Chapter 2
Design and Measurements

National Forest Inventory of Finland (NFI) has evolved from a line survey to a plot-based inventory (Sect. 1.3). Simulated sampling was introduced as a tool for planning the design during NFI8 and it was fully adopted in NFI9 (Sect. 2.1). The main assessment units in the field work are stands and individual trees, although some of the variables are assessed on circular plots with fixed radius (Sect. 2.2). Section 2.3 explains how the centre points of the sample plots were located in the field.

A fairly detailed and comprehensive description of the variables assessed in NFI9 is given in Sects. 2.4–2.20. For some variables, this is essential for the interpretation of the results reported in Chap. 4 and the Appendix tables, but the description also contains many variables for which results are not presented. The aims are to demonstrate the full extent and complexity of a real-life NFI, to give a realistic picture of the amount of information achieved with the reported effort (Sect. 2.24), and to provide the kind of details that might be useful to those actually implementing an inventory. This text, in particular Tables 2.1–2.34, can also serve as a reference to the users of NFI9 data, which is facilitated by listing the codes actually used in the NFI database.

Section 2.21 presents the measurement devices employed and Sect. 2.22 details a correction to height and height increment measurements which was found necessary after the first year's experiences with a new instrument. The training of the field crews and the control measurements are described in Sect. 2.23.

2.1 Field Sampling Design

The general approach in recent NFIs has been to group sample plots into clusters, the measurement of which should amount to approximately one day's work. The plots of one cluster should be so close to each other that it is feasible to move between them on foot, but sufficiently far apart to avoid too many cases, where one stand contains multiple plots. With the exception of the sparsely forested

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northernmost part of the country (see Sect. 2.1.4), the clusters have been spread out systematically, in the form of a rectangular grid. The design has been adapted to the large-scale spatial variability in the forests so that the sampling is sparser in the north, where the stands are larger and the variation in the stock is smaller. Also the administrative regions, for which inventory results are required, are larger in the north.

Forestry centres (Fig. 2.1a) are the most important administrative units, for which NFI results are reported. The measurements of NFI9 also proceeded by forestry centres.

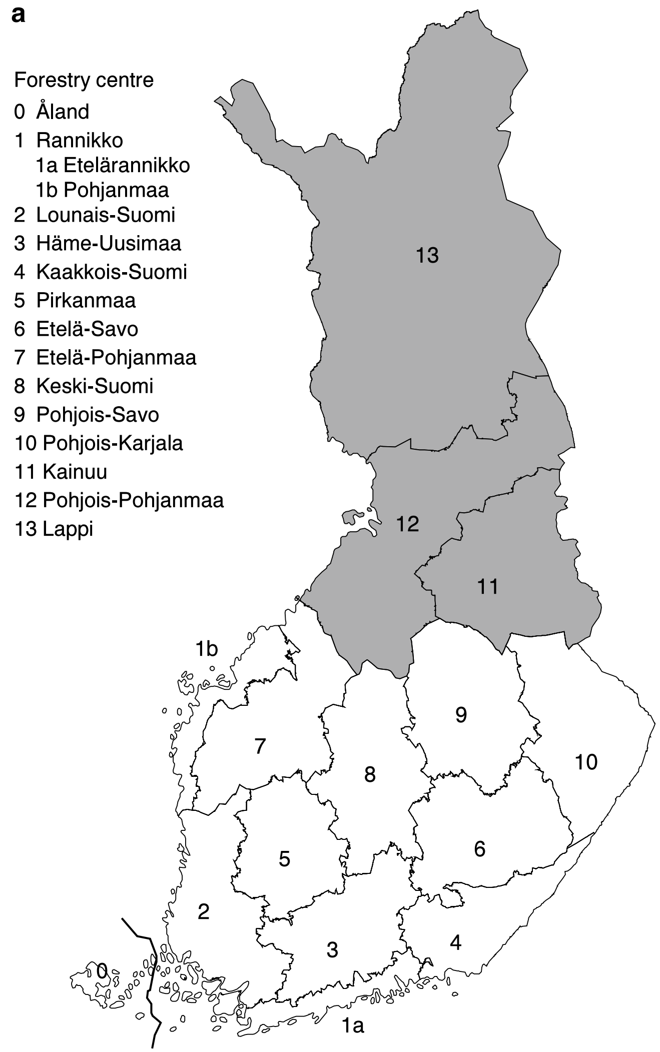

Fig. 2.1 (**a**) Forestry centres 1.1.2003 (North Finland grey). Digital map data: © National Land Survey of Finland, licence No. 6/MYY/11. (**b**) Sampling density regions and the locations of the field plot clusters in the 9th National Forest Inventory. In the entire country, there were 81,249 sample plot centres on land, 67,264 on forestry land, 62,266 on forest land and poorly productive forest land, and 57,457 on forest land

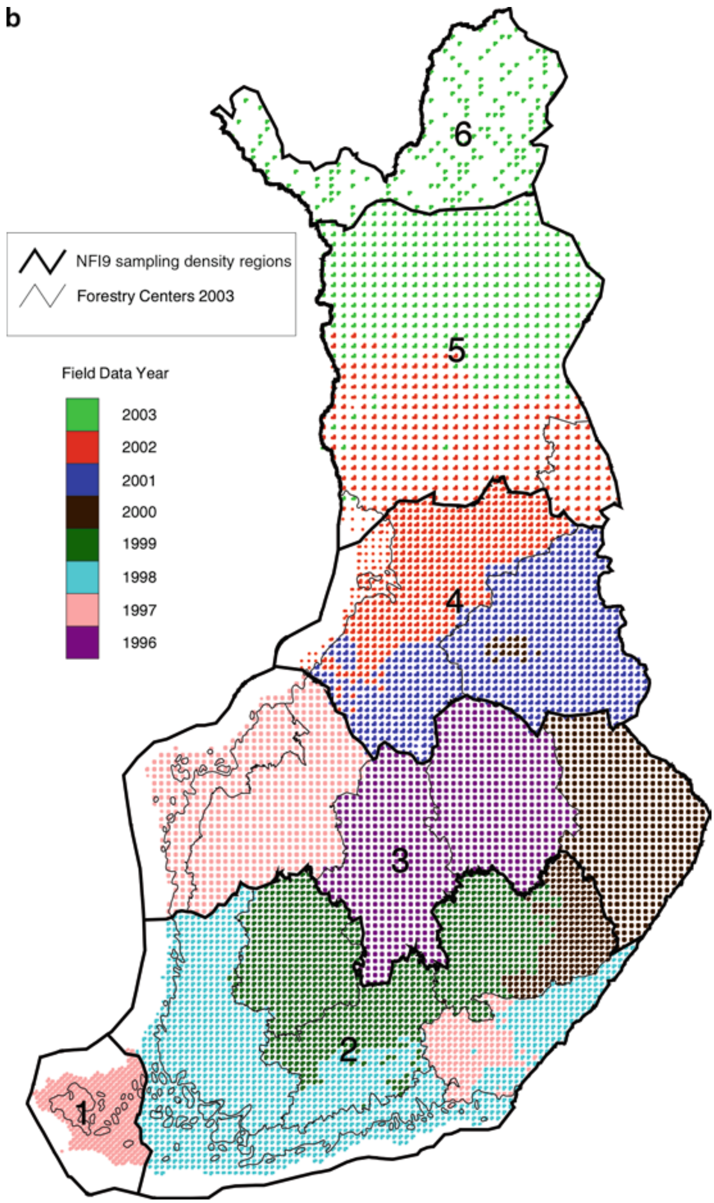

Fig. 2.1 (continued)

The adopted inventory design (e.g., the density of clusters, and the number of and distances between the plots in a cluster) varied between *sampling density regions* (Fig. 2.1b). The borders between these regions generally followed those of the forestry centres. The exceptions were caused by changes in the administrative units.

Permanent plots were introduced in the later stages of NFI8, when North Finland was measured. Three permanent plots were established in each cluster and re-measured in NFI9. However, a new strategy was adopted in NFI9, where every fourth cluster was made permanent except in Åland (Fig. 2.2). Because the workload per plot is heavier on permanent than temporary clusters, a smaller number of plots was assigned for a permanent cluster than for a temporary one.

2.1.1 Sampling Simulation

The sampling designs in each region were chosen on the basis of sampling simulation studies (Henttonen 1991, 1996; Tomppo et al. 1998a, 2001) using digital maps of land use and of the volume of growing stock. Pixels in the digital maps were repeatedly sampled (1,000–2,000 repetitions) according to each potential design, and the *simulated error*, the standard deviation of the sample means, was assumed to anticipate the sampling error associated with that design in relation to the competitive designs. The implementation varied by region depending on the available data (for details, see Sects. 2.1.2–2.1.4), but the general idea was to choose the design with the smallest simulated error among those satisfying the budget constraints. The time consumption of the different phases, such as walking to a cluster, moving from one plot to the next, measuring a tree, conducting the stand level assessment, and mapping the trees on the permanent plots, were partly taken from a study by Päivinen and Yli-Kojola (1983) and partly collected from field crews and earlier experiences (Henttonen 1991; Tomppo et al. 2001).

2.1.2 South Finland

Test areas of 60 km × 60 km were selected from sampling density regions 2 (13 areas) and 3 (8 areas). The sampling was simulated on a thematic map of land use and the volume of growing stock on forestry land produced by the multi-source NFI using digital map data, satellite images and NFI8 field data (Tomppo et al. 1998b, 2008). In addition to the aim of measuring South Finland in three field seasons, an upper limit of approximately 3% was set to the simulated relative sampling error of the mean volume estimates for the test areas, based on the simulated error obtained with the design of NFI8.

It was found that the ‘optimum’ design depended on, for instance, the distribution of forest land and the heterogeneity of the forests and therefore varied from south to north (Fig. 2.3). An L-shaped cluster with 14 plots was selected for region 2 (10 plots on the permanent clusters) and a rectangle with 18 plots for region 3 (14 plots on a permanent cluster). The distances between the clusters were 6 km × 6 km in region 2 and 7 km × 7 km in region 3 (Fig. 2.2b, c). For sampling density region 1 (the county of Åland) with land area much smaller than that of the

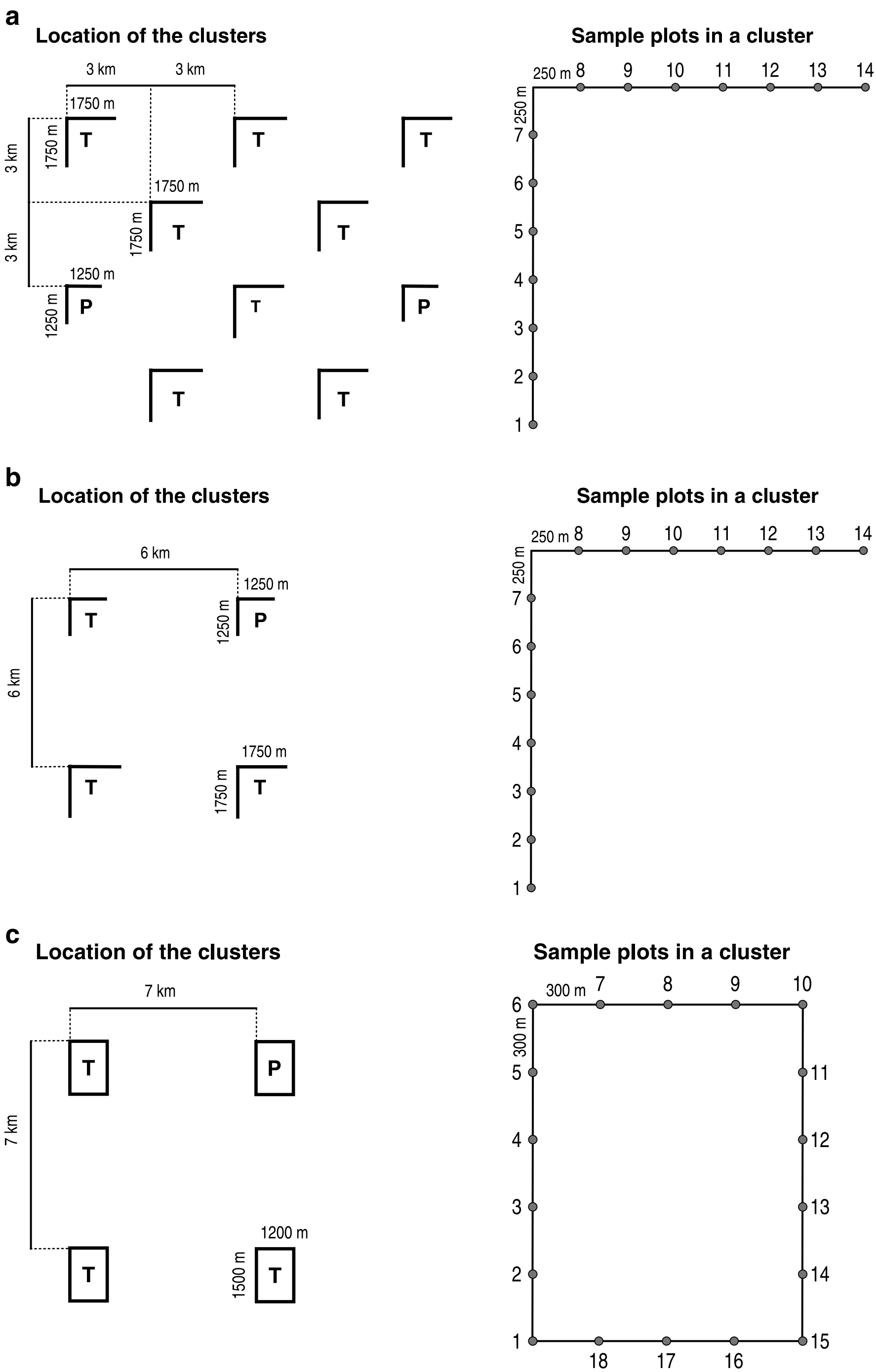

Fig. 2.2 Sampling design employed in the 9th National Forest Inventory in the different sampling density regions of Fig. 2.1b: (**a**) region 1; (**b**) region 2; (**c**) region 3; (**d**) region 4 (in region 5, the design is same but the distance between clusters is 10 km × 10 km); (**e**) region 6, stratified sampling was applied in region 6

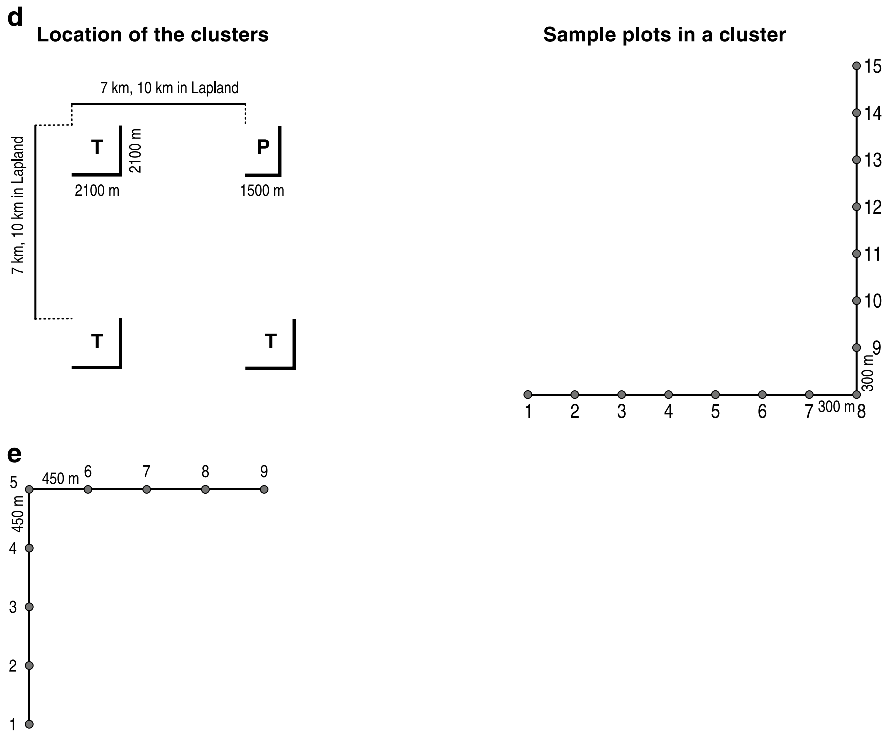

Fig. 2.2 (continued)

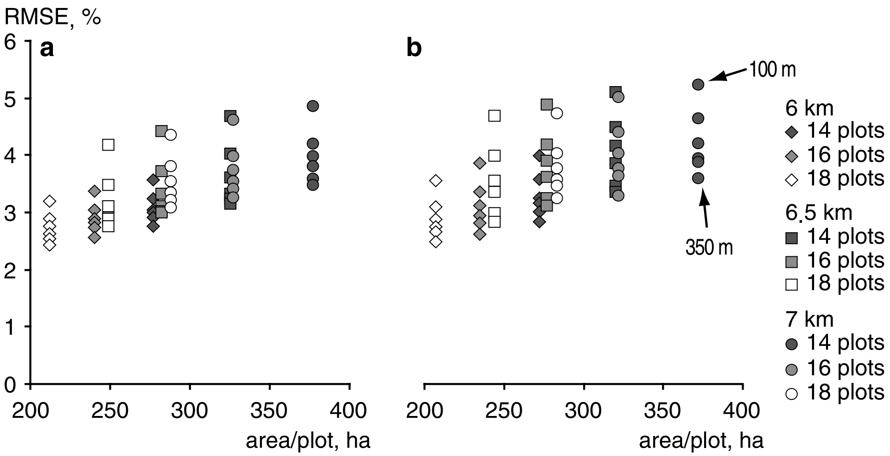

Fig. 2.3 Estimated root mean square errors (%) of total volume for alternative sampling designs in an area of 60 km × 60 km in South Finland. Cluster shape (**a**) is a semi-rectangle and shape (**b**) is rectangle

other forestry centres, the sampling density was approximately doubled by adding an extra row of clusters between each row in the design of region 2 (Fig. 2.2a).

2.1.3 North Finland (Excluding North Lapland)

The design of NFI9 in sampling density regions 4 and 5 was dictated by that of NFI8, owing to the need to re-measure the permanent plots. Thematic maps of the multi-source inventory were not available when the design of NFI8 in region 4 was determined. Instead, sampling was simulated on the maps of the land use and growing stock classification by the National Land Survey, which was based on Landsat 5 TM data and diverse field data sources. For region 5, NFI7 data was used to develop a regression model for predicting the mean volume for each pixel of Landsat 5 TM image.

The aim of the design was to measure each of the two regions (with a land area of approximately 5.7 million ha in region 4 and 6.5 million ha in region 5) in one field season. Among those designs fulfilling this criterion, two designs yielded the smallest simulated sampling errors: a cluster with 15 plots in L-form with plot distance of 300 m, and a rectangular-shaped cluster with 13 plots and plot distances of 400 m. The distance between clusters was 7 km in region 4 and 10 km in region 5. The cluster with 15 plots was selected for both regions in order to allocate more time for field measurements.

The designs were kept the same for NFI9 as in NFI8, except that the direction of the sides of the L-form was changed in such a way that the three permanent plots could be re-measured and the number of the plots in permanent clusters was reduced to 11 (Fig. 2.2d).

2.1.4 North Lapland

Double sampling for stratification (Cochran 1977, sec. 12.2) was employed in North Lapland (sampling density region 6). The proportion of forest land is low, there are large areas without any forest land, the occurrence of forests is patchy, and the road network is sparse. These facts support the use of methods other than systematic sampling when the efficiency requirements are taken into account. A special study was conducted to determine an efficient statistical sampling design (Henttonen 2003).

The study began with measurements of 50 m×50 m test areas to compare the efficiencies of the alternative field plot sizes and shapes, as well as possible field plot cluster sizes, and to determine the 'optimal' field plot and field plot cluster. In total, 18 test areas were measured, together with the planar coordinates of the trees ($d_{1.3}$ at least 2.5 cm), as well as breast height diameter, height and upper diameter at a height of 6 m (for trees taller than 8 m). The plot alternatives tested were angle count plots with several basal area factors (see Sect. 2.2.1 for details on angle count plots) and concentric fixed radius plots with different lengths of the radius. Furthermore, a single plot versus a plot split into two or three sub-plots was studied. Judgements between options were made on the basis of time consumption and the differences between the 'true' mean values over all test areas and their estimates obtained by simulating one plot to each test area. The characteristics employed were volume per hectare and the number of trees per hectare. The number of boundary trees was also taken into consideration when estimating time consumption, in addition to the other phases in measuring a field plot and a field plot cluster.

As a result, an angle count plot with a basal area factor of 1.5 was selected. The selected cluster, using a constraint of one working day for its measurements, consisted of nine plots with a distance of 450 m of two adjacent plots (Fig. 2.2e).

In North Lapland, the measurement costs are dominated by the time required to reach a plot from the closest road. The first phase sample consisted of a regular (systematic) grid of the clusters with a spacing of 7 km × 7 km. The proportion of unproductive land and the measurement costs were the main criteria when selecting the second phase sample. The clusters were stratified for the second phase sample as follows (note that all the plots in a cluster belonged to a same stratum): for each cluster, the proportion of the pixels on unproductive land was calculated using a window of 9 × 9 pixels around each plot. The predictions of land classes based on the multi-source national forest inventory principle were employed (Tomppo et al. 1998b). To reduce the effect of the estimation error, the mean volume of the growing stock was also calculated for the same pixels using the same data source. Further, the 95% confidence interval of the prediction of the effective long term temperature sum was used for each plot. The observations of the Finnish Meteorological Institute and kriging interpolations were used (Henttonen 2003). Further, topographic maps from the National Land Survey were used for assessing the costs to reach a cluster.

Denoting the prediction of the effective temperature sum by d.d. and its 95% upper confidence limit by $u_{t,95}$ and the proportion of the pixels of a cluster on unproductive land (as given presented above) by p_u, the six strata were:

1. $0\% \leq p_u \leq 25\%$, difficult access to the cluster, and $u_{t,95} > 550$ d.d. for at least one plot of the cluster.
2. $0\% \leq p_u \leq 25\%$, easy access (distance to road not more than 1 km without major water bodies between) to the cluster, and $u_{t,95} > 550$ d.d. for at least one plot of the cluster.
3. $25\% < p_u \leq 50\%$, and for at least one plot of the cluster $u_{t,95} > 550$ d.d.
4. $50\% < p_u \leq 90\%$, the mean volume > 14 m^3/ha for at least one pixel of the cluster, and $u_{t,95} > 550$ d.d. for at least one plot of the cluster.
5. $50\% < p_u \leq 90\%$, and the mean volume ≤ 14 m^3/ha for all pixels of the cluster,
   plus the clusters with $90\% < p_u \leq 100\%$, if the cluster does not belong to stratum 6,
   plus the clusters with $u_{t,95} \leq 550$ d.d. for all plots, if the cluster does not belong to stratum 6
6. The clusters with $u_{t,95} \leq 400$ d.d. for all plots,
   plus the clusters with $u_{t,95} \leq 550$ d.d. for all plots and the mean volume ≤ 10 m^3/ha for all pixels,
   plus the clusters with $90\% < p_u \leq 100\%$ and the mean volume ≤ 8 m^3/ha for all pixels.

The clusters in strata 1–4 were at least partly on combined forest land and poorly productive forest land. The plots of strata 5 and 6 are probably either on unproductive land or on poorly productive land with a low volume of growing stock. The 95% upper confidence limit of the effective temperature sum was $u_{t,95} \leq 550$ d.d. for all the plots of these two strata.

The number of clusters for the second phase sample was selected on the basis of the available budget and was set to 180 clusters. These clusters were allocated to the six strata using an optimal allocation (e.g. Cochran 1977). The between-cluster standard deviations of the mean volume within each stratum were used, as well as the assessed relative measurement costs of a cluster. The relative cost was 0.8 for the clusters with easy access and 1 for those with difficult access.

2.2 Assessment Units

2.2.1 Angle Count Plots

Tally trees were selected using angle count sampling (see Sect. 2.16 for the definition of a tree and the tally tree measurements). A tree with a breast height (1.3 m) diameter of $d_{1.3}$ is included in an *angle count plot* (Bitterlich plot), if its distance from the *sample plot centre* (a point determined by the sampling design, Sect. 2.1) is at most $r = 50d_{1.3} / \sqrt{q}$, where q is the *basal area factor* (Fig. 2.4). In NFI9, q was 2 in South Finland and 1.5 in North Finland, where trees are smaller and sparser. However, the tally tree plots were restricted to maximum radii of 12.52 m in South Finland and 12.45 m in North Finland corresponding to breast height diameters of

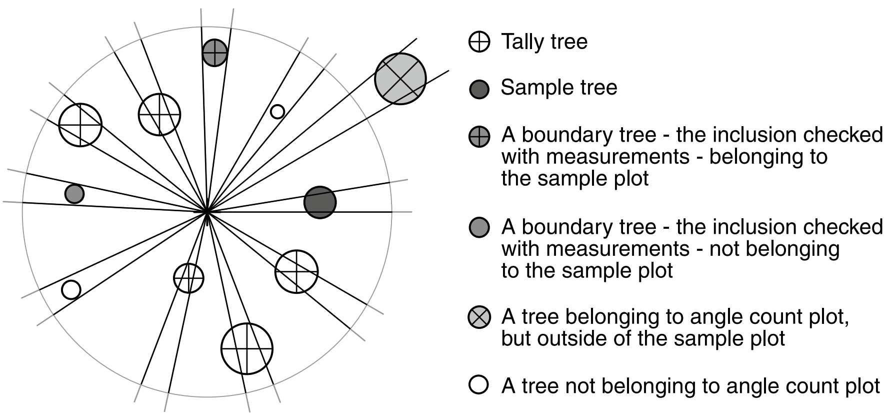

Fig. 2.4 A sample plot as used in the 9th National Forest Inventory. The maximum radius for trees to be counted was 12.52 m in South Finland ($q = 2$) and 12.45 m in North Finland ($q = 1.5$). Every seventh tree was measured as a sample tree, except in North Lapland where every fifth was measured

35.4 and 30.5 cm, respectively. Reducing the radius of a sample plot detracts very little from the precision of the estimates, but it does ease the amount of fieldwork noticeably in some cases, as the number of divided sample plots, i.e. sample plots belonging to two or more stands, decreases. The use of maximum distance also reduces systematic errors caused by unobserved trees, located a long distance from the plot centre and behind other trees. Where a relascope could not be used reliably, inclusion was checked by measuring the distance and diameter of the tree at a height of 1.3 m.

A subsample of tally trees was selected as *sample trees*, from which many additional characteristics were assessed (see Sect. 2.16, Table 2.27). Every 7th tally tree was measured as a sample tree, except in North Lapland where it was every 5th tally tree.

2.2.2 Stands

Most of the variables described in Sects. 2.4–2.14 were assessed at the level of a stand. For the Finnish NFI, a *stand* is defined as a connected land and its possible growing stock that is judged by the field crew leader to be homogeneous with respect to certain variables. Main criteria for delineating stands are administrative boundaries, land use, principal site class, site fertility, and the structure of the growing stock, such as maturity class and tree species composition, as well as the extent of accomplished or needed silviculture and cutting regimes. All of these variables are discussed in detail in the following sections. Note that, for simplicity, the term ‘stand’ may also refer to a patch of non-forestry land, such as an agricultural field or road, or even to a water body. This is in contrast to the use of the word in some other literature, where stand refers to the growing stock only.

The NFI sample included all *centre point stands*, i.e., stands containing at least one of the sample plot centres, and those *bi-stands*, i.e., stands not containing a plot centre, that contained tally trees.

2.2.3 Other Assessment Units

In case of a multi-storied tree stand, some characteristics concerning the growing stock were assessed by *tree storey* (Sect. 2.11). Furthermore, some variables were assessed within a *fixed radius circular sample plot* around the plot centre; namely, topography and coverage of peatland mosses, as described in Sect. 2.6, soil variables of Sect. 2.7, and key habitats of Sect. 2.15. To enable unbiased estimation of the area of key habitats (Sect. 3.1), the area of combined forest land, poorly productive forest land and unproductive land inside the 30 m circle, the key habitat plot, was assessed (as tenth parts).

Dead wood was measured on centre point stands on forest land and poorly productive forest land within a circle with a radius of 7 m, with the exception of the first year of NFI9, 1996, when forestry centres 8 (Keski-Suomi) and 9 (Pohjois-Savo) were measured and the radius was 12.52, see Sect. 2.20. For unbiased estimation of the amount of dead wood, it was necessary to assess the area of the centre point stand inside the dead wood plot (see Sect. 3.4). Fixed-radius plots were also used to sample large trees of keystone species (Sect. 2.18) and to assess the number of tree species (Sect. 2.19).

2.3 Locating the Field Plots

The first attempt to locate the field plots with GPS (Global Positioning System) devices was carried out in the first year of NFI9 (1996). A Garmin GPS 45 single channel device was used. The RDS signal provided by the Finnish Broadcasting company was used to correct the obtained locations and a minimum of three satellite observations was required from the GPS measurements stored in the field. The obtained locations were not precise enough and the collection of GPS data fulfilling the above requirements tended to take too much time. In a study by Rouvinen et al. (1999), the computed GPS locations from the above GPS data were compared to the field plot locations using map measurements, precision compass and measuring tape, as described below, and the minimum average difference obtained between GPS and map based measurements was 24 m in a selected set of field plots.

Thus the field plots in South Finland (1996–2000) were located using *map measurements*. First, a fixed point close to the line between two plots was selected. Estate corner marks and roads crossings or ditches were often used as fixed points. The distance from the fixed point to the line between two plots and distance from this point to the nearest plot was measured from the map and with a measuring tape and a precision compass in the field. Once the location of one plot had been defined, the field team moved from one plot to the next using a compass and measuring tape. The map had to be checked frequently to make sure that orientation was correct. If the difference between the real location and the expected location was more than 30 m, a new fixed point had to be selected.

By 2001, when NFI9 proceeded to North Finland, a sufficiently precise GPS receiver (Trimble ACE II) had been purchased. The GPS system was assembled at Metla installing the receiver into a backpack together with battery and cabling. A field computer was used for display and storage of GPS data. The external antenna was mounted on the backpack.

In North Finland, GPS was used to locate sample plots on forestry land and in other land use classes when the distance from the field plot to the nearest forestry land polygon was less than 20 m. GPS was used both for navigating to the predefined plot location, and for recording the precise location of the plot. Emphasis was placed on the latter aspect because it is very important in multi-source inventory to know the exact locations of the plots.

The field computer software computed the location of the next field plot and guided the crew to the plot. At the plot, GPS data (including the raw data from the receiver) was collected for 2 min to compute a more accurate plot location.

To improve accuracy, the collected GPS data was corrected using reference data from two sources. For the years 2000–2002 the reference data was obtained from the Geodetic Institute of Finland (station in Joensuu for 2000 and station in Oulu for 2001–2002). In 2003, publicly available data from the EUREF Permanent Network Sodankylä station was used. The precise GPS satellite orbits from International GNSS Service (IGS) were used in 2003. The post-correction software was created at Metla.

It is very difficult to assess the accuracy of a GPS system in realistic forest conditions. It is well known that the expected errors are much larger than the errors given by manufacturers for favourable conditions. No systematic accuracy studies have been made with the GPS system used in NFI9. Comparisons with other systems suggest that most of the computed locations are within 6 m of the correct location under "average forest conditions". However, errors larger than 10 m may occur in some cases. The accuracy of field plot locations based on map measurements is poorer. A rough estimate of the average location error when using maps was 20 m (Halme and Tomppo 2001). This is caused by map error and the errors in using the compass and tape.

2.4 Administrative Information

The administrative information includes the municipality, village, the register number of the holding, ownership information (Table 2.1), and possible restrictions on wood production (Tables 2.2 and 2.3). NFI covers the forest of all ownership groups, as well as wood production forests and protected forests of different protection categories. The forest holding register numbers were obtained before field work from the National Land Survey of Finland, and ownership information from databases of the Population Register Finland and the National Land Survey.

Table 2.1 Ownership categories

1	Private forest owners, farmers and other private owners separated from other data sources for special studies if needed
2	Forest companies
3	Other companies
4	Metsähallitus (main administrator of state owned forests)
5	Other areas owned by the state
6	Jointly owned forests
7	Municipalities, religious communities (parishes), and other communities
8	Other undivided ownership, e.g. estates of deceased

Table 2.2 Main categories of restrictions on wood production

0	Areas with no restrictions
1	Areas where wood production was restricted by the Nature Conservation Act, e.g., strict nature reserves and national parks, protected herb-rich forest areas.
2	Areas where wood production was restricted by other laws, e.g., wilderness reserves, recreation areas owned by the state, archaeological sites.
3	Areas where wood production was restricted by authorities responsible for management, e.g., other than statutory protection areas, breeding and research forests, military areas.
4	Areas where wood production was restricted by government resolution including areas reserved for nature protection.
5	Areas where wood production was restricted by land-use planning, e.g., regional and local land use plans, local detailed plans.
6	Areas where wood production should be restricted, e.g. due to the special location, amenity values or habitat of threatened species.

Table 2.3 Categories of the intensity of restrictions

–	No restrictions on wood production.
1	No forest management activities permitted.
2	Areas where only activities to maintain or enhance nature values or biodiversity were permitted.
3	Areas where only specific forest management activities were permitted, e.g. single tree harvesting.
4	Areas under temporary preservation orders; e.g., areas allocated to conservation.
5	Areas requiring a permit to conduct activities, e.g. land-use planning areas.
6	Areas where wood production was affected by the closeness of other land use classes than forestry land (e.g. the closeness of arable land or power line). Fellings can be more intensive than usual.
7	Areas where forest land drainage was not permitted (felling was permitted).
8	Areas where the forest regime did not restrict wood production.

The wood production restrictions were obtained from various sources, e.g., from documents concerning the decisions to establish nature reserves, and maps of the land-use plans as well as the nature conservation databases of the Finnish Environment Institute and Metsähallitus. New restrictions identified during the field work were also recorded.

Category 6 in Table 2.2 was very diverse and it diverged from the other categories since the detection of these areas was based only on field observations by the field crew leader and not on documentation, as in the other cases. Within each category the intensity of the restriction varied according to the management regime. For example, in category 2, the sub-category "wilderness reserves" was divided into areas where all forestry activities were forbidden and areas where only specific forestry activities were permitted. Eight categories for permitted forest management activities were defined according to the regimes by sub-categories (Table 2.3).

2.5 Land-Use and Classification of Forestry Land

Both the national land-use classification (Table 2.4; Tomppo et al. 1998a) and the UNECE/FAO Temperate and Boreal Forest Resources Assessment classification, TBFRA 2000 (Table 2.5; UNECE/FAO 2000) were employed in NFI9. National land-use classes 1–4 make up what is called *forestry land*. The national definitions of land-use classes 1–4 have been employed since NFI5 (1964–1970, Kuusela and Salminen 1969).

Table 2.4 The national land-use classes in NFI9

1	*Forest land*: stocked or temporarily unstocked land with potential capacity to produce a mean annual increment of at least 1 m^3/ha of stem wood over bark over the prescribed rotation under the most favourable stock conditions. Parks and yards are excluded.
2	*Poorly productive forest land*: stocked or temporarily unstocked land with potential capacity to produce a mean annual increment of 0.10–0.99 m^3/ha of stem wood over bark. Parks and yards are excluded.
3	*Unproductive land*: either naturally treeless land or has the potential capacity to produce a mean annual increment of less than 0.10 m^3/ha of stem wood over bark.
4	*Other forestry land*: forestry roads, forest depots and camp lots, small gravel and peat soil pits and game fields within forestry land.
5	*Agricultural land.*
6	*Built-up land*: urban areas, buildings etc.
7	*Land required by transport infrastructure.*
8	*Land under power lines.*
A	*Inland water bodies*: e.g., lakes and rivers with a width of at least 5 m.
B	*Salt water.*

Table 2.5 Land classes according to the FAO definitions (the definitions of a tree, shrub and bush in Sect. 2.16)

1	*Forest*: land with a tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10% or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest. For linear formations, a minimum width of 20 m is employed. Parks and yards, for example, are excluded regardless of whether they would meet the definition of forest land (UNECE/FAO 2000).
2	*Other wooded land*: land with a tree crown cover (or equivalent stocking level) of 5–10% of trees able to reach a height of 5 m at maturity in situ; or a crown cover (or equivalent stocking level) of more than 10% of trees not able to reach a height of 5 m in situ (e.g. dwarf or stunted trees) and shrub and bush cover. The area must be at least 0.5 ha in size and, in the case of linear formations, a minimum width of 20 m.
3	*Other land*: land not classified as forest land or other wooded land as they are defined above.

The *specification of land-use class* indicates, e.g., the location of the stand with respect to the surrounding land, or the area of the stand, if they were affecting the wood production. An example was a small forest stand surrounded by non-forest land. This information is useful when considering cutting possibilities.

The *change of the previous land-use class* and the *time since the change* describe any forestry land changes and changes from forestry land to other land-use classes and vice versa. In this way, changes which were small in area could be estimated more accurately with temporary plots than by using the differences of the area estimates. The gain is similar to that of using permanent plots. A possible failure to recognise changes several years back is a problem. The change within forestry land and changes from forestry land classes to other land-use classes were identified only during the last 10 years, and the changes from other land-use classes to forestry land classes during the last 30 years.

FAO TBFRA 2000 definitions (Table 2.5) were employed together with national definitions in field measurements starting in the summer of 1998 because of the need to employ FAO definitions in international reporting. The FAO definition of forest includes national forest land, a part of the poorly productive forest land, and forest roads of the national classification. The FAO classifications for the first 2 years of NFI9, 1996 and 1997, were derived from other stand level variables. In 1998–2002, the FAO land categories were assessed in the field only for the national land class of poorly productive forest land. It was assumed that all stands on national forest land were included in FAO forest while the stands belonging to national unproductive land belonged to neither FAO forest nor FAO other wooded land. In 2003, assessments based on FAO definitions were made for all centre point stands if the stand belonged to forest land, poorly productive forest land or unproductive land. Assessments were also made for those bi-stands on poorly productive forest land from which tally trees were measured. To support the assessments of the land categories based on FAO definitions, the actual canopy cover was assessed when the plot centre was on national forest land, poorly productive forest land or unproductive land. This assessment was adopted in 1998. The cover was assessed from a full circle with a radius of 12.52 m in South Finland and 12.45 m in North Finland, also when a circle possibly included other land classes than forest land and other wooded land.

2.6 Site Variables

For each sample plot centre, the *elevation* (dm above sea level) was obtained from a digital elevation model provided by the National Land Survey of Finland, and the average *effective temperature sum* (d.d.) over the 30-year period 1951–1980 was estimated as described in Ojansuu and Henttonen (1983).

The principal site class divides forest land, poorly productive forest land and unproductive land into mineral soil and peatland site classes (Table 2.6). A site is classified as *peatland* if the organic layer is peat or if more than 75% of the ground vegetation is peatland vegetation. Otherwise, the site is *mineral soil*.

Table 2.6 Principal site classes

1	Forest on mineral soil
2	Spruce mires
3	Pine mires
4	Treeless peatland (open bogs and fens)

Table 2.7 Site class specifications

0	Genuine peatland or mineral soil
1	Peatland with features of a forest on mineral soil
2	Spruce swamp features
3	Pine peatland features
4	Open bog or fen features
5	Eutrophic brown moss fen features
6	Naturally or artificially forested former non-forestry land

Table 2.8 Site fertility classes

1	Herb rich sites, eutrophic mires and fens and corresponding drained peatlands
2	Herb rich heath forests, mesotrophic mires and fens and corresponding drained peatland forests
3	Mesic forests on mineral soil and meso-oligotrophic natural and drained peatlands
4	Sub-xeric forests on mineral and oligotrophic natural and drained peatlands
5	Xeric forests on mineral soil and oligo-ombrotrophic natural and drained peatlands
6	Barren forests on mineral soil and *Sphagnum fuscum* dominated (ombrotrophic) natural and drained peatlands
7	Rocky and sandy soils and salt marsh (alluvial lands)
8	Summit and fell forests

Drained peatlands that have been open peatlands in their natural states but forested either naturally or by artificial regeneration are also classified as spruce- or pine-dominated peatlands.

Site class specification (Table 2.7) separates genuine and mixed classes. A site is classified as mixed if two different types are clearly discernible. On mineral soils, only codes 2, 3, and 6 are appropriate.

The site fertility classification (Table 2.8) in the Finnish NFI is based on the composition of ground vegetation on the site. The classification was created in the beginning of the twentieth century and further developed for forestry and NFI purposes (Cajander 1909, 1926; Kalela 1961, 1970). On the basis of the definition, a site category describes the vegetation composition when the growing stock is at the mature state and natural tree species composition is natural for the site. The large area climatic variation, as well as treatments such as accomplished cuttings, age of stand and variations in tree species composition, cause variations in the composition of the ground vegetation within the site category (e.g. Cajander 1949). Studies that analyse the effect of climatic variation on ground vegetation are summarised in Kalela (1961). Forest and peatland site types used in NFI refer to the forest vegetation zones (e.g. Lehto and Leikola 1987).

Table 2.9 Site fertility class specification

0	No specification.
1	Patterned fen (>30% of the site covered with relict glacial flakes and pools).
2	*Molinia caerulea* as one of the dominant species.
3	*Sphagnum fuscum* dominated hummocks cover (>30% of the surface).
4	Inundation (that exceeds the normal spring flooding), and significant nutrient input by surface waters or by ground waters (the site eutrophy by surface waters is present (water-front, stream, spring etc.)). The vegetation includes flood meadow species such as *Alnus glutinosa*, *Salix* spp., *Calamagrostis canescens*, *C. purpurea*, tall sedges (*Carex* spp.), *Calla palustris*, *Caltha palustris*, *Phragmites australis* and *Filipendula ulmaria*. Even on drained sites, the surface water effect is visible in the vegetation by the presence of meadow species and the absence of forest species. Also sites that experience short-term eutrophying inundations are included in this class.
5	Shallow peat layer (<30 cm).
6	Mineral soil forest of the *Pyrola* type.

In national land-use classification (Table 2.4), all stands on mineral soil with site fertility class in 1–6 were classified as forest land. Class 7 can be forest land, poorly productive forest land, or unproductive land, and class 8 either poorly productive forest land or unproductive land. The site fertility class specification (Table 2.9) was specifically employed for mires, fens and bogs to specify the site type and its wood production potential.

Wood production potential is also described by topography and coverage of peatland mosses. *Topographical information* describes the variation of elevation and slope of the plot and its surroundings, mainly from the hydrological point of view. The unit of observation was a circle with a radius of 20 m around the sample plot centre. An assessment was made only if the plot centre was on forest land or poorly productive forest land.

Coverage of peatland mosses describes the moisture condition of the sample plot. This variable was adopted in NFI9 and was estimated on forest land, poorly productive forest land and unproductive land based on a circle with a radius equal to the maximum radius of the tally tree plot (12.52 m in South Finland and 12.45 m in North Finland). On mineral soils, mosses considered as peatland mosses were *Sphagnum* mosses and *Polytrichum commune*. On peatlands, open water surfaces (for example patterned fens and water depressions in spruce swamps) and other visibly wet surfaces with coverage of small true mosses (*Mniaceae*, *Calliergon* spp. and *Limprichtia* spp. etc.) were also included in the coverage estimate.

2.7 Soil Variables

Soil variables were assessed by stand on forest land, poorly productive forest land and unproductive land, but the assessment was restricted to a circle with a radius equal to the maximum radius of the tally tree plot. Measurements were taken at the points of a square grid with 4 m spacings (Fig. 2.5).

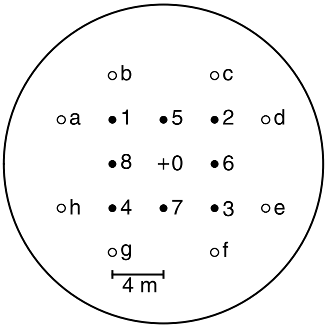

Fig. 2.5 Measurement points for soil variables; '0' is the sample plot centre, and primary measurement points were selected among points '1' to '8' (see descriptions of each variable for details). In a plot intersecting more than one stand, supplementary points (a–h) could be used to yield a sufficient number of points per stand

Table 2.10 Soil types

0	Organic soil
1	Bedrock
2	Stony soil, boulder field
3	Glacial till
4	Sorted soil

The soil variables employed in NFI9 were: soil type, mean grain size, depth of the soil, stoniness, decomposition stage of surface peat, organic layer type and the depth of the organic layer. Stoniness and decomposition stage of surface peat were assessed only on permanent plots in NFI9. The depth of the organic layer was measured down to 4 m for the first time since NFI3 (1951–1953) (Ilvessalo 1957).

Soil type (Table 2.10) was determined at the depth of 10–30 cm from the surface. Depending on the homogeneity of the site, 2–5 observations were made, primarily at points 1–4 of Fig. 2.5. Soil type was always recorded as bedrock or stony soil if the thickness of the soil (organic and mineral layers) was less than 10 cm. If the thickness of the organic layer on top of the mineral soil was less than 30 cm or if the thickness of the soil (organic and mineral) was 10–30 cm and there was mineral soil between the organic layer and the bedrock, the soil type was determined on the basis of the mineral soil.

Mean grain size was assessed if the soil type was glacial till or sorted soil. The classes were 'fine', 'medium', and 'coarse'. *Stoniness* measurements were made only on forest land and poorly productive forest land stands and only if the thickness of the organic layer was less than 15 cm. The measurements were made at points 1–4 of Fig. 2.5 using a soil probe, and the recorded result was the average of the measurements.

On permanent plots, the type (Table 2.11) and thickness of the organic layer were assessed at points 1–4 of Fig. 2.5; on temporary plots, points 1–3 were selected. In NFI, mull soil is classified as an organic layer. *The thickness of the organic layer*

Table 2.11 The types of organic layer

0	Very thin (<1 cm) or missing organic layer
1	Raw humus
2	Moder
3	Mull soil
4	Peat
5	Raw humus on peat
6	Mull-like peat

Table 2.12 Drainage situation

0	Undrained
1	Drained mineral soil forest
2	Drained peatland, drainage effect not yet visible
3	Transforming stage of drained peatland
4	Transformed stage of drained peatland

was recorded with an accuracy of 1 cm, but an accuracy of 5 cm was sufficient if the thickness was 10–30 cm and an accuracy of 10 cm if the thickness was over 30 cm. The thickness of the organic layer was measured to the depth of 4 m.

2.8 Drainage Situation

The assessments concerning the drainage situation were made from the point of view of wood production, but these variables also give information about the naturalness of the site and can be used as biodiversity indicators.

Drainage situation (Table 2.12) distinguishes undrained and drained forestry land and classifies drained peatland on the basis of the progress of the drainage effect (the drainage stage). The improvement in hydrology and lowering of the water table to increase timber productivity has been the aim of the forest drainage, and is seen also in the class definitions. Drainage for other than forestry purposes (road ditches, agricultural cut-off ditches, individual main ditches etc.) was considered only if the drainage had had an effect on tree growth or if the drainage covered the entire stand. The final aim of the drainage operation (the transformed stage) is a drained peatland site whose ground vegetation resembles one of the mineral forests site types and the hydrology does not limit the closure of the stand. The transforming and transformed sites can be classified as poorly productive forest land or unproductive land if, due to the poor fertility of the site, they cannot be classified as forest land.

2.9 Taxation Class

The income taxation of wood production was based on the potential productivity of the sites and the area owned by the land owner. All individual forest land stands were classified into site fertility classes for taxation purposes. The system was

Table 2.13 Taxation classes

0	Herb rich sites and herb rich heath sites (site fertility classes 1 and 2) on mineral soils excluding the *Pyrola* type
1	Mesic forests and herb rich heath sites of *Pyrola* type on mineral soils
2	Sub-xeric forests and mesic forests of a very thick raw humus layer
3	Xeric and barren mineral soil forests, forests of a very thick raw humus and *Pleurozium schreberi* moss layer, natural spruce swamps (productivity ≥1 m^3/ha per year)
4	Natural pine fens and bogs

adopted in 1921 and lasted until the end of 2005. During the years 1993–2005 it ran parallel with a revenue based income taxation system. NFI played a central role in establishing the system and provided the average production figures based on the average tree stem volume increments and timber assortment distributions by municipalities. For this purpose, the NFI field work classified forest land stands into taxation classes (Table 2.13), which closely resembled site fertility classes (Table 2.8) but also took into account possible factors that lowered the wood production capacity.

Where the productivity of forest land was significantly lower than normal for any given site fertility class it was placed into the class that best described its productivity. Examples of sites of lowered productivity are forests on bedrock or exceptionally stony soil, forests on shores susceptible to wind, forests on hills where there is frequent snow damage, paludified forests, forests on excessively wet soils and intensively burned forests. If the wood productivity of the site did not even equal that of the lowest taxation class, the site had to be classified as poorly productive forest land or unproductive land. In the inventory, the taxation class was determined based on the current stage of the site.

Drained peatland forests in the transformed stage were classified in the same way as the corresponding mineral soil forests. Drained peatlands in the transforming stage were normally placed into a higher taxation class than the corresponding undrained peatlands, but into a lower taxation class than the corresponding mineral soil forests. On undrained peatlands and on peatlands, where the drainage effect was not yet visible, it was not necessary to follow the coding of Table 2.13, if the wood productivity of the stand corresponded to another taxation class.

2.10 Retention Trees to Maintain Biodiversity of Forests

The current forest management guidelines (Metsätalouden kehittämiskeskus Tapio 1994, 2001, 2006) recommend leaving some living trees, dead trees, snags, long stumps etc. in regeneration cuttings to decay and maintain biodiversity of forests. One goal of NFI9 was to provide information about the extent of the areas with retention trees and about the volume of these trees. For this purpose, retention trees on forest land were described, either as a separate tree storey (see Sect. 2.11) if the number of these trees per hectare was high enough, or otherwise, in fact in most

Table 2.14 Retention tree classes

0	No retention trees
1	Large, saw timber-sized living retention trees
2	Pulpwood-sized living retention trees
3	Snags left on (former) regeneration area
4	Fallen trees, e.g., wind thrown retention trees
5	High stumps (minimum height 2 m) left in the regeneration cutting
6	Clusters of natural seedlings, usually under growth trees of the previous tree generation left in the regeneration cutting
7	Retention trees left as a buffer zone to protect springs, streams etc. or a group of retention trees (but too few be regarded as a stand)
8	Retention trees forming a stand, possibly within a larger management stand

cases, using variables retention trees class (Table 2.14) and abundance of retention trees. *Abundance of retention trees* was assessed in terms of the number of the stems per hectare or in terms of the connected areas per hectare.

2.11 Description of the Growing Stock of the Stand

The growing stock of a forest land stand was described for most variables by *tree storeys*, and for some variables for the entire growing stock, i.e. for the combined tree storeys. The key rules for separating tree storeys were that they must be adequately distinguishable, the difference of the mean age of the tree storeys is usually at least 40 years and the volume or stem number of growing stock for both tree storeys is sufficiently high. The tree storey categories were: dominant, standards and under storey. The standards could be seed trees, shelter trees or retention trees. The under storey could be classified as usable undergrowth, non-viable undergrowth or unstable seedling material. Note that the within tree storey variation of the age of the trees could also be higher than 40 years, e.g., in the case of naturally originated stands on poor sites. The difference could also be lower than 40 years, e.g., in the case of different species, such as young spruces under broadleaved trees, particularly on fertile sites. The difference of the mean heights of the trees of the two storeys was significant in those cases. A general rule is that the tree storeys are of different development classes (Table 2.17). However, in the case of development class advanced seedling stand, separate tree storeys could have the same development class. In such cases the upper storey was typically broadleaved trees.

Only the two most significant tree storeys were described (Table 2.15). The significance was assessed from the point of view of the development of the stand. Other possible parts of the growing stock were combined to these storeys. A stand was classified as uneven-aged when the growing stock consisted of a mixture of parts of clearly different storeys and even-aged structure could not be achieved with

Table 2.15 Number of tree storeys

0	Uneven-aged stand
1	Single-storied stand
2	Two-storied stand

cuttings or silvicultural operations. Selective thinning from above could be recommended for these stands. The description of the growing stock in uneven-aged stands was similar to the description of even-aged single-storey stands. Temporarily unstocked areas were classified as single-storey stands. Regeneration stands with seedlings of viable regeneration material or with retention trees were described as two storeys with treeless clear cut area as the first storey.

Rules to determine the positions of the storeys (Table 2.16) were as follows: the dominant tree storey was the tree storey that determined cutting and silvicultural operations for the stand. In a stand with two storeys, the upper storey was usually dominant. The lower storey was classified as dominant if it consisted of seedlings that were vital and the most suitable tree species for the site and if the upper storey consisted of seed trees or shelter trees that could already be removed (from the silvicultural point of view). The lower storey was also classified as dominant if the upper storey was mature or low-yielding and if the upper storey was not so dense that its removal would lead to the destruction of the lower storey. Development class (Table 2.17) describes the development phase of the growing stock in relation to the expected rotation. It also reflects possible cutting regimes.

The establishment type of a stand separated artificially and naturally regenerated stands, and the artificially regenerated stands further into succeeded and failed ones. It was assessed for seedling and thinning stands (development classes 2–5) and also for temporarily unstocked stands if already planted or seeded growing stock was completely damaged. A forest stand was classified as artificially regenerated if the major part of the trees capable for further development, or left in a thinning, were planted or seeded. The artificial regeneration was failed if the number of vital seedlings planted or seeded was less than the minimum number of stems per hectare required for a stand capable of further development. However, a failed artificial regeneration stand was not necessarily low-yielding if the growing stock had been complemented with natural regeneration.

Tree species proportions were described in NFI9 more thoroughly than in the previous inventories as a contribution to biodiversity monitoring. In total, 22 tree species, 7 species groups plus temporarily unstocked stands were listed (Table 2.29) whereas only 7 codes were available in NFI8. The proportions were assessed by tree storeys on the basis of the volume in development classes 4–8, and on the basis of the number of stems capable of further development in the seedling stand classes (2–3). The most important storeys, from the point of view of the further development of the stand, i.e. storeys with position 1, 2, or 5, (Table 2.16) were described in more detail than the other storeys.

The *dominant tree species and its proportion* were always assessed (except for development class 1). Determination of the dominant tree species started with the

Table 2.16 Position of tree storey

1	*Dominant storey*, not shelter trees.
2	*Over storey* was recorded when it was clearly distinguishable and when it should be considered in the management of the stand. At least some of the over storey trees must be seed or shelter trees or trees that were obviously left for further growing. This class also includes seed or shelter trees that were no longer necessary for the development of the dominant (lower) storey up to the point in time when they could be removed without damaging the dominant (lower) storey. After this time point, the trees were classified as retention trees.
3	*Retention tree storey* was recorded when it consisted of trees of merchantable size and it could not be regarded as seed or shelter trees or trees left for further growing as described in class 2. There must be at least 10–30 trees per hectare – if there were fewer trees they were not described as a storey. Instead, they were recorded as single retention trees as described in Sect. 2.10.
4	*Nurse crop* consists of broadleaved trees and should be of such density that it protects the existing or future spruce seedlings from frost. A single-storied nurse crop was described in a similar manner as the dominant storey.
5	*Under-storey capable of further development* was recorded when (a) the number of seedlings was larger than the minimum number of seedlings for a productive stand as presented in Appendix 10 of the field guide (Valtakunnan metsien 9. inventointi. Maastotyön ohjeet 1996–2003), or (b) the number of seedlings was less than the minimum but the seedlings would significantly support the regeneration of new growing stock. In these cases, a regeneration cutting or planting or seeding (in the case of an already cut regeneration area) was usually proposed for the coming 10 year period. The seedlings must be distributed so that no soil preparation or planting/seeding would be required for some parts of the stand. The seedlings were already established. The species of the under-storey seedlings must be suitable for the site and the upper storey must not be too dense to destroy the under-storey when removed. Usually under-storey seedlings were regenerating continuously.
6	*Under-storey not capable of further development* was recorded if the storey could not be managed to develop a productive growing stock for the stand. The reason can be that the species was not suitable for the site, that the storey was partly destroyed, or that the upper storey was so dense that its removal would destroy the under-storey seedlings. Under-storey not capable of further development was recorded only if the number of seedlings was higher than the minimum presented in Appendix 10 of the field guide (Valtakunnan metsien 9. inventointi. Maastotyön ohjeet 1996–2003).
7	*Non-established seedlings* showing regeneration capability of the site: the storey consisted of suitable species for the site but the density of the upper storey prohibited its development.

assessments of the proportions of the coniferous trees and broadleaved trees. In the case of equal proportions, the assessment was made on the basis of future treatments and predicted favoured tree species. The dominant tree species in the coniferous dominant storeys was the coniferous species with the highest proportion. A similar approach was used for broadleaved dominant storeys. The dominant species of the dominant storey was also the dominant tree species of the stand.

The *second species and its proportion*, a possible *third species and its proportion* as well as the *proportion of coniferous trees* in the total growing stock of the storey

Table 2.17 Development classes

1	*Temporarily unstocked regeneration stand*: a treeless area with possible retention trees and/or single trees that should be removed in clearing of the regeneration area. Small groups of seedlings may also occur on stands belonging to this class.
2	*Young seedling stand*: a stand with a dominant height of the dominant tree species less than 1.3 m.
3	*Advanced seedling stand*: a stand with a dominant height of the dominant tree species of more than 1.3 m. For a major part of the dominant trees (trees that are not removed in thinning), the diameter at breast height ($d_{1.3}$) must be less than 8 cm, and for the largest trees, less than 10 cm. The mean age (at breast height) of the dominant trees should not be more than 50 years in South Finland and not more than 120 years in North Finland.
4	*Young thinning stand*: a stand with a young growing stock at the thinning cuttings stage. The major part of cutting removal should be pulpwood-sized. The minimum mean age (at breast height) is 11 years and maximum 120 years in South Finland and 200 years in North Finland.
5	*Advanced thinning stand*: a stand with an older growing stock and a larger pole size than in young thinning stand. Saw-timber sized stems are typical and also the thinning removal typically contains saw timber. The minimum mean age (at breast height) is 20 years and maximum 140 years in South Finland and 200 years in North Finland. The development class was determined mainly on the basis of mean age if the site was too poor or the species was not suitable for the site to produce timber-sized trees.
6	*Mature stand*: a stand with a growing stock either old and/or large enough for the goal of the management of the stand to be regeneration cutting and establishment of a new stand but regeneration cutting had not yet been started. The maturity for regeneration was primarily determined with the help of the age of growing stock, and to some extent with the help of mean diameter. The stocked parts of strip cutting areas were classified into mature stands.
7	*Shelter tree stand*: a natural regeneration area, usually with 150–300 stems per hectare. The density and structure of the seeding trees allowed natural regeneration. In some cases, the density of the shelter trees may be so high that they must be removed in two stages. A shelter tree stand is usually created with a regeneration cutting (not by natural processes). The regeneration may also call for planting or seeding. The need for planting or seeding determined whether a shelter tree stand was classified as low-yielding or capable of further development.
8	*Seed tree stand*: a natural regeneration area usually with 30–150 fairly large seed trees per hectare (the minimum for birch is 10–30). A guiding maximum basal area for a seed tree stand when creating the stand was 5 m^2/ha.

were assessed for the important tree storeys. Furthermore, the proportion of coniferous stems of the total number of the stems of the storey was recorded in seedling stands. An exception to the previous rules in NFI9 was that the third species in seedling storeys was the broadleaved tree species that had the highest proportion of the total number of seedlings.

The *number of stems* was recorded only for development classes 2 and 3. The stems were counted on three circular plots with a radius of 2.30 m (with a total area of 50 m^2) to support the assessment. The centre points of these circles were the plot centre and two other points within the centre point stand 20 m away from the plot centre to the opposite directions.

The *mean diameter of trees* (cm) was assessed in development classes 4–8 on forest land. It was defined as the diameter of the basal area median tree, and normally estimated by the arithmetic mean of diameters of the tallied trees of the dominant crown storey. However, the mean diameter was also estimated in the field, and the field crew leader recorded his/her judgement on whether the tally trees give a reliable estimate of the mean diameter of the tree storey.

In seedling stands and on poorly productive forest land, the pole size was described by the *mean height of the trees* (dm). In North Finland the mean height was assessed for all development classes. For seedling stands, the mean height was the average height of the dominant and co-dominant seedlings. For development classes 4–8, the mean height was the height of the basal area median tree. For poorly productive forest land, the mean height was defined as the dominant height.

Age of growing stock was assessed on forest land and poorly productive forest land. The age for development classes 4–8 was defined as the weighted average of the ages of the trees with the volume of a tree as the weight. For development class 3 (advanced seedling stand), age was the average age of dominant and co-dominant trees capable of further development. The age of the dominant tree storey had to be measured; subjective assessment could be used for other storeys. The age was not assessed for tree storeys 6 and 7.

The total age was assessed as the sum of the age at breast height and the age of reaching breast height. The *age at breast height* (years) was measured from cores taken at 1.3 m height (later referred to as age cores) or using the annual branch whorls. If the annual rings could not be discerned without a microscope, the age was determined in the laboratory.

The *age of reaching breast height* is the age of a tree on obtaining a height of 1.3 m. If the stand was planted or sown or the trees grew from sprouts, the age of reaching breast height was determined in the field. For naturally regenerated stands, it was obtained using models with tree species, site fertility, and the length of thermal growing season as explanatory variables.

Basal area was assessed on forest land and poorly productive forest land. All living trees were included independently of tree species and diameter. Three angle count samples, completely within the stand if possible, were used as primary observations. The preferred locations of measurement points were the plot centre and the points 20 m in any cardinal direction from the plot centre. If these points did not fulfil the inclusion criteria, additional points were taken from locations close to these points. It was also possible to use half-circles. The basal area factor of the angle-count sample was 2 in South Finland and 1.5 in North Finland. *The basal area of the growing stock* (m^2/ha) was the mean of the three measurements. If the measurement points were not representative for the entire stand, the basal area for the growing stock was estimated. In a two-storied stand, the basal area included trees from both of the storeys. *The basal area of the second tree layer* in a two-storied stand was the basal area of the trees not belonging to the dominant tree layer.

2.12 Damages

NFI included damage assessment for the first time in NFI7 (1977–1984) and more complete assessments were made in NFI8. The assessments were further revised in NFI9 (Table 2.18). Some new damage descriptions were added, such as 'Abnormal flows of resin observed along the stem', 'Deformed stem, sweeps or forks in the stem' caused by former die-back or poor planting, for example, and 'Abnormal dying of branches in the lowest part of the crown', typically caused by fungi (normal competition of neighbouring trees was not recorded as this damage). In NFI8, in addition to damage description, needle loss of trees was assessed as a separate variable both for the entire stand and for the specific needle loss target trees. In NFI9, needle loss was no longer recorded as a stand level variable, but only at the tree level.

Damage was assessed on forest land, and only for tree storeys 1, 2, and 5 (see Table 2.16). Where several types of damage were observed only the most serious one was described. The variables used in damage assessment were symptom description, age of the damage, causal agent and degree of the damage. The symptom description indicated the type of symptoms that were observed, and which part of the trees was affected (Table 2.18).

Table 2.18 Symptom description

0	*No damage*.
1	*Dead standing trees*: dead trees or trees dying before the next growing season.
2	*Fallen or broken trees*: fallen trees or trees that were broken below the midpoint of the living crown. The trees could be dead or living. Also, trees leaning badly were regarded as fallen trees.
3	*Decayed standing trees*.
4	*Stem or root damage*: damage that was either on the trunks or on the roots not further than 1 m from the stem. The cause of the damage could be e.g., fungi, frost, browsing or harvesting.
5	*Resin flows*: abnormal flows of resin observed along the stem higher than 1.5 m from the stump (flow lower than this was recorded with code 4). The length of the visible flows had to be at least 30 cm.
6	*Dead or broken tops*: the main trunk was broken within the upper half of the living crown and the tree had not yet formed a new top recovering the damage.
7	*Other top damage*: die-back, deformation or other damage at the top that had not yet developed to damage on the trunks (code 8).
8	*Stem deformation*: sweeps or forks in the stem, caused. by, e.g., former die-back or poor planting.
9	*Branch damage*: several dead or broken branches within the living crown.
A	*Abnormally pruned crown (from below)*: abnormal dying of branches in the lowest part of the crown, typically caused by fungi. The normal competition of neighbouring trees was not recorded as damage.
B	*Defoliation*: fallen needles, leaves or shoots. Falling of needles or leaves caused by normal annual cycle or male flowering was not recorded as damage.
C	*Discolouration*.
D	*Multiple symptoms*: the growing stock was degenerating because of the age. Several different types of damage were observed.

Table 2.19 Causal agents

0	Unknown		
A	Abiotic/anthropogenic		
	A1	Wind	
	A2	Snow	
	A3	Frost	
	A4	Other climatic factors	
	A5	Fire	
	A6	Soil factors	
	A7	Logging	
	A8	Air pollution (identified source)	
	A9	Other human activity	
B	Animals		
	B1	Voles	
	B2	Moose, deer or reindeer (Cervidae)	
	B3	Other vertebrates	
	B4	Pine shoot beetles (*Tomicus* sp.)	
	B5	Pine weevil (*Hylobius abietis*)	
	B6	Pine sawflys (Diprionidae)	
		(BA)	Common pine sawfly (*Diprion pini*)
		(BB)	European pine sawfly (*Neodiprion sertifer*)
	B7	Other defoliators	
	B8	Spruce bark beetles (*Ips* sp.)	
	B9	Other identified insect	
	B0	Unidentified insect	
C	Fungi		
	C1	Annosum root rot (*Heterobasidion annosum*)	
	C2	Other decay fungi	
	C3	Scleroderris canker (*Gremmeniella abietina*)	
	C4	Pine twisting rust (*Melampsora pinitorqua*)	
	C5	Blister rust (*Peridermium pini*)	
	C6	Other rust fungi	
	C7	Needle cast fungi	
	C8	Other identified fungi	
	C9	Unidentified fungi	
D	Other factors		
	D1	Competition between plants	

The age of the damage described when the damage had started and whether it was still continuing. The age classes for the onset of the damage were less than 2 years, 2–5 years, and more than 5 years.

The causal agent responsible for the damage was identified with the help of observed symptoms and other signs indicating the occurrence of the causing factor, e.g., insects, fungal fruiting bodies. In total, about 30 different causal agents were in the list of the agents (Table 2.19). They could be grouped into abiotic and biotic agents. Examples of abiotic agents are wind, snow, frost, fire and soil factors

Table 2.20 Degree of damage

0	*Slight*: does not affect the silvicultural quality of the stand (Sect. 2.13) and does not change the development class of the stand.
1	*Moderate*: lowers the silvicultural quality of the stand by one class (e.g., from good to satisfactory; see Sect. 2.13) or makes a low-yielding stand even less productive.
2	*Severe*: decreases the quality of the stand by more than one class, changes the development class into unstocked, or makes a low-yielding stand significantly less productive.
3	*Complete*: immediate regeneration required.

(e.g., drought, deficiency of nutrients, frozen soil). The biotic agents could be divided into insects, fungi or vertebrates. Human activity was recorded as the causal agent only in case the damage was not intended (e.g. not stand tending).

The degree of the damage was a stand level variable describing the cumulative effect of all the damage observed (Table 2.20). The baseline for the assessment was the state of the growing stock before the damage attack. The effect of the damage on the growth and yield, mortality and quality of timber was the main criteria for assessing the degree of damage.

During NFI9 (in 1998) a separate assessment of *the deficiency of potassium* was introduced. The deficiency of potassium was observed only for the forest land stands on peatland.

2.13 Silvicultural Quality of Stand

Field plot stands on forest land were classified on the basis of *silvicultural quality* into categories ‘capable of further development’ and ‘low-yielding’. For low-yielding stands, the mean annual yield over the whole rotation period is so much lower than that of a managed stand on a similar site that the stand must be regenerated at a younger age than normal (according to the management schedules) (Metsätalouden kehittämiskeskus Tapio 1994). This assessment was made with reference to a managed stand with species suitable for the site, fully stocked and with a saw timber proportion (in m^3) of at least 45% for coniferous and 40% for broadleaf stands.

As a rule of thumb, the stand was considered to be low-yielding if the yield was less than 60% of that of a managed stand. Usually, the low-yielding stands should be regenerated immediately. In some cases, it would be profitable to postpone the regeneration due to the current or expected high increase in value (a notable increase in the percentage of merchantable or timber-sized stems in the near future). However, the rotation age of an low-yielding stand is always less than the “normal” rotation age for the site. Low-yielding stands can occur in all development classes. The reason for low yield may vary by development classes.

The rules for classifying a stand considered to be capable of further development on the basis of silvicultural quality were as follows. The quality was classified as good if the dominant species was suitable for the site and the stand had been managed

Table 2.21 Reasons for decreased quality

1	Age (the growing stock was over-aged)
2	Species composition
3	Over dense
4	Neglected management
5	Under-stocked
6	Cuttings (low density or poor technical quality caused by cutting or tending of a seedling stand)
7	Structure or spatial distribution of the growing stock (causing reduced yield)
8	Technical quality
9	Damage

according to the management schedules and the number of stems or the basal area of the dominant tree layers was adequate and trees were spatially distributed, evenly enough (Metsätalouden kehittämiskeskus Tapio 1994). For stands with dominant height less than 17–18 m, the basal area should be at least 95% of the minimum given in the recommendations. The corresponding limit was 85% if the dominant height was more than 17–18 m. For a satisfactory stand, the basal area limits were 80% and 70% and for a passable stand 70% and 60% respectively. A high percentage of tree species of low value, damages, poor technical quality, or the other reasons listed above could lower the silvicultural quality of the stand (Table 2.21). On an unstocked regeneration stand, the quality depended on the time since the cutting for artificial regeneration. The quality was good if the time was not more than 2 years, but low-yielding if the time was more than 4 years and the establishment of a new stock had not been started. In assessing the quality of a shelterwood and seed tree stand, time since the cutting for natural regeneration was not so important as in the case of artificial regeneration. Other factors were also considered, such as the accomplished establishment measures (i.e. site preparation and cleaning) and suitability for natural regeneration in a reasonable time.

2.14 Accomplished and Proposed Measures

Accomplished cutting operations were recorded on forest land and poorly productive forest land. The coding was changed during NFI9 (in 2001) in such a way that instead of one cutting, the three most recent cuttings during the past 10-year period were recorded. The proposed cutting operations, as well as accomplished and proposed silvicultural and soil preparation measures, were recorded only on forest land.

The observation period for accomplished cuttings and silvicultural operations was 10 years preceding the inventory time. The cuttings from the period 11–30 years before the inventory time point were also recorded but without the assessment of the cutting type. The proposals for cuttings and silvicultural measures were made

Table 2.22 Accomplished drainage operations

0	*No drainage* during the last 30 years
1	*Initial drainage*
2	*Cleaning of the ditches*
3	*Complementary drainage*
4	*Other than forestry drainage* (road ditches, agricultural ditches etc.)
5	*Blocking of the ditches*. Aiming to restore the peatland back to its natural state; this class was taken into use in NFI9

for the coming 10-year period. However, the need for planting or seeding was recorded in the case of proposed regeneration cutting with artificial regeneration.

The accomplished soil preparation and drainage operations (Table 2.22) were assessed from a 30-year period before the inventory time point. Only the latest operation and its time were recorded.

Prospective needs for drainage were assessed for the next 10 years. Suitability of peatland sites for timber production was assessed using the minimum effective temperature sums and site fertility class, which indicate the nutrient availability and balance. In assessing the suitability for timber production, the age, volume, technical quality and recovering capacity of the growing stock were also stressed. *Erroneous drainages* were assessed, together with their cause, which could be, e.g., a poor site for timber production or the fact that the site is technically unsuitable for drainage. If only a small part of the drainage of a larger peatland complex was erroneous, this was distinguished in the field work from a large-area erroneous drainage. *Ditch spacing* and *condition of ditches* were introduced in NFI9 to support the needed drainage operations and to assist in wood production scenarios.

It should also be born in mind that the proposed operations in NFI are based on the state of each single stand in which the assessment is made. These assessments did not take into account the sustainability of wood production. This should be remembered, particularly in the case of regeneration cuttings. The long-term sustainability of forestry is taken into account when making the long-term cutting scenarios (MELA 2010). Restrictions on wood production (e.g. forest protection) have been taken into account in all proposals (Tables A.29, A.31 and A.33).

2.15 Key Habitat Characteristics

Key habitats are local biodiversity hotspots that, according to the original definition, are rare and likely to host red-listed species (Nitare and Norén 1992). The key habitats are likely to maintain an important part of the biodiversity at local and landscape levels because these sites often have diverse flora and fauna that differ strongly from those of the surrounding areas. Many of the key habitats are small in area and within a regular stand. However, even habitats that could be classified as individual stands were found, especially on peatlands.

From a legislative point of view there are three types of key habitats recognised in Finland. First, *habitats of particular significance* are described in and protected by the Forest Act (1996). The landowner has to leave those areas untouched, or only cutting regimes which support the naturalness of the site are allowed. Only natural and semi-natural key habitats are considered in the Act. The landowner has the responsibility to be aware of the locations of these habitats. Secondly, *protected habitat types* are listed in and protected by the Nature Conservation Act (1996). It is prohibited to alter these habitats in such a way as to jeopardize their preservation, but it is not the landowner's responsibility to find the sites, and most of the habitats occur outside forests. Thirdly, *valuable habitats* are described in the Finnish Guidelines for Forestry Practices (Metsätalouden kehittämiskeskus Tapio 2006) and it is recommended that they and their characteristics are taken into account when managing forests. All three key habitat types are included in the FFCS forest certification criteria (FFCS 1002-1 2003).

In NFI9, the aim was to inventory all types of key habitats as given in the Forest Act, Nature Conservation Act and the other sources described above, regardless of their naturalness, and separately evaluate the naturalness and ecological value of the habitats. This was done in order to examine not only the most valuable sites, but also the potentially valuable sites.

In the legislation, the regional commonness of certain habitat types determines whether an individual habitat is considered as a Forest Act habitat or not. In NFI, however, this regional factor regarding the commonness of a certain habitat class or habitat characteristics was not taken into account (except for eutrophic fens that were not appointed a Forest Act status in Lapland).

A small size was another requirement for some habitats of the Forest Act. This requirement was included in the NFI field instructions only in 1999. Earlier, also large sites of herb-rich forests and oligo- and ombrotrophic mires with only sparse tree stands may have been regarded as Forest Act habitats, more precisely classes I, B, V, C, and E in Table 2.23.

Key habitat plot, a circle of 30 m radius, was established when the plot centre was on forest land, poorly productive forest land or unproductive land. The area of the key habitat patches was assessed within this plot. If a road, river or power line was defined as an individual 'stand' and intersected the 30 m circle, the habitat assessment was not extended beyond the intersection. Up to three habitats could be recorded in one plot. The existence of a key habitat in a stand could also be taken into account when assessing the restrictions on wood production (Sect. 2.4).

The normative minimum area for a key habitat was 300 m^2. However, springs, areas where groundwater surfaces without a visible spring, limestone areas and small rock formations did not have a minimum area, and the minimum area for open rock was 1,000 m^2. In practice, the habitats that could be considered to be individual stands, such as mire habitats and islands of mineral soil forest in undrained peatlands, were often presumed to be larger than the minimum 300 m^2 area.

The aim was to evaluate also those key habitats that were strongly altered by human activities. On drained peatlands at transforming or transformed stage, key habitat was recorded only if the original mire site type could be ascertained.

Table 2.23 Key habitat classes

1	Spring
2	Area where groundwater surfaces without a visible spring
3	Brook-side forest
4	Stand surrounding a small (<1 ha) pond
5	Fen or bog surrounding a small pond
6	Other small wetland area
7	Eutrophic paludified hardwood-spruce forest
8	Eutrophic birch fen or Eutrophic hardwood-spruce fen
9	Eutrophic pine fen
A	Mesotrophic hardwood-spruce mire
I	Oligotrophic hardwood-spruce and pine fens
B	Oligotrophic spruce mires and fens (not on forest land)
V	Ombrotrophic pine bogs (not on forest land)
C	*Sphagnum fuscum*-dominated bogs
D	Eutrophic and mesotrophic fens
E	Open fens and bogs (excluding *S. fuscum*-dominated)
F	Alluvial meadow. The influence of surface water can be seen in the vegetation
G	Dry mesotrophic herb-rich forests on mineral soils
H	Dry eutrophic herb-rich forests on mineral soils
J	Mesic mesotrophic herb-rich forests on mineral soils
K	Mesic eutrophic herb-rich forests on mineral soils
L	Moist mesotrophic herb-rich forests on mineral soils
M	Moist eutrophic herb-rich forests on mineral soils
N	Naturally regenerated rare hardwood forests
P	Islet (<1 ha) of mineral soil forest on undrained peatland
R	Gorge
S	Ravine
T	Precipice (>10 m high)
U	Open rock (soil layer at most patchy, only few trees)
W	Small formations of rock
X	Stonefields, boulder fields
Y	Sand fields
Z	Other rare biotope

The observed key habitat classes varied slightly by vegetation zones because of differences in the occurrence of the key habitats. Table 2.23 gives the set of key habitat classes that includes all key habitats in the entire country. The key habitats are described in more detail in the NFI Field Instructions (Valtakunnan metsien 9. inventointi. Maastotyön ohjeet 1996–2003). Note that habitats may actually be surroundings of a specific element in the forest, such as brook-side forest or area surrounding a spring.

The naturalness of a key habitat (Table 2.24) described how well the key characteristics of the habitat had been preserved. Human influence on the structural elements of the habitat, living and dead trees, vegetation characteristics and species present was considered. Silvicultural and other measures affect the nature of the habitat differently in different habitat types.

Table 2.24 Naturalness of a key habitat

0	Natural
1	Signs of human activity present, but they have not altered the characteristics of the habitat
2	Signs of human activity present and they have altered the characteristics of the habitat to some extent
3	Strongly altered key habitat

Table 2.25 Measures accomplished on key habitats

0	Nature of the key habitat has not been taken into account during measures
1	Careful operations inside key habitat
2	Careful operations inside key habitat and the recommended buffer area
3	Key habitat left untouched during management measures
4	Key habitat and buffer left untouched
5	Key habitat managed for enhancing habitat value (e.g., removal of spruce in herb-rich forests and rare hardwood stands)
6	No measures on the key habitat or in the surrounding stands during past 30 years

Table 2.26 Ecological value of key habitat

0	No special management considerations.
1	The habitat is valuable and should be left unmanaged or managed carefully.
2	The habitat is very valuable and is a habitat of particular significance as described in and protected by the Finnish Forest Act.

The accomplished measures on a key habitat (Table 2.25) described the degree to which the characteristics of the habitat had been taken into account and preserved when operations were performed. Note that some valuable key habitats can be carefully managed, whereas it is recommended to leave others unmanaged in order to maintain biodiversity.

The ecological value of the key habitat (Table 2.26) is an approximate evaluation of whether or not the key habitat is sufficiently valuable that it has to be left unmanaged or managed carefully. Factors such as key habitat class, naturalness, and management history of the habitat, characteristics of the habitat and surrounding stands, and value for the landscape were considered. This variable also distinguished Forest Act habitats from less valuable habitats.

2.16 Tally Tree Measurements

The definition of a *tree* in the Finnish NFI is compatible with that of COST Action E43 (Gschwantner et al. 2009): a woody perennial of a species typically forming a single self-supporting main stem and having a definite crown. Bush-like species, such as bushy junipers (*Juniperus communis*) and willows (*Salix* spp.), are not trees. Goat willow (*Salix caprea*) and bay willow (*Salix pentandra*) can be either trees or bushes depending on their form.

The determination of the breast height and the height of a tree can be problematic on sloped or rugged terrains. For that purpose, *ground level* was defined as the level of the ground against the base of the stem, and on a slope, the point where the ground and the extension of the trunk intersect on the uphill side. Normally, the *origin point* of a tree was determined as the point where the pith meets the ground level. But where a tree grew on top of a stump or a rock, for example, the origin point was determined as point where the seed had most likely sprouted. The *breast height* was 1.3 m from the origin point. A *fork tree* is forked above breast height; if a tree was forked below breast height, each fork was measured as a separate tree.

Tally trees were selected using angle count (Bitterlich) sampling (Sect. 2.2.1). The sampling was restricted to *living trees* and *usable dead trees* with a minimum height of 1.35 m. A tree was declared as living if it had living branches and would survive until the next growing season. A dead tree was considered usable, if the wood could be used at least as fuel wood. Small dimensions or damaged timber did not rule out the dead tree to be of use. A broken tree was considered as a standing dead tree if the standing part of the tree included more than half of the original trunk volume and the branches were dead, and as a lying dead tree if the fallen part of the tree included more than half of the original trunk volume, and the fallen part had not been harvested. If more than half of the volume had been harvested, the broken tree was considered to be a stump and was not tallied (except in the re-measurement of permanent plots). A standing dead tree was considered to be usable if the standing part was usable, and a lying dead tree was usable if the fallen part of the tree was usable. A *stump* originated from felling a living tree or a standing dead tree, or when over half of the trunk volume had been removed from the fallen dead tree, even if the felled or sawn part had not been harvested.

Only the trees on forest land or poorly productive forest land were included in the NFI sample. Thus, the trees in parks, yards and on unproductive land, for example, were not measured. Nor were *shrubs* and *bushes*, woody perennials of a species typically not forming a single main stem and not having a definite crown. However, the angle count plot was also established on those plot centres that were not on forest land or poorly productive forest, but close enough to the stand boundary so that trees on those land-use classes could be included. *Sample trees* (every 5th tally tree in North Lapland, every 7th in the rest of the country) were measured more intensively (Table 2.27). Only the upper diameter, height, and damage were recorded from dead sample trees.

Each tally tree that was measured on those plots which were established as permanent in NFI8 was identified, coded and measured in a way depending on the status of the tree in NFI9 (Table 2.28), even if it was an unusable dead tree. A tree map was used to assist in finding the trees.

Coordinates of the tree were recorded in NFI9 on newly established permanent plots using the *bearing* and the *distance* (cm) from the plot centre. The bearing was measured to the pith of the tally tree at breast height and recorded using a scale

Table 2.27 Tree-level variables

Measured from all tally trees:	
Tree type	(Table 2.28)
Coordinates of the tree (on permanent plots only)	
Tree species	(Table 2.29)
Diameter at breast height ($d_{1.3}$)	
Tree class	
Tree class specification	
Crown layer	
Measured from sample trees only:	
Origin type of the tree	(Table 2.30)
Upper diameter at the height of 6 m ($d_{6.0}$), for trees with a height of at least 8.1 m	
Bark thickness ($b = b_1 + b_2$)	
Lower limit of dead and dry branches	
Lower limit of green crown	
Height (h)	
The length of the broken part, if tree was broken	
Height increment over the past 5 years (i_h), only for coniferous trees, models were applied for broadleaved trees	
Height increment of the measurement year (i_{hm})	
Diameter increment over the past 5 years at a height of 1.3 m (= 2 × radius increment) (i_d)	
Age at 1.3 m	
Age from ground level to 1.3 m, using models	
Variables related to damage, similar to stand level damage	
Defoliation	
A possible change of tree class, with increased information after sample tree measurements, e.g., information based on increment and age boring	
A possible change in the specification of tree class	
The lengths of timber assortment classes	

ranging from 0 to 400. The horizontal distance was measured at breast height from the plot centre to the side of a tally tree facing the plot centre.

The *diameter over bark at breast height* (mm, at 1.3 m from the origin point of the tree) was measured perpendicular to the radius from a tree to the plot centre. The lowest diameter below breast height was measured if the tree was deformed at breast height. Breast height was redefined even if the old marks could be seen on trees on re-measured permanent plots. The diameter of the trees classified as dead trees in NFI8 was not measured but the old diameter was re-entered. Erroneous diameter measurements were corrected.

Tree class was based on the current tree volume and the current volume of the timber assortments, or, in the case of pulpwood size or smaller trees, on the expected volumes. The goal was a grouping in which trees of a same diameter have a similar current or expected saw-timber and pulpwood volume. The main criterion was the current or expected proportion of the highest quality saw-timber of the stem volume.

Table 2.28 Tree type (recorded on permanent plots established in NFI8)

V	Old tally tree. The tree was a tally tree in NFI8 and also in NFI9.
U	New tally tree, height over 1.3 m in NFI8. Within angle gauge in NFI9 due to diameter growth.
S	New tally tree, height under 1.3 m in NFI8.
T	New tally tree. New due to a reason other than growth, e.g., fallen tree, land use change, error or different inclusion criterion in NFI8.
K	Tally tree in NFI8, stump in NFI9, trunk removed between NFI8 and NFI9.
R	Tally tree in NFI8, stump in NFI9, trunk had not been removed.
N	Mistakenly measured tally tree in NFI8, tally tree in NFI9.
Z	Mistakenly measured tally tree in NFI8, not a tally tree in NFI9.
M	Tally tree in NFI8, land use class had changed and the tree did not exist in NFI9.
J	Tally tree in NFI8, land use class had changed, tree still existed in NFI9.
E	Tally tree in NFI8, tree could not be found in NFI9.
P	Tally tree in NFI8, but did not belong into the sample plot in NFI9.

Table 2.29 Tree species

1	Scots pine (*Pinus sylvestris*)
2	Norway spruce (*Picea abies*)
3	Silver birch (*Petula pendula*)
4	Downy birch (*Petula pubescens*)
5	European aspen (*Populus tremula*)
6	Grey alder (*Alnus incana*)
7	Black alder (*Alnus glutinosa*)
8	European mountain ash (*Sorbus aucuparia*)
9	Goat willow (*Salix caprea*)
A1	Lodgepole pine (*Pinus contorta*)
A2	Swiss stone pine (*Pinus cembra*)
A3	Other pine
A4	Larch (*Larix* sp.)
A5	Fir (*Abies* sp.)
A6	Other spruce or fir species
A7	*Thuja* (*Thuja* sp.)
A8	Common juniper *(Juniperus communis)*
A9	English yew (*Taxus baccata*)
A0	Other conifer
B1	Bay willow (*Salix pentandra*)
B2	Fluttering elm (*Ulmus laevis*)
B3	Wych elm (*Ulmus glabra*)
B4	Small-leaved lime (*Tilia cordata*)
B5	Poplar (*Populus* sp.)
B6	European ash (*Fraxinus excelsior*)
B7	Pedunculate oak (*Quercus robur*)
B8	Bird cherry (*Prunus padus*)
B9	Norway maple (*Acer platanoides*)
B0	Other broadleaved

Table 2.30 Origin types of trees

0	Unknown
1	Natural seed originated
2	Natural sprout originated
3	Planted
4	Seeded

The tree class was also utilized in volume estimation, see Sect. 3.2.4. Five different classes were available for trees smaller than saw-timber sized trees, six classes for trees of saw-timber size, three classes for dead trees and three classes for stumps (of tally trees of NFI8 on re-measured sample plots). The saw-timber criteria employed by forest industry companies were used to classify trees into saw-timber and pulpwood. The reason for lowering the tree class was given in *tree class specification*.

The *crown layer* of a tree indicated its storey (Table 2.16), and its vertical position with respect to the other trees of the storey. The current position of a tree was used in development classes 2–6 (Table 2.17). The position with respect to the full stocking phase, i.e., before cutting, was used as criteria in development classes 1, 7 and 8, and also in under-productive stands treated by selective cuttings. Individual trees could also be located to storeys that were not included in the stand-level description of the growing stock (cf. Sect. 2.11).

The origin type of a tree (Table 2.30) can be used in growth and yield studies and as a stratification factor in volume estimation.

The *upper diameter* (cm) was measured at the height 6 m above the origin point of the tree from trees with heights of at least 8.1 m, perpendicular to the radius to the plot centre. The upper diameter was 0 for fork trees.

The *bark thickness* (mm) is measured from trees on temporary plots perpendicular to the radius of the plot and from both sides of each tree. The sum of the measurements is recorded. The bark thickness is used in the estimation of volume increment (Sect. 3.3).

The *lower limit of dead and dry branches* was assessed as the minimum height at which dead branches with a minimum thickness of 15 mm occur; individual dead branches in an otherwise branchless part of a trunk do not count. This variable was used in assessing the quality classes of saw-timber and the lower limit was the height at which the dead branches start to affect the quality classes of saw-timber. The variable was measured only for tree types and species capable of producing saw-timber. The *lower limit of the connected living crown* (dm) was measured from all living sample trees.

The *height of a tree* (dm) was measured along the stem axis from the origin point to the tree top. If a tree, or the main stem in case of a fork tree, was broken, then the *length of the broken part* was also measured and recorded. The length was estimated, if the broken part could not be found.

The *height increment over 5 years* (dm) was measured for coniferous trees using either binoculars or a measurement pole or using a combination of Vertex and binocular records (see Sects. 2.21 and 2.22). The height increments of broadleaved trees were estimated using height increment models, and a *growth space* code was recorded in the field to be used as an explanatory variable in the models. The 5-year height increment was also assessed, in addition to the growth space, for broad-leaved trees with a height of less than 8.1 m. This change was adopted in 1997. The *height increment of the inventory year* was measured from living sample trees. Until 31 July, it is an incomplete increment and not included in the 5-year increment used in the volume increment calculations.

Diameter increment over 5 years at the height of 1.3 m was measured in laboratory from increment cores. The increment cores were bored to the pith in order to obtain data for age calculation and growth variation modelling. The increment borings and bark thickness measurements were carried out only on temporary plots. When it was not possible to obtain a complete increment core, e.g., from a partly decayed tree, the increment was calculated in the field (as 2 times the radial increment).

The *age at breast height* (1.3 m) of a sample tree was calculated from the increment core. In the case of a broken core, the age was either calculated from the core in the field or by counting the whorls of a tree. The *age from ground level to breast height* was assessed either by counting the whorls or by using the known or assessed cultivation time, or by recording the site fertility codes for assessing the time to reach breast height. These codes were inputs for the models to assess the time.

The damage assessments of sample trees were similar to those of stand level assessments (Sect. 2.12). The variables *symptom description*, *age of the damage*, *causal agent*, and *degree of the damage* had the same values as the respective stand level variables (Tables 2.18 and 2.19), except that the description ‘multiple symptoms’ was not applied at the tree level.

The *defoliation class* was assessed for coniferous trees using 5% class intervals. The target trees for defoliation assessments were standards in development classes ‘young seedling stand’ and ‘advanced seedling stand’ and trees in the dominant storey in other development classes.

With more complete information from a sample tree, e.g., through boring, it is possible to assess the tree class more precisely. The *possible change of tree class* was recorded. The original tree class remained unchanged. The *possible change in the specification of tree class* was similarly recorded.

The bucking of a sample tree was carried out using the recorded stem lengths, taper curve models, the quality and length requirements, the relative prices and optimisation of the value of the timber, see Sect. 3.2.3. The lengths of different timber assortment quality classes were recorded in the field. The trees with a saw-timber part were divided into *quality parts*, i.e., the connected parts of a stem of one timber assortment class that did not contain a mandatory cut point. The mandatory cut point was also recorded as a separate quality part. The quality class (Table 2.31), the *length* of the part (in decimetres; 0 for the cut point) and a possible *quality lowering reason* or the reason for the mandatory cut were recorded for each quality part. The quality classes and the criteria for lowering the quality were determined as a compromise of different quality requirements set by forest industries. Examples of reasons for lowering the quality or recording a mandatory cut point are branches,

Table 2.31 Timber assortment quality classes

1	Branch-free saw-timber (high quality saw-timber)
2	Saw-timber with living branches
3	Saw-timber with dead branches
4	Bottom part of the stem usable as pulpwood but not as saw-timber
5	A part in the middle of the stem usable as pulpwood but not as saw-timber (recorded only for broadleaved trees)
6	Waste wood (unusable for pulpwood)
7	Saw-timber part of a fork tree
8	Mandatory cut point in the middle of a quality part

sweepness, decay, and defected stem. The only length requirement for the quality part was the minimum saw-timber length in the case that parts above and below had a poorer quality.

2.17 Epiphytic Lichens

The abundance of some epiphytic lichens growing on trunks and branches of trees was assessed as an air purity indicator. The assessments were carried out on the permanent plots in development classes 4–8 with at least three coniferous tally tress with a $d_{1.3}$ of at least 5 cm. The following groups were assessed: beard lichens, (the most vulnerable lichens) (*Alectoria*, *Bryoria* and *Usnea* species), leaf lichens (e.g. *Hypogymnia*, *Parmelia* and *Pseudevernia* species, usually more resistent to air pollution than beard lichens), as well as *Scoliciosporum clorococcum* and *Desmococcus olivaeus* species.

2.18 Keystone Tree Species

Many broadleaved tree species have an important role in maintaining the biodiversity of flora and fauna. These tree species are usually rare in managed boreal forests. The sampling errors of the frequency and volume estimates of these species would be high when using sparse angle count sampling. Therefore the keystone species were measured from fixed-radius plots. The radii of the plots were 12.52 and 12.45 m in South and North Finland respectively. Individual trees of keystone species within the plot were measured from the centre point stands on either forest land or poorly productive forest land. Species-specific minimum thresholds for diameter were assigned according to biodiversity-related characteristics of the species. The location of the pith of the tree determined whether the tree belonged to the plot or not. The locations of the keystone trees were mapped on the permanent plots. The minimum diameter thresholds were:

- 30 cm for European aspen (*Populus tremula*),
- 20 cm for Grey alder (*Alnus incana*),

- 10 cm for Black alder (*Alnus glutinosa*), European mountain ash (*Sorbus aucuparia*) and Goat willow (*Salix caprea*)
- 5 cm for Fluttering elm (*Ulmus laevis*), Wych elm (*Ulmus glabra*), Small-leaved lime (*Tilia cordata*), European ash (*Fraxinus excelsior*), Pedunculate oak (*Quercus robur*), Norway maple (*Acer platanoides*) and Hazel (*Corylus avellana*).

2.19 All Tree Species

The abundances and occurrences of tree species and their temporal and spatial variations can be assessed by means of permanent plots more efficiently than by temporary plots. All tree species were identified on the permanent plots if the plot centre was on forest land, poorly productive forest land or unproductive land. The tree height had to be at least 1.35 m. Only living trees were included. The radius of the plot was 12.52 and 12.45 m in South and North Finland respectively. All tree species were recorded regardless of whether they had already been recorded as tally trees. The identified species were the same as for tally trees, 22 species and 7 species groups (Table 2.29).

2.20 Dead Wood Measurements

The amount and quality of dead and decaying wood is considered to be one of the most important indicators of biodiversity in the boreal region. The natural old-growth forests of the boreal zone have a large amount of dead wood at different stages of decay. Dead wood is an important habitat for many specialized insect, polypore, moss and liverwort species. Tree species, degree of decay and trunk diameter, for instance, influence the composition of these communities. Some species are even restricted to certain kinds of dead wood.

Only usable dead trees were measured up to NFI8, not decayed trees. The measurement of decaying and decayed trees was introduced in NFI9 to describe the biodiversity of forests. Dead wood was measured on those centre point stands that belonged either to forest land or poorly productive forest land up to the plot radius of 7 m. The plot radius was 12.52 m in the first year of NFI9 (1996) when the areas of forestry centres 8 (Keski-Suomi) and 9 (Pohjois-Savo) were measured. Furthermore, in those centres dead wood measurements were done only on every second plot.

Both standing and lying dead trees and tree parts were measured, including advanced decayed trees covered by mosses. A tree was classified as standing if the angle between the tree and the terrain normal was less than 45°. Otherwise a tree was classified as lying. The measurements differed slightly for standing trees and lying trees.

A standing tree was measured if its height was at least 1.3 m and the diameter at breast height was at least 100 mm. A lying tree was measured if the diameter at the distance of 1.3 m from the thicker end was at least 100 mm and the length at least 1.3 m.

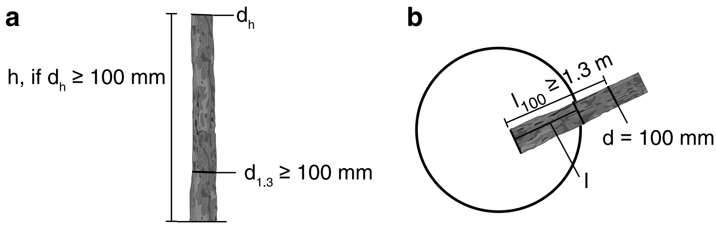

Fig. 2.6 Measurements of dead wood: (**a**) standing dead wood, (**b**) lying dead wood. The maximum radius was 12.54 m in forestry centres 8 (Keski-Suomi) and 9 (Pohjois-Savo) and 7 m elsewhere

Table 2.32 Recorded species of dead wood

0	Unidentified species
1	Scots pine (*Pinus sylvestris*)
2	Norway spruce (*Picea abies*)
3	Silver birch (*Betula pendula*)
4	Downy birch (*Betula pubescens*)
5	European aspen (*Populus tremula*)
6	Grey alder (*Alnus incana*)
7	Black alder (*Alnus glutinosa*)
8	European mountain ash (*Sorbus aucuparia*)
9	Goat willow (*Salix caprea*)
A0	Unidentified coniferous species
A1	Other coniferous species
B0	Unidentified broadleaved species
B1	Other broadleaved species
B2	Unidentified birch species

Table 2.33 Physical appearance class of dead wood

1	Unknown (usually advanced decayed lying tree)
2	Whole standing dead tree (less than 1/3 from the top broken)
3	Snag, broken standing dead tree (more than 1/3 broken)
4	Lying tree, uprooted
5	Broken tree
6	Cut stump or snag
7	Cut and abandoned butt end or bolt
8	Logging waste

Only those parts of lying trees were measured that were within the plot perimeter, met the thickness requirement, and were on forest land or poorly productive forest land (Fig. 2.6). Overall, the dead wood estimates based on NFI did not include all parts of the dead wood, for instance stem parts with a diameter of less than 100 mm, branches, stumps or roots were not included.

The common variables assessed for standing and lying trees were tree species (Table 2.32), physical appearance class (Table 2.33), *bark coverage percentage*

Table 2.34 Decay classes of dead wood (estimated by sticking a knife into the tree)

Standing trees	
1	*Hard*: a knife penetrates only a few millimetres into the wood. Bark (almost) intact, branches remain. Also includes hard barkless trees, the wood of which has not started to decay.
2	*Fairly hard*: a knife penetrates 1–2 cm into the wood. Branches have started to fall off, bark of coniferous trees has started to peel off, broadleaved species often host multiple fruiting bodies of polypores on the upper part of the tree.
3	*Fairly soft*: a knife penetrates 3–5 cm into the wood. With coniferous species, bark only left at the base of the stem, with broadleaved species the bark remains but the trunk has started to decay, branches have mainly fallen off, only larger branches remain but are not intact, part of the crown has often collapsed.
4	*Soft*: a knife easily penetrates deep into the wood. The trunk remains standing only because of support from the bark, branches have totally fallen off of broadleaved species, the tree is usually broken – only the stem snag is standing.
Lying trees	
1	*Hard*: a knife penetrates only a few millimetres into the wood. A recently fallen trunk with bark remaining, possible epiphytes are associated with standing trees. Also includes hard trunks that have fallen down long after dying but the wood has not started to decay.
2	*Fairly hard*: a knife penetrates 1–2 cm into the wood. The bark often remains. Only a few epiphytes that are mostly associated with standing trees.
3	*Fairly soft*: a knife penetrates 3–5 cm into the wood. The bark is often torn and peeled, locally abundant epiphytes but small growths. The category often includes e.g. pines, where sapwood is advanced decayed and only heartwood is hard.
4	*Soft*: a knife easily penetrates deep into the wood. Often barkless and covered by epiphytes. Large growths of mosses and lichens.
5	*Very soft*: disintegrates on being touched. Usually entirely covered by epiphytes, most epiphytes (mosses, lichens and shrubs) associated with forest ground, only a slight bulge distinguishes trunk from the surrounding ground.

(in classes of 20% intervals), decay class (Table 2.34), and *number of trees* (in the case of a very high number of dead tree trunks, only the mean tree was measured and the number of tree parts recorded). For standing trees, $d_{1.3}$ was measured, and also the *height* of those standing trees which were broken and the top diameter was at least 100 mm. The variables for lying trees were measured only inside the plot and were *butt diameter* (or diameter at the plot border), *top diameter* (or diameter at the plot border), *length of the tree part*, and *position to the ground,* which distinguished between tree parts not touching the ground and tree parts broken into small pieces and lying on the ground.

2.21 Equipment for Measurements

Field crews were equipped with the instruments presented in Table 2.35. Most of the measuring instruments were technically simple, but precise enough for the NFI purposes. This kind of instruments remain functional in the field conditions.

For instance, calliper is technically a simple tool but enables measurement of *diameter over bark at breast height* in 1 mm classes and fast. As the number of tally trees per plot is relatively small calliper is preferable instead of technically more complicated instruments. Some instruments were justified by the usefulness of the measured variable in the estimation of a derived variable, e.g. the measurement of *upper diameter* of sample trees with Finnish parabolic calliper and calliper pole. The upper diameter was measured in one cm classes only but has been proved to increase the accuracy of the stem volume estimate of the sample trees (cf. Sect. 3.2.3). A review and a study of the accuracy of some variables measured using the same instruments as in NFI9 – *diameter over bark at breast height, upper diameter, height increment of 5 years* – are presented in Päivinen et al. (1992).

The *height* of the trees was first measured with Suunto hypsometer but since 2001 with a new instrument, Vertex hypsometer. An ultrasound transponder was

Table 2.35 The equipment of a NFI9 field crew

Instrument/equipment	Producer, trademark and model
Portable computer (PC)	–
Field computer	Rufco-900 or Husky FS3
Vertex-gauge	Haglöf, Vertex III-60
Mobile phone	NOKIA 6250
GPS-receiver	Trimble Ace II
GPS-backpack	–
Binoculars	Bidox 6×30, Bresser 8×40, Optilyh 8×30
Precision compass	Suunto KB-14/400
Hypsometer	Suunto PM5-1520PCP
Increment borer, 25 and 30 cm	–
Calliper, normal size and small	–
Measuring tape, 20 and 50 m, distance marking sticks	–
Borer for stoniness	–
Compass	Suunto
Bark gauge	Suunto E60
Calliper pole, 5 m	–
Finnish parabolic Callipers	–
Relascope	–
1.3 m pole, metal or plastic	–
Earth drill	–
Peat bore, 4 m	–
Talmeter tape	–
Backpack for equipments	–
Axe, billhook and knife	–
Spray paint, permanent markers	–
First aid kit	–
Vest, raincoat, rainpants	–

used with Vertex to measure the distance from the tree. The heights can be measured at any distances from the tree using the transponder. The binoculars marked with a specific scale were used to measure the *height increment of 5 years* of conifer sample trees. The binocular records were converted to dm as a function of the distance from the tree and the height of the tree above the horizontal plane.

The data collected in the field was entered into digital form with field computers. First the Rufco-900 field computer was employed in NFI9 until 2000. After that, the Husky FS3 was used. The software necessary for data capturing was programmed in NFI using Rucfo macro language and Pascal 7.0 programming language for Husky computers.

The measurement of *diameter increment of 5 years* and the *age at breast height* (partially) from increment cores of sample trees was carried out as in-house work. First a microscope was used to measure the tree-rings. Since 2001 the majority of the ring measurements were done using WinDENDRO ring scanner and software version 6.2. WinDENDRO is a semi-automatic image analysis system specifically designed for annual tree-rings analysis (Windendro 2010).

2.22 A Correction to the Height Measurements of Year 2001

A new height measurement instrument (Vertex III) was introduced during the 2001 field season. The instrument requires a daily calibration for temperature and a further calibration that depends on the user. When analysing the early measurement data, some illogical combinations of the height and breast height diameter of the trees were noticed. Furthermore, height increments as a function of the age and diameter deviated from the earlier height increments. The functioning of the instruments was re-checked and the overestimations in both the heights and height increments were confirmed (Tomppo et al. 2003).

In order to remove systematic measurement errors, a sub-set of sample trees was re-measured in autumn 2002. The exact measurement times, both the original one and new one, were taken into account in the new measurements. The height of a tree and the height increment over 5 years as measured in the original inventory in 2001 were measured. Furthermore, either the 2-year or 1-year height increment was measured depending on whether a tree was measured in May–July or in August–September 2001. Exactly the same height points could be compared using these measurements and two different instruments. The new measurements were made using a Suunto hypsometer and a measuring tape. The height from the trees with a height less than or equal to 8 m was measured using measuring rod, although this upper limit varied to some extent between field crews. In total 1,427 of 5,085 sample trees were re-measured.

2.22.1 *The Height Correction Models for the Sample Trees not Re-measured*

A height correction model had to be estimated for those sample trees that were not re-measured, i.e., for the majority of the sample trees. The model was:

$$\partial h = b_i (h - c_i) + \varepsilon \tag{2.1}$$

where

∂h is the difference of the height measurements
b_i is the parameter for field crew *i*,
h is the height of a tree in 2001, measured with Vertex III, minus the incomplete height increment for a tree measured in May–July 2001,
c_i is a constant within each field crew and corresponds to the height to which the height of a tree was measured using a rod, and
ε is the error term of a model distributed normally with a mean of 0.

The values of c_i by field crews and the estimates of the parameter b_i by crew *i* are given in Table 2.36. This type of model can be justified by the fact that its purpose is to estimate the height measurement error, not the height itself. It was assumed that the measurement error of the hypsometer was normally distributed with an expected value equal to 0. It was also assumed that the measurement error was 0 to the height that was measured using a rod. The estimated correction should also be 0 at that height in order to avoid the discontinuity of the estimated corrections.

Table 2.36 The estimates of parameter b_i by crew *i* and the employed values c_i of model (2.1)

Crew *i*	b_i	c_i (dm)
1	0.0229617076	80
2	0.0214100170	70
3	0.0202801474	50
4	0.0228972103	50
5	0.0435055007	50
6	0.0110885069	50
7	0.0225653503	50
8	0.0035038770	50
9	0.0233500157	50
10	0.0275041007	70
11	0.0317391590	70
12	0.0228483217	60

2.22.2 Models for Correcting the Height Increments

Recall the height increment measurements from Sect. 2.16. The height increment of the sample trees measured before August 1 is the increment during the 5 years preceding the inventory year, and from August 1 onwards, the increment during the measurement year and the 4 years preceding the inventory year. The increment during the measurement season is measured in both cases independently of whether or not it is complete. The models for correcting height increments had to be estimated for the sample trees without re-measurements. Separate models were derived for pine and spruce. Recall that the height increments for broadleaved trees were originally estimated using models. The height increment correction model for pine and spruce was of the form:

$$\partial i_h = b_i h + c_i i_{h,5} + \varepsilon \tag{2.2}$$

where

∂h is the difference of the height increment measurements
b_i is a parameter for the field crew i,
h is the height of a tree in 2001, measured with Vertex III, minus the incomplete height increment for a tree measured in May–July 2001,
c_i is a parameter for the field crew i
$i_{h,5}$ is the height increment measured in 2001
ε is the error term of a model distributed normally with a mean of 0.

The parameters of the model are given in Table 2.37. They could not be estimated for field crew number 8 in the case of pine when taking into account the

Table 2.37 The estimates of the parameters b_i and c_i of model (2.2) for correcting the increment measurements. The rest of the estimates of the parameters did not deviate statistically significantly from zero

Crew i	b_i	c_i
Pine		
1	−0.0025977485	0.0713221806
2	0.0050685255	0.0115224699
3	0.0085255888	0.0607187127
4	−0.0018601766	0.0585288669
5	0.0026833095	0.0878951062
6	0.0023153978	0.0473136568
7	0.0030847189	0.0200283304
9	0.0109833981	−0.0303720707
10	0.0167366709	−0.0583678684
11	0.0042402959	0.0666121481
12	−0.0077422304	0.0404369006
Spruce		
5	0.0112041026	0.0223372261
6	−0.0018758874	0.1883298238
7	−0.0142952657	0.0655153234

measurement errors. The estimates of the parameters did not deviate statistically significantly from 0. In the case of spruce, the parameters of the models could be estimated for only three field crews.

2.23 Training and Quality Assurance

One of the essential roles of a national forest inventory is to provide consistent time series data on forest resources. The assessments and measurements need to be carried out in the same manner by all inventory crews, not only during the current inventory season, but also in consecutive seasons. Only professionals are employed by the Finnish NFIs and specific training is given to ensure the consistency. A field crew in NFI9 consisted of a leader and two measurement technicians. A university degree in forestry (forester) or a degree from a university of applied sciences in forestry (forestry engineer) is a standard required from the field crew leaders. The measurement technicians also preferably have some vocational education in forestry.

From 2–4 weeks lasting training periods were organised for the crew leaders before the field season and one or two-day training sessions were arranged during the season. New crew leaders were given a longer training period than experienced ones. A one week orientation course for technical assistants concerning the tree measurements was also arranged with the crew leaders' contribution. Since many new variables were introduced in NFI9, the training was more comprehensive during the initial years than in the later ones. During NFI9 new measurement devices were also implemented, the use of which required the practice.

Comparative sessions were arranged for the field crews to control the quality of the assessments and measurements. Each field crew acted as a control crew approximately twice a season depending on the number of the crews. Separate guidelines and forms were issued for the control, comparison and reporting of the results. The control crew received the data collected by the crew subject to control and then re-measured the same sample plots and trees. The stand variables were also re-assessed. Control crew then compared the data of their own measurements to the measurements of the original crew and provided feedback of the outcomes. The results were also filed. In this way, information on possible systematic errors was obtained and recorded.

The portable computer enabled the measured data to be checked in the field. The allowed codes and the limiting values of variables were incorporated in the data recording programmes. Some variables were tested against other variables for logicality. For example, the lower limit of the green crown could not be greater than the height of a tree. In permanent plots, the measured results were compared to the former results. The most obvious errors were therefore discovered and corrected already in the field. The checking of data continued as office work after the field season. The data from different types of measurements were compiled and organised into one file with different types of records for stands, trees, dead wood, keystone tree species, and all tree species. Comparisons and checks between variables of different record types were not possible until that phase. The age and increment information from laboratory measured age cores were also combined the stand and tree data. The development class and estimated age of a stand were compared to the measured age, which also affected the silvicultural quality of a stand and the proposed measures.

An important quality assurance measure is the verification of the results. A natural mode of operation is to compare the results to those of previous inventories. All changes should be explicable, and if they are not, the reasons for them should be critically examined. The following case provides an example the importance of checking all the phases of the NFI data from forest to the final results. In 2001, a new height measurement device, the Vertex III-60, was introduced (see Sect. 2.22; Tomppo et al. 2003). The device was sensitive to temperature and also required daily calibration. Its employment was practised by the field crews. The instrument was used to measure the height of a sample tree, and also to measure the 5-year height increment of coniferous trees. In control measurements, some divergences between the field crews were detected, but they were not reported as systematic differences. The control system did not therefore respond quickly enough to the signals of odd results, but the data analysis did. In Sect. 2.22, the Vertex case is described in more detail, as well as the correction procedures. The case revealed a weak spot in the quality control system. The implementation of the device should not have occurred before a controlled experiment and stricter training sessions. The Vertex continued to be used as the main height measurement device, but with more specific instructions for its use.

In 2001, a more successful introduction of a new method occurred with the WinDENDRO semi-automatic year-ring scanner system, which was used for the age and increment core measurements (Sect. 2.21). Traditionally NFI had measured all cores using visual count and a microscope. The aim was to compare these two methods and find out if the scanner-based image analysis would be suitable for NFI purposes. In the first phase the experiment was planned measuring the increment cores of only one tree species, Scots pine. The experiment was carried out from the sampling of increment cores, measurements with both devices, analysis of the data, to the reporting of the results. When all these phases of the experiment were ready and the system revised, it was applied to increment cores of Norway spruce and birch species. The experiments proved the semi-automatic image based system to be appropriate for NFI. A spin-off of the experiment was a discovery of the effects of the different measurement techniques when using the microscope. A final result was that a routine control system for increment core measurements was implemented.

2.24 The Workload and Costs

The number of field crews per year varied from 10 to 17 during NFI9 (Table 2.38). The average number of clusters measured on forestry land was 836 per year. The number of field plots measured on land by a field crew during one day was 12.7 on

Table 2.38 The number of field crews, clusters and plots on land, length of the field work season and total working days of field crews in NFI9

		Land		Field work season		Field crews	
Year	No. of field crews[a]	Clusters	Plots	Starting date	End date	Total working days	No. of field plots measured on land per day
1996	17	807	11,305	27.5.	18.10.	808	14
1997	13	974	12,253	28.5.	25.10.	803	15
1998	12	1,213	12,773	29.5.	7.11.	906	14
1999	12	1,007	10,875	1.6.	29.10.	882	12
2000	13	654	8,297	26.5.	10.10.	662	13
2001	13	718	8,998	9.6.	12.10.	848	11
2002	13	757	9,775	8.6.	4.10.	839	12
2003	11	599	6,974	5.6.	3.10.	609	11
Average	–	841	10,156	–	–	–	13
Total	–	6,729	81,250	–	–	6,357	–

[a] Some field crews worked only part of the field work season

average. On the last year only 11.6 plots on land per day were measured. This was due to the larger distances between the clusters in northern Finland, forestry centre 13 (in Fig. 2.1a), and fewer plots per cluster in the northernmost sampling density region (Fig. 2.2). The total cost of the "Monitoring of forest resources" project, which carried out the NFI9 fieldwork, data processing and report writing of the forest resources, was 8.4 million euros i.e. an average cost of 1.1 million euros per year during the 8 years of the field inventory. The budget also included the salaries of the researchers not directly involved in the field measurements. The sum consisted of 4.0 million euros salaries of the permanent staff (on average six of the crew leaders belonged to the permanent staff during NFI9) and to 4.5 million euros of other costs. The other main expenses were: the salaries of the temporary field personnel (crew leaders and field assistants), training, travelling costs of the crews, the purchase of measurement devices and other equipment, data transfer and phone bills and GIS data. The planning costs of NFI9 are not included in the above expenses.

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