 Decay Status

Definition: Decay status describes the level of decomposition of the deadwood.

Application: Assessing the decay status of logs and stumps allows for the quantification of carbon lost from the decaying wood. The status of the decaying wood will also influence the type of organism that can utilise the wood, thus affecting the biological diversity.

Description and Measurement: The decay status of all stumps and dead logs recorded on the 12.62 m plot is assessed.

Attribute Decay Status

1. **Solid wood**: Wood is intact, no signs of decomposition.
2. **Rotten sapwood, solid heartwood**: Outer part of wood is rotten, inner core is solid.
3. **Rotten heartwood, solid sapwood**: Outer part of wood is solid, inner core is rotten.
4. **Rotten wood**: Timber is rotten throughout, but maintains its original shape.

Section D

Validation and Data Analysis

Chapter 13
Validation of Fieldwork

13.1 Background

A total of 50 plots were included in the NFI validation exercise. Validation was divided into four stages, starting in November 2005 the first stage covered 12 plots; the second started in January 2006 and covered 13 plots, the third stage started in May 2006 covering 15 plots, and the fourth starting in July 2006 and covered 10 plots. Depending on the results feeding back from each stage, the total number of validation plots was to remain the same or to be increased.

The validation work was undertaken by one team, comprising one Forest Service and one IFER staff member.

13.2 Methodology

The individual team makeup was subject to considerable and ongoing change over the course of the validation campaigns and thus selection had to be from across the range of the individual members and the team combinations. In order to select and achieve objective sampling of the validation plots, stratified random sampling was used. The sampling frame (i.e. grid of completed plots) was stratified by field team, with selection being proportional to the number of plots completed by each.

For the first and second validation campaigns, 25 plots ware randomly selected from each strata (Figure 71). In order to minimise logistical issues associated with visiting a small number of plots over a large area, it was decided to cluster plots together for the third and fourth stages of the validation. Three geographically close plots that were completed by the same field team were clustered together. These groups of plots were then selected randomly for inclusion in the validation. This minimised the travel time between plots.

13.3 Plot Measurement

All validation plots were completely re-measured and described using the same technology and methodology as used by the NFI field teams.

A direct on-site comparison of the data collected by the field-team with the validation data was carried out at the end of each plot validation. The individual trees were identified from the field team data and all the tree attributes were compared using a customised Field-Map™ software extension.

Important differences were discussed directly at the forest plot, and trees with a significant dbh or height difference were again re-measured to verify the validation measurements.

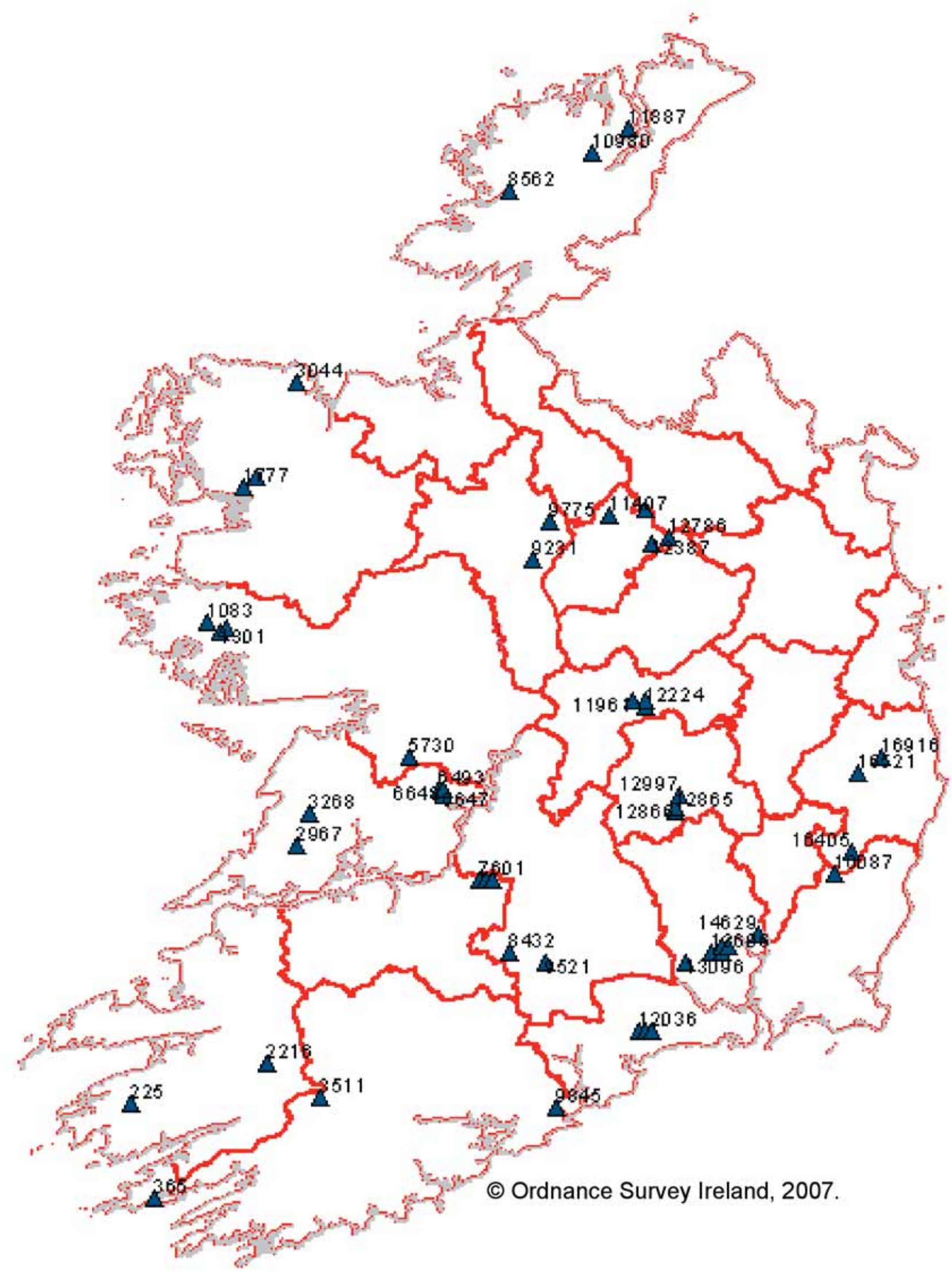


Figure 71. Location of validated plots.

13.4 RANKING SYSTEM

Each plot was given an overall ranking as to the quality of the original data obtained by the field team when compared with the validation data.

13.4.1 Importance of Mistakes

The mistakes were ranked according to the importance of the attributes and scored accordingly.

1. **No mistake:** Score 0. There were no mistakes present.
2. **Very minor:** Score 1. A mistake that will not have any effect on the results generated.
3. **Minor:** Score 2. A mistake that will have minimal effect on the results generated.
4. **Acceptable:** Score 3. A mistake that will have some small effect on results generated, usually a subjective measurement e.g. physiographic division.
5. **Unacceptable:** Score 4. A mistake that will have a large effect on results generated, usually an objective measurement e.g. dbh, not including all trees on plot.
6. **Major:** Score 5. A mistake that will detrimentally affect national results e.g. Forest or Non-Forest.

13.4.2 General ranking

The general ranking is broken down into 3 areas (Table 6):

1. **Dendrometric and equipment measurement:** this ranks the quality of all equipment-measured attributes on the plot and is mainly concerned with tree measurement.
2. **Trees and forest layers description:** this ranks the descriptive attributes associated with the trees on the plot e.g. Species identification, stand layer, deadwood and small trees description.
3. **Site description:** describes all non-tree attributes e.g. soil, plants, lichens, etc.

Table 6. General ranking areas.

Ranking Area	Description
Dendrometric and equipment measurement *	Navigation, trees (position, dbh, height, crown projection, number of trees, 1/3 height diameter).
Trees and forest layers description	Forest, Stand layers, Small trees and Deadwood.
Site description	Plot, Soil, Litter, Plants, Shrubs, Game, Lichens.

*Plot centre navigation is included in this category; differences of more than 5 m in Forest Open Area & 8 m under canopy between field team and validation team are deemed major mistakes.

13.4.3 General ranking weight

General ranking is weighted on the basis of: Land-use category (Forest, Forest Open Area and Non-Forest) and the type and/or quantity of trees present.

Two weighting systems were employed:

1. On Forest plots with trees above threshold dbh, all dendrometric and equipment measurement mistakes are multiplied by 3 to give a higher weighting to these mistake types, trees and forest layers are multiplied by 2 and site description by 1 as shown in table 7.

Table 7. General ranking weight – Forest plots (trees above threshold diameters).

Ranking Area	Weight
Dendrometric and equipment measurement	X 3
Trees and forest layers description	X 2
Site description	X 1

2. In Forest plots with trees under threshold dbh only or without trees, Forest Open Area and Non-Forest plots dendrometric measurement no longer applies. Also for Non-Forest and Forest Open Area the Trees and Forest data are not relevant. Therefore the weighting is increased on the 'site description', as these are the only attributes left to measure as shown in table 8.

Table 8. General ranking weight – Forest plots (trees under threshold diameters), Forest Open Area and Non-Forest plots.

Ranking Area	Weight
Dendrometric and equipment measurement	X 1
Trees and forest layers description	X 2
Site description	X 3

13.4.4 Overall ranking

The overall ranking is a summation of the above general rankings and is divided into three categories as follows:

1. **Good:** Score 0-9. The data from these plots are acceptable and can readily be processed for results generation.
2. **Acceptable:** 10-19. Data from these plots at the lower end of this scale have small effect errors that can be processed. Plots at the higher end of this scale may have some larger errors. Some of these errors can be eliminated during data processing, some cannot and need to be further evaluated.
3. **Re-Measure:** 20-30. Data in all plots in this category have unacceptable mistakes and the plots should be completely re-measured.

13.5 Results

Out of 50 plots, the number to be re-measured was 5 (10%), the number categorized as 'borderline' was 16 (32%) and those termed as 'good' was 29 (58 %).

In total 716 trees were validated for dbh, of which 272 trees were measured for height along with 83 upper diameter measurements. In the 50 validation plots, 38 more trees were measured than recorded by the field teams on the same plots. The reasons for the inclusion of these extra trees were as follows:

- Seven new trees were recorded as a result of the time lag, and consequent tree growth, between reaching the plot for validation and when it was first recorded by the field team.
- On one plot 21 trees were not measured (see section 15.6.3)
- Two dead trees should have been recorded by the teams but were not.
- The remaining eight live trees (1% of the 716 trees) should have been recorded by the teams but were not.

In two plots the positional error of the centre pole was 10 m or more. The centre was re-checked four times to verify the team error.

To conclude, one team carried a very high percentage 're-measure' rate (43%) and it was recommended that the NFI plots be completely re-surveyed in Longford and Roscommon. Further to this it was recommended that all plots surveyed by this team in Co. Wicklow should be completely re-surveyed, along with a spot check on the other team's work in Wicklow, as this had been the first county surveyed.

In summary, the results from the validation showed that in general data quality was good and that the data will form a reliable basis for results generation.

13.6 Actions

This section details the actions taken after assessing the validation results, which include: plot re-measurement, field team update and project management.

13.6.1 Plot re-measurement

The validation exercise identified three counties where the plot data was not of sufficient quality. In the interest of maximising data quality, which ultimately increases the precision of the results and instils confidence in the results, NFI plots in counties Longford, Roscommon and Wicklow were re-measured. Only those plots that had individual mapped tress (≥70 mm) were re-measured, as the validation showed that plots with small trees (<70 mm) were of good quality.

13.6.2 Field team update

Field teams were brought together for briefing sessions following each stage of the validation process. During these sessions, the field team members would discuss the classification of attributes. This ensured consistency in the classification of NFI attributes across all field-teams.

13.6.3 Project management

The validation process also identified a plot on which assessment had begun but not completed. This was due to a project management oversight and led to the establishment of a tracking system for monitoring the completion of plots.

CHAPTER 14
DATA ANALYSIS

Analysis of the NFI data is carried out using Field-Map™ Inventory Analyst, which was developed by IFER. The information supplied in sections 14.3 to 14.5 is taken from the Field-Map™ Inventory Analyst user guide (Černý *et al.*, 2005).

14.1 HEIGHT MODELS

A sub-sample of trees was measured for tree height during the field survey. A maximum of seven trees (dbh over 7 cm) per species per plot were sampled for height. The sample trees were chosen regularly along the range of tree diameters within the plot. Based on this rule, 7,559 (i.e. 33.6%) of the 22,477 trees have been measured for height. For the height model calculations, only live and undamaged trees were used.

14.1.1 Modelling tree height

Based on the number sample trees, a plot dbh-height model was calculated. Wherever the number of sampled trees for a species within a plot was sufficient, greater than four, the local (i.e. plot) model was parameterised using linear or non-linear least squares. If the parameterisation of the local model was not carried out due to an insufficient number of measured trees or their unfavourable distribution, then the global model (i.e. species model for all plots) was used.

Several dbh-height models were used (Table 9). Chapman-Richards exponential model, which is often used for growth modelling, is very flexible and accurately describes the dbh-height relationship. It is efficient, especially for global models where a large number of measurements are involved. The other two models were used if the model higher in hierarchy could not been parameterised. Model number 1 was used in 14.8% of cases, model number 1 with P_3 fixed to 0.7 was used in 78.9% of cases, model number 2 in 6.0% and model number 3 in 0.3% of cases.

The overall model fit is demonstrated using the chart of predicted versus observed heights (Figure 72). The standard deviation of 1.0 m and correlation coefficient 0.98 document good fit.

Table 9. Models for dbh-height relationship

Model	Equation	Adjustment of global model
1 exponential (Chapman-Richards)	$h = 1.3 + P_1 \times \left(1 - e^{-P_2 \times dbh}\right)^{\frac{1}{P_3}}$	P_1
2 exponential	$h = 1.3 + e^{P_1 + \frac{P_2}{dbh}}$	P_1
3 logarithm	$h = 1.3 + P_1 + P_2 \times \ln(dbh)$	P_1

Examples of dbh-height models for particular species within individual inventory plots are presented in Figures 73 and 74. If the number of measured tree is sufficient then the local model is parameterised and used for the height calculation (Figure 73). If the local model could not be parameterised the global model for the respective species was used. However if at least one tree has been measured the global model was adjusted using the available data (Figure 74). One of the parameters (Table 9) was adjusted using least square method whereas the other parameters of the global model remained unchanged. Thus the global model was localised for particular inventory plot. An example of the global model for Sitka spruce is presented in Figure 75. The global model has a characteristic curve, representing a mean height for a given diameter, across for whole country. Considering the method of localisation, the global model can be considered as a family of curves.

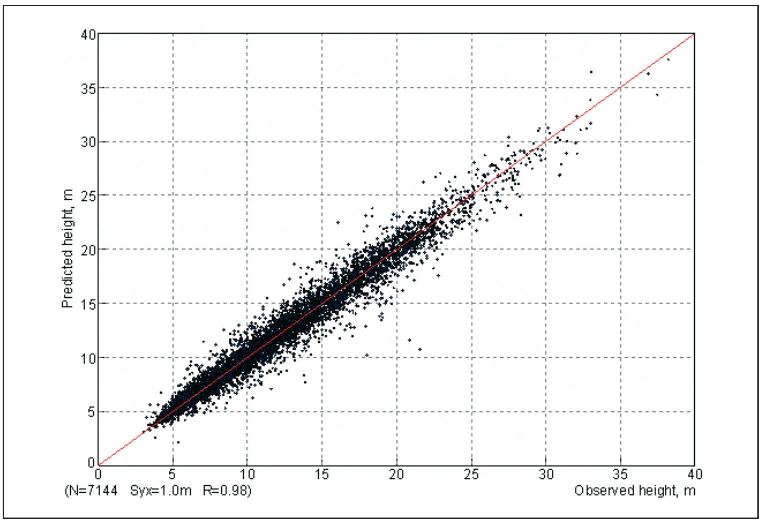


Figure 72. Predicted versus observed tree height.

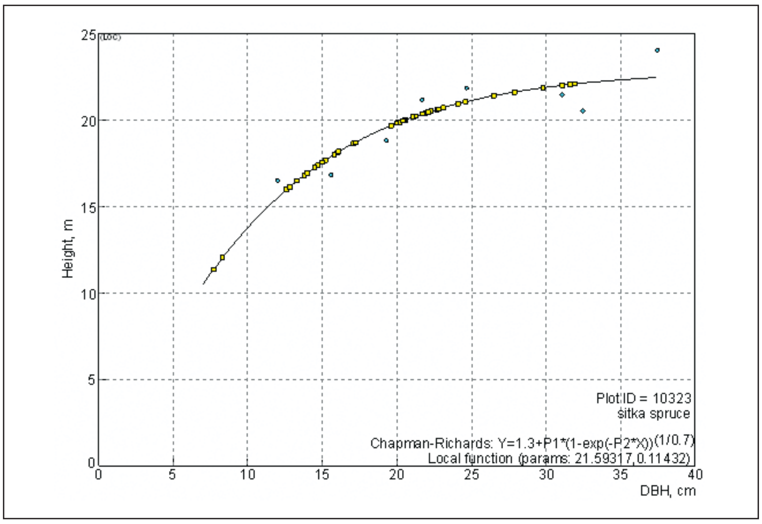


Figure 73. Example of local dbh-height model for an inventory plot (Plot No. 10323).

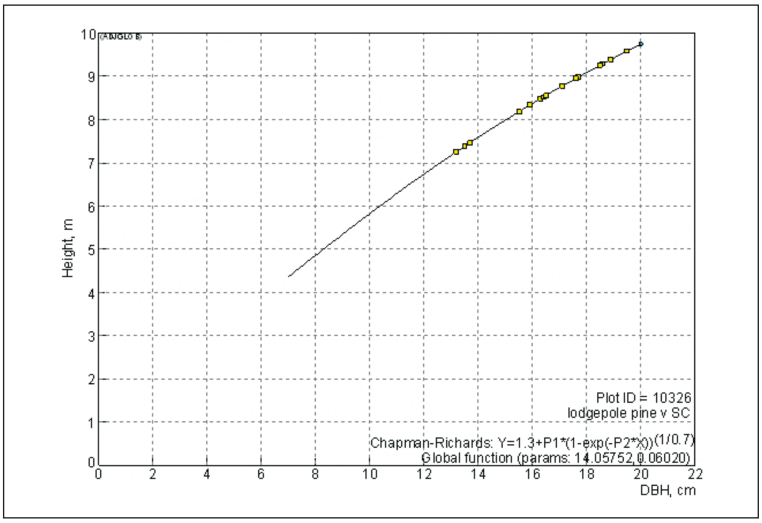


Figure 74. Example of the use of the global dbh-height model for an inventory plot; adjusted using one measured tree (Plot No. 10326).

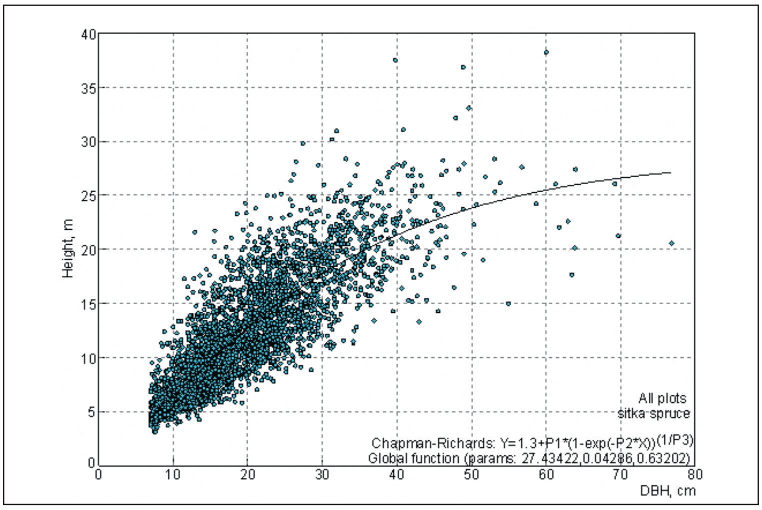


Figure 75. The global dbh-height model (Sitka spruce).

The modelled tree heights were used for all further analysis involving tree height, even for those trees for which height was directly measured in the field. In fact, there was very little difference when measured or modelled height was used, because the dbh-height model has been parameterised using NFI data and the sum of residuals was minimised – the estimate is unbiased. Consideration was given for future surveys where the use of modelled values will be more appropriate. The height increment will be calculated as a difference of the consecutive modelled tree height values for every tree. Since there is no guarantee that the particular tree will be again measured for height in the field the calculated difference might combine growth and deviation from the model for those trees which were once measured and once not. This will not happen if modelled heights are used in both consecutive inventories.

14.1.2 Broadleaf timber height

Tree height is an important attribute for a number of subsequent calculations particularly for tree volume, biomass and carbon content. It was intended to use new national volume equations for Ireland which will be based on total tree height. This research project is currently underway and will provide an alternative to the Forestry Commission equations which were used in this NFI.

The Forestry Commission tariffs (Matthews and Mackie, 2006), which have been used for broadleaf species, require timber height as an input variable. Timber height concerns merchantable material only, and is the distance from the base to the highest point on the main stem where the diameter is not less than 7 cm top diameter overbark (Matthews and Mackie, 2006). The spring of the crown is frequently the timber point, but it may extend into the crown if there are merchantable lengths present. As the NFI collected total tree height, this had to be adjusted to timber height.

Three species were selected for sampling: oak, beech and ash. Thirty sites were sampled for each tree species across the land base of Ireland, with ten trees measured at each site. The dbh, total height and timber height was measured for each tree. The ratio between timber height and total height for oak, ash and beech was: 0.477, 0.470 and 0.449 respectively (Table 10). While this procedure may not represent the true situation at an individual tree level, it was deemed to be an acceptable procedure for the purposes of estimating broadleaf volume at a national level.
The ratio between timber height and total height.

Table 10. The ratio between timber height and total height.

Species	Mean value	Confidence interval (a=0.05)	Sample size
Oak	0.477	±0.012	330
Ash	0.470	±0.023	311
Beech	0.449	±0.013	310

14.2 Volume Models

This section details the estimation of standing volume for conifer and broadleaf species.

14.2.1 Conifer volume models

The British Forestry Commission (BFC) single tree volume equations (Matthews and Mackie, 2006) were used to estimate standing volume for each tree on the plot with a minimum dbh of 70mm. The stem volume is measured from ground to 7 cm top diameter overbark.

14.2.2 Broadleaf volume models

The BFC single tree volume equations (Matthews and Mackie, 2006) are used to estimate standing merchantable volume for each tree on the plot with a minimum dbh of 7 cm. The broadleaf stem volume is measured from ground to timber height.*

*Total tree height was measured during field data collection, while timber height was required for the calculation of broadleaf volume. It was therefore necessary to estimate the timber height for each broadleaf tree from total height. Using the calculated timber height (section 14.1.2), broadleaf volume was calculated.

There is currently a project underway to generate the Irish single tree volume equations, which will have total tree height as the explained variable. As these models will form the basis of future volume calculations it was decided to collect total height for this NFI instead of timber height.

14.2.3 Volume assortments

Tree volume was categorised by top diameter, on the basis of individual tree dbh (Matthews and Mackie, 2006). The percentage overbark volume to specified overbark top diameter (no minimum length) was calculated for three assortment categories:

- Pulp (7-13.9 cm top diameter)
- Pallet (14-19.9 cm top diameter)
- Sawlog (20 cm+ top diameter).

Total volume stock by top diameter assortment assumes that there are no defects in the trees and all timber is merchantable. The reality in any forest stand is that there are factors, such as stem break or forking that will reduce the recoverable timber. Table 11 outlines how other NFI attributes (fork, tree break and stem straightness) were used to adjust the volume based on top diameter class to a more realistic potential end product volume.

Table 11. Volume assortment downgrading basis.

Variable	Category	Downgrade to
Fork	Up to 1.3m	Pulp
	1.3m to 3m	Pulp
Tree Break	Stem Break	Pulp
Stem Straightness	One 3m and one 2m log	Pulp
	One 2m log	Pulp
	Two 2m logs	Pulp
	No straight logs	Pulp

14.3 Plot Area vs Representative Area

Forest area statistics for the purposes of NFI results are derived using two methods:

1. Plot Area
   Variables collected at plot level (e.g. Ownership, Soil Group) represent the total plot area at a national level. The entire land base of Ireland is represented by 17,423 NFI plots, each one representing approximately 400 ha. For example, one plot classified as being privately owned will represent 400ha privately owned nationally.

2. Representative Area
   A representative area is calculated for each measured tree on the plot that is proportional to the tree size, i.e. the larger the tree volume, the greater the representative area. For each forest plot, where trees are present, the sum of the individual tree representative areas will equal the total plot area, 500 m^2. Where the evaluated variable, forest area, is classified in terms of tree variables (e.g. species), representative area is used to calculate forest area. For example, total area of Norway spruce: the portion of each plot represented by Norway spruce is aggregated to a national level based on how representative Norway spruce was in each plot.

14.4 Evaluated Variables, Classifiers, Stratifiers

Various statistics are calculated for various evaluated variables in most cases represented by the area, volume or number of individuals. Statistics of evaluated variables are calculated for different classes (such as tree species, ownership class etc.) and different strata (such as counties).

The following statistical variables can be estimated using Inventory Analyst. A review the associated formula is detailed in Table 12.

1. Population total (for example, the total stand volume of a forested area);
2. Mean value (for example, mean volume per hectare). Several variants of mean calculation can be applied.
   a) A simple **arithmetic mean** of plot totals.
   b) **Mean value per hectare** is calculated as a mean value of plot totals recalculated per hectare.
   c) A **weighted mean** can be calculated as a mean value of weighted means calculated for individual plots. For instance the weighted mean of the tree defoliation is calculated via weighing tree defoliation by tree basal area.
   d) Another way is so called **normalized mean**. It is calculated in such a way that the calculated value of the variable under consideration for a plot is divided not by the whole plot area, but by the area of the plot where the given variable is represented. An example of this would be normalised mean volume per hectare by species.
3. The confidence limit for a = 0.05 for each statistical variable was estimated as well.

Table 12. Review of equations applied in the Inventory Analyst statistical calculations for individual inventory plots and for the whole dataset.

Variable	Calculation for plot	Plot weight	Calculation for the set of plots	*Example*
Total	$X_j = \sum_{i=1}^{m} x_i$	$w_j = 1$	$Y = \sum_{j=1}^{n} X_j$ $Y_{tot} = \frac{Y}{\sum_{j=1}^{n} s_j} S$	*Total volume for inventory plots;* *Total volume for the whole territory under study.*
Average sum	$X_j = \sum_{i=1}^{m} x_i$	$w_j = 1$	$\bar{y} = \frac{1}{n}\sum_{j=1}^{n} X_j$ $\bar{y}_{ha} = \frac{\bar{y}}{s}$	*Mean volume (mean volume per plot; divided by plot area it gives mean volume per hectare).*
Mean of means	$\bar{x}_j = \frac{1}{m}\sum_{i=1}^{m} x_i$	$w_j = 1$	$\bar{y} = \frac{1}{n}\sum_{j=1}^{n} \bar{x}_j$	*Concentration of carbon in the wood, mean wood density etc.*
Mean of weighted means	$\bar{x}_j = \frac{\sum_{i=1}^{m}(x_i v_i)}{\sum_{i=1}^{m} v_i}$	$w_j = 1$	$\bar{y} = \frac{1}{n}\sum_{j=1}^{n} \bar{x}_j$	*Mean tree defoliation (weighted by tree volume).*
Normalized mean of sums	$\bar{x}'_j = \frac{\sum_{i=1}^{m} x_i}{\sum_{i=1}^{m} v_i}$	$w_j = \sum_{i=1}^{m} v_i$	$\bar{y} = \frac{\sum_{j=1}^{n}(\bar{x}'_j w_j)}{\sum_{j=1}^{n} w_j}$	*Volume per hectare by species (tree volume of individual species is related to the representative area of this species).* *The plot weight can be, e.g., the sum of individual tree areas.*
Normalized mean of weighted means	$\bar{x}_j = \frac{\sum_{i=1}^{m}(x_i v_i)}{\sum_{i=1}^{m} v_i}$	$w_j = \sum_{i=1}^{m} v_i$	$\bar{y} = \frac{\sum_{j=1}^{n}(\bar{x}_j w_j)}{\sum_{j=1}^{n} w_j}$	*Mean defoliation by species.* *The plot weight can be, e.g., the sum of tree individual areas.* *This approach points out the different share of the given species within a plot; in contrast with mean of weighted means the weights of different plots are not the same.*

Where

x_i is the value of the variable under study for the *i*-th entity (e.g., tree) within the plot *j*
v_i is the weight of *i*-th entity within the plot *j*
m is the number of entities within the plot *j*
X_j is the sum of the variable under study for plot *j*
$\bar{x}_j$ is the mean value of the variable under study for plot *j*
$\bar{x}'_j$ is the mean value of the variable under study per unit *v* for plot *j*
w_j is the weight of the *j*-th plot from the set of inventory plots
Y is the total of the variable under study for the whole dataset of plots
Y_{tot} is the total of the variable under study for the whole territory of interest
$\bar{y}$ is the mean value of the variable under study for the dataset of plots
$\bar{y}_{ha}$ is the mean value of the variable under study for the dataset of plots per hectare
n is the total number of inventory plots in the dataset
S_j is the area of inventory plot j in hectares
S is the area of the total territory of interest in hectares
μ_h is the stratum mean
N is the total number of units in the population

14.5 Statistical Methods

The statistical methods used in the Inventory Analyst represent standard methods used for simple and stratified sampling design (e.g. Thomson, 1992).

14.5.1 Stratifying the population

A geographical region or population may be stratified into more homogenous areas (i.e. strata) such as habitat type, elevation, or soil type. Each stratum is treated as a separate sub-population, with the results from different strata combined using appropriate weights to obtain an overall estimate for the population. Even if a large geographic study area appears to be homogeneous, stratification into blocks (e.g. counties) can help to ensure that the sample is spread out over the whole study area.

The variable of interest associated with *i*th unit (single plot) of stratum *h* will be denoted y_{hi}. Let N_h represent the number of units in stratum *h* and n_h the number of units in the sample from that stratum.

L represents total number of strata.

The total number of units in the population is $N = \sum_{h=1}^{L} N_h$

and the total sample size is $n = \sum_{h=1}^{L} n_h$

The total of the *y*-values in stratum *h* is $\tau_h = \sum_{i=1}^{N_h} y_{hi}$

and the mean for the stratum is $\mu_h = \tau_h / N_h$

The total for the whole population is $\tau = \sum_{h=1}^{L} \tau_h$

The overall population mean is $\mu = \tau / N$

Note: All the calculations set forth below concern normally distributed variables. Often, in practice the variables are not normally distributed, in particular they may have a significant skewness. In such a case, special methods of calculation of a mean (or total) and its confidence interval can be applied. In particular, not the arithmetic mean, but another statistic (such as median, geometric mean, etc.) with its confidence interval can be the best estimator of the population mean (see e.g. Meloun *et al*., 1992). In the case of stratified sampling, when applying the special methods for non-normal distributions, the sum of stratum totals or the mean of stratum means may differ from the population total or mean, calculated without stratification or using different stratification. Consequently, in order to avoid such a contradiction, only standard calculations supposing the normal distribution of variables were applied.

14.5.2 Estimating the population total

Suppose that within stratum *h*, any specified sampling design is used to select the sample s_h of n_h units, and one has an estimator $\hat{t}_h$ with respect to that design. Let $\mathrm{var}(\hat{t}_h)$ denote the variance of $\hat{t}_h$, and suppose that one has an unbiased estimator $\widehat{\mathrm{var}}(\hat{t}_h)$ of that variance.

Then an unbiased estimator of the overall population total t is obtained by adding together the stratum estimators:

$$\hat{\tau}_{st} = \sum_{h=1}^{L} \hat{\tau}_h$$

The variance of the stratified estimator, because of the independence of the selections in different strata, is the sum of the individual stratum variances: $\mathrm{var}(\hat{\tau}_{st}) = \sum_{h=1}^{L} \mathrm{var}(\hat{\tau}_h)$

An unbiased estimator of that variance is the sum of individual stratum variance estimators:

$$\hat{\mathrm{var}}(\hat{\tau}_{st}) = \sum_{h=1}^{L} \hat{\mathrm{var}}(\hat{\tau}_h)$$

If the sample in each stratum is selected by a simple random sampling procedure without replacements then $\hat{\tau}_h = N_h \bar{y}_h$

is an unbiased estimator of t_h, where $\bar{y}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} y_{hi}$

is the sample mean for stratum *h*.

An unbiased estimator for the population total t is $\hat{\tau}_{st} = \sum_{h=1}^{L} N_h \bar{y}_h$

having variance $\mathrm{var}(\hat{\tau}_{st}) = \sum_{h=1}^{L} N_h (N_h - n_h) \frac{\sigma_h^2}{n_h}$

where $\sigma_h^2 = \frac{1}{N_h - 1} \sum_{i=1}^{N_h} (y_{hi} - \mu_h)^2$

is the finite population variance from stratum *h*.

An unbiased estimator of the variance of $\hat{t}_{st}$ is $\hat{\mathrm{var}}(\hat{\tau}_{st}) = \sum_{h=1}^{L} N_h (N_h - n_h) \frac{s_h^2}{n_h}$

where $s_h^2 = \frac{1}{n_h - 1} \sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2$ is the sample variance from stratum *h*.

14.5.3 Estimating the population mean

Since $\mu = t / N$, the stratified estimator for μ is $\hat{\mu}_{st} = \hat{\tau}_{st} / N$

Assuming that the selection in different strata has been made independently, the variance of the estimator is $\mathrm{var}(\hat{\mu}_{st}) = \frac{1}{N^2} \mathrm{var}(\hat{\tau}_{st})$

with unbiased estimator of variance $\hat{\mathrm{var}}(\hat{\mu}_{st}) = \frac{1}{N^2} \hat{\mathrm{var}}(\hat{\tau}_{st})$

With stratified random sampling, an unbiased estimator of the population mean μ is the stratified sample mean $\bar{y}_{st} = \frac{1}{N} \sum_{h=1}^{L} N_h \bar{y}_h$

Its variance is $\mathrm{var}(\bar{y}_{st}) = \sum_{h=1}^{L} \left(\frac{N_h}{N}\right)^2 \left(\frac{N_h - n_h}{N_h}\right) \frac{\sigma_h^2}{n_h}$

An unbiased estimator of this variance is $\hat{\mathrm{var}}(\bar{y}_{st}) = \sum_{h=1}^{L} \left(\frac{N_h}{N}\right)^2 \left(\frac{N_h - n_h}{N_h}\right) \frac{s_h^2}{n_h}$

14.5.4 Confidence intervals

When all the stratum sample sizes are sufficiently large, an approximate 100(1-a)% confidence interval for the population total is provided by

$$\hat{\tau}_{st} \pm t\sqrt{\hat{\text{var}}(\hat{\tau}_{st})}$$

where *t* is the upper a/2 point of the normal distribution. For the mean, the confidence interval is

$$\hat{\mu}_{st} \pm t\sqrt{\hat{\text{var}}(\hat{\mu}_{st})}$$

Usually, the normal approximation may be used if all the sample sizes are at least 30. With small sample sizes, the *t*-distribution with an approximate degrees of freedom may be used. The Satterthwaite (1946) approximation for the degrees of freedom *d* to be used is

$$d = \left(\sum_{h=1}^{L} a_h s_h^2\right)^2 \Big/ \left[\sum_{h=1}^{L} (a_h s_h^2)^2 / (n_h - 1)\right]$$

where

$$a_h = N_h (N_h - n_h)/n_h$$

14.5.5 Considering variable weights

Let us consider the variable x_i weighted by value w_i (i = 1,…,n). In equations for y observations we should multiply any terms as y_i or $(y_i - \overline{y})^k$ by w_i and replace n by $W = \sum_{i=1}^{n} w_i$. Consequently we receive the following set of equations:

$$\overline{y} = \frac{1}{W}\sum_{i=1}^{n} y_i w_i \,, \qquad D(\overline{y}) = \frac{s^2}{W}$$

$$s^2 = \frac{1}{W-1}\sum_{i=1}^{n} (y_i - \overline{y})^2 w_i$$

where *D(.)* is the operator of variance.

In the current version of the statistical data processing weights were standardised before their further application in such a way as *W=N*, i.e. each w_i is replaced by $w_i.N/W$.

14.5.6 Using concentric circles at inventory plots

Data of trees of different dimensions (based on dbh limits) were collected using concentric circles (see description of field data collection). Data collected using the concentric circle approach were processed as having been collected from independent inventories within strata. Thus an unbiased estimator of the overall population total *t* was obtained by adding together the stratum and concentric circle estimators:

$$\hat{\tau}_{st} = \sum_{h=1}^{L}\sum_{c=1}^{M}\sum_{i=1}^{N_h} y_{hci}$$

where *M* is the total number of concentric circles used in the inventory design.

For the calculation of variance and, subsequently, of the confidence interval for stratified sampling, the variance related to individual concentric circles was summarised, assuming that the data from individual circles were uncorrelated:

$$\text{var}(\hat{\tau}_{st}) = \sum_{h=1}^{L}\sum_{c=1}^{M} \text{var}(\hat{\tau}_{hc})$$

Chapter 15
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Appendix 1 Information Needs

In 1996, a policy document *'Growing for the Future* - A Strategic Plan for the Development of the Forestry Sector in Ireland was formulated with the overall aim: **To develop forestry to a scale and in a manner which maximises its contribution to national economic and social well-being on a sustainable basis and which is compatible with the protection of the environment.**

Forest inventory was seen as an integral component in meeting the overall aim of the strategic plan. The policy statement in relation to inventory and planning was: **To develop a comprehensive inventory and planning system to provide forest resource, geographical and environmental data for management, control and planning purposes.**

A comprehensive stand level inventory of the public estate is in place, but no detailed information is available for the private estate. Private estate managers do maintain inventories, but a comprehensive and standardised inventory of the entire private forest estate was not available. As the private estate constitutes approximately 45% of the total forest area, information on this resource is long overdue.

The need for reliable information on Ireland's forest resource has developed gradually over time. This appendix details a selection of these information needs.

Carbon Accounting

The United Nations Framework Convention on Climate Change (UNFCCC) sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. Activities in the Land-Use and Land-Use Change and Forestry (LULUCF) sector can provide a relatively cost-effective way of offsetting emissions, either by increasing the removals of greenhouse gases from the atmosphere (e.g. by planting trees or managing forests), or by reducing emissions (e.g. by reducing deforestation). However, there are drawbacks, as it may often be difficult to estimate greenhouse gas removals and emissions resulting from activities under LULUCF. In addition, greenhouse gases may be unintentionally released into the atmosphere if a sink is damaged or destroyed through a forest fire or disease outbreak.

Under Article 3.3 of the Kyoto Protocol, Parties decided that greenhouse gas removals and emissions through certain activities — namely, afforestation and reforestation since 1990 – can be accounted for in meeting the Kyoto Protocol's emission targets. Conversely, emissions from deforestation activities will be subtracted from the amount of total emissions that Ireland may emit over its commitment period. Under Article 3.4 of the Kyoto Protocol, countries can elect additional human-induced activities related to LULUCF, specifically forest management, cropland management, grazing land management and recolinisation, to be included in their accounting for the first commitment period. Ireland has committed to greenhouse-gas emissions level of not higher than 13% above 1990 levels in the commitment period 2008-2012.

The NFI will be used to quantify the net changes in greenhouse gas emissions by sources and removals by sinks, resulting from direct human-induced afforestation and deforestation which have taken place since 1990.

Ministerial Conference on the Protection of Forests in Europe

At the second Ministerial Conference on the Protection of Forests in Europe (MCPFE) held in Helsinki, 1993, four resolutions were signed by 32 countries, including Ireland. A system of six criteria and 27 indicators for the sustainable management of European forests was developed at the First Expert Level Follow-up Meeting held in Geneva 1994. At the Ministerial Conference in Lisbon 1998, Ireland committed itself to report, on a regular basis, on SFM indicators as outlined in the Irish National Forest Standard (Anon., 1998a).

The criteria by which SFM will be monitored are:

Criterion 1: Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles;

Criterion 2: Maintenance of Forest Ecosystem Health and Vitality;

Criterion 3: Maintenance and Encouragement of Productive Functions of Forests (Wood and Non-Wood);

Criterion 4: Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems;

Criterion 5: Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (notably Soil and Water);

Criterion 6: Maintenance of Other Socio-Economic Functions and Conditions.

Since the first set of Pan-European indicators for SFM were developed in the early 1990s, experience has shown that criteria and indicators are a very important European forest policy tool. Thus, initiated through the Lisbon Conference in 1998, the MCPFE decided to improve the existing set of Pan-European indicators for SFM (Anon., 2002).

An Advisory Group, representing relevant organisations in Europe, was formed to ensure that best use is made of the existing knowledge on indicators and data collection aspects, and to assist the MCPFE during the improvement process. The Advisory Group consulted with a wide range of experts through a series of workshops. These workshops ensured that the diversity of national situations and experiences, as well as the work undertaken by various bodies in Europe, were adequately reflected. The process resulted in 35 quantitative indicators being put in place to ensure the six criteria could be properly assessed (Anon, 2002).

UNECE/FAO

One of the main tasks of the United Nations Economic Commission for Europe (UNECE) and the Food & Agricultural Organisation (FAO) Timber Section (Geneva) is to monitor all aspects of forests and forest resources in the region. The Timber Section plays an important role in the implementation of the Global Forest Resource Assessment (FRA) in Europe.

Global FRA's, coordinated by the FAO, have been carried out at five to ten year intervals since the FAO was established in 1945. The mandate for these assessments is found in the FAO Constitution, which states that "The Organization shall collect, analyse, interpret and disseminate information relating to nutrition, food and agriculture. In this Constitution, the term 'agriculture' and its derivatives include fisheries, marine products, forestry and primary forestry products" (Article I, Functions of the Organization, paragraph 1 (Anon., 1999)).

The Global FRA 2005 (Anon., 2006) is the most comprehensive assessment to date, both in terms of contributors and content. More than 800 people were involved, including 172 national correspondents and their teams, an advisory group, international experts, FAO staff, consultants and volunteers from around the world. The FRA examines the current status and recent trends for about 40 attributes covering the extent, condition, uses and values of forests and other wooded land, with the aim of assessing all benefits from forest resources. The scope and content of the global assessments have evolved over time to respond to changing information needs. Ireland was included in this assessment, but, with the presence of NFI results, is now in a position to provide more comprehensive, up-to-date and reliable data.

Appendix 2 List of all Field Equipment used in the NFI

Field Computer and Accessories

Hammerhead XRT™ 833 MHz field computer
Hammerhead XRT™ carry-case and pen
Hammerhead serial port replicator (Champs connector)
Hammerhead XRT™ battery x 6 (Rechargeable)
Hammerhead XRT™ mains 'ac adaptor' with power cable
Hammerhead XRT™ charger
Hammerhead XRT™ battery charger 'switching adapter' with power cable
Hammerhead XRT™ gold peak cigarette charger
Hammerhead XRT™ harness and docking plate
Cruzer mini usb flash drive 256 MB x 2

Compass/laser and accessories

Mapstar™ Electronic compass
Impulse™ Laser
Compass bracket
36" cable compass to computer
20" cable laser to compass
8 x AA batteries (re-chargeable)
Battery charger for AA batteries and power supply
Carbon monopod
1 x compass/laser cover bag

Reference pole and accessories

Telescopic main pole 4.57 m
Cover for telescopic main pole
2 x 1m reference poles
2 x circular reflectors
1 x cylindrical reflectors
2 x large locking bolt for circular reflector
2 x small locking bolts for cylindrical reflectors

GPS and accessories

Trimble PRO XRT DGPS unit in hard case unit - 4 x GPS batteries and charger
Trimble PRO XRT backpack - 1 x Trimble PRO XRT carry case

Other items

- 2 x laminated sets of numbers
- 1 x backpack
- 1 x metal hard case
- 1 x Philips screwdriver
- 4 x socket extension lead
- 1 x spade
- 2 x tree loppers
- 2 x 'builders' 5 m tape
- 2 x 500 mm dbh tape
- 1 x 800 mm dbh tape
- 2 x silky hand saws
- 1 x slash hook
- 1 x 15 m loggers tape
- Centre poles
- Thumb-tacks (Plastic topped)
- Marking paint
- 2 x mobile phones (Vodafone and O_2)
- 1 x First-aid kit
- 1 x digital camera
- 1 x lump hammer

Reference Books

- Rushes, grasses and sedges (Fitter and Fitter, 1984)
- Wild Flower ID (Rose, 1981)
- Tree ID book (Johnson and Moore, 2004)
- Fern ID (Merryweather and Hill, 1992)
- General Soil map of Ireland, (Gardiner and Radford, 1980).

Appendix 3 Hardware Components

Field Computers

A hammerhead XRT™ (HHXRT) field computer was chosen as the computer for field data collection in the NFI (Figure 76). The HHXRT is a rugged pen-tablet field computer with similar capabilities to most office base PCs. It offered the suitable durability and performance necessary in harsh environmental conditions associated with the field phase of the NFI. Some technical specifications on the HHXRT are displayed below:

- Pentium III 933 MHz processor with 256 MB RAM, 40 GB HDD and 8 MB ATI Rage Mobility graphics;
- Operating system is Microsoft Windows XP;
- 8.4" Daylight readable SVGA TFT with resistive touch screen;
- Ports are 1 x USB, 1 x RS232, 1 x docking, mic/spk, 2 x internal mini PCI slots, 2 x Type II/1 x Type III PCMCIA slots, Primary Li-ion battery (3 hrs operation)(external secondary option –additional 4 hrs);
- Dimensions are 250 x 190 x 35 mm;
- Weight is 1.6 kg.

Figure 76. Hammerhead XRT™ field computer.

Global Positioning System (GPS)

The purpose of the GPS is to aid navigation to the plot centre. The Trimble Pro XR series of GPS units (Figure 77) use differential correction (DGPS) in order to achieve the accuracy needed in the NFI. This differential signal was provided from radio signals broadcast by the Commissioners for Irish Lights. As the DGPS signal is delivered in real time, the variation around the real position could be three metres.

Figure 77. A Trimble™ Pathfinder Pro XR Series GPS.

Laser Range Finder and Electronic Compass

The Impulse™ laser range finder, with built in inclinometer (Figure 78) and Mapstar™ electronic compass (Figure 79) are used for many purposes in the NFI. For example, to aid navigation to plot centres, to map tree positions, to measure tree height and crown projections, record the slope and aspect of plots.

Figure 78. Impulse™ laser range finder and remote diameter scope.

Figure 79. Mapstar™ electronic compass.

Remote Diameter Scope

A magnified remote diameter scope (Figure 78) is fitted to the laser rangefinder. This is used to obtain upper diameters of trees and to aid viewing objects. A graduated scale within the scope is used in the measurement of upper stem diameter (+/-10mm).

Configuration of the Field Equipment

The laser rangefinder, remote diameter scope and electronic compass are arranged on a carbon monopod. GPS, Laser and compass are connected to the field computer via a serial port replication cable with two communication ports. The tablet PC is mounted in a harness, which is supported by shoulder straps, both hands are free for equipment control. The tablet PC remains visually clear at all times, during navigation to the plot and while plot measurement is undertaken (Figure 80).

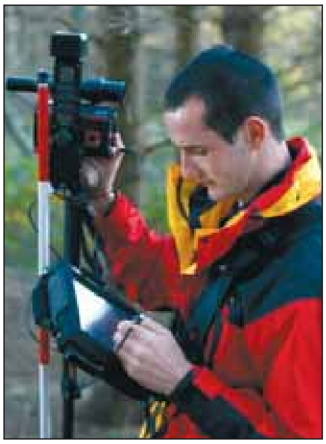

Figure 80. Configuration of field equipment.

Reference Pole and Reflector

Two types of poles are used, namely a graduated telescopic main pole with built in plumb level and a graduated reference pole. The main pole is used for laser measurements while the reference pole is used for positioning on the plot.

Mobile Phone

The mobile phone is an integral component of field-work as it allowed communication links to be maintained to provide:

- Element of safety;
- Technical support;
- The relay of instructions;
- Private owner contact.

Appendix 4 Plant Species

Plant Species	Plant Species	Plant Species
Aegopodium podagraria	Chamerion angustifolium	Galanthus nivalis
Agrostis capillaris	Chelidonium majus	Galeobdolon sp.
Agrostis sp.	Chenopodium album	Galeopsis tetrahit
Agrostis stolonifera	Chrysosplenium oppositifol	Galium aparine
Achillea millefolium	Circaea lutetiana	Galium odoratum
Ajuga reptans	Cirsium arvense	Galium saxatile
Alliaria petiolata	Cirsium palustre	Geranium pratense
Allium ursinum	Cirsium vulgare	Geranium robertianum
Anemone nemorosa	Clematis vitalba	Geranium sanguineum
Anemone ranunculoides	Conopodium majus	Geranium sp.
Angelica sylvestris	Convallaria majalis	Geranium sylvaticum
Antennaria dioica	Cystopteris fragilis	Geum urbanum
Anthriscus sylvestris	Cytisus scoparis	Glechoma hederacea
Anthoxanthum odoratum	Dactylis glomerata	Grimmia pulvinata (moss)
Aquilegia vulgaris	Deschampsia caespitosa	Gymnocarpium dryopteris
Arctium minus	Deschampsia flexuosa	Hedera helix
Arrhenatherum elatius	Dianthus sp.	Heracleum sphondylium
Arum maculatum	Dicranum sp.	Hieracium sp.
Asplenium sp.	Digitalis purpurea	Holcus lanatus
Asplenium ceterach	Dryopteris sp.	Holcus mollis
Asplenium viride	Dryopteris affinis	Homalothecium sericeum
Aspelium scolopendrium	Dryopteris carthusiana	Hordelymus europaeus
Aspelium tricohomanes	Dryopteris dilatata	Hyacinthoides non-scripta
Athyrium filix-femina	Dryopteris filix-mas	Hymenophyllum tunbrigense
Atropa bella-donna	Empetrum nigrum	Hymenophyllum wilsonii
Betonica officinalis	Epilobium hirsutum	Hypericum pulchrum
Blechnum spicant	Epilobium montanum	Hypnum cupressiforme
Brachypodium pinnatum	Equisetum arvense	Hypochoeris radicata
Brachypodium sylvaticum	Equisetum sylvaticum	Hypochoeris glabra
Bromus sp.	Erica cinerea	Impatiens grandulifera
Buglossoides purpurocoerulea	Erica tetralix	Impatiens parviflora
Calamagrostis epigeios	Eriophorum agustifolium	Iris pseudacorus
Calamagrostis sp.	Eriophorum sp.	Isothecium myosuroides
Calluna vulgaris	Eriophorum vaginatum	Juncus acutiflorus
Caltha palustris	Euphorbia amygdaloides	Juncus articulatus
Calystegia sepium	Euphorbia sp.	Juncus conglomeratus
Campanula sp.	Festuca altissima	Juncus effusus
Capsella bursa-pastoris	Festuca heterophylla	Juncus inflexus
Cardamine sp.	Festuca ovina	Juncus sp.
Carex binervis	Festuca ruba	Juncus squarrosus
Carex pilulifera	Filipendula ulmaria	Koeleria glauca
Carex sp.	Fragaria sp.	Lamiastrum galeobdolon
Carex sylvatica	Fuchsia magellanica	Lamium purpureum
Cerastium fontanum	Funaria hygrometrica (moss)	Lathyrus pratensis
Ceterach officinarum	Fuscia sp.	Lathyrus montanus

Plant Species	Plant Species	Plant Species
Leucobryum glaucum	Polypodium sp.	Trifolium pratense
Lilium martagon	Polystichum aculeatum	Trifolium repens
Lolium multiflorum	Polystichum setiferum	Trifolium sp.
Lolium perenne	Polytrichum sp. (moss)	Typha sp.
Lonicera periclymenum	Potentillia erecta	Ulex europaeus
Lotus corniculatus	Primula veris	Urtica dioica
Lotus pedunculatus	Primula vulgaris	Urtica urens
Luzula campestris	Pteridium aquilinum	Vaccinium myrtillus
Luzula luzuloides	Pulmonaria sp.	Vaccinium oxycoccos
Luzula multiflora	Ranunculus ficaria	Vaccinium vitis-idaea
Luzula pilosa	Ranunculus flammula	Valeriana officinalis
Luzula sylvatica	Ranunculus repense	Veronica chamaedrys
Lycopodium sp.	Ranunculus sp.	Veronica montana
Lysimachia nemorum	Rhodendron ponticum	Veronica sp.
Lysimachia sp.	Rhytidiadelphus sp.	Vicia sativa
Lysimachia vulgaris	Rosa arvensis	Vicia sepium
Maianthenum bifolium	Rubus caesius	Vicia sp.
Matteuccia struthiopteris	Rubus fruticosus	Vinca minor
Melampyrum pratense	Rubus idaeus	Viola riviniana
Melampyrum sp.	Rubus sp.	Viola sp.
Melica uniflora	Rumex acetosa	
Mercurialis perennis	Rumex acetosella	
Milium effusum	Rumex obtusifolius	
Mnium sp.	Rumex sp.	
Molinia caerulea	Sanicula europaea	
Mycelis sp.	Schistidium apocarpum	
Myosotis arvensis	Scirpus sylvaticus	
Myrica gale	Senecio sp.	
Nardus stricta	Sesleria albicans	
Oenanthe crocata	Sesleria sp.	
Osmunda regalis	Schoenus nigricans	
Oxalis acetosella	Silena sp.	
Papaver rhoeas	Silene dioica	
Papaver dubium	Silybum marianum	
Pedicularis sylvatica	Solidago virgaurea	
Petasites albus	Sphagnum sp.	
Phalaris arundinacea	Stachys sylvatica	
Phegopteris connectilis	Stellaria holostea	
Phleum pratense	Stellaria media	
Phyllitis scolopendrium	Succisa pratensis	
Pleurozium schreberi	Symphytum officinale	
Poa annua	Teucrium scorodonia	
Poa nemoralis	Teucrium sp.	
Poa sp.	Thuidium tamariscinum	
Poa trivialis	Tortula muralis	
Polygonatum multiflorum	Trichomanes speciosum	
Polygonum sp.	Tricophorum cespitosium	

Appendix 5 Shrub Species

Shrub Species	Shrub Species	Shrub Species
Alnus viridis	Euonymus verrucosa	Ribes sp.
Amelanchier ovalis	Frangula alnus	Ribes uva-crispa
Berberis sp.	Hedera helix	Rhodendron ponticum
Betula nana	Humulus lupulus	Rosa sp.
Buxus sempervirens	Ilex aquilifolium	Salix sp.
Calluna vulgaris	Juniperus sp.	Salix caprea
Clematis vitalba	Ligustrum sp.	Sambucus nigra
Cornus mas	Lonicera sp.	Sambucus racemosa
Cornus sanguinea	Malnus sylvestris	Solanum sp.
Corylus avellana	Prunus laurocerasus	Staphylea pinnata
Cotoneaster integerrima	Prunus mahaleb.	Syringa vulgaris
Crataegus monogyna	Prunus padus	Tamaris communis (Yam)
Crataegus. sp.	Prunus spinosa	Viburnum lantana
Daphne mezereum	Rhamnus cathartica	Viburnum opulus
Escallonia sp.	Rhamnus frangula	
Euonymus europaea	Rhamnus sp.	

Appendix 6 List of Tree Species used in the NFI

Tree Species	Tree Species	Tree Species
Abies alba	Larix kaempferi	**Tree Species**
Abies concolor	Larix sp.	Prunus spinosa
Abies grandis	Malus silvestris	Pseudotsuga menziesii
Abies nordmanniana	Notofagus sp.	Pseudotsuga taxifolia
Abies procera	Picea abies	Pyrus communis
Acer campestre	Picea engelmanni	Quercus cerris
Acer negundo	Picea glauca	Quercus palustris
Acer platanoides	Picea mariana	Quercus petraea
Acer pseudoplatanus	Picea omorika	Quercus pubescens
Aesculus hippocastanum	Picea pungens	Quercus robur
Ailantus altissima	Picea sitchensis	Quercus robur f. slavonica
Alnus glutinosa	Pinus banksiana	Quercus rubra
Alnus incana	Pinus cembra	Quercus sp.
Alnus viridis	Pinus contorta v. inland	Robinia pseudoacacia
Betula pendula	Pinus contorta v. lulu	Salix caprea
Betula pubescens	Pinus contorta v. NC	Sorbus aria
Betula sp.	Pinus contorta v. SC	Sorbus aucuparia
Carpinus betulus	Pinus mugo var. mughus	Sorbus torminalis
Castanea sativa	Pinus mugo var. uncinata	Taxus baccata
Corylus avellana	Pinus nigra v. maritima	Thuja plicata
Cupresus macrocarpa	Pinus radiata	Tilia cordata
Fagus silvatica	Pinus silvestris	Tilia platyphylla
Fraxinus americana	Pinus strobus	Tilia tomentosa
Fraxinus excelsior	Platanus acerifolia	Tsuga heterophylla
Chamaecyparis lawsonia	Populus alba	Ulmus carpinifolia
Ilex aquifolium	Populus canescens	Ulmus glabra
Juglans nigra	Populus cultivated	Ulmus laevis
Juglans regia	Populus nigra	Ulmus procera
Juniperus communis	Populus tremula	Ulmus scabra
Larix decidua	Prunus avium	

INDEX

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