

# Chapter 1

## Swiss NFI at a Glance



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**Abstract** This chapter provides a general overview of the Swiss National Forest Inventory (NFI), as well as of its tasks, organisation, contents, methods and applications. Cross-references are given to those chapters in the book where the particular topic is dealt with in more detail.

### 1.1 Introduction

This chapter provides a general overview of the Swiss National Forest Inventory (Swiss NFI, syn. NFI), as well as of its tasks, organisation, contents, methods and applications. In the following sections cross-references are given to those chapters in the book where the particular topic is dealt with in more detail.

### 1.2 History and Objectives

This section is based on a recent publication by Lanz et al. (2016), which begins by describing how forests and wood resources in Switzerland have been used intensively since the eighteenth century. The overexploitation and clear-cutting of forests in the alpine and mountainous parts of the country during the first half of the nineteenth century are widely believed to have led to debris flows and floods that caused extensive damage in the lower-elevation parts of the country.

Shortly after Switzerland was founded as a modern federal state in 1848, a series of important decisions on forestry were taken nationally. In 1855 the then new Polytech, today's Swiss Federal Institute of Technology (ETH), was established with

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C. Fischer, B. Traub (eds.), *Swiss National Forest Inventory – Methods and Models of the Fourth Assessment*, Managing Forest Ecosystems 35,  
[https://doi.org/10.1007/978-3-030-19293-8\\_1](https://doi.org/10.1007/978-3-030-19293-8_1)

a School (or Department) of Forestry. In 1874 the federal administration set up a forestry inspectorate, which later developed into the Federal Office for the Environment (FOEN). Finally, in 1876 a national Forest Act specifying legislation for the mountain forests came into force. Its primary aim was to prevent natural hazards, which is why clear-cutting regimes were banned, and the restoration of forests mostly through reforestation was promoted. In 1915 the Act was extended to include all Swiss forests. As a result, forest cover in Switzerland increased from around 19% in 1850 to nearly 32% in the year 2010.

The information on forests available remained limited and mainly only on public forests, which cover 69% of Switzerland's forest area. Estimates for e.g. timber volumes at the national level were unreliable because the cantons, the member states of the Swiss Confederation, had different systems for collecting data. In the late 1950s, a professor of forestry at ETH in Zurich, Alfred Kurt, initiated a political discussion about the need for a forest survey (Kurt 1957), which led, 25 years later, to the first National Forest Inventory (NFI) in Switzerland being started in 1983 (Mahrer and Vollenweider 1983). Kurt maintained that a national forest inventory should provide enough information to: (a) establish a national forest policy to ensure that Switzerland's forestry remains internationally competitive, (b) support forest managers in maintaining social, protective and recreational services and raise public awareness about forests, and (c) take forests into account in planning regional and national land use (Kurt 1967). His original vision was, therefore, to carry out a national inventory in the form of a thematically broad survey that covered the many different products and services of forests.

By the 1960s, it had become clear that reliable data about forest conditions in Switzerland was urgently needed to improve silvicultural planning and its implementation. The first small NFI was carried out by what was then called the *Eidgenössische Anstalt für das forstliche Versuchswesen* (EAFV), which later became the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. The survey involved interpreting not only aerial images, but also the responses to questionnaires sent out to the cantonal forest administrations (Ott 1972).

Work then began on preparing a more extensive national forest inventory, where the focus was mainly on assessing the productive functions of forests rather than on conducting a thematically broad survey as originally planned. This change in focus was probably largely due to the methodological difficulties involved in assessing and validating other forest goods and services, but it was also influenced by the 1973 oil crisis. Politically, it was seen as essential to have more information on the immediate and potential availability of wood resources, the expected timber harvesting costs, and the requirements for investment in forest roads and other infrastructure (BAR 1981). Monitoring social and protective functions was still, however, considered important.

It was not until new legislation was introduced in 1991 in the Federal Act on Forest that it became mandatory to consider all forest functions in sustainable forest management. The Act also required the national authorities to inform the public periodically about the state of the forests. By then the NFI had already become well

established and was recognised as the main instrument for fulfilling the requirement to monitor and report on the state of Switzerland's forest.

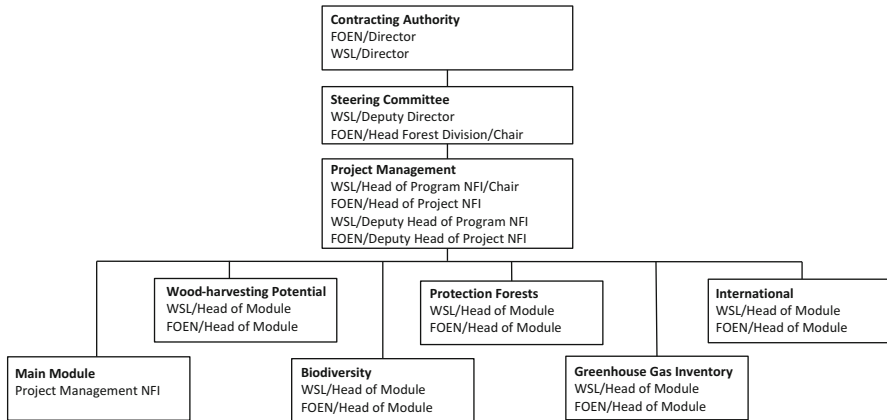
Field data was collected on permanent sample plots established for the first National Forest Inventory (NFI1 1983/1985) in 1983–1985. The inventory was repeated 10 years later (NFI2 1993/1995). One of the main findings from these surveys was that it would be possible to increase the timber yield (SAEFL 1999). Since the third inventory conducted 11 years later (NFI3 2004/2006), the NFI plot-level scenario model MASSIMO (Chap. 17) has been used to analyse the role and capacity of Swiss forests in mitigating greenhouse gas effects and fulfilling the demand for wood.

With the fourth NFI (NFI4 2009/2017), it was decided to change to a 9-year 'rotating system' whereby field data on the sample of permanent plots are no longer collected periodically but continuously, using nine sub-grids, each of which is selected from the full grid and covers the entire country. A different sub-grid is used each year until the full 9-year cycle has been completed. This continuous inventory design allows representative reports on the state of the Swiss forest to be produced more frequently. The plan is for the NFI methods and/or content to be re-evaluated every 9 years, by when the whole sample has been measured. The inventory is carried out by WSL in collaboration with FOEN on a 4-year contract basis. The current mandate includes the main inventory module and specific modules on: (a) the greenhouse gas inventory (GHGI) (Chap. 14 and Sect. 19.3) and (b) scenario modelling (Sect. 19.2). In addition, (c) the forests' protective functions (Sect. 15.3) and (d) biodiversity functions (Sect. 15.2) are analysed in more detail. A further requirement is for (e) international reporting and cooperation to take place. The NFI additionally supports several cantons in the planning and implementation of regional inventories.

### 1.3 Legal Status, Obligations and Organisations

The first National Forest Inventory (NFI1 1983/85) was carried out after the Federal Council decided a survey was necessary in August 1981. The initial legislative basis for the NFI was first created in 1991 with the Federal Act on Forest (Forest Act), which has been in force since 1993. Today the NFI is mentioned in two federal acts and is subject to their regulations. In Art. 33 of the Forest Act (SR 921.0), the regulations for the data collections and the disclosure obligations of the authorities and private individuals are specified.

Since 2008 the Federal Office for the Environment (FOEN) has been responsible for collecting data on forests, according to Art. 37a of the Forest Ordinance (SR 921.01). It collects the basic data on the sites, the functions and the condition of the forest in the NFI in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (Fig. 1.1). Art. 34 of the Forest Act specifies informing the authorities and the public as a requirement, which means also publishing the findings. The cantons are responsible for forest planning and management (SR 921.0, Art. 20), which are thus not part of NFI's tasks.



**Fig. 1.1** NFI Organisational chart 2017

The data storage, availability, access and use of the NFI data as basic geo-data for Switzerland have been regulated in the Federal Act on Geoinformation GeoIA (SR 510.62) and in the Ordinance on Geoinformation (SR 510.620) since 2008, as have the responsibilities of WSL and FOEN. Access of the survey teams to the permanent sample plots for the data collection is guaranteed in Art. 20 and Art. 21 of GeoIA, as are the support of the local authorities and the marking of the sample-plot centres. This ensures NFI has the right to access private property to collect data and to install markings. The ETH Law (SR 414.110) grants, in Art. 5, NFI the freedom to do research and independence from political influence in the scientific interpretation of the data and in publishing findings.

With these legal bases, NFI has been organised as a Project that is jointly managed by FOEN and WSL (Fig. 1.1). The two Directors act as the joint Contracting Authorities on behalf of the Swiss Confederation. The aims and financial terms are regulated in a contract between FOEN and WSL for 4 years, which is revised at the end of each 4-year period. The Steering Committee of NFI directs the Project through the Project Management, which manages NFI operationally. A Master Plan serves as the basis for planning and management, which essentially operationalises the agreed services. It can be revised every 6 months. All the management staff are on the same levels as FOEN and WSL employees, with equal representation. They make decisions by consensus.

The Project itself is currently organised as a basic module plus five additional modules: biodiversity, wood-harvesting potential, protection forests, greenhouse gas inventory and international. The heads of each module are responsible for the module and for reporting to the Project Management (Fig. 1.1). WSL is in charge of the planning (Sects. 1.4, 1.5 and Chap. 8), development of methods (Part II, III and V), implementation (Part III, IV and VII), analysis (Part VI), scientific reporting and scientific services (Sect. 1.6). FOEN is responsible for the political interpretation of the results and for political support.

At WSL, NFI is organised as a programme with a matrix structure. It receives support from WSL's different Research Units, as well as the Service and Support Units, with the largest contributions coming from the Research Unit "Forest

Resources and Management”. Expertise and information are consistently shared between at least two people (following the deputising principle) to ensure that the operation can be maintained reliably. The field surveyors are employed on annual contracts and paid an hourly wage. Piece-working is excluded to ensure the data is of high quality (Part VII).

About 30% of the funding is spent collecting data in the field surveys, conducting remote sensing, and interviewing the forestry services. Around 50% goes towards modelling, analyses, publications and reporting. About 15% is spent on the design, survey method and inventory statistics, and approx. 5% on data storage and providing access to the data on the Internet. All these proportions include the costs for research and development in the corresponding categories.

## 1.4 Assessing Information Needs and NFI Impacts

The federal government has been legally bound, since 1991, to carry out periodic surveys (Sect. 1.3) of forest sites, the forest’s functions and condition, and the production and use of wood, as well as of the structures and economic situation in forestry (SR 921.0, Art. 33). To this end, FOEN and WSL should collect basic data about the sites, functions and condition of the forest in the National Forest Inventory (SR 921.01, Art. 37a). FOEN is responsible for informing the authorities and the public about the surveys.

The legislation contains no specifications about the NFI’s contents, methods, products and services. There is considerable freedom to act – constrained, of course, by the limited resources available. This means the focus must be on the most important social issues. The information needs must also be clarified with the target groups. The relevance of a national inventory can be increased through periodic discussion (needs assessments), a good provision of products and services (output), a widespread use of the NFI (impact) and a retrospective evaluation. Satisfied users are potential advocates for long-term data series even in times when funding is tight. This is the conviction the NFI has followed for the past three decades.

What should be recorded in an NFI and at what spatial resolution? Even before the first National Forest Inventory (NFI1), the ‘father’ of the NFI (Kurt 1967) wrote: “It should not be underestimated that procedural questions are much easier to answer than those referring to the specific aims.” A national work group with representatives from the present-day institutions FOEN and WSL, from the Association of Forest Owners (WaldSchweiz), from forestry and the wood industry and from the head foresters of the cantons (heads of the cantonal forest administrations) was directly or indirectly involved up to 1981 in designing the first NFI (Mahrer and Vollenweider 1983). During the long preparatory design process, the original idea of conducting an intensive, fully comprehensive forest inventory (Sect. 1.2) with the canton as the recording unit was reduced to a programme that ensured that the most important goals could be achieved at the level of Switzerland, with the creation of a sound basis for the forest policy of the federal government. As collection methods and models

for the forest functions were lacking, the main focus was on forest resources and their availability (network of forest roads, costs of timber harvesting).

To define the aims for the second NFI (**NFI2**), a ten-member advisory committee was set up with representatives from FOEN, the cantons, WSL and other experts. In addition to recording the developments since the first NFI, the thematic areas forest functions, forest soil and ground vegetation were discussed as possible extensions (Zierhofer 2000). Models of the forest functions and ways to assess the forest services were developed and introduced in NFI2. The funding was not, however, sufficient to include soil and vegetation. In 1991, 276 national stakeholders were asked for the first time in a written questionnaire about what they needed the NFI data for and how they used it. The results served as input for the data catalogue NFI2 and for future reports on results and services (Brändli 1992). The responses (response rate of 47%) were almost all only positive, and showed that the NFI is well known among forest experts and widely applied.

In the run up to the third NFI (**NFI3**) after the completion of the second NFI, the effects of NFI1 and NFI2 were analysed and the needs for a third survey were ascertained. The formal bases (programme agreements), the NFI services (output) and the satisfaction and use of NFI users (impacts) were evaluated, and corresponding recommendations were made for implementing the NFI in the future (e.g. new products and user groups). The NFI's core business and its spatial and temporal resolution were defined and questions to be answered in NFI3 were formulated on the basis of structural interviews with 30 individual experts, subsequent extensive discussions in four workshops with 60 experts, and a final internet survey with 300 stakeholders (users). These expected responses were grouped in accordance with the Helsinki criteria (Ministerial Conference 1994), and priorities were defined for the Swiss government, cantons and research. NFI3 was designed in the form of eight modules, which makes it easier to assess its implementation capacity, decide on priorities and plan budgeting (Bättig et al. 2002). Bättig et al.'s study was also decisive for **NFI4** and for the planning of NFI5.

The output, impact and outcomes of NFI3 were evaluated in 2012 in a similar way to the previous NFI (Bernath et al. 2013) and assessed, with an independent consultant again performing the evaluation with WSL support. The feedback was once again largely very positive, and helpful in deciding on the priorities and outputs for future surveys. One of the recommendations implemented was to run periodic workshops for NFI users. These NFI-user workshops with 20–40 participants have been of great value in improving NFI products and services (Brändli and Bernasconi 2014, Abegg and Brändli 2016).

## 1.5 Content, Data Collection and Methods

Which survey method is used in the NFI depends on the information and degree of accuracy needed (Mahrer and Vollenweider 1983). With the first NFI, the goals to be taken into account were: to determine the forest area and the total wood volume in Switzerland with an accuracy of  $\pm 0.5\%$  (relative standard error); to provide a basis

for estimating the increment and use; and to develop a sampling grid, which could later be made denser for cantonal inventories. With these requirements, a nationwide uniform quadratic sampling grid (1 km × 1 km) was established with permanent sample plots at the nodes in the sampling grid (Part II). To minimise the amount of work in the field needed for the forest/non-forest decision and for determining the location of the sample plots, the aerial images from swisstopo (Federal Office of Topography) were interpreted before the field data was collected (Part III). The information required for NFI1 already included ownership, forest access roads, the methods and distances for transporting (hauling) wood to the roads, and the amount of potential wood for harvesting and its availability (harvesting costs). It was therefore decided to obtain this information for each sample plot, through interviews with the local foresters and cantonal forest administrations (Mahrer and Vollenweider 1983, Chap. 10).

### 1.5.1 Content

The content of the NFI (data catalogue) has been continuously developed further to take into account the aims (Sect. 1.2), the legal requirements (Sect. 1.3), the current information needs (Sect. 1.4), the methodological state of the art, as well as the technical and financial feasibility.

The data catalogue today contains around 350 attributes, the most important of which are summarised in Table 1.1 (Appendix). The development of the NFI content can be presented quantitatively and thematically by referring to the manuals for data collection (Zingg and Bachofen 1988; Stierlin et al. 1994; Ginzler et al. 2005; Keller 2011; Keller 2013; Düggelein and Keller 2017). In NFI1, the focus was not only on the forest resources, but also on the health of the forest and the use of the wood. In NFI2 many features concerning the forest as a habitat (biodiversity) were added, and in NFI3 the introduction of forest functions led to the inclusion of all the criteria for sustainable forest management. The level of detail of the information also increased considerably and the number of features nearly doubled. When the continuous inventory approach of NFI4 started in 2009, a few additions to the NFI's central themes of wood production and biodiversity were made. Since 2018 various attributes in NFI5 have been augmented, and three new groups of features related to biodiversity and resources have been introduced, namely: microhabitats on sample trees, problematic herbaceous neophytes and stump inventories (Appendix). Including this last feature means that the time needed just to record the data has reached a mean of almost 120 min per sample forest plot, which is the maximum a team of two can take to cover, on average, the target of two sample plots per day.

In relation to the international indicators, NFI today obtains about 50% of the required information on sustainable forest management (Brändli and Duc 2009). Important sources of national data for the other indicators include, for example, the federal Land-Use Statistics, the Sanasilva Inventory, the Forest Statistics and the Biodiversity Monitoring (Brändli et al. 2010a).

Of the information obtained with the different data-collection methods, 6% of the features are derived from interpreting aerial images, 74% from field surveys and 20% from the interview survey and forest road survey. Thus, even though only a small proportion of the NFI features are recorded through remote sensing, this approach is becoming increasingly important. To supplement the results obtained with the statistical samples, the following remote sensing products (maps) covering the whole country have been developed for the NFI since the start of the continuous survey: a vegetation-height model, a forest cover map, a tree type map (coniferous/broadleaved mixture) and a map of the total wood volume. The field-survey data is generally used in developing and checking these models (Chap. 7).

### ***1.5.2 Design, Sampling Methods and Periodicity***

Sections 1.5.2 and 1.5.3 are largely based on the recent publication by Lanz et al. (2016).

In developing the sample-plot network of NFI1 1983/1985, the results of a pilot inventory in Canton Nidwalden were used, the forest area was assumed to be 1.3 million ha, and the target accuracy for assessing the growing stock in Switzerland was set at around  $\pm 0.5\%$  (p-value = 68%). The result was a systematic 1 km  $\times$  1 km grid covering the whole country, i.e. one sample plot per square kilometre of forest (Mahrer and Vollenweider 1983). As the forest area was smaller than originally assumed, the number of sample plots was 11,863 (including shrub forest). The field surveys in accessible forest excluding shrub forest (10,975 sample plots) recorded the growing stock as  $330 \text{ m}^3 \text{ ha}^{-1} \pm 0.7\%$ . The corresponding estimation error for the most important survey units, the five production regions Jura, Central Plateau, Pre-Alps, Alps and Southern Alps (Southern Slopes of the Alps), varied between  $\pm 1.3\%$  and  $\pm 2.6\%$ .

Although all the sample plots and trees had been marked for re-measurement in NFI1, budget constraints meant the number of plots had to be reduced by half in NFI2 1993/1995. Since then, field data has been recorded on a 1.41-km grid. To obtain, nevertheless, the target level of precision, a dense 500 m  $\times$  500 m grid of systematically distributed plots was introduced for stereo-image interpretation. The auxiliary variables gained from photo interpretation were combined with the field data using an estimation procedure known as two-phase (double) sampling for post-stratification (Köhl 1994; Mandallaz 2008).

The two main design changes introduced in NFI3 2004/2006 were to extend: (a) the field-data collection to include 'shrub forest', and (b) the aerial-photo interpretation to include tree resources outside forest and the FAO's 'other wooded land' category (OWL). 'Shrub forest' is a subcategory of OWL, and refers to a low productivity type of forest found mainly in high mountain areas.

The NFI switched from a periodic to a continuous survey in 2009, when NFI4 2009/2017 began, to ensure balanced budgets, continuity in specialist knowhow and regular up-to-date information. It was decided to collect the data over 9 years and to use, each year, a different one of the nine independent sub-grids selected from the original grid



(Sect. 2.4.4). Each sub-sample of re-measured plots on the annual sub-grid is fully representative of the entire country and each region. This rotating system makes it possible to rapidly introduce new attributes as needed and to obtain corresponding results within a year. The main content, general methods, models and statistical algorithms should not, however, be changed within the 9-year period, but only after the whole sample has been measured, if necessary. For NFI4, the photo interpretation has been reduced to the  $1.41 \times 1.41$  km grid of the terrestrial survey, and the new forest cover map (Sect. 7.2) was used to derive first-phase sampling information (Sect. 2.5.2).

Since the new continuous survey system was introduced, the results for NFI4 2009/2011 and NFI4 2009/2013 have been compiled and published ([www.lfi.ch](http://www.lfi.ch)). The final report for NFI4 2009/2017 will be available in 2020. The aerial-photo interpretation for all of NFI4 was again restricted to the grid on which the field-data collection takes place. Thus the main focus was on detecting new forest plots and measuring tree resources outside the forest and OWL.

Depending on the data collection method used (aerial-photo interpretation, field survey or interview survey) and survey feature, the information obtained from surveying the sample plots will refer to different parts of the plot: the sample-plot centre, the interpretation area, the raster points, the (concentric) sample circles, the transects, or a taxation stretch on the forest boundary line (Fig. 1.2).

In the field surveys (Chap. 9), standing and lying stems are measured and described in detail (e.g. any damage is recorded) on two nested circular sample plots. The smaller plot has a horizontal radius of 7.98 m and is 200 m<sup>2</sup> in area, while the larger one has a horizontal radius of 12.62 m and is 500 m<sup>2</sup> in area. On the smaller plot, trees and shrubs with a diameter at breast height (dbh)  $\geq 12$  cm and  $< 36$  cm are measured, whereas all trees with a dbh  $\geq 36$  cm are measured on the larger plot (Keller 2011). Tree height and upper stem diameter at a height of 7 m are measured only on a randomly selected sub-sample of the living and standing tally trees. These trees are used in the NFI two-stage

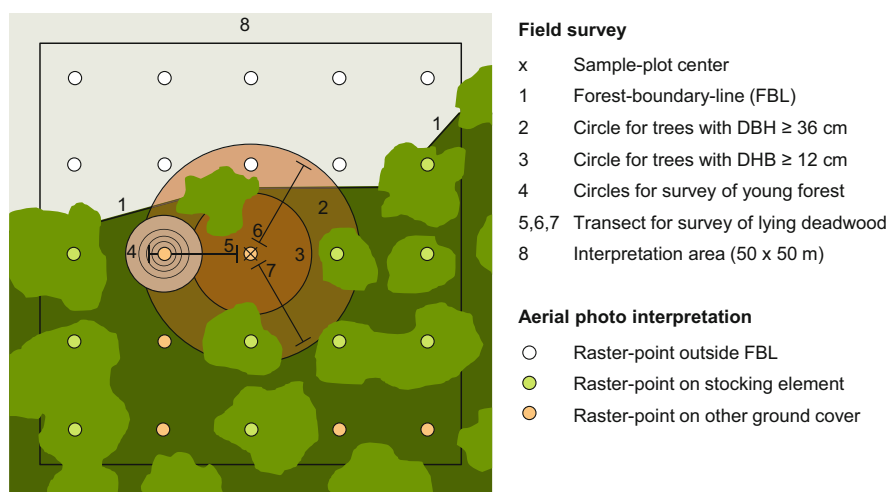


Fig. 1.2 Design of an NFI4 forest plot

procedure to estimate the tree volume (and biomass) with the aim to avoid potential bias in these estimates (Mandallaz 2008). On average, 11.9 tally trees are measured per plot, and a sub-sample of 2.3 tariff trees are selected from them.

Young trees and the main shrub species with a minimum height of 10 cm and a dbh of less than 12 cm are assessed on a separate set of four circular sample plots with radii between 0.9 and 4 m. The centre of this set of nested plots is displaced from the plot centre by 10 m.

For the assessment of lying deadwood, a line-intersect sampling technique is used (Böhl and Brändli 2007), involving three transect lines 10 m in length. The transects start 1 m from the plot centre and go in three different directions (35 gon, 170 gon and 300 gon). The diameter threshold for the lying deadwood is 7 cm at the point of intersection with the transect line.

If the plot centre is less than 25 m from a forest edge, the woody plant species and several structural and biodiversity-related features of the stocking at the forest edge are measured along a taxation stretch of 50 m.

For the assessment of several site and stand features in the field and in the aerial images, a quadratic interpretation area of  $50 \times 50$  m is used. The land cover is then assessed and vegetation height measured at 25 systematically distributed raster points on the interpretation area in the photos (Ginzler et al. 2005).

Finally, the NFI also interviews the local foresters and cantonal forest administration about each sample plot and the hauling route to the next road (Sect. 10.3). From the forest-road survey with the local foresters, a complete overview of the forest-road network, including several NFI features, can then be obtained for the whole country (Keller 2013; Müller et al. 2016).

### 1.5.3 Data Collection and Analyses

The data used in the NFI comes from interpreting aerial images (Part III), field surveys, oral interviews with the forest services and assessments of the forest-road network on topographic maps (Part IV). Data is collected in a step-by-step process (Lanz et al. 2010). The first step involves distinguishing each year the forest and non-forest plots in the aerial images on one of the nine NFI sub-grids, and the second collecting field data on the (potential) forest plots identified. In a third step, every 4 or 5 years, interviews referring to about half of all plots are conducted. In the fourth step every 9 years, the GIS layers of the forest-road network are updated. In addition, information from various external sources is used, such as digital maps of the administrative regions, soil characteristics or forest reserves. Further external input sources are specific models, e.g. for single-tree volume and biomass, the extent of the potential vegetation or the prediction of site quality (Brassel and Lischke 2001; Part V).

The **interpretation of aerial images** (Part III) is intended to reduce the cost of NFI by excluding plots that are clearly non-forest from the field survey, and by providing reference points to measure the sample-plot centre of new forest plots in the field. The main variables assessed in the manual photo interpretation are land cover (11 classes) and vegetation height on 25 systematically distributed raster

points in the interpretation area (Ginzler et al. 2005). NFI data from the photo interpretation have been used for: assessing tree resources outside forest areas (Ginzler et al. 2011), analysing landscape patterns and diversity (Mathys et al. 2006), estimating small areas (Steinmann et al. 2013) and calculating forest road lengths (Brändli et al. 2016).

In the **terrestrial survey** (Part IV) a forest engineer and a forester form one field team. The season for field data collection lasts from April to October. About 820 plots are visited in the field per year, of which about 700 are forest plots and 40 are shrub-forest plots (OWL). Since 2009, three teams have normally been in action at any one point in time. Fieldwork includes periodic training courses (three per year) and the re-assessment of about 8% of plots by a second team (blind checks). All variables assessed in the field (Appendix Table 1.1) are described in the field manual (Düggelin and Keller 2017).

Every 4–5 years, the foresters from the local **forest service** are interviewed by the field team to obtain a range of information for each forest or shrub-forest sample plot, relating to forest functions, planning, silviculture, harvesting techniques and forest history (Chap. 10). Every 9 years, the entire network of forest roads is updated in collaboration with the local foresters (Keller 2013; Müller et al. 2016; Sect. 10.3). The cantonal forest service is periodically asked in written form for an updated digital map of the forest districts and for information on the status of the regional forest planning (forest development plans) for each plot.

Field teams are equipped with a tablet computer and specially designed software developed at WSL for data collection (Sect. 23.2). Plausibility tests based on current input and previous measurements are implemented. The mobile phone network is used to transfer field data to the raw database at WSL.

All variables needed for producing the result tables are transferred to a separate database (Sect. 20.3) of derived variables. The derivation may be a direct copy from the raw database, but it is often the result of a complex combination (model) of various raw data and external data sources (Part V). All scripts are stored in a structured way so that re-calculations with the original raw data can be made at any time. The current NFI database runs on Oracle and most of the scripts for the derivations of the variables are written in Structured Query Language (SQL), but some complex derivations are written in SAS®.

The production of result tables is governed through a web interface software written in PHP (Sect. 20.2.1). Users can select the inventories, target variables, domains of interest and various technical parameters they want. The result tables are produced in real time with the statistical estimation procedures of a data analysis application (software). In the background, the steering parameters for the production of a specific table are stored in the database and can be reused (Traub et al. 2017). All scripts are currently being rewritten in Python in order to make NFI and WSL independent of user licenses and allow them to give third parties free access to the source code and to the NFI Data Analysis System NAFIDAS (Chap. 20).

## 1.6 Reporting, Products and Services

How valuable a forest inventory is depends on how the data is used. The more intensive, widespread and relevant the uses of the data are, the more valuable the inventory is as the source of data. To ensure that stakeholders use and trust the data and products, these aspects of the inventory should cover a wide range and be relevant and reliable. This is why the outreach activities of the NFI, which includes reports, products, services and publicity work, has—since the first NFI—been considered as strategically very important and resources have, correspondingly, been made available. The results of the impact assessments (Sect. 1.4) show that the outreach activities of the NFI have, to a great extent, met its goals for the primary stakeholders, partly thanks to the periodic needs analyses carried out (Bättig et al. 2002; Bernath et al. 2013).

Initially it was necessary, given Switzerland's federal system, to overcome the considerable scepticism of the forest services in some cantons. Today, practically all the federal and cantonal forest services are in favour of the NFI, and all of them actively support the data collection (in the interviews and forest-road survey). The NFI has become an important source of data for the federal and cantonal reporting on the forest, and thus also for forest policy. It is moreover increasingly appreciated in environmental science research, thanks to its characteristic, systematic, representative and unbiased design. Researchers constitute today the largest group of users interested in the data supplied by the NFI (Fig. 1.3). The impact assessments for NFI2 already revealed that 44% of the people involved in forest research who were asked said they could not do without the NFI in their personal field of activity (Bättig et al. 2002). The corresponding proportion for all stakeholders from forestry circles was around 60%.

WSL is responsible for the NFI data analyses, the scientific interpretation of the results and the reporting, as well as for the products and services, while the Federal Office for the Environment (FOEN) is responsible for the political evaluation of the results.

### 1.6.1 Reporting

Since the introduction of a continuous survey in 2009, the NFI has been able to produce up-to-date results every year. This is required for the Greenhouse Gas Inventory and is currently provided in the form of annual reports (Sect. 19.3). While FOEN generally needs information that is relevant for political issues and is as up to date as possible, most other stakeholders still prefer to receive results that relate to the whole sample, with a higher spatial resolution and very low estimation errors (statistically significant changes), only once a decade (Abegg and Brändli 2016).

WSL publishes the main NFI results in the form of carefully edited books with illustrations and tables every 9–10 years (EAFV/BFL 1988; Brassel and Brändli 1999; Brändli 2010). Since NFI3, the content has been structured according to the Pan-European criteria and indicators (Forest Europe 2011), with scientific interpretations of the results. In addition, thousands of output tables (Fig. 1.4) and maps

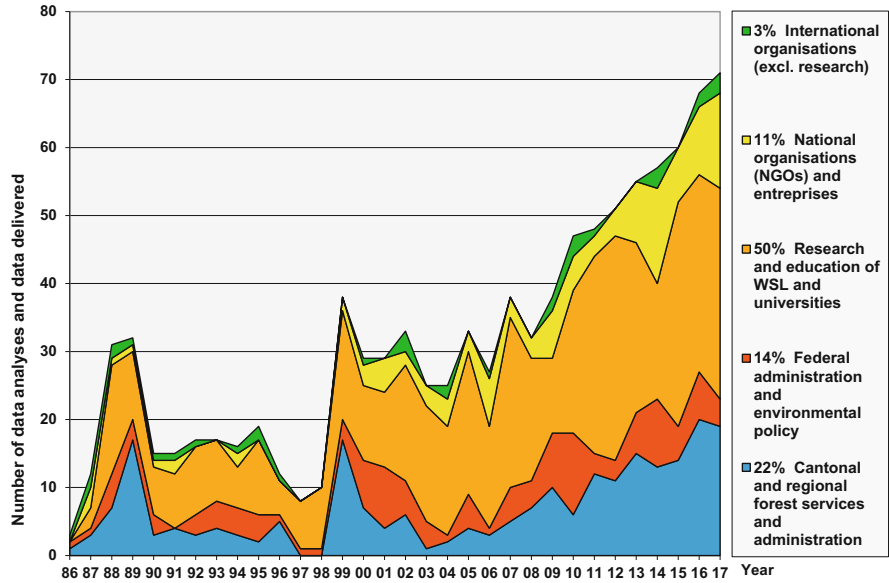


Fig. 1.3 Annual requests for data and data analyses from 1986 to 2017, classified according to user group

NFI4b

forest area: altitude (400 m classes) - production region

unit: 1000 ha  
 unit of evaluation: forest  
 grid:  
 state 2009/13

altitude (400 m classes)	production region											
	Jura		Plateau		Pre-Alps		Alps		Southern Alps		Switzerland	
	1000 ha	± %	1000 ha	± %	1000 ha	± %	1000 ha	± %	1000 ha	± %	1000 ha	± %
above 1800 m	.	.	.	.	2.5	38	103.7	5	27.1	10	133.3	5
1401-1800 m	4.4	29	1.8	45	42.5	9	171.4	4	52.0	7	272.0	3
1001-1400 m	61.3	7	4.9	27	95.1	5	107.0	5	47.6	7	316.0	3
601-1000 m	85.4	5	94.9	5	85.1	5	61.6	7	34.6	9	361.7	3
to 600 m	52.6	7	132.2	4	6.8	23	9.7	19	23.7	11	225.0	3
total	203.7	1	233.8	1	232.0	1	453.4	1	185.1	1	1308.0	1

calculated by unit of reference: production region

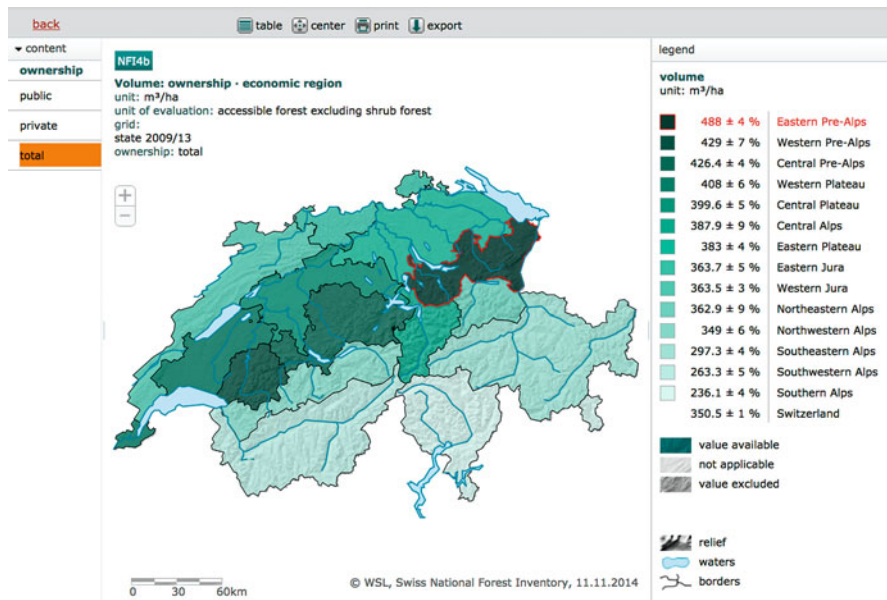
© WSL, Swiss National Forest Inventory, 03.11.2014 #161305/147684

[definitions](#) (in German) [methods](#) (in German) [download](#) [display map](#)

Table citation

Abegg, M.; Brändli, U.-B.; Cioldi, F.; Fischer, C.; Herold-Bonardi, A.; Huber M.; Keller, M.; Meile, R.; Rösler, E.; Speich, S.; Traub, B.; Vidondo, B., 2014: Swiss national forest inventory - Result table No. 161305: forest area Birmensdorf, Swiss Federal Research Institute WSL <https://doi.org/10.21258/1332151>

Fig. 1.4 Example of a result table from [www.lfi.ch](http://www.lfi.ch) showing forest area (including shrub forest) according to altitude and production region



**Fig. 1.5** Volume per hectare by ownership and economic region. Example of a result map available on the Internet ([www.lfi.ch](http://www.lfi.ch))

(Fig. 1.5) have been put on the Internet in four languages, German, French, Italian and English, and can be downloaded (<http://www.lfi.ch/resultate>, Speich et al. 2010; Speich and Meile 2013; Abegg et al. 2014). These tables, such as the scenario simulations for future supplies of wood (Sect. 19.2), are updated every 4 to 5 years.

The NFI supplies about 50% of the data for the national reporting on sustainable forest management, e.g. the Forest Report 2005 (SAEFL, WSL 2005) and the Forest Report 2015 (Rigling and Schaffer 2015). The conclusions from such reports provided the basis for the development of the Action Programme 2004–2015 for the Swiss National Forest Programme (SAEFL 2004) and the Forest Policy 2020 (FOEN 2013).

The NFI also provides information for international reporting. Examples are: The Global Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations; the FOREST EUROPE reports on the State of Forests and Sustainable Forest Management in Europe; and Switzerland's Greenhouse Gas Inventory (Sect. 19.3), which is submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

## 1.6.2 Other Products

To supplement the reporting (Sect. 1.6.1), scientific staff at NFI are also responsible for further analyses of the NFI data as part of their own research, for example on forest growth and (future) forest development. In addition, they cooperate with

researchers from other institutions on projects and papers if possible, rather than just supplying raw data. This requires specialisation in topics such as resources, biodiversity, protection forests and socioeconomics, but ensures at the same time better professional networking and a greater output of scientific articles and special reports, such as scenarios for the wood supply. Publications on methods make the know-how of NFI specialists accessible to third parties.

As interest and demand have grown, the NFI management team decided to use remote sensing to produce area-wide records and maps in NFI4, in addition to the digital forest-road network, and to update it every year. The first four products are the vegetation-height model, the forest cover map, the coniferous/broadleaved tree map and the wood-volume map (Chap. 7). These data can be obtained under the same conditions as those from the sample surveys.

The online portal [www.lfi.ch](http://www.lfi.ch) (Brändli and Heller 2000; Brändli and Speich 2005) should be of use to all stakeholder groups who are interested in information on the forest. This is why you will find there, in addition to countless tables and maps, other products, some of which are explicitly aimed at PR, such as a virtual walk in the forest (Brändli 2000), which introduces schoolchildren to findings of interest for laypeople. Another highly valued section is that on Forest trees of Switzerland (Brändli 1998), which now contains 150 distribution maps of trees and shrubs. Those who would like to have a general overview of forest development over the past 30 years will find what they are looking for in the NFI-Cockpit with its interactive graphics (Brändli and Brändli 2015). The vivid NFI-Film (Brändli et al. 2010b) explains the goals and methods of the NFI in four different languages.

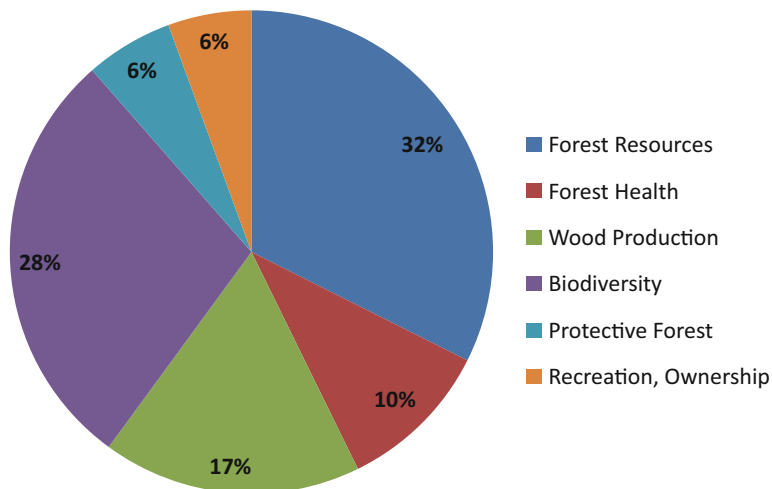
In order to inform forest managers and forest owners about NFI findings, the most important results are summarised in an easily comprehensible form and published in the specialist media. As part of the public relations work of different institutions and the forest services, a travelling exhibition (Brändli 1993) was produced, together with leaflets (Brändli and Speich 2015) and a series of weatherproof posters for foresters (Brändli et al. 2015) in all the national languages.

The wider public receives information about the NFI programme and its findings through periodic media releases. From time to time reporters accompany the field team or interview members of the NFI management team about the findings in newspapers or on the radio or television.

### **1.6.3 Services**

NFI data is made available to third parties, Swiss institutions and their representatives as soon as the specific official results have been published by WSL. Data extracts are provided for specific research and statistical purposes under contractual agreements (<http://www.lfi.ch/dienstleist/daten-en.php>). In the case of research projects, a collaboration with NFI researchers is usually sought. Since the first NFI, hundreds of responses to data requests have been sent. Special data analyses are also





**Fig. 1.6** Topics of NFI data extracts for third parties and analyses on request

made on request, amounting currently, together with data extracts, to around 65 per year (Fig. 1.3). The forest road network layer and the national area-wide remote sensing products have led to a steadily growing demand for data. The main consumer groups are research and education institutions (50%), cantonal and regional forest administrations (22%), the federal administration (14%), non-governmental national organisations and enterprises (11%) and international organisations (3%). The main topics of data requests concern forest resources, biodiversity and wood production (Fig. 1.6).

NFI know-how is in demand and appreciated by monitoring specialists in Switzerland and abroad. As far as NFI's personnel resources allow, NFI staff may also become involved in inventory consulting and cooperation. The NFI provides support in planning, material, training of field teams, data hosting (database) and data analyses of cantonal inventories according to NFI methods. To date, the Principality of Liechtenstein and the cantons Aargau, Appenzell, Berne, Grisons, Lucerne, Obwalden and Zurich have conducted such regional inventories using NFI methods on denser sampling grids (<http://www.lfi.ch/dienstleist/inventur-en.php>). International consulting to advise on inventory design and statistics has so far benefited Kirgizstan, Romania, France, Czech Republic, Slovakia and Bulgaria, and is currently being carried out in Belize. The NFI participates in, and sometimes coordinates, projects and activities of the European Network of Forest Inventories (ENFIN, <http://enfin.info/>). In the Carpathian Biosphere Reserve CBR (Ukraine), first and second inventories of Europe's largest primeval beech forest were planned and carried out with NFI support (Commarmot et al. 2013).



## Appendix

**Table 1.1** Development of the NFI data catalogue during the four inventories, NFI1, NFI2, NFI3 and NFI4, and during NFI5 since 2018 according to data-collection method and the criteria for sustainable forest management (SFM)

Data collection method	Feature	Inventory					SFM criterion (topic) to which the feature contributes										
		NFI1	NFI2	NFI3	NFI4	NFI5	Forest resources	Health and vitality	Forest use	Biodiversity	Protection forest	Social economy					
Aerial photo	Pre-determined data for 'forest/non-forest' decision	X	X	X	X	X											
	Reference points for the field plot location	X	X	X	X	X											
	Altitude	X	X				X										
	Forest boundary line		X	X	X	X	X										
	Degree of crown cover		X	X	X	X	X										
	Forest gaps			X	X	X	X										
	Deciduous/evergreen tree cover at 25 raster points		X	X	X	X	X										
	Land cover class at 25 raster points		X	X	X	X	X										
	Vegetation height/Altitude at 25 raster points		X	X	X	X	X										
	Stage of development		X	X	X	X	X										
	Degree of closure		X	X	X	X	X										
	Relief		X														

(continued)

Table 1.1 (continued)

Data collection method	Feature	Inventory					SFM criterion (topic) to which the feature contributes						
		NFI1	NFI2	NFI3	NFI4	NFI5	Forest resources	Health and vitality	Forest use	Biodiversity	Protection forest	Social economy	
	Stocking element outside forest			X	X	X	X						
	Single trees outside forest			X	X		X						
	Potential forest use				X	X	X						
Terrestrial area	Forest/non-forest decision	X	X	X	X	X	X						
	Reason for forest decrease			X	X	X	X						
	Reason for forest increase			X	X	X	X						
	Previous use before forest increase			X	X	X	X						
	Photos of the sample plot				X	X	X						
	Accessibility and walkability	X	X	X	X	X	X						
	Soil samples from topsoil	X		(x)			X						
	Thickness of soil horizon in topsoil				(x)		X						
	Slope	X	X	X	X	X	X						
	Aspect	X	X	X	X	X	X						
Relief	X	X	X	X	X	X							
Landslide	X	X	X	X	X	X						X	
Erosion	X	X	X	X	X	X						X	
Rockfall	X	X	X	X	X	X						X	



Table 1.1 (continued)

Data collection method	Feature	Inventory					SFM criterion (topic) to which the feature contributes						
		NFI1	NFI2	NFI3	NFI4	NFI5	Forest resources	Health and vitality	Forest use	Biodiversity	Protection forest	Social economy	
	Dry stonewalls, heaps of stones		X	X	X	X				X			
	Geomorphological objects		X	X	X	X				X			
	Recreational facilities		X	X	X	X							X
	Root plates			X	X	X				X			
	Ants (presence, species)				X					X			
	Ant-heaps (number, dimensions)				X					X			
	Number of tree cavities with detritus				X					X			
	Problematic herbaceous neophytes									X			
Terrestrial stand	Forest type	X	X	X	X	X				X			
	Forest origin and management type	X	X	X	X	X				X			
	Stage of development	X	X	X	X	X				X			
	Stand age	X	X	X	X	X				X			
	Degree of mixture	X	X	X	X	X				X			
	Degree of cover of tree species in the upper layer			X	X	X				X			
	Degree of crown closure	X	X	X	X	X				X			
	Type of gap		X	X	X	X				X			
	Stand structure	X	X	X	X	X				X			

Degree of cover of stand layers	X	X	X	X	X	X	X	X	X	X	X	X							
Type of cover of stand layers	X	X	X	X	X	X	X	X	X	X	X	X							
Stand's top height										X									
Stand stability (loads, resilience)	X	X	X	X	X	X	X	X	X	X	X	X							
Type of areal forest damage (areal damage)	X	X	X	X	X	X	X	X	X	X	X	X							
Extent of areal damage	X	X	X	X	X	X	X	X	X	X	X	X							
State of clearing	X	X	X	X	X	X	X	X	X	X	X	X							
Stocking border, forest edge	X	X	X	X	X	X	X	X	X	X	X	X							
Stand border	X	X	X	X	X	X	X	X	X	X	X	X							
Inner edges	X	X	X	X	X	X	X	X	X	X	X	X							
Stand size	X	X	X	X	X	X	X	X	X	X	X	X							
Type of regeneration	X	X	X	X	X	X	X	X	X	X	X	X							
Protection of regeneration	X	X	X	X	X	X	X	X	X	X	X	X							
Distribution of regeneration	X																		
Degree of cover of regeneration	X	X	X	X	X	X	X	X	X	X	X	X							
Degree of cover of established regeneration	X	X	X	X	X	X	X	X	X	X	X	X							
Main tree species in established regeneration																			
Degree of cover of shrub layer	X	X	X	X	X	X	X	X	X	X	X	X							

(continued)



Living / dead / standing / lying	X	X	X	X	X	X	X	X	X	X	X								
Date of death			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tree age			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stem height of broken snag			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Treetop used			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Growth form			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tree status		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tree-rings on stumps of used trees		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Height of stumps of used trees			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Diameter of stumps of used trees			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Inventory of stumps																			
Layer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Crown class (length)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Crown class (shape)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Social position		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Height where crown starts			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Crown dimensions			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Damages (type, location, dimensions)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mistletoe			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stem quality	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lopsided or bent tree		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

(continued)

Table 1.1 (continued)

Data collection method	Feature	Inventory					SFM criterion (topic) to which the feature contributes					
		NFI1	NFI2	NFI3	NFI4	NFI5	Forest resources	Health and vitality	Forest use	Biodiversity	Protection forest	Social economy
	Fork	X	X	X	X	X			X			
	Length of sawable round wood					X			X			
	Stump shoots		X	X	X	X	X					
	Seed trees in regeneration, pioneer planting		X	X	X	X	X					
	Proportion of dry parts > 20%		X	X	X	X				X		
	Coppicing above 2 m height		X	X	X	X	X					
	Reaction to bark marking of dbh position		X					X				
	Stem heights of broken snags			X	X	X				X		
	Woodpecker cavity			X	X	X			X			
	Fungus species (perennial fruiting bodies)			X	X	X			X			
	Lichen species			X						X		
	Length of lying tree			X	X	X			X			
	Twigs on dead tree/deadwood twig			X	X	X			X			
	Bark cover on dead tree			X	X	X			X			
	Hardness of dead tree			X	X	X			X			
	Ground contact of dead tree			X	X	X			X			



	Degree of moss cover on dead tree								X													
	Degree of lichen cover on dead tree								X													
	Number of shrubs on dead tree								X													
	Number of saplings on dead tree								X													
	Microhabitats (cavities, holes, cracks, bark pockets, fungal fruit bodies, cover with ivy, moss and lichens)																					
	Tree species	X							X													
	Height class, dbh	X							X													
	Damage, browsing	X							X													
	Length of leading shoot (next plant)								X													
	Regeneration type (next plant)								X													
	Natural or artificial regeneration (next plant)								X													
	Measures to protect against game (next plant)								X													
	Substrate (next plant)	X							X													
	Silvicultural assessment (next plant)	X							X													
	Degree of shading	X							X													
	Proportion naturally poor regeneration conditions	X							X													

(continued)

Table 1.1 (continued)

Data collection method	Feature	Inventory					SFM criterion (topic) to which the feature contributes						
		NFI1	NFI2	NFI3	NFI4	NFI5	Forest resources	Health and vitality	Forest use	Biodiversity	Protection forest	Social economy	
	Proportion anthropogenically poor regeneration conditions			X	X	X	X						
	Proportional area with good regeneration conditions		X		X		X						
	Proportional area with competing vegetation		X		X		X						
	Competing plant species		X		X		X						
	Main type of topsoil		X		X		X						
	Broadleaved/coniferous wood				X		X				X		
	Cross diameter			X	X		X				X		
Lying dead-wood (Line intersect sampling)	Length $</\geq$ 1 m				X		X				X		
	Slope			X	X		X				X		
	Degree of decomposition				X		X				X		
	Length of intersect with heap of branches			X	X		X				X		
	Piece of deadwood in heap of branches				X		X				X		
	Exposition of forest edge		X		X		X				X		
	Composition of forest edge		X		X		X				X		
Terrestrial forest edge	Width of shelterbelt		X		X		X				X		

	Width of shrub belt	X	X	X	X	X	X	X					X			
	Width of herbaceous fringe	X	X	X	X	X	X	X					X			
	Shape of forest edge	X	X	X	X	X	X	X					X			
	Density of forest edge	X	X	X	X	X	X	X					X			
	Condition of forest edge	X	X	X	X	X	X	X					X			
	Barrier delimiting forest edge	X	X	X	X	X	X	X					X			
	Immediate neighbourhood of forest edge	X	X	X	X	X	X	X					X			
	Woody species along the forest edge	X	X	X	X	X	X	X					X			
Interview survey and forest road assessment	Ownership	X	X	X	X	X	X	X							X	
	Forest road network (condition, type of surface, newly built, renaturalised)	X	X	X	X	X	X	X					X			
	Width of forest road												X			
	Vehicle type												X			
	Obstacles on forest road												X			
	Connection of forest roads to main road network												X			
	Concept for opening-up forest land												X			
	Intentions concerning concept for opening-up forest land												X			
	Pre-hauling distance	X	X	X	X	X	X	X	X					X		

(continued)

Table 1.1 (continued)

Data collection method	Inventory						SFM criterion (topic) to which the feature contributes					
	NFI1	NFI2	NFI3	NFI4	NFI5		Forest resources	Health and vitality	Forest use	Biodiversity	Protection forest	Social economy
Feature												
Hauling distance	X	X	X	X	X				X			
Means of hauling	X	X	X	X	X				X			
Limitations in choice of means of hauling	X	X	X	X	X				X			
Marking of skid roads				X	X			X				
Hauling destination		X							X			
Hauling direction		X	X	X	X				X			
Hauling route			X	X	X				X			
Altitude of helicopter timber depot			X	X	X				X			
Length of cable line			X	X	X				X			
Location of mobile tower yarder			X	X	X				X			
Timber sorting (short, long)		X	X	X	X				X			
Year of last use	X	X	X	X	X				X			
Type of last use		X	X	X	X				X			
Year and type of silvicultural treatment since the previous inventory			X	X	X				X			
Salvage cuts (proportion, reason)		X	X	X	X			X				
Date of next silvicultural treatment			X	X	X				X			



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