
# NATIONAL FOREST INVENTORY AND MONITORING OF THE SLOVAK REPUBLIC 2005–2006

## Basic concept and selected summary information

NATIONAL FOREST CENTRE

# 1 GOALS OF AND NEEDS FOR FOREST NATIONAL INVENTORY AND MONITORING IN THE SLOVAK REPUBLIC, DECISION ON ITS REALISATION

One of the basic assumptions for the systematic management and intentional public utilisation of forests is to have objective and actual information about the forest condition and development. Such information represents the basis for decision-making, planning, controlling, and prognostic activities at different management levels not only in forestry, but also in all other related sectors, mainly in wood industry, nature protection, and environment formation. The requirements on the spectrum and the level of detail of this information have been broadening out as the importance of forests for society grows. Nowadays, the information covers not only the traditional forest production characteristics and the potential woodcutting possibilities, but also ecology, forest health status, forest value, and biological diversity. At the same time, the quality (error range) of information needs to be known in order to enable the objective evaluation of the provided data and their spatial and temporal comparison at a specified confidence level.

At national level, such varied and extensive information of the required quality and with adequate time and financial costs can only be obtained by sampling methods, i.e. when the whole area is inventoried and monitored on the network of sampling points or plots. The number, density, and distribution of the plots are optimised to specific conditions of the particular area, and to pre-defined professional requirements and economic capacities. In most European countries, e.g. in Scandinavia, Austria, Switzerland, Germany, and the Czech Republic, such national inventories were already established in the past, and in some countries they were already repeated (in 5 to 15-year intervals). Other countries including some neighbouring countries of Slovakia are currently in the process of intensive preparation of forest inventory. Lately, at EU level the project ENFIN was established to support national inventories of forest ecosystems with the aim to harmonise their content and methodology at both national and international levels.

In the Slovak Republic, there are currently several information sources on the condition and the development of forest stands available. At national level, it is the document Summary information on forest condition in the Slovak Republic (SLH, PIL), which is annualy prepared by the National Forest Centre – Institute of Forest Resources and Informatics Zvolen (ULZI). The information published in this report is based on a simple summation of data from the database of valid forest management plans (LHP). The database consists of the data collected during the inventories for management planning in basic forest management units (JPRL) – forest compartments, partial plots, and parts of stands. Inspite of the fact that such data are of good quality, they also have several disadvantages:

- summed stand data are related to different time points within a decennium, i.e their temporal validity varies (from 1 to 10 years),
- various assessment methods are used, while predominantly the method of yield tables and visual estimation are applied, and the extent of direct measurement is gradually reduced, which can cause systematic bias,
- the accuracy and precision of the summary data remain unknown and cannot be after calculated, which disables objective evaluation and especially comparison, i.e. monitoring,
- although the information spectrum of the summary information is broad, it is not sufficient for the complex assessment of the condition and the change of all components of forest ecosystems that can meet the actual requirements.

Considering the above-stated facts, and the international trends in the field of forest condition assessment, and the obligations of the Slovak Republic resulting from its membership in the EU, it became topical to prepare and realise national forest inventory entitled "National forest inventory and monitoring of the Slovak Republic" (NFIM SR). Its aim was to create a new integral system, which is able to give objective, up-to-date, and comprehensive information about the condition and the development of all components of forests ecosystems at national and regional levels in the specified time point (at best in regular 10-year intervals), and which can be used as a basis for the analyses and strategic decision-making of the competent managing bodies in forestry and other related sectors.

The decision to realise the NFIM SR was made by the Ministry of Agriculture of the Slovak Republic by adopting the point 5.B.a) as a part of the material No. 3473/2004-710 "Proposal for the realisation of large-scale inventory of the Slovak Republic (SR) in the years 2004–2005" on 23rd meeting of the directorate of the Ministry of Agriculture of SR held on July 1st, 2004. The steering committee of the NFIM SR established in the Forestry section of the Ministry of Agriculture by the end of August 2004 discussed the initial project (Šmelko et al. 2004), and from the several prepared proposals the committee selected the variant of 2-year field inventory 2005–2006 on the base of sampling methods in the grid 4×4 km. This grid density (where one sampling unit of 5 ares represents approximately 1,600 ha) was chosen as optimum from the point of the resources disposable for the realisation of the NFIM SR and the required accuracy of the results that was acceptable for the steering committee (to determine the forest area at national level with the error ±1.0%, volume per hectare with the error ±1.8%, and total volume with the error ±2.1% at 68% confidence level). The variants, which could reduce the error to one half or to one quarter would require to make the network of the inventory plots denser and to increase the costs four to six times when compared with the selected variant.

The Forest Research Institute in Zvolen was authorised to prepare the methodology and to realise the NFIM SR in cooperation with other institutions of the present National Forest Centre (from now on only "NLC"). In the year 2004, a special working team called "Management Centre of the NFIM SR" and the "Methodological and Technical Board of the NFIM SR" consisting of forestry and ecology professionals from the relevant institutions in Slovakia were established. Owing to the restricted temporal and financial capacities, the NFIM SR was performed simultaneously as a pilot project and as its practical realisation (while abroad the methodological project always preceded the national inventory 2 to 3 years in advance).

# 2 BASIC CONCEPT OF THE NFIM SR AND ITS REALISATION

## 2.1 Methodological principles

From the methodological point of view, the NFIM SR is a combined aerial-terrestrial sampling method with a systematic distribution of sample units over the whole country (Figure 2.1–1).

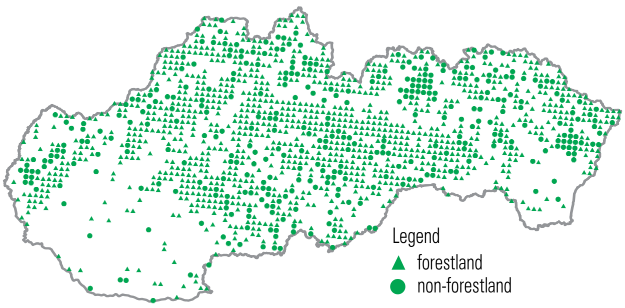


*Figure 2.1–1 Distribution of inventory plots in the grid of 4×4 km*

The terrestrial inventory, which is the basis of the assessment, was realised in the sampling units (inventory plots IP) consisting of four types of sample plots (Figure 2.1–2). The inventory plots were optimised to the qualities of the information spectrum, which was very broad and covered more than 100 features and variables. In homogeneous IPs, all four circle sample plots A to D were established in the same centre. If the IP was not homogeneous, i.e. it comprised parts of different land or forest categories; the IP was divided into partial subplots located next to each other (as shown in Figure 2.1–2b). If the plot was vertically differentiated and the coverage of each layer exceeded 20%, individual stand storeys were also distinguished (subplots below each other).

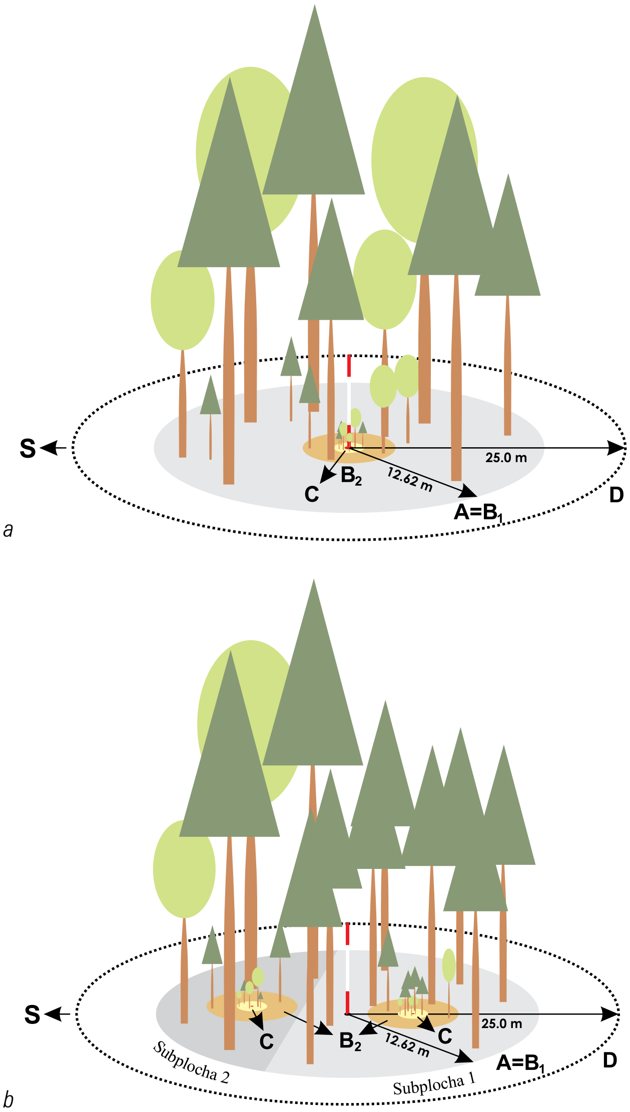


*Figure 2.1–2 Ground inventory plot (A, B, C, D), a – homogeneous, b – divided into two sub-plots*

*A – a constant circle with radius r = 12.62 m on which terrain, site, stand, and ecological characteristics are assessed and lying deadwood and stumps are inventoried, $B_1$ and $B_2$ – two concentric circles (r = 12.62 m and 3 m) for detecting tree characteristics of trees with diameter at breast height $d_{1.3} \geq 12$ cm and $d_{1.3}$ = 7–12 cm, C – a variable circle for thin trees with diameter $d_{1.3} < 7$ cm (its radius r = 1.0, 1.41 or 2.0 m is chosen according to the particular tree density), D – an enlarged constant circle with radius r = 25 m established for the inventory of forest edges, forest roads and water sources*

The aerial inventory was performed as a visual interpretation of orthophotomaps (Geodis–Eurosense, 2002 with the resolution of 1 m). Here, the sampling units were the circular plots of the size 2,500 $m^2$ distributed in the grid of 2×2 km; in total 12,667 plots were inventoried. These plots were primarily used for the identification of Forest/Non-forest area, as well as a support for the orientation and navigation in the field, but also for a more precise determination of the forested area and its categories at national and regional levels. The combination of ground and aerial inventory reduced the sampling error of the forest area by more than one half.

Within the NFIM SR, all forested land over the whole area of Slovakia was inventoried, i.e. forests on forestland, which are such registered in the cadasdre, as well as forests on non-forestland (agricultural or other land). The plot was considered to be a "forest", when it met the following criteria of the definition: tree species were growing on the plot, the area exceeded 0.3 ha and was a minimum of 20 m wide, the coverage – tree closure exceeded 20 %, and the potential height of tree species was greater than 5 m (except for mountain pine *Pinus mugo*).

## 2.2 Field data collection

The field data collection followed a uniform and a detailed working manual (Šmelko et al. 2005, 2006), which had been reviewed and approved by the Methodological and Technical Board of the NFIM SR. Every year, 5 inventory crews, each consisting of 3 members experienced in practical forest management planning (Lesoprojekt, ULZI, in the year 2005 also private taxatory agency EuroForest, Ltd.) were in the field and collected the data. At the beginning of the season, all workers participated in one-week training. The establishment of IPs, mapping, data collection, and data editing was performed using the computer-based technology Field-Map (IFER 1992–2005) supplemented with the GPS navigator (Figure 2.2–1).


*Figure 2.2–1 Technology Field-Map and GPS Garmin GPSMAP 60 CS*

The control group consisting of the members of the Management Centre of the NFIM SR (headman V. Šebeň) fulfilled a very significant role, as it coordinated and managed field works, checked approximately 10% of the established inventory plots, gave immediate consultations, and established problematic IPs. The performance of the working crews was above standard and of the required quality. Table 2.2–1 contains information about the overall extent of the performed work separately in three categories: forest on forestland, forest on non-forestland, and non-forest.

Table 2.2–1 Number of established and controlled inventory plots, number of taken increment cores and humus and soil samples.

| Category | Inventory plots | | | | Increment cores | | Humus samples | | Soil samples (500 g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | estab-lished | % | con-trolled | % | pcs | % | pcs | % | pcs | % |
| Forest on forestland | 1,229 | 82.7 | 105 | 8.5 | 1,347 | 85 | 3,588 | 87 | 2,452 | 87 |
| Forest on non-forest-land | 210 | 14.1 | 45 | 21.4 | 235 | 15 | 557 | 13 | 371 | 13 |
| Non-forest | 64 | 4.3 | 9 | 14.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 1,486 | 100.0 | 159 | 10.7 | 1,582 | 100 | 4,145 | 100 | 2,823 | 100 |

*Note: 1) The total number of the points in the grid 4×4 km is 3,071 over the whole Slovakia. 1,486 inventory plots were established, from which 64 IPs were assessed in the field as non-forest. 2) Humus samples were collected from an area of 0.25×0.25 m.*

## 2.3 Data processing and generalisation

During the NFIM SR, a very extent and a very diverse data set was obtained, which was further processed and evaluated using adequate mathematical–statistical methods and algorithms that were specially prepared and thoroughly tested prior to their applications. They consist of the three interconnected parts:

*1) Data analysis, verification, and completion* – this phase encompassed the advanced preparation, thorough check-up and the completion of the whole database. It was aimed at controlling data integrity, their numerical and logical accuracy, and the relationships between the attributes and the variables. Special algorithms were used to make the control. For example, missing original heights of the trees with the broken top or the stem were filled in with modelled heights. The plausible ranges (minimum and maximum values) of basic dimensions, such as diameter, height, crown length, etc., were specified. In each IP, stand age was determined by several methods (taken over from the management database, counting the whorls, counting the annual rings on stumps, visual estimation), which were complemented by the information obtained from the increment cores that were taken from a minimum of three trees. Specifically, it was examined wheather the trees were classified into storeys, growth classes, and age categories of inventory plots (IP) correctly. Field information about soil and site characteristics of IPs was supplemented with more precise results from chemical analyses (C, N, C/N, dry mass, pH $H_2O$, pH $CaCl_2$) of 4,145 humus samples, and 2,823 soil samples. The analyses were made in the Central Forestry Laboratory of the National Forest Centre, where the samples are also archived.

*2) Calculation of the so-called derived variables for trees and inventory plots* – a large portion of the data assessed on individual trees or whole inventory plots are of primary nature. Their further processing requires the determination of the so-called derived variables by means of the appropriate dendrometric models and specific computation methods. From the most important we name the following:

- *Data processing from the combined assessment estimation/measurement,* which was with advantage applied to tree height and crown length (Šmelko 1994).
- *Completion and verification of volume equations for main and related tree species,* which are used for the derivation of tree volume ($v$) from the assessed tree diameter ($d_{1.3}$) and tree height ($h$). To ensure a more general utilisation of the results and the comparison with other EU countries, volume equations were prepared for the following five volume units: timber to the top diameter of 7 cm inside bark (HBK), which represents the official timber volume unit in Slovakia; timber to the top diameter of 7 cm outside bark (HSK), which is most common in EU countries; stem inside bark (KBK); stem outside bark (KSK); and tree outside bark (SSK), which is important for other calculations, e.g. for the estimation of carbon storage in the aboveground biomass, etc. The applied tree volume equations represent the regression $v = f(d,h)$, and were derived for 12 tree species from the data collected in the Czech Republic and Slovakia by various authors (Petráš, Pajtík 1991). Prior to their applications, all equations had been verified and analysed in detail. The results showed that the relationship between tree volume $v$ and tree diameter $d_{1.3}$ and tree height $h$ follow fundamental assumptions in the whole considered range ($d$ = 0.1 – 100 cm and $h$ = 1 – 50 m), i.e. that volume $v$ increases with increasing diameter $d_{1.3}$ and height $h$. The analysis revealed new foundings that these equations approximate this relationship not only in the diameter range above 7 cm, which was so far the subject of the main interest, but also in the range from 0.1 to 7 cm (for KBK, KSK, and SSK). Hence, these equations are also applicable to thin trees, which are inventoried within the scope of the NFIM SR for the first time (in a small inventory plot C). In addition, the existing volume equations were also assigned the tree species, for which no equations have been derived, yet. The assignment considered the methodological procedures used in common forest management practice in Slovakia.
- *Assortment calculation (s)* made for every tree with minimum diameter $d_{1.3}$ of 7 cm followed mathematical models of the national tree assortment tables (Petráš, Nociar 1991, Mecko, Petráš, Nociar 1993). The result is the tree volume distributed to the quality classes I, II, IIIA, IIIB, V and VI in $m^3$ of the timber to the top of 7 cm inside bark.
- *Quantification of deadwood* was, unlike abroad, performed in such a way that all its components were determined in the same volume units ($m^3$ outside bark) in order to enable their aggregation. The volume of standing dead trees was determined from the volume equations of living trees (HSK). In order to determine the stump volume, new regression equations were derived, while the diameter at the top of the cut area $D$ and the stump height $H$ represent input variables. The volume of the lying deadwood with the top diameter of

7 cm was calculated from the measured diameters $d_1$ and $d_2$ (cm) outside bark at both ends and the length of each piece inside the IP or a sub-plot using the Smalian equation (Šmelko 2000). The volume of small-sized lying deadwood (having diameter from 1 to 7 cm) was estimated by the original method, where the volume of small-sized lying deadwood (in $m^3$) densely arranged in 1 $m^2$ is calculated from the biometrical model as a function of the middle diameter of small-sized lying deadwood multiplied by the area of IP, estimated coverage of small-sized lying deadwood, and tree species proportion.

- Assignment of the tree growth area to the trees belonging to different tree species and storeys. This was solved as a separate and a rather difficult problem, because in the NFIM SR inventory plots were divided into subplots situated next to each other or one above the other, if they consisted of different age classes, growth stages or forest categories. The particular tree growth area was determined from the regression models derived from the whole NFIM data set separately for the individuals with the height below 1.3 m (in this case tree growth area is a function of height), and for the trees with the height above 1.3 m (in this case tree growth area is a function of diameter).

*3) Generalisation of data obtained from inventory plots to higher regional units* – data collected in inventory plots are of random (stochastic) nature. Their actual value is only one value from the great number of possible values that would be obtained if the inventory with the same design were repeated several times, but every time on a slightly shifted grid. The generalisation of this sample information means the determination of the real values, i.e. the values that are valid for a specific inventoried region (the whole basic population). This is performed by the method of statistical estimation, when the confidence interval (IS), in which the value of the particular parameter lies with the selected probability P (68% or 95%), is determined. If the selected parameter of the basic population, the sampling characteristic, and its sampling error are assigned the symbols $\mu_y$, $\bar{y}$ and $S_{\bar{y}}$, respectively 68% confidence interval can be stated in either of two forms:

- the corresponding error frame is attached to the sampling characteristic

$$\mu_y = \bar{y} \pm S_{\bar{y}}$$

- or as a range (from – to) by calculating the bottom and the top limits of the interval

$$\bar{y} - S_{\bar{y}} \qquad \text{and} \qquad \bar{y} + S_{\bar{y}}$$

To enable the comparison of the results accuracy, it is convenient to express the sampling error $S_{\bar{y}}$ relatively (in per cent) from the mean value $\bar{y}$ according to the relationship

$$S_{\bar{y}}\% = \frac{S_{\bar{y}}}{\bar{y}}.100$$

The range of the confidence interval (sampling error) is directly dependent on the variability of the values of the assessed variable, and inderectly dependent on the sample size ($n$ – number of IPs, grid density). Within the NFIM, several biometrical models for the statistical estimation of the parameters were analysed, and the most suitable models, which account for the selected sampling design of the inventory and for the nature of particular variables, were applied. The determining features were mainly: whether the variable was qualitative or quantitative, tree or stand, and whether the variable referred to the constant or to the variable area of IP, or to the constant or the variable number of the assessed individuals in IP (Šmelko, Merganič 2008). The following models were applied for the majority of the variables from the information spectrum (the formulas are given in this order: a sampling characteristic, its absolute and relative (in per cent) mean error; the following symbols are used: $A_{FOREST}$, $A_U$ – area of the forest and the region, respectively, $X$ – area of IP, subplot, storey, $n$ – number of sampling units, $j$ – ranking of sampling units, and other symbols that are explained in the text):

*a)* relative proportion of the category "forest" $p_{FOREST}$ (forest coverage)

$$p_{FOREST} = \frac{\sum_{j=1}^{n} X_{j(FOREST)}}{\sum_{j=1}^{n} X_{j(FOREST+NONFOREST)}} \qquad S_{p(FOREST)} = \pm\sqrt{\frac{p_{FOREST}.(1-p_{FOREST})}{n-1}} \qquad S_{p(FOREST)}\% = \frac{S_{p(FOREST)}}{p_{FOREST}}.100$$

*b)* area of the category "forest" $A_{FOREST}$ (ha)

$$A_{(FOREST)} = A_{(U)} \,.\, p_{(FOREST)} \qquad S_{A(FOREST)} = A_{(U)} \,.\, Sp_{(FOREST)}$$

$$S_{A(FOREST)}\% = \frac{S_{A(FOREST)}}{A_{(FOREST)}} \cdot 100 = Sp_{(FOREST)\%}$$

*c)* average value (arithmetic mean) of the quantitative stand variable Y (method "Ratio of Means", Cochran 1977), e.g. average volume per hectare

$$\bar{Y}_{ha} = \frac{\bar{Y}}{\bar{X}} = \frac{\sum_{j=1}^{n} Y_j}{\sum_{j=1}^{n} X_j} \qquad S_{\bar{Y}ha} = \sqrt{\frac{\sum_{i=1}^{n}(Y_j - \bar{Y}_{ha}.X_j)^2}{n.(n-1).\bar{X}^2}} \qquad S_{\bar{Y}ha}\% = \frac{S_{\bar{Y}ha}}{\bar{Y}_{ha}}.100$$

*d)* total of the quantitative variable Y, e.g. total volume on the area of the region

$$Y = A_{FOREST} \,.\, \bar{Y}_{ha} \qquad S_Y = \sqrt{A_{FOREST}^{\,2}.S_{\bar{Y}ha}^{\,2} + \bar{Y}_{ha}^{\,2}.S_{A(FOREST)}^{\,2}} \qquad S_Y\% = \sqrt{S_{A(FOREST)}\%^2 + S_{\bar{Y}ha}\%^2}$$

*e)* relative portion of the qualitative characteristic "a" related to the whole IP, e.g. forest type

$$p_a = \frac{n_a}{n} \qquad S_{pa} = \sqrt{\frac{p_a.(1-p_a)}{n-1}} \qquad S_{pa}\% = \frac{S_{pa}}{p_a}.100$$

*f)* relative portion of the qualitative characteristic "a" related to the partial IP, sub-plot, storey of the area $X_{aj}$, e.g. growth stage

$$p_a = \frac{\sum_{j=1}^{n} X_{aj}}{\sum_{j=1}^{n} X_j} \qquad S_{pa} = \sqrt{\frac{p_a.(1-p_a)}{n-1}} \qquad S_{pa}\% = \frac{S_{pa}}{p_a}.100$$

*g)* application of post-stratification – this is of great importance for the evaluation process of the inventory results. IPs are divided into more homogeneous groups, so called strata. Such a distribution decreases the variability of characteristics and increases the precision of the results. In the NFIM SR, this method was used for the calculation of average stand quantitative variable Y related to a specific area, while the stratification attributes were age, growth stages, and tree species. For each stratum h=1,2…L, the data from IPs were processed separately using the algorithm described in the point c). The average value per hectare was expressed in two ways: first the same value $Y_j$ was related to the area $X_j$ of the whole IP to obtain a so-called *"current (unreduced) average"*, while for the second time this value was related to that part of IP, on which the particular stratum occurred and in this way a so-called *"standardised (reduced) average"* was obtained. The final "stratified" characteristics for all strata were in the first case calculated as a sum of average values in the strata, while in the second case they were obtained as average values of the strata weighted by the area portion $W_h$ of the strata according to the relationships:

$$\bar{Y}_{ha(strat)} = \sum_{h=1}^{L} W_h.\bar{Y}_{ha(h)} \qquad S_{\bar{Y}ha(strat)} = \sqrt{\sum_{h=1}^{L} W_h^{\,2}.S_{\bar{y}ha(h)}^{\,2}} \qquad W_h = \frac{\sum_{j=1}^{n(h)} X_{j(h)}}{\sum_{j=1}^{n} X_j}$$

The poststratification of qualitative characteristics was performed similarly.

## 3 SELECTED SUMMARY OUTPUT OF THE NFIM SR

Due to the limited extent of this supplement, only the selection of basic information from the broad information spectrum assessed in the NFIM SR is presented here. In general, the presented information specifies forests on both forest and non-forestland together, only some selected characteristics (area, forest cover, stand volume) are given separately for forest and non-forestland, and sporadically the summary was prepared only for the forests on forestland (forest regeneration, health and silvicultural condition). The outputs distinguished between the categories of forest management (split up into state and nonstate subjects) are briefly described only for the basic characteristics (area, stand volume) in the text.

The information presented here is the result of data processing and summarisation of the data, which were directly measured, assessed, and derived. The information given in the text, as well as in the tables, and graphs is an average value of the particular variable and the interval of the sampling error with 68% confidence. In tables and pie graphs, the interval is either indicated by the symbol ± and the value of the sampling error, or directly by the bottom and top limits ("from – to"). In histograms, error lines display the interval. Combined map graphs present the results separately for the regions with additional information (forest coverage, stand volume per hectare, or total volume) in the background.

## 3.1 Forest area

In the scope of the NFIM SR, forest inventory was realised over the whole country regardless of the land type specified in the real estate registry, i.e. not only on forestland but also on other land, which is in reality covered by forest (here called as non-forestland). In total, forest (according to the definition of the NFIM SR) was detected on the area of over 2.17 mil. ha (± 1%). From this number the 1.90 mil. ha (± 1%) was forest on forestland, which coincided with the information published in the Green report 2006 (i.e. 1.93 mil. ha, the detected difference – 1.5% between the two values is insignificant). The forest area on non-forestland reached almost 275 thousand ha (± 3.7%), which is several times higher than the estimations presented by now. These forests make together almost 13% of the total forest area, while the substantial group of these forests is located in the central and eastern Slovakia.
State organisations manage forests on the area of 1.15 mil. ha (± 3.2%), while the forest area of 0.74 mil. ha (± 4.7%) is managed by non-state organisations, which means that their ratio is 60 : 40 in favour of state management organisations.
The inventory has confirmed the trend towards the increasing forest area, which is a very positive tendency from the point of sustainable development.

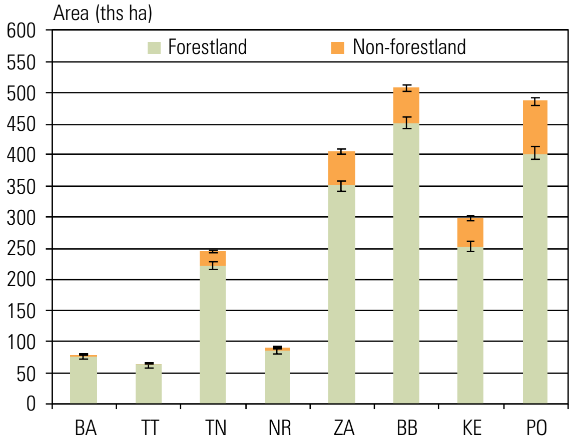


*Figure 3.1–1 Forest area in the regions of Slovakia*

*Forest coverage*
Forest coverage represents the ratio between the area of the forested land and the total area of the region. Hence, higher total forest area also affects forest coverage. By adding 5% of the forest coverage on non-forestland that has not been registered by now, forest coverage of Slovakia has increased to more than 44.3% (± 0.4%). Significantly lower forest coverage is recorded in the southwestern part of Slovakia, while the forest coverage of the rest of the country fluctuates around the average forest coverage. The Žilina region has the highest forest cover.

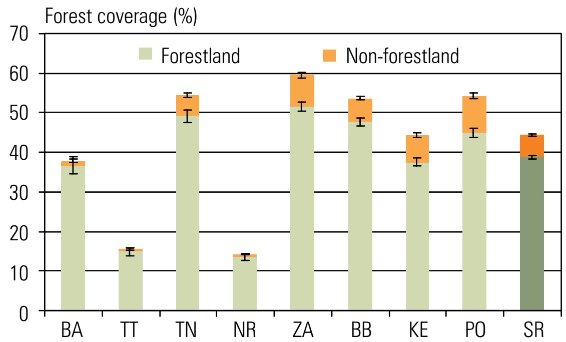


*Figure 3.1–2 Forest coverage in the regions and in Slovakia*

*Forest categories*
In the whole Slovakia, management forests prevail (they cover more than 70% of the area). The proportion of protection forests (17%), which have to be managed in order to sustain and enhance their ecological functions (above all soil protection and water management roles) and their area depends on site characteristics, coincides with the data from forest management plans. The proportion of the forests of specific purposes that preferentially fulfil public services (spa and therapeutic function, recreation, research and education, hunting, nature protection, etc.) exceeds 12%. The Žilina region has a significantly high proportion of protection forests.
The proportion of forest categories managed separately by state and non-state organisations correspond with the data for the whole country.

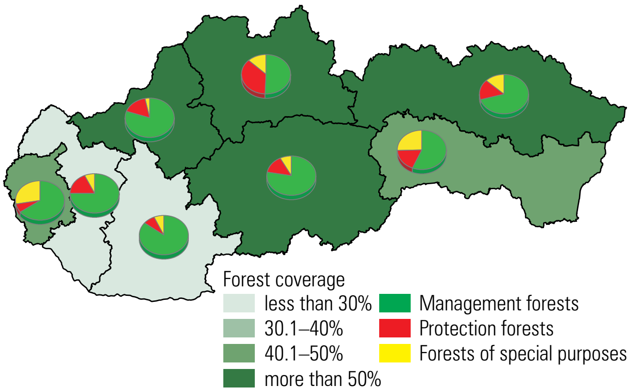


*Figure 3.1–3 Forest categories in the regions*

## 3.2 Inner structure of forest stands

*Age structure*
Forest age structure belongs to traditional information used in forestry. It is mainly important in order to ensure production sustainability and balance. Commonly, the classification into age degrees (VS, 10-year intervals) or age classes (VT, 20-year intervals) is used. Normal age structure characterised by equal proportion of the majority of age classes (degrees) within the rotation period and by the decreasing proportion of higher age classes (degrees), is considered to be the optimum structure. However, this idea was conceived for even-aged stands (clearcutting management), and therefore, its application in uneven-aged and in close-to-nature forests is problematic.
To determine the age is in general a very complex task, and in structurally differentiated stands it is even more difficult. The main problem is to classify an uneven-aged stand consisting of several storeys of different age into one age class. When processing the results from the NFIM SR, traditional age classification was found to be inappropriate. Due to this, a differentiated approach was applied: even-aged single-storied stands were classified into age classes, while for uneven-aged stands (in which age differences between structural elements – tree species, storeys, exceeded 20 years) three new classes were established: A – uneven-aged younger stands (in which the structural elements were maximum 60 years old), B – uneven-aged older stands (stands with the age over 60 years), and C – two-storied regenerated stands with the parent stand and the regeneration below.
The obtained results were very interesting, since they revealed a more objective information about the real forest condition from the point of age structure, when for the first time uneven-aged stands were not artificially classified into other homogeneous groups. As much as one quarter of all forests in Slovakia belong to older uneven-aged stands. Even-aged stands cover only 50% of the forest area, and 10% is covered

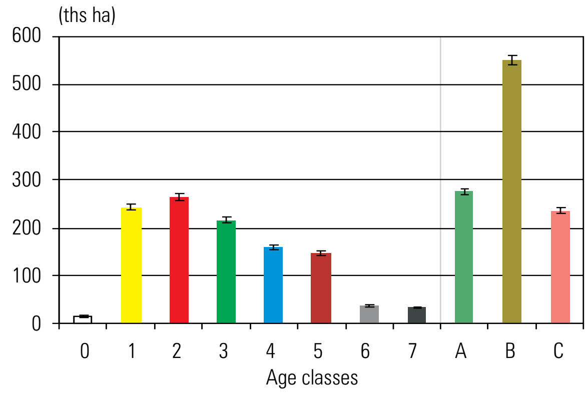


*Figure 3.2–1 Area of age classes of even-aged (0–7) and uneven-aged (A–C) stands in Slovakia*

*Even-aged stands: 0 – clearing, 1 – 1 to 20 years, 2 – 21 to 40 years, 3 – 41 to 60 years, 4 – 61 to 80 years, 5 – 81 to 100 years, 6 – 101 to 120 years, 7 – more than 120 years,*
*Uneven-aged stands: A –under the age of 60 years, B – over the age of 60 years, C – two-storied regenerated stands*

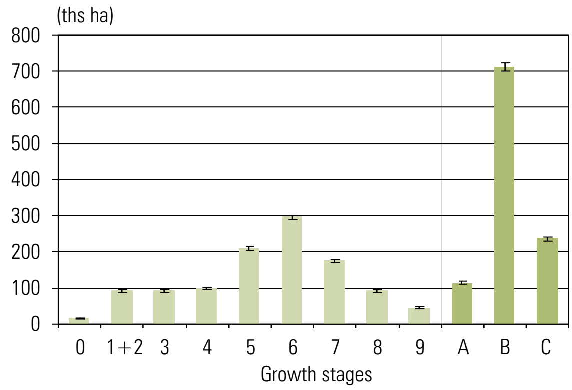


*Figure 3.2–3 Area of the growth stages in homogeneous (0–9) and heterogeneous (A–C) stands in Slovakia*

*Homogeneous stands: 0 – clearing, 1 + 2 – natural seeding, advanced regeneration, young plantation, 3 – thicket, 4 – small pole stage, 5 – pole stage, 6 – small-sized large-diameter stands, 7 – medium-sized large-diameter stands, 8 – large-sized large-diameter stands, 9 – very large-sized large-diameter stands*
*Heterogeneous stands: A – inferior mixed growth stage (with mean stand diameter below 20 cm), B – advanced mixed growth stage (with mean stand diameter above 20 cm), C – regenerated stands*

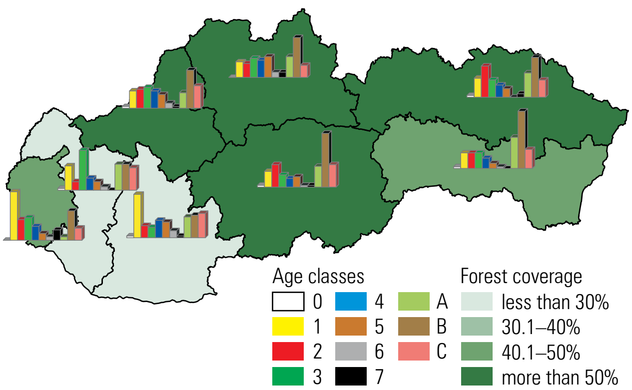


*Figure 3.2–2 Area of age classes of even-aged (0–7) and uneven-aged (A–C) stands and forest coverage in the individual regions of Slovakia*

*Even-aged stands: 0 – clearing, 1 – 1 to 20 years, 2 – 21 to 40 years, 3 – 41 to 60 years, 4 – 61 to 80 years, 5 – 81 to 100 years, 6 – 101 to 120 years, 7 – more than 120 years,*
*Uneven-aged stands: A –under the age of 60 years, B – over the age of 60 years, C – two-storied regenerated stands*

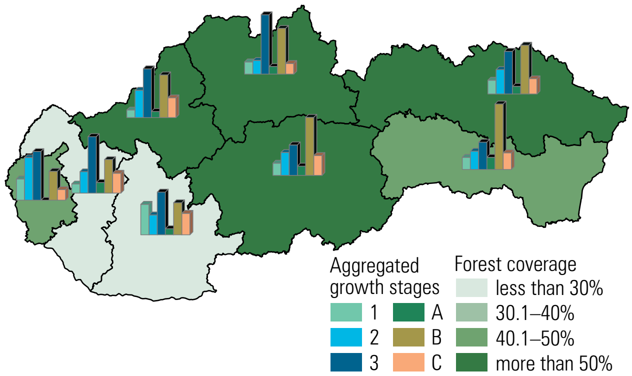


*Figure 3.2–4 Area of the aggregated growth stages in the individual regions and their forest coverage*

*Homogeneous stands: 1 – natural seeding, advanced regeneration, young plantation, thicket, 2 – small pole stage, pole stage, 3 – large-diameter stands*
*Heterogeneous stands: A – inferior mixed growth stage (with mean stand diameter below 20 cm), B – advanced mixed growth stage (with mean stand diameter above 20 cm), C – regenerated stands*

by regenerated stands. These facts indicate that from the point of close-to-nature management the actual forest condition is good, and that the potential to sustain and increase the area of uneven-aged stands is excellent. It is assumed that in future the traditional classification of forests into age classes will be replaced by the classification based on other attributes (growth stages etc.).

In the majority of the regions, age structure corresponds with the proportion over the whole Slovakia. An unbalanced proportion (to the disadvantage of older classes) was observed in the southwestern part of Slovakia, where the felling possibilities are lower due to the predominance of young stands.

### *Growth stages*

Although the classification into growth stages (RS) is closely related to the classification based on age, the systems are not identical. The advantage of this classification over the classification based on age is that the stand is classified into a growth stage on the base of the measured variables (mean height, mean diameter), which is easier and more objective.

However, also in this case it was problematic to classify heterogeneous stands into growth stages. Therefore, similarly as in the case of age classes, the new system was developed: in the diameter-homogeneous stands the common growth stages were used, while for the diameter-heterogeneous and regenerated stands three categories (A, B, C) were created.

The structure defined by growth stages detected a higher proportion of heterogeneous stands in the advanced mixed growth stage B than the age structure indicated. It means that younger forest stands often have greater dimensions. The composition of growth stages confirms that the large portion of Slovak forests have a diversified diameter structure.

The comparison of the structure of aggregated growth stages in the individual regions revealed a balanced ratio between homogeneous and heterogeneous stands, although in the western part of the country slightly more homogeneous stands occur, while in the eastern part there are more stands with a diversified diameter structure.

### *Tree species composition*

Tree species composition was determined from the derived tree growth areas, i.e. the areas utilised by trees for their growth. Using these growth areas, it is possible to estimate the area occupied by a particular tree species (unlike the derivation of tree species composition from the number of trees, basal area, or stand volume).

It is obvious that coniferous tree species cover less than one third of the area. When compared with other sources, e.g. with the Green report (2006, which presents the information about forestland only), the NFIM SR results revealed a significantly lower proportion of spruce (21% versus 27%). However, the proportion of spruce calculated from stand volume (Table 3.4–6) was also according to the NFIM SR results

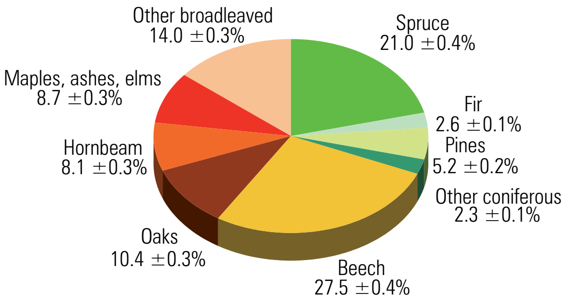


*Figure 3.2–5 Tree species composition expressed as the area proportions (proportion of tree growth areas) of tree species in Slovakia*

28%. In general, Slovak forests are diverse with a relatively balanced tree species composition, while beech covers the highest proportion of the area.

In Slovakia, broadleaved forests dominate (they cover approximately 50%), while pure coniferous stands (with the proportion of coniferous tree species equal to or greater than 90%) cover only 20%. The proportion of coniferous and broadleaved tree species in individual regions corresponds approximately with the average values for the whole country. The exceptions are the Žilina region and the Nitra region, since in the Žilina region coniferous tree species prevail, while in the Nitra region broadleaved tree species cover 98% of the area.

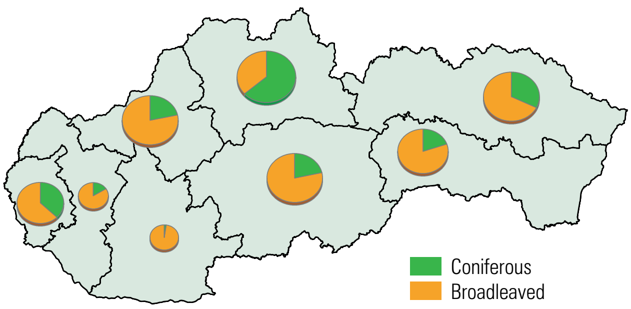


*Figure 3.2–6 Area proportion of coniferous and broadleaved tree species in the regions*

*Vertical structure*

Similarly, vertical structure of the stands revealed positive findings: single-storied stands with a simple structure cover approximately one half of the forest area in Slovakia. Two-storied stands cover one third, and the most diversified multi-storied stands cover one sixth of the area. Multi-storied stands encompass three-storied stands, selection forests, and forests with a mixed structure (mainly forests on non-forestland that are being developed without any direct interference of a manager). Selection forests cover not more than 1% of the whole forest area. The presented results obtained from the NFIM SR do not coincide with the published information (Green report 2006) according to which single-storied stands cover 80%. Slovak forests seem to have a much more diversified vertical, age and diameter structure.

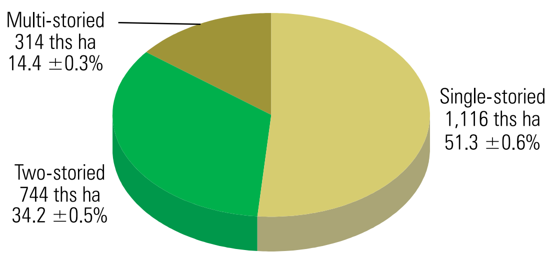


*Figure 3.2–7 Vertical structure of forests in Slovakia (proportion is given in thousands of hectares and in %)*

Simple vertical structure was observed mainly in the forests of the southern part of Slovakia. In spite of the predominance of the coniferous tree species in the Žilina region, the vertical structure of this region is similar to other regions where broadleaved tree species prevail.

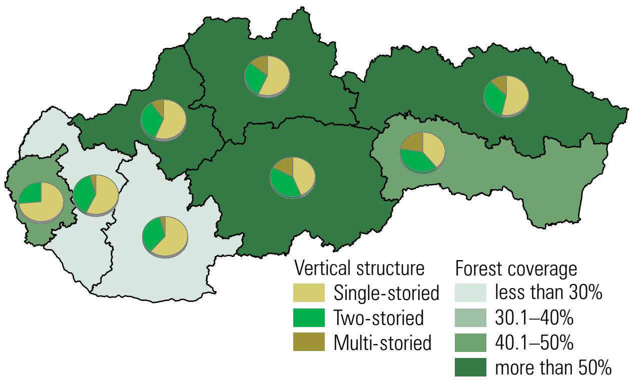


*Figure 3.2–8 Vertical structure of forests and forest coverage in the regions of Slovakia*

## 3.3 Forest regeneration on forestland

*Regeneration occurrence and coverage*

Completely new information was obtained about the regeneration occurrence over the entire area of the country, which had not been published before (Green report presents only annual amount of the realised regeneration). In addition to the commonly used estimation of coverage, within the NFIM a precise recording of individuals in the sample plots has been applied, which excluded subjective assessment. To ensure methodological exactness, all trees with diameter at breast height smaller than 7 cm are considered to be regeneration individuals, although the comprehension of regeneration (e.g the growth stages natural seeding, advanced regeneration, thicket, etc.) varies depending on the point of view (silviculture, protection). The coverage was calculated from the derived tree growth areas of all individuals.

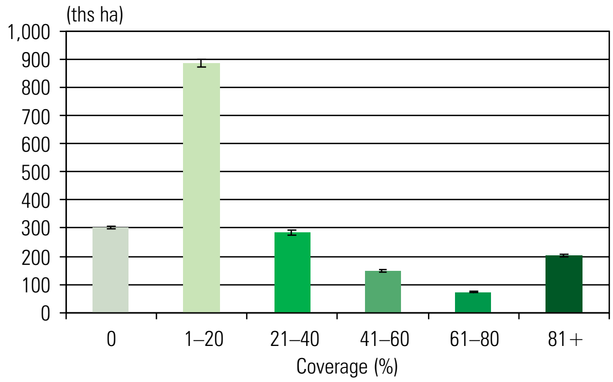


*Figure 3.3–1 Regeneration occurrence specified by its coverage in the forests of Slovakia located on forestland*

The findings revealed that the regeneration individuals occur very often, and hence, the potential to utilise the natural regeneration is high. The regeneration occurs on 85% of the area of all forests located on forestland, although the proportion of regenerated stands is significantly lower (Figure 3.2–3 – growth stages 1+2 and two-storied regenerated stands). As shown in Figure 3.3–1, on more than a half of the area of forestland the coverage of regeneration is low, less than 20%. This information confirms that regeneration occurs also in the stands, where the management is not oriented at the support of regeneration processes. Very high regeneration coverage was detected on one tenth of the area of all forests.

*Tree species composition of regeneration*

Tree species composition of regeneration was derived from tree growth areas of the trees with diameter below 7 cm. The analysis of regeneration tree species composition on forestland revealed considerably different results as the analysis of tree species composition calculated from the whole set of trees (i.e. also mature trees). In regeneration, broadleaved tree species highly prevail as their proportion exceeded 88%.

Similarly to the overall tree species composition, beech has the highest proportion, and is followed by the group of maples, ashes and elms that have quite a high proportion, too. The following tree species are hornbeam, oaks, and other broadleaves. The proportion of spruce in regeneration is by one half lower when compared with the spruce proportion in the overall tree species composition (all individuals). Due to this, it can be expected that without any active management treatments, the proportion of spruce will be naturally reduced in time.

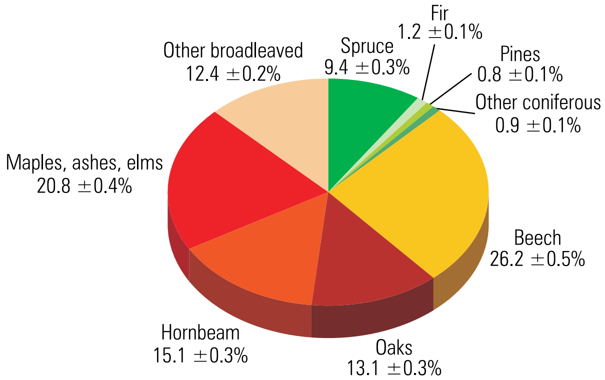


*Figure 3.3–2 Tree species composition of regeneration expressed as an area proportion (of tree growth areas) in the forests of Slovakia located on forestland*

The predominance of broadleaved tree species in regeneration was observed in all regions, even in the Žilina region (where coniferous species prevail in the overall tree species composition, Figure 3.3 – 3).

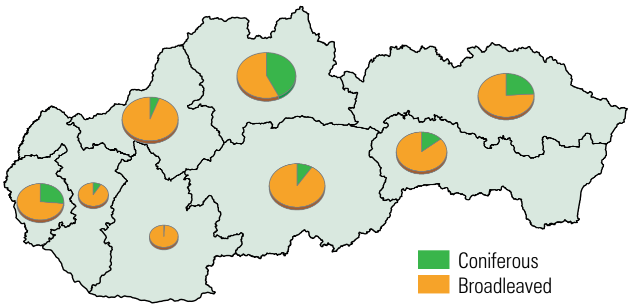


*Figure 3.3–3 Proportion of coniferous and broadleaved tree species in regeneration in the individual regions, forests on forestland*

*Number of individuals of natural and artificial regeneration per hectare*

When the regeneration is classified according to its origin, a view different from the traditional output is obtained. Instead of the records of annual regeneration, the actual total status of regeneration in all stands is obtained to one assessment time point. From the perspective of regeneration establishment, natural regeneration prevails. In the homogeneous growth stages, average numbers per hectare fluctuate from 2 to 4 thousand in the thicket, and up to 10–30 thousand in the natural seeding. The number of individuals in the artificial regeneration fluctuate around 2 to 2.5 thousand of individuals per hectare.

From the point of the occurrence of the regeneration categories on the area of the forestland, natural regeneration (seeding, advanced natural regneration, thicket) has a considerable predominance over the artificial regeneration (Table 3.3–1).

This indicates that natural regeneration has a great potential, which can be utilised in forest management. However, this potential is restricted by the fact that in certain site conditions suitable tree species composition of regeneration does not have to be achieved; this applies mainly to the occurrence of suitable commercial tree species (beech, oak, spruce, fir, etc.).

The highest proportion of the regeneration is situated below the canopy of the older stand (Figure 3.3–4), although it is of lower average coverage (approx. up to 10–20%) due to the fact that the stands are younger and middle-aged. The proportion of the regeneration next to the parent stand is low, but its average coverage is greater.

The highest proportion of the regeneration is situated below the canopy of the older stand (Figure 3.3–4), although it is of lower average coverage (approx. up to 10–20%) due to the fact that the stands are younger and middle-aged. The proportion of the regeneration next to the parent stand is low, but its average coverage is greater.

*Table 3.3–1 Number of individuals per hectare in the regeneration growth stages of the forests on forestland*

| Growth stage | Seedings | | | Advanced regeneration | | | Thicket | | |
|---|---|---|---|---|---|---|---|---|---|
| | number | error | occurrence | number | error | occurrence | number | error | occurrence |
| Tree spec. | ths pcs/ha | | % | ths pcs/ha | | % | ths pcs/ha | | % |
| Coniferous | 10.2 | ± 2.4 | 14.5 | 5.4 | ± 1.7 | 6.8 | 2.2 | ± 0.7 | 6.9 |
| Broadleav. | 31.8 | ± 2.7 | 65.6 | 8.0 | ± 1.1 | 34.5 | 3.2 | ± 0.9 | 30.3 |

| Growth stage | Young plantation | | | Advanced plantation | | |
|---|---|---|---|---|---|---|
| | number | error | occurrence | number | error | occurrence |
| Tree spec. | ths pcs/ha | | % | ths pcs/ha | | % |
| Coniferous | 2.0 | ± 0.9 | 0.6 | 2.9 | ± 0.5 | 1.5 |
| Broadleav. | 2.7 | ± 1.6 | 0.5 | 1.9 | ± 0.9 | 0.6 |

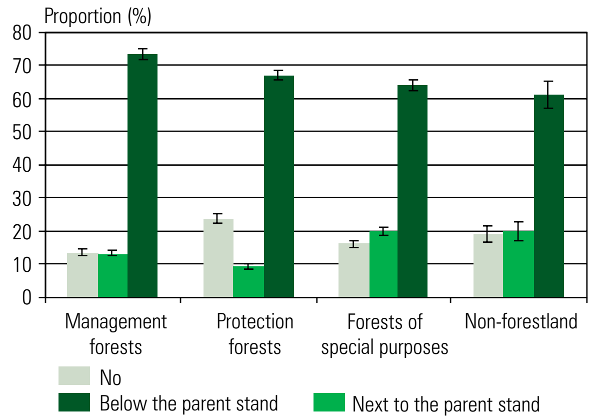


*Figure 3.3–4 Occurrence of regeneration in different categories of the forest*

## 3.4 Stand volume, quality and assortments

*Stand volume*

The data about timber volume provide the information about the actual production of forest stands. In the NFIM SR, stand volume was determined in the following units: timber to the top diameter of 7 cm inside bark (HBK), timber to the top diameter of 7 cm outside bark (HSK), stem inside bark (KBK), stem outside bark (KSK), and tree outside bark (SSK). In the aggregated outputs, timber to the top of 7 cm inside bark was applied, which is currently a conventionally used unit in Slovakia. The comparison of the values per hectare shown in Table 3.4–1 revealed that the differences between individual volume units reached up to 30%, and that the bark and the branches thinner than 7 cm in diameter make approximately 12% and 15% of the volume, respectively.

Average stand volume in the forests on forestland (283.2 ±5.2 m$^3$) is more than 100% larger than on non-forestland (133.3 ±9.5 m$^3$), which is normal. Average stand volume in individual forest functional categories is 288.5 ±6.3 m$^3$ in management forests, 257.8 ±10.3 m$^3$ in protection forests, and 290.7 ±16.5 m$^3$ in the forests of special purposes. As expected, stand volume in protection forests is slightly lower than in other forests. Stand volume of the forests in the two user categories is approximately equal, since state forests are characterised by 287.2 ±6.9 m$^3$ per ha, and non-state forests by 276.9 ±7.9 m$^3$ per ha.

The significant finding is that the average stand volume estimated from the NFIM data on forestland is by +54 m$^3$, i.e. by +23% greater than the volume obtained from the summary forest management plans (229 m$^3$ per ha, Green report 2006). According to the experience gained from foreign national inventories, this difference could have been expected and results from several factors:

- in the NFIM SR, each tree was measured (each diameter greater than 7 cm, and each height) by a small group of trained specialists

(15–20 workers) who were not influenced by outside environment (they realised the works within a short 2-year interval over the whole area of Slovakia) using an up-to-date technology (Field-Map, Vertex), and the measurements were checked on 10% of all established plots,

- aggregated data from forest management plans are obtained by summing up the information coming from the sources that are differently actual (1–10 years); mean stand variables (mean height and mean diameter) or yield tables are used as input variables for the calculation of stand volume, while direct measurements are applied to a lesser extent; stand volume of the secondary crop is not recorded; increment during the current period (1 to 10 years) is not accounted for in the aggregates; a subjective factor plays an important role (forest management plans have been prepared by a number of plan-makers with a different level of experience and confidence).

Other outputs (Table 3.4–1 to 3.4–7) inform about the structure of the stand volume per hectare and total stand volume in relation to age, growth stages, and tree species. The methodology of the calculation distinguishes current and standardised stand volume per hectare. Current stand volume per hectare is always related to the whole forest area of Slovakia, while standardised stand volume refers to the area of the particular category. As it is seen, in even-aged stands the highest proportion of timber volume is located from 3rd to 5th age classes (41 to 100 years), and in 6th and 7th growth stages (small-sized and medium-sized large-diameter stand with mean diameter from 20 to 35 cm), but three times higher proportion of stand volume is located in heterogeneous structures in the aggregated category B (uneven-aged stands older than 60 years and advanced mixed growth stages with mean diameter greater than 20 cm). From tree species, the highest volume proportion falls upon beech (35%) and spruce (28%). Total timber volume in all forests reached the value 574 mil. $m^3$ of timber to the top of 7 cm inside bark, out of which 538 mil. $m^3$ is on forestland and 36 mil. $m^3$ on non-forestland.

At national level, stand volumes determined from the NFIM SR data are sufficently accurate and reliable, relative mean error was ±2%. In smaller forest parts (regions, age classes, growth stages, tree species, etc.), the accuracy is lower since the accuracy decreases with the decreasing area of the part.

*Table 3.4–1 Comparison of average stand volume per hectare in the Slovak Republic expressed in different volume units*

| Volume unit | Abbreviation | Value | Error | Ratio to HBK |
|---|---|---|---|---|
| | | $m^3$/ha | | |
| Stem inside bark | KBK | 252.6 | ± 4.9 | 0,96 |
| Timber to the top diameter of 7 cm inside bark | HBK | 264.2 | ± 5.2 | 1.00 |
| Stem outside bark | KSK | 282.4 | ± 5.3 | 1.07 |
| Timber to the top diameter of 7 cm outside bark | HSK | 295.9 | ± 5.7 | 1.12 |
| Tree outside bark | SSK | 331.0 | ± 6.1 | 1.25 |

*Table 3.4–2 Stand volume of timber to the top of 7 cm inside bark distributed to age classes (VT)*

| Age class | Stand volume per hectare | | | Total stand volume | | | Proportion |
|---|---|---|---|---|---|---|---|
| | current | standard. | error | value | from | to | |
| VT | $m^3$ | | | million $m^3$ | | | % |
| 0 | 0 | 0 | ± 0 | 0.0 | 0.0 | 0.0 | 0 |
| 1 | 2 | 17 | ± 3 | 4.1 | 3.4 | 4.8 | 1 |
| 2 | 16 | 130 | ± 6 | 34.2 | 32.4 | 35.9 | 6 |
| 3 | 28 | 280 | ± 13 | 60.4 | 57.6 | 63.1 | 11 |
| 4 | 26 | 352 | ± 18 | 55.7 | 52.7 | 58.7 | 10 |
| 5 | 30 | 444 | ± 20 | 65.7 | 62.7 | 68.7 | 11 |
| 6 | 7 | 429 | ± 49 | 16.1 | 14.2 | 17.9 | 3 |
| 7 | 7 | 436 | ± 60 | 14.4 | 12.5 | 16.4 | 3 |
| A | 20 | 155 | ± 9 | 42.5 | 39.9 | 45.0 | 7 |
| B | 88 | 350 | ± 8 | 192.3 | 187.4 | 197.2 | 33 |
| C | 41 | 378 | ± 15 | 89.1 | 85.5 | 92.7 | 16 |
| Total | 264 | 264 | ± 5 | 574.4 | 562.4 | 586.5 | 100 |

*0 – clearing, 1 VT – 1 to 20 years, 2 VT – 21 to 40 years, 3 VT – 41 to 60 years, 4 VT – 61 to 80 years, 5 VT – 81 to 100 years, 6 VT – 101 to 120 years, 7 VT – more than 120 years, A – uneven-aged stands under the age of 60, B – uneven-aged stands over the age of 60 years, C – two-storied regenerated stands*

*Table 3.4–3 Stand volume of timber to the top of 7 cm inside bark distributed to age classes (VT) – forest on forestland*

| Age class | Stand volume per hectare | | | Total stand volume | | | Proportion |
|---|---|---|---|---|---|---|---|
| | current | standard. | error | value | from | to | |
| VT | $m^3$ | | | million $m^3$ | | | % |
| 0 | 0 | 0 | ± 0 | 0.0 | 0.0 | 0.0 | 0 |
| 1 | 2 | 16 | ± 3 | 3.2 | 2.5 | 3.9 | 1 |
| 2 | 14 | 139 | ± 7 | 27.4 | 26.0 | 28.9 | 5 |
| 3 | 29 | 284 | ± 12 | 55.4 | 52.9 | 57.8 | 10 |
| 4 | 29 | 357 | ± 19 | 54.6 | 51.7 | 57.5 | 10 |
| 5 | 34 | 444 | ± 20 | 65.1 | 62.1 | 68.1 | 12 |
| 6 | 8 | 429 | ± 49 | 16.0 | 14.2 | 17.8 | 3 |
| 7 | 8 | 436 | ± 60 | 14.4 | 12.5 | 16.4 | 3 |
| A | 16 | 180 | ± 12 | 30.7 | 28.6 | 32.8 | 6 |
| B | 97 | 351 | ± 8 | 184.0 | 179.2 | 188.8 | 34 |
| C | 46 | 388 | ± 15 | 87.0 | 83.5 | 90.5 | 16 |
| Total | 283 | 283 | ± 5 | 537.9 | 526.6 | 549.2 | 100 |

*Table 3.4–4 Stand volume of timber to the top of 7 cm inside bark distributed to growth stages (RS)*

| Growth stage | Stand volume per hectare | | | Total stand volume | | | Proportion |
|---|---|---|---|---|---|---|---|
| | current | standard. | error | value | from | to | |
| RS | $m^3$ | | | million $m^3$ | | | % |
| 0+1+2 | 0 | 0 | ± 0 | 0.0 | 0.0 | 0.0 | 0 |
| 3 | 0 | 5 | ± 1 | 0.5 | 0.4 | 0.6 | 0 |
| 4 | 2 | 52 | ± 5 | 5.1 | 4.6 | 5.6 | 1 |
| 5 | 12 | 128 | ± 7 | 26.9 | 25.5 | 28.3 | 5 |
| 6 | 34 | 254 | ± 8 | 75.0 | 72.4 | 77.6 | 13 |
| 7 | 33 | 408 | ± 15 | 70.9 | 68.3 | 73.6 | 12 |
| 8 | 22 | 507 | ± 26 | 46.8 | 44.3 | 49.3 | 8 |
| 9 | 12 | 579 | ± 48 | 25.4 | 23.2 | 27.5 | 4 |
| A | 4 | 76 | ± 7 | 8.7 | 7.9 | 9.5 | 2 |
| B | 104 | 318 | ± 7 | 226.1 | 220.3 | 231.8 | 39 |
| C | 41 | 378 | ± 15 | 89.1 | 85.5 | 92.7 | 16 |
| Total | 264 | 264 | ± 5 | 574.4 | 562.4 | 586.5 | 100 |

*0 – clearing, 1+2 – natural seeding, advanced regeneration, young plantation, 3 – thicket, 4 – small pole stage, 5 – pole stage, 6 – small-sized large-diameter stands, 7 – medium-sized large-diameter stands, 8 – large-sized large-diameter stands, 9 – very large-sized large-diameter stands, A – inferior mixed growth stage (below 20 cm), B – advanced mixed growth stage (above 20 cm), C – regenerated stands*

*Table 3.4–5 Stand volume of timber to the top of 7 cm inside bark distributed to growth stages (RS) – forest on forestland*

| Growth stage | Stand volume per hectare | | | Total stand volume | | | Proportion |
|---|---|---|---|---|---|---|---|
| | current | standard. | error | value | from | to | |
| RS | $m^3$ | | | million $m^3$ | | | % |
| 0+1+2 | 0 | 0 | ± 0 | 0.0 | 0.0 | 0.0 | 0 |
| 3 | 0 | 5 | ± 1 | 0.4 | 0.3 | 0.5 | 0 |
| 4 | 2 | 56 | ± 6 | 4.0 | 3.5 | 4.4 | 1 |
| 5 | 12 | 144 | ± 7 | 23.5 | 22.3 | 24.7 | 4 |
| 6 | 38 | 267 | ± 9 | 71.9 | 69.5 | 74.3 | 13 |
| 7 | 35 | 414 | ± 15 | 67.0 | 64.5 | 69.5 | 12 |
| 8 | 24 | 512 | ± 27 | 46.3 | 43.9 | 48.8 | 9 |
| 9 | 12 | 577 | ± 51 | 23.0 | 21.0 | 25.1 | 4 |
| A | 3 | 87 | ± 11 | 5.5 | 4.8 | 6.2 | 1 |
| B | 110 | 332 | ± 8 | 209.2 | 203.9 | 214.5 | 39 |
| C | 46 | 388 | ± 15 | 87.0 | 83.5 | 90.5 | 16 |
| Total | 283 | 283 | ± 5 | 537.9 | 526.6 | 549.2 | 100 |

*Table 3.4–6 Stand volume of timber to the top of 7 cm inside bark distributed to tree species*

| Tree species | Stand volume per hectare | | | Total stand volume | | | Proportion |
|---|---|---|---|---|---|---|---|
| | current | standard. | error | value | from | to | |
| | $m^3$ | | | million $m^3$ | | | % |
| SM | 74 | 354 | ± 12 | 161.7 | 155.9 | 167.5 | 28 |
| JD | 10 | 387 | ± 26 | 22.5 | 20.9 | 24.0 | 4 |
| BO | 15 | 272 | ± 18 | 31.9 | 29.8 | 34.1 | 6 |
| OI | 4 | 179 | ± 27 | 8.9 | 7.5 | 10.2 | 2 |
| BK | 93 | 340 | ± 9 | 202.6 | 196.9 | 208.3 | 35 |
| DB | 29 | 284 | ± 11 | 64.1 | 61.4 | 66.7 | 11 |
| HB | 10 | 120 | ± 7 | 20.8 | 19.6 | 22.1 | 4 |
| JV,JS,BT | 12 | 134 | ± 10 | 25.3 | 23.3 | 27.2 | 4 |
| OL | 17 | 121 | ± 9 | 36.7 | 34.0 | 39.4 | 6 |
| Total | 264 | 264 | ± 5 | 574.4 | 562.4 | 586.5 | 100 |

*SM – spruce (Picea sp.), JD – Silver fir (Abies alba), BO – pine (Pinus sp.), OI – other coniferous, BK – Common beech (Fagus sylvatica), DB – oak (Quercus sp.), HB – European hornbeam (Carpinus betulus), JV, JS, BT – maples, ashes, elms (Acer sp., Fraxinus sp., Ulmus sp.), OL – other broadleaves*

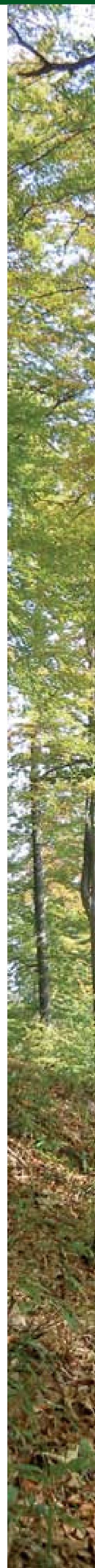

*Table 3.4–7 Stand volume of timber to the top of 7 cm inside bark distributed to tree species – forest on forestland*

| Tree species | Stand volume per hectare | | | Total stand volume | | | Proportion |
|---|---|---|---|---|---|---|---|
| | current | standard. | error | value | from | to | |
| | m³ | | | million m³ | | | % |
| SM | 80 | 370 | ± 13 | 151.9 | 146.3 | 157.5 | 28 |
| JD | 11 | 396 | ± 28 | 21.5 | 19.9 | 23.0 | 4 |
| BO | 16 | 293 | ± 20 | 30.0 | 27.9 | 32.0 | 6 |
| OI | 5 | 180 | ± 28 | 8.7 | 7.4 | 10.1 | 2 |
| BK | 104 | 345 | ± 9 | 197.3 | 191.8 | 202.9 | 37 |
| DB | 33 | 295 | ± 12 | 62.7 | 60.1 | 65.2 | 12 |
| HB | 10 | 130 | ± 8 | 18.6 | 17.4 | 19.8 | 3 |
| JV,JS,BT | 13 | 143 | ± 11 | 24.0 | 22.1 | 25.8 | 4 |
| OL | 12 | 126 | ± 11 | 23.2 | 21.1 | 25.3 | 4 |
| Total | 283 | 283 | ± 5 | 537.9 | 526.6 | 549.2 | 100 |

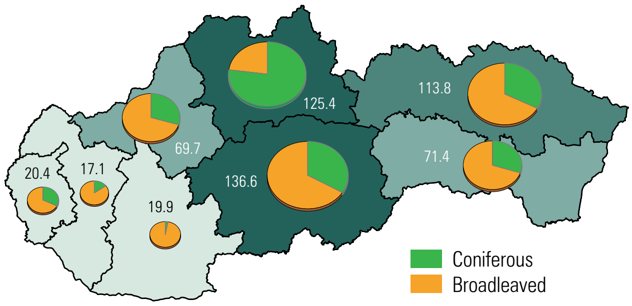


*Figure 3.4–1 Total stand volume of timber to the top of 7 cm inside bark (million m³) in individual regions distributed to tree species groups*

*Quality classes*

Quality structure informs about the potential and the real utilisation of standing timber (timber of standing trees) and provides the details required for the assessment and consequent monitoring of qualitative forest stand condition, as well as for sorting of timber volume. The quality of every tree was assessed, while in mature stands it was evaluated as an actual condition, and in the rest as a potential (assummed development) on the base of external (visible) signs regardless of the current dimensions (diameter, height). The tree was classified into one of the three quality classes: A (healthy, straight, untwisted, full boled, centrical, with no shape deformations, meeting the requirements on the quality of the selective assortments of the top quality), B (slightly twisted, with smaller technical faults, thin or medium branches or knots are allowed, but no large knots, the timber meets the requirements on the assortments of the average quality), C (with great technical faults, great branchiness, twisted, with various deformations, crooked, suitable for industrial processing).

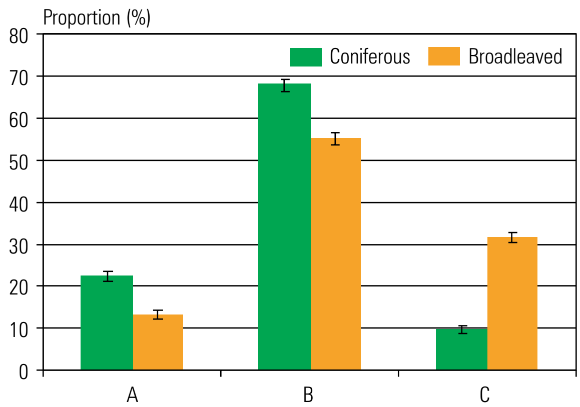


*Figure 3.4–2 Quality classes (A, B, C) of coniferous and broadleaved tree species in the forests of the Slovak Republic (proportion from volume of the timber to the top of 7 cm inside bark)*

As presented in Figure 3.4–3, average volume of the timber to the top of 7 cm inside bark per hectare fluctuates in individual regions, though the fluctuation is not as distinct as in the case of the total volume. From quality classes, average quality class prevails, and in the western part of the country this class is markedly dominating (while the proportion of the trees of the highest and lowest quality is balanced). Significant proportion of the top quality trees was found in the central Slovakia (almost one third). On the contrary, in the Prešov region more than a half of the trees were classified into the lowest quality class C.

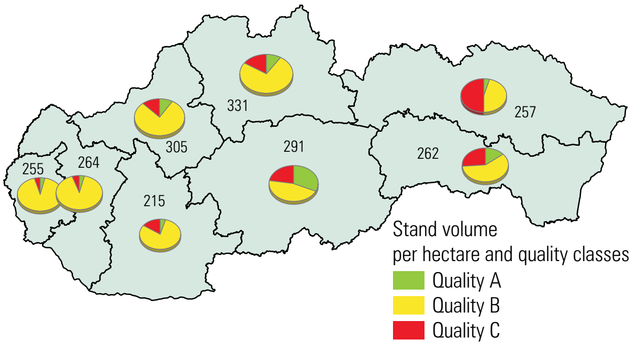


*Figure 3.4–3 Stand volume of timber to the top of 7 cm inside bark per hectare (m³/ha) and the proportion of quality classes from stand volume on forestland in individual regions*

*Timber assortments*

The output about the proportion of the quality classes of logs (Figure 3.4–4) on forestland of the whole Slovakia is based on the tables of tree assortment models (Petráš, Nociar 1991, Mecko et al. 1994). Such an output about standing trees is published for the first time. The results are derived from more than 34 thousand of measured trees with the diameter greater than 7 cm, while the proportions of the quality classes were calculated from the total stand volume.

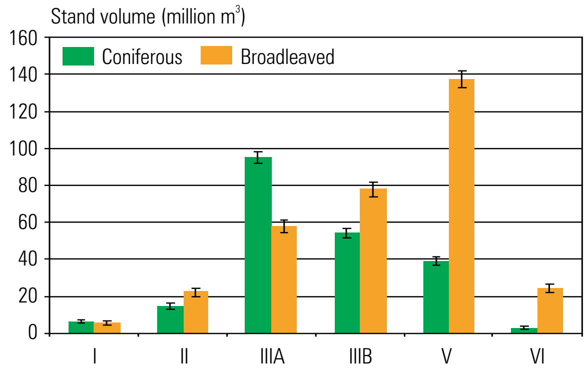


*Figure 3.4–4 Quality classes of logs of coniferous and broadleaved tree species in the forests on forestland*

The quality structure of coniferous tree species is better than that of broadleaves, since in the group of coniferous species the quality class IIIA prevails, while in the group of broadleaved species the quality class V, i.e. pulpwood, is dominant with its proportion 40%. Note that the results encompass both mature and premature stands. If the calculation included only mature stands, the proportion of better quality classes would be significantly higher.

## 3.5 Health and silvicultural condition of forests

Various indicators based on the measure of damage can describe health forest condition. The philosophy how to measure health condition is ambiguous, as there exist several partial or complex indicators, but none was explicitly selected as the most appropriate one. The annual Monitoring of forest health condition (Pavlenda et al., Forest Focus – ČMS Lesy) utilises the assessment of defoliation and the proportion of trees in individual defoliation classes, the change of colour, symptoms of damages caused by abiotic, biotic, and human-induced (anthropogenic) factors on individual trees and monitoring plots. Other possible indicators are the proportion of dead standing trees – stumps, and the proportion of lying damaged timber, or it is possible to evaluate the area of damage – area of the clearings caused by disturbances. It is possible to quantify the amount and the proportion of salvage cuttings caused by particular agents. The health condition of mature trees is evaluated differently as the health condition of regeneration.

In the NFIM SR, the damage of every tree was assessed, as well as the influence of adverse factors on each IP. For this first report the following indicators were selected as indicators of health condition: stem damage caused by felling and wildlife (as a significant stem damage); crown damage, which can be compared with the commonly used assessments, and regeneration damage (of trees with diameter below 7 cm).

For the first time, the state of silviculture was evaluated to such an extent for the whole republic. Two categories were distinguished: good and neglected state of silviculture. Good state does not require reformative measures to be planned. If the silvicultural state is neglected, the treatments that should be realised in a short time period (5 to 10 years) are suggested.

*Stem damage of trees caused by felling*

The proportion of damaged trees is determined from the volume (timber to the top of 7 cm inside bark). No significant differences in stem damage caused by felling and skidding operations between coniferous and broadleaved tree species were detected in the forests on forestland. More than 20% of damaged trees (Table 3.5–1) are a relatively high value that indicates less considerate forest management, although severe damage was detected on only 2% of the stems. For example, national forest inventory in the Czech Republic revealed only 13% of the damaged trees.

*Table 3.5–1 Stem damage of trees caused by felling and skidding operations of the groups of tree species on forestland*

| Tree species | Extent of stem damage | Proportion | from | to |
|---|---|---|---|---|
| | | % | | |
| Coniferous | No damage | 78.6 | 77.5 | 79.7 |
| | Slight (up to 1/8 of stem girth) | 11.0 | 10.2 | 11.9 |
| | Medium (from 1/8 to 1/2 of stem girth) | 8.1 | 7.4 | 8.8 |
| | Severe (above 1/2 of stem girth) | 2.3 | 1.9 | 2.7 |
| Broadleaved | No damage | 78.6 | 77.5 | 79.7 |
| | Slight (up to 1/8 of stem girth) | 13.9 | 13.0 | 14.8 |
| | Medium (from 1/8 to 1/2 of stem girth) | 5.6 | 5.0 | 6.3 |
| | Severe (above 1/2 of stem girth) | 1.8 | 1.5 | 2.2 |

*Stem damage of trees caused by wildlife*

Unlike the stem damage caused by felling, in the case of stem damage caused by wildlife, an obvious difference between coniferous and broadleaved tree species was revealed (Table 3.5–2). The proportion of damaged broadleaved tree species in the forests on forestland is almost negligible. Stem damage caused by wildlife is in general very low, almost four times lower than the damage caused by felling. Unlike in Slovakia, the neighbouring Czech Republic had a higher proportion of stem damage caused by wildlife, where it reached the value 12%.

*Table 3.5–2 Stem damage of trees caused by wildlife in the groups of tree species on forestland*

| Tree species | Extent of stem damage | Proportion | from | to |
|---|---|---|---|---|
| | | % | | |
| Coniferous | No damage | 95.6 | 95.0 | 96.1 |
| | Slight (up to 1/8 of stem girth) | 1.3 | 1.0 | 1.6 |
| | Medium (from 1/8 to 1/2 of stem girth) | 2.0 | 1.6 | 2.4 |
| | Severe (above 1/2 of stem girth) | 1.2 | 0.9 | 1.5 |
| Broadleaved | No damage | 99.7 | 99.5 | 99.8 |
| | Slight (up to 1/8 of stem girth) | 0.2 | 0.1 | 0.3 |
| | Medium (from 1/8 to 1/2 of stem girth) | 0.1 | 0.0 | 0.2 |
| | Severe (above 1/2 of stem girth) | 0.0 | 0.0 | 0.1 |

*Crown damage*

The subjective expert estimation was used to assess the extent of crown damage on each measured tree with the accuracy of 10%. The results correspond with the foundings from the annual Monitoring of forest health condition in the grid 16×16 km quite well, in which the defoliation is assessed only on dominant and co-dominant trees. Coniferous tree species seem to have a higher crown damage, which can however result from an easier and a more unambiguous visual assessment than in the case of broadleaves, or from the fact that the foliage of broadleaved tree species could not have been evaluated (spring, autumn). From the point of the damage type, an unknown cause of damage (pollution, drought) prevails.

*Table 3.5–3 Crown damage of trees in the groups of tree species on forestland*

| Tree species | Extent of crown damage | Proportion | from | to |
|---|---|---|---|---|
| | | % | | |
| Coniferous | 0, 10 and 20% | 66.4 | 65.2 | 67.7 |
| | 30 and 40% | 24.6 | 23.5 | 25.8 |
| | 50 and 60% | 6.6 | 6.0 | 7.3 |
| | 70 and 80% | 1.8 | 1.5 | 2.2 |
| | 90 and 100% | 0.5 | 0.3 | 0.7 |
| Broadleaved | 0, 10 and 20% | 92.9 | 92.2 | 93.6 |
| | 30 and 40% | 3.8 | 3.3 | 4.4 |
| | 50 and 60% | 1.6 | 1.3 | 2.0 |
| | 70 and 80% | 0.9 | 0.7 | 1.2 |
| | 90 and 100% | 0.8 | 0.5 | 1.0 |

*Negative effects on regeneration*

In inventory plots, the occurrence of factors that have a negative effect on regeneration was assessed, while several factors could co-occur in the same plot (the sum of area proportions can exceed 100%). Wildlife represents the highest risk for the regeneration, since this kind of damage occurred on one third of all forests. The other significant negative effects were light shortage (common in maturing and mature stands) and weeds (more likely in young forest stands). No negative effects were recorded on only one quarter of the plots.

*Table 3.5–4 Negative effects on regeneration on forestland*

| Negative effects | Proportion | from | to |
|---|---|---|---|
| | % | | |
| Game | 35.5 | 34.1 | 36.8 |
| Shortage of light | 31.9 | 30.5 | 33.2 |
| No | 27.3 | 26.1 | 28.6 |
| Competition of grasses, herbs and bushes | 24.9 | 23.7 | 26.2 |
| Unfavourable soil conditions | 10.0 | 9.1 | 10.8 |
| Absent seed trees | 5.8 | 5.2 | 6.5 |
| Unfavourable microclimate | 4.6 | 4.0 | 5.2 |
| Insects | 3.2 | 2.7 | 3.7 |
| Harvest and skidding | 1.9 | 1.6 | 2.3 |
| Snow | 1.6 | 1.2 | 2.0 |
| Others (lack of nutrients, air pollution) | 1.4 | 1.0 | 1.7 |
| Waterlogging | 0.8 | 0.6 | 1.1 |
| Fungi | 0.1 | 0.0 | 0.2 |

*Damage of regeneration individuals on forestland*

Almost 25,000 trees with the diameter smaller than 7 cm were assessed, out of which approximately two thirds were not damaged. Browsing by deer was found to be the most frequent damage, while the other agents except insects were negligible.

*Table 3.5–5 Types of regeneration damage on forestland*

| Type of damage | Proportion | from | to |
|---|---|---|---|
| | % | | |
| No damage | 64.9 | 63.6 | 66.3 |
| Game | 24.0 | 22.8 | 25.2 |
| Insects | 7.4 | 6.6 | 8.1 |
| Harvest and skidding | 1.6 | 1.3 | 2.0 |
| Fungi | 0.9 | 0.7 | 1.2 |
| Others | 0.8 | 0.6 | 1.1 |
| Abiotic agents | 0.4 | 0.2 | 0.6 |

*State of silviculture of stands*

The assessment of the state of silviculture provides us with the information about the quality of the realised silvicultural treatments. In order to determine this forest status, three groups of stand development phases were created (A – young forest stands – natural seeding, advanced regeneration, young plantation; B – stands in tending – thicket, small pole stage, pole stage, large-diameter stands; C – regenerated stands). The evaluation of the condition of forests on forestland (except for reserves, natural forests, succession stages, etc., which covered approximately 5% of the area) was based on expert's judgement.

The largest proportion of the stands in Slovakia is currently in the phase of the application of tending treatments. In general, the state of silviculture in the stands is good, as the neglected condition was observed in approximately 15% of all stands. From this percentage, the neglected tending prevailed; the proportion of the neglected regenerated stands was smaller. The fact that one third of all forest stands were evaluated as neglected indicates a very unfavourable situation. Interestingly, no difference between the state of silviculture in management and protection forests was detected.

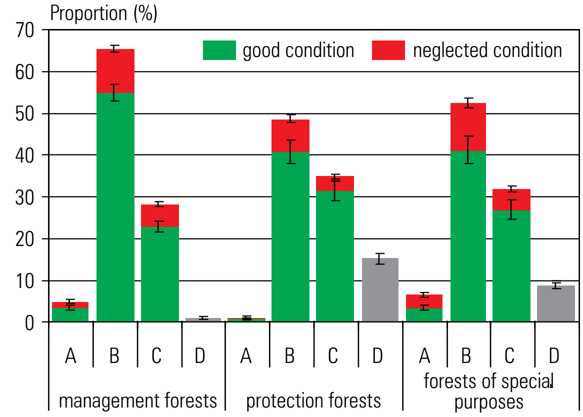


*Figure 3.5–1 State of silviculture in forest functional categories*

*A – young forest stands; B – stands in tending; C – regenerated stands*

## 3.6 Site and ecological characteristics

*Forest naturalness*

The naturalness degree represents the level of approximation of the natural status in the given site conditions by the current stand condition. For the first time, this degree was assessed over the whole country using the single methodology with 5-degree scale (Figure 3.6–1). Although the proportion of the best-preserved natural forests is relatively low, only approximately 5%, in the Central-European conditions this value is very favourable. In the category of protection forests, the proportion of natural forests exceeded 16%. Semi-natural forests, characterised by the original tree species composition and by partially changed structure due to human treatments, cover the highest forest area, 60%. The proportion of predominantly semi-natural forests, in which the natural features still prevail but the structure was more influenced by human activities, is also high. Altered stands (predominantly spruce and pine pure stands) cover only 15% of the area. Their proportion is large mainly in the forests of specific purposes, though their proportion in the protection forests is also not negligible. Sampling inventory did not record sparsely occurring artificial forests and plantations with the proportion around 0.1%.

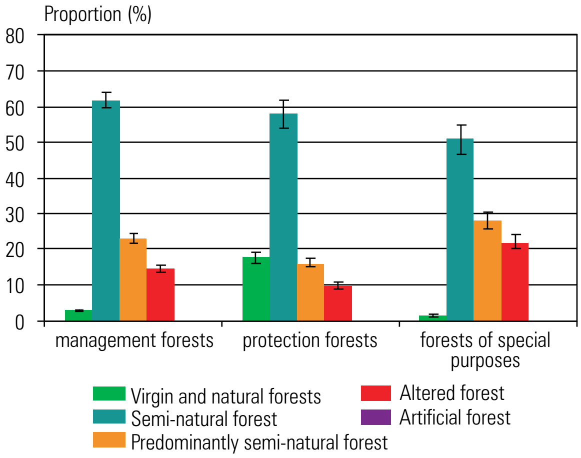


*Figure 3.6–1 Degree of forest naturalness in the functional categories*

### *Tree species richness*

The number of species is a very simple and an easily understood indicator of species diversity. In the NFIM SR, tree species diversity was assessed from the group of 20 trees situated around the centre of the inventory plot with the diameter $d_{1.3}$ larger than 7 cm. The results of the inventory revealed high tree species diversity and richness, since two to three tree species recorded in the group of 20 nearest trees were found in more than a half of all forests. The forests in which only one tree species was recorded in the group of 20 nearest trees cover one fifth of the area. Quite a high proportion, more than 5%, is covered by communities, in which 6 or more tree species were recorded in the group of 20 trees. Clearings and plots with less than 20 trees having the diameter 7cm or more were not evaluated. Tree species richness of management and protection forests is almost equal, which indicates favourable condition of managed forests.

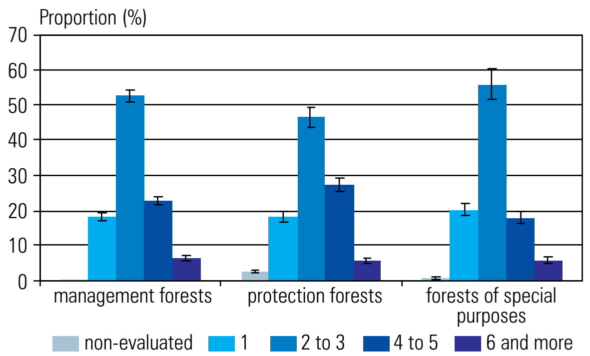


*Figure 3.6–2 Tree species richness in the functional categories of forests*

### *Anthropogennic load*

The assessment of the occurrence of anthropogennic load in inventory plots revealed that in Slovakia its effects were not very evident. Weak effects were observed on 14% of the area, while heavy load was found on only 2%. From the individual types of load, pollution prevailed (40%), followed by recreational activities (27%). Less than 10% of the area was affected by dumps (7%), building activities (4%), illegal cutting (3%), transport (3%), grazing (3%), explotation of raw materials (2%), and fires (1%).

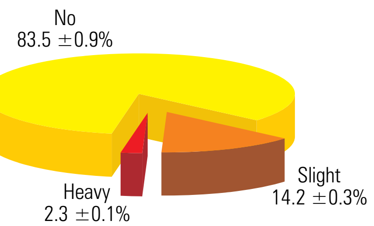


*Figure 3.6–3 Degree of anthropogennic load in the forests of Slovakia*

### *Deadwood*

For the first time, the information about deadwood volume was revealed by the inventory results, since in Slovakia no reliable data about deadwood except for standing dead trees had been available. Total deadwood volume reached 38 $m^3$ per hectare, which is almost 15% of the total volume of living trees (timber to the top diameter of 7 cm). Surprisingly, high amount of small-sized lying deadwood (branches and stems with the butt diameter below 7 cm) was detected – almost a quarter of the total deadwood volume, which approximately equals the volume of standing dead trees and stumps.

In total, deadwood volume exceeded 80 million $m^3$, out of which 95% is located on forestland. Although this number is quite high, most of deadwood is not suitable for further processing and is left in the forests as an important component of forest environment. Only a very small proportion of standing dead trees and of lying deadwood in a lower decomposition grade could be utilised as a biomass.

*Figure 3.6–4 Decomposition grades of deadwood*

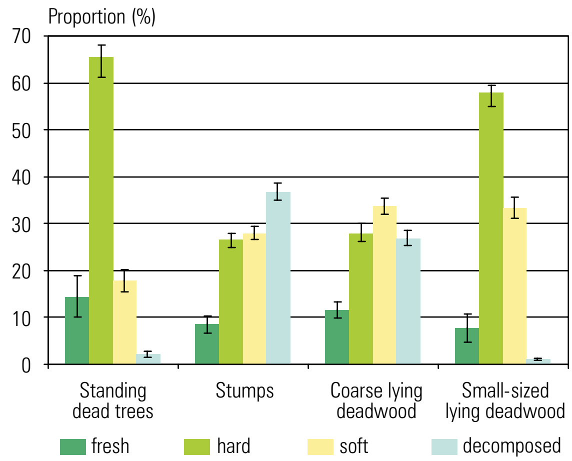


*Table 3.6–1 Deadwood volume*

| Type | Tree species | Volume | Error | Total volume | from | to | Proportion |
|---|---|---|---|---|---|---|---|
| | | m³/ha | | million m³ | | | % |
| Standing dead trees | Coniferous | 4.1 | ± 0.3 | 8.8 | 8.0 | 9.6 | 11 |
| | Broadleav. | 2.2 | ± 0.2 | 4.7 | 4.3 | 5.1 | 6 |
| Stumps | Coniferous | 3.0 | ± 0.1 | 6.4 | 6.1 | 6.8 | 8 |
| | Broadleav. | 2.2 | ± 0.1 | 4.8 | 4.6 | 5.1 | 6 |
| Coarse lying deadwood | Coniferous | 9.8 | ± 0.7 | 21.3 | 19.8 | 22.7 | 26 |
| | Broadleav. | 8.0 | ± 0.4 | 17.3 | 16.3 | 18.3 | 21 |
| Small-sized lying deadwood | Coniferous | 3.2 | ± 0.2 | 7.0 | 6.5 | 7.5 | 9 |
| | Broadleav. | 5.2 | ± 0.3 | 11.4 | 10.8 | 11.9 | 14 |
| Total | | 37.7 | ± 2.1 | 81.9 | 77.3 | 86.6 | 100 |

### *Site character*

The analysis of the proportion of edaphic-trophic categories, which indicate site fertility, detected that Slovak forests predominantly belong to fertile sites. The fertile category (B), in which the most fertile forest communities occur, has a proportion of more than 60% of the forest area. Transitional acid-fertile (A/B), and fertile-nitrophillic categories (B/C), as well as the acid category A have approximatelly equal 10% proportions. The calcareous category covers approximately 5%, the rest are stony nitrophilic and waterlogged sites.

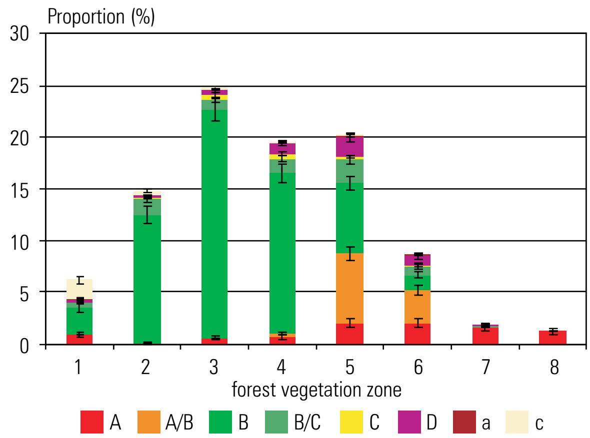


*Figure 3.6–4 Proportion of edaphic-trophic categories in forest vegetation zones*

*Edaphic-trophic categories: A – oligotrophic; A/B – semi-oligotrophic; B – mesotrophic; B/C – semi-nitrophillic; C – nitrophillic; D – alcaliphillic; a – acidophillic azonal; c – nitrophillic azonal*

*Forest vegetation zone: 1. oak, 2. beech–oak, 3. oak–beech, 4. beech, 5. beech–fir, 6. spruce–beech–fir, 7. spruce, 8. mountain pine*

## 4 IMPORTANCE AND APPLICABILITY OF NFIM SR RESULTS

The National forest inventory and monitoring in the Slovak Republic, which was realised in the years 2005–2006, is a completely new sampling method for complex assessment and evaluation of forest ecosystem condition in Slovakia. It became a historical milestone, since for the first time it covered all forested land, it encompassed a very broad spectrum of characteristics and variables that are important from the point of forestry, ecology, economy, and society; the obtained data are highly objective with a known error range and represent the same time point. The established network of permanent, though invisibly fixed inventory plots will enable to repeat the assessment and evaluation of forest condition in the same way in future in arbitrary time intervals (5 to 10-year intervals) with no risk that they could be purposely managed differently than the other parts of the forest stands. This will ensure objective comparison of forest condition in a longer time series, and for the first time it will reveal information about the real changes and real increment of all assessed variables.

The result of the NFIM SR 2005–2006 is a compact and an actual set of information about the forests of SR by 31st December 2005. The obtained data are divided in such a way that they provide national and regional institutions of public authority of the Ministry of Agriculture with the required information, and that the information can be used for an effective, ecologically bearable, and economically efficient forest management and utilisation at national and regional level, as well as on the level of forest owners and forest managers. At the same time, the data represent an important information source for the elaboration of the reports on the participation of the Slovak Republic in international conventions and EU projects (biodiversity preservation, sustainable development, NATURA 2000, carbon sequestration in forest ecosystems, etc.). Apart from the short selection of the NFIM SR results presented here, all obtained data will be elaborated and published in a special book, and the significant part from them will also be available for scientific and public community on Internet.

The whole process of preparation and the first realisation of the NFIM SR followed the approved methodology and all planned works were realised to the full extent and on a satisfactory quality level. The assessed value of the results coincides well with the accuracy range that was expected at the time of the decision to assign the task. The information about forest area corresponds well with the aggregated data of forest management plans. Higher volumes obtained from the NFIM SR by 23% (on forestland) can be explained by different assessment methods, by lower registration threshold diameter $d_{1.3}$, by the measurement of the dominant crop (main crop including thinning), and by the differences in the estimated age structure. However, this difference is not exceptional. The first forest inventories in foreign countries revealed even larger differences, e.g. in Austria by +40%, in the Czech Republic by +33%. The common attitudes in Germany were that the results of the national forest inventory and of the forest management were not comparable, since the methods differ in their focus and objectives. Higher amount of timber volume detected by national inventories does not automatically increase opportunities for cutting, because inventories record volume in a more complex way, and the whole volume cannot be cut immediately.

The accuracy of the obtained results of the NFIM SR is not the same on all assessment levels. The best accuracy is obtained at national level (the whole Slovak Republic). The accuracy decreases as the area of the regions and their parts (tree species, age classes, etc.) decreases. This is a common principle and a common feature of all sampling assessment methods. However, it can be intentionally regulated in such a way that, according to the needs and financial possibilities, additional plots will fill in the established network 4×4 km either over the whole area or only in the areas with lower forest coverage or with higher forest value from the production or ecological point of view. Nowadays, such trends are quite common abroad.

It is also necessary to note that the implementation of the NFIM SR does not replace present assessment methods of forest condition, which are applied in the survey of forest ecology, in the renewal of forest management plans, and in the monitoring of forest helath condition. Each of these methods has its own specific mission and different possibilities to provide information for the areas of various sizes and for the managament units. These methods and their results are not mutually exclusive; on the contrary, they can be effectively connected.

Apart from the great practical contribution, the NFIM SR provides research with extremely valuable and extensive data that can be used for the solution of many up-to-date problems in forestry and other related sectors, while their top priority lies in objectivity, methodological unity, and mutual link of the assessed data. The obtained database of the NFIM SR, which is due to the proposed spectrum multi-functional, has been further analysed and transformed into an integral information system, and the assumptions have been made for its comprehensive utilisation.

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# NATIONAL FOREST INVESTORY AND MONITORING OF THE SLOVAK REPUBLIC 2005–2006

## Basic concept and selected summary informations

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