

2.3 Terrestrial Inventory

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2.3.1 Introduction

The terrestrial inventory is the most important source of data for the National Forest Inventory. Within the forest, and along the forest edges, approximately 100 different attributes are recorded. These attributes are the basis for most of the 400 derived attributes, such as growing stock, increment, and utilization. They are also the basis for measures which quantify forest functions or the ecological importance of the forest. The “Manual for the Field Survey of the Inventory 1993–1995” (STIERLIN *et al.* 1994) was the most important document of the terrestrial inventory. In it the definition and the survey instructions for the individual attributes; the organization and the flow of operation while recording sample plots; as well as the equipment used and documents are described in detail. The “NFI2 manual” sets the standard for the terrestrial survey at the sample plots and for the forest service’s inquiry. This standard had to be followed exactly and was ensured through the schooling and training of the survey team. Changes and refinements of the manual were given to the survey team in writing. These refinements were collected in a folder, which each team carried together with the manual. The only permitted changes of the manual were contained in the folder.

2.3.2 Preparation and Implementation of the Field Survey

2.3.2.1 Pilot Inventory

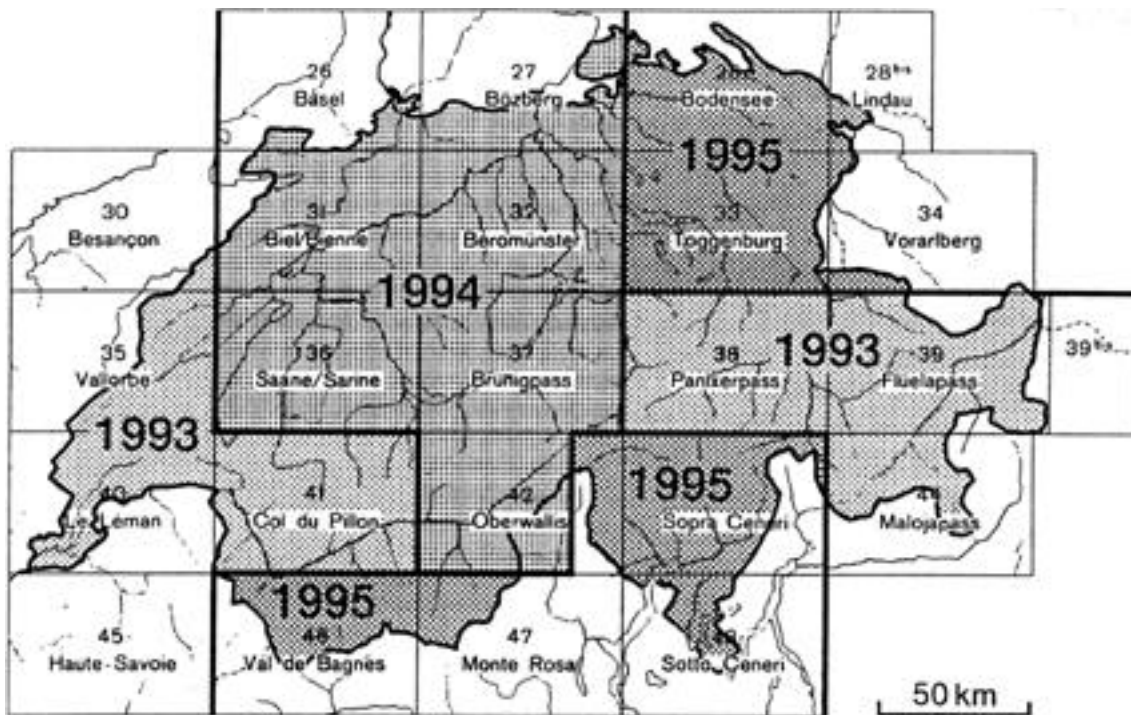
A pilot inventory of 1992 was the main test for the terrestrial inventory. Several different new survey attributes, which were defined before in some method tests, were checked in the pilot inventory and partially included as a useful addition to the catalog of attributes. Even the first NFI was not solely concerned with the production function of the forest. Since that time the information required about the other functions of the forest has increased immensely. The main focus in mountainous regions was the protective function of the forest. It was also intended to describe and evaluate the forest as an important, near-natural habitat for animals and plants, as well as for recreation (BRÄNDLI 1992).

Important new elements were: the evaluation of forest edges and the quantification of ecological parameters such as dead wood, dry or humid sites, recreational facilities, and gaps in the forest. The objectives of the pilot inventory were: to develop survey instructions for the field survey, examine their practicality in the field, evaluate the measuring instruments and tools, and optimize the flow of work. Time studies for the different working phases provided valuable information for planning the field survey of the second NFI. The pilot inventory was conducted in five test areas, which represented the different conditions within the five regions of Switzerland.

An important goal of the pilot study was the selection of a suitable field computer. The American product “PARAVANT” turned out to be the one selected (see also Chapter 2.3.4). The program for the data collection had to be adjusted to the work routine of the terrestrial sample survey and for the forest service’s inquiry. The flow of data from the WSL to the survey teams and back was developed in the pilot study.

2.3.2.2 Planning the Field Survey

The planning of the field survey was primarily based on the first NFI. At that time the NFI survey conformed to the flight plan of the Swiss Federal Office of Topography, so that the forest/non-forest decision could be accomplished using the most recent aerial photographs. This resulted in a three-year task with regions divided schematically according to sheets of the national map. These regions were also used for the second NFI (Figure 1).



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Figure 1. Survey years of the second NFI. Planned time frame for the data gathering in the forest.

For the estimation of the total expenditure and the number of survey teams needed, several different bases and empirical figures were available. From the first NFI survey the number of permanent sample plots were known. Due to decreased funding, only half of the permanent sample plots could be measured in the field for the second NFI. Besides the sample plots that were measured from the first NFI, an additional 10% were measured, which helped in the study of the representativeness of the sample grid, and up to 13% of the sample plots were newly interpreted in the aerial photograph as forest. The planning of details depended on the cantonal forest districts. For each forest district the number of sample plots was estimated. From the expenditure of time per sample plot, which was estimated based on the empirical numbers from the first NFI and the pilot inventory, as well as the number of sample plots, the expenditure of work per forest district was calculated. As a rule, only one survey team worked in a forest district. This team was responsible for measuring all sample plots in the forest district and for the forest service's inquiry. The next step was to put the sequence of forest districts for each survey team together in a way that the teams would start in March/April with their work in the lowland, continue in the summer months in the mountains, and return to work again in the lowland forest districts during the autumn (Table 1, Figure 2).

Table 1. Process of the field survey – example of the workload of a group. Field survey of 1994 – group 13.

Forest district	Number of sample plots	Survey data
Basel-city / Basel-county 1	23	7.3. to 20.3.
Zurich 8	9	21.3. to 23.3.
Zurich 7	42	24.3. to 26.4.
Solothurn 4	38	27.4. to 24.5.
Bern 16	39	25.5. to 17.6.
Wallis 2	69	20.6. to 15.8.
Bern 20	43	16.8. to 16.9.
Jura 4	33	19.9. to 10.10.
Bern 8	71	11.10. to 25.11.
Total	367	

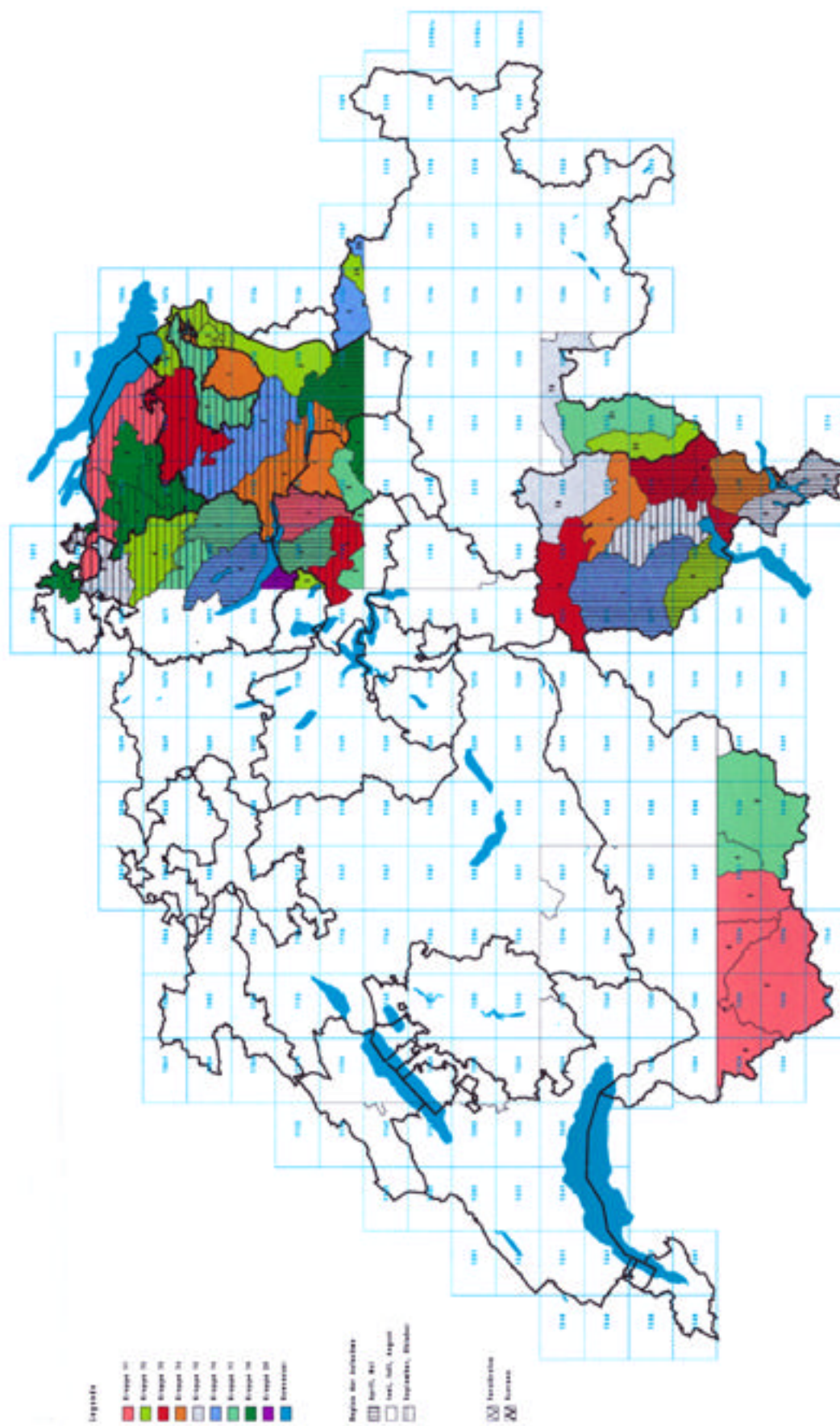


Figure 2. Employment plan for the field survey NFI, 1994.

2.3.2.3 Survey Administration and Organization

The field survey for the second NFI was planned, organized, and carried out by the board at the WSL. This board consisted of one supervisor and three assistants. The board was responsible for instruction and training, equipment, optimal employment of the survey teams, and to act as the contact between the WSL and the teams.

Apart from the above mentioned tasks, the board was also in charge of updating the forest roads on the national map, digitizing the forest road network (Chapter 2.6), as well as transferring the data between the data bank and the field (Chapter 2.3.4).

2.3.2.4 Survey Team

A forest engineer, usually coming straight from a forestry college as a team leader, and a forester or forest ranger as an assistant with practical experience, formed a survey team. The combination of theoretical knowledge and practical experience was the ideal condition for good quality work. The good fellowship between the team leader and the assistant in all of the survey teams helped, so that during the three years no accident occurred and the work proceeded practically without any difficulties. Up to 12 survey teams were employed, while the number varied depending on the yearly survey quota and the time of year.

The survey teams were paid by the hour. The hourly wage proved to be a huge advantage, especially in hard to reach regions. The survey teams were largely free, with respect to the organization of their daily assignments. This allowed the team to adjust their time for the day's work to the local conditions. In turn, this maximized the number of sample plots measured every day. The team's expenses for food and accommodations were reimbursed on a per diem basis. Travel expenses were separately reimbursed.

The following was all a part of the survey team's tasks: planning the details of the field survey in the forest districts (daily and weekly programs), contacting to the forest service, measuring all sample plots in the forest district and conducting inquiries, working on public relations in the survey regions, maintaining vehicles and equipment, and writing the work reports.

2.3.2.5 Equipment of the Survey Teams

The WSL provided the survey teams with all of the necessary measuring instruments and working equipment (Figure 3). Important factors for the selection of the measuring instruments were robustness, simplicity, and whenever possible, independence from the use of batteries. During the pilot inventory, for example, an ultrasound distance instrument was tested. It was found that the measuring tape gave better overall results. The survey teams had, apart from the survey equipment, a VW-bus and a mobile phone at their disposal. With this, the teams were self-sufficient and could work independently. The board and forest service could reach the teams easily. The teams could ask for support or help if needed, and could arrange appointments with the forest ranger or the district forest officer. During the pilot inventory and the three years of field survey, the survey equipment proved to be reliable in often very difficult and impassable terrain. Even the relatively clumsy telescopic poles, for the diameter measurement in 7 m height, as well as upper stem calipers, were not too much of an obstacle.

2.3.2.6 Visiting the Sample Plots

Before the survey team could start their work in the survey area, they had to contact the responsible district forest officer and announce their start and the anticipated duration of the work. The district forest officer had already been informed earlier about the NFI field survey and the general schedule.



Figure 3. Equipment of an NFI survey team.

Within the survey area it was up to the team to decide in which order they wanted to visit the sample plots. Based on a list which contained all the sample plots, the team was able to compile the weekly and daily work schedule. This list also contained information whether the sample plot was measured in the first NFI or whether it was a new one. Other pertinent information included: the elevation above sea level, the stage of development according to the aerial photography interpretation, whether a forest edge survey was planned, and whether the forest/non-forest decision from the aerial photography interpretation had to be verified.

In order to conduct the sample plot survey, the team drove with the VW-bus close to the sample plot. For this, they used the national map with a scale of 1:25,000. Before the team was allowed to leave the car, they had to choose the sample plot with the handheld computer and record the starting time of the first work phase. If the sample plot had been measured during the first NFI, the team had a copy of the form “sample-plot center and location marking” and “layout sketch” in their records. In addition, a printout for each sample plot was prepared, which showed the position of the sample trees on the sample plot, the sample plot radii, and the permanently marked points (Figure 4). With the help of these records and the map, the teams were able, in most cases, to go directly to the sample plot and identify the blue permanently marked points. For new sample plots, which first had to be located on the ground, the team looked for a suitable reference point (e.g., a prominent point on the ground, which could be identified on the ground and in the aerial photograph or the map without any doubt). The sample plot center was surveyed in from this point.

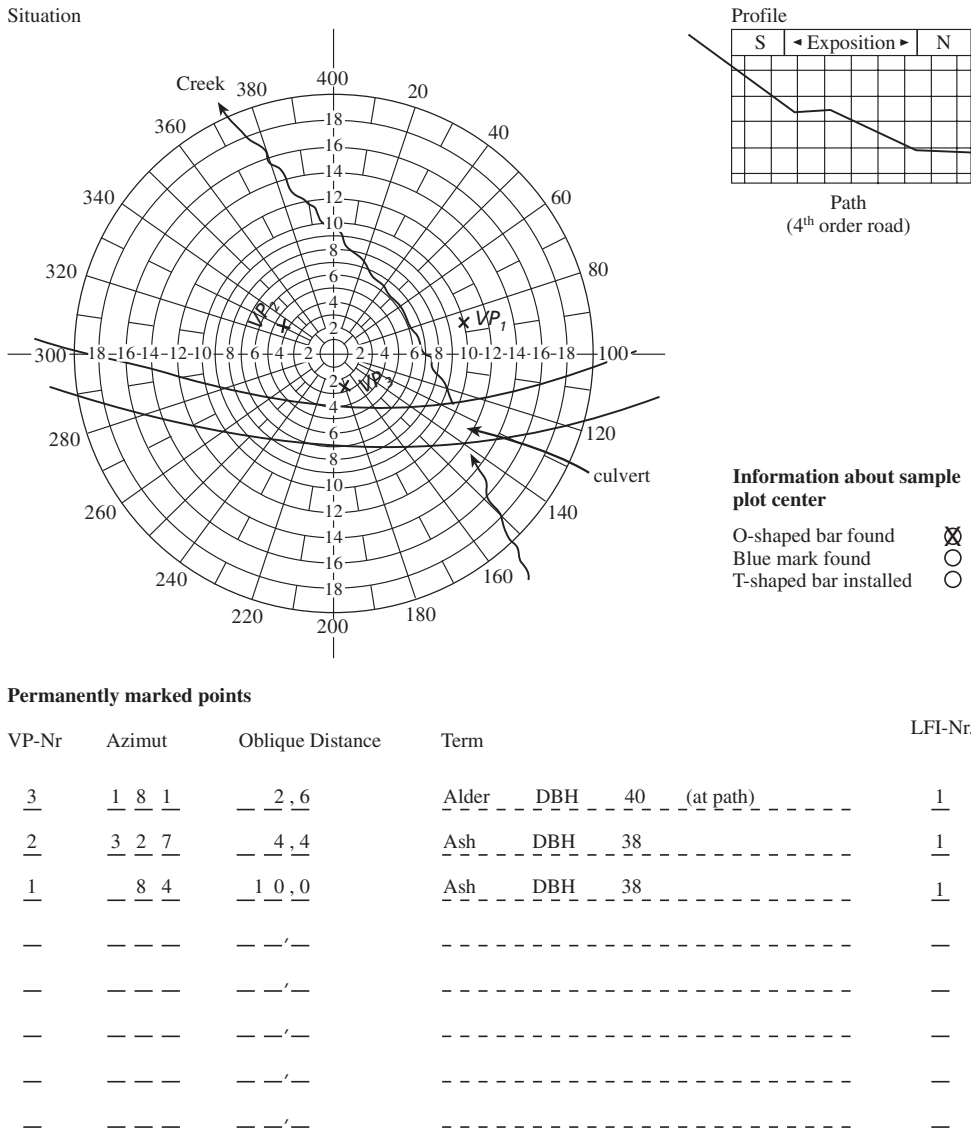


Figure 5. Example of a layout sketch for the sample plot x = 679,000 and 246,000.

2.3.3 Attribute Catalog

On the one hand, the attribute catalog was determined by the first inventory. On the other hand, the catalog was improved based on the experience made during the analysis of the first NFI and, moreover, complied with the current informational needs. If changes between the first and the second NFI had to be quantified, the definitions for the attributes could not be modified. However, in some cases, changes and refinements were necessary because some attributes of the first NFI were difficult to quantify or to interpret.

About half of the first NFI attributes were used without any changes for the second survey. These are notated in the following catalog with **NFI1=NFI2**. They are not further discussed, since they are explained in detail in the manuals for the first NFI (ZINGG and BACHOFEN 1988) and for the second NFI (STIERLIN *et al.* 1994).

The revised attributes are notated by **NFI1≠NFI2**. The commentary describes the revisions. For some attributes the implications of the revisions are documented.

Some of the attributes were relinquished in the second survey, since they were either not used in the analysis or no change was expected. The relinquished attributes are notated in the catalog mentioned below as “**NFI1**”, and the reasons why they have been given up are explained.

New needs for information required the definition and quantification of approximately 60 new attributes, which are notated with **NFI2**. Most of the attributes are not discussed further as

they are defined and described in the manual for the second NFI. For some attributes, which allow statements about the survey methods, comments or results of the NFI2 survey are stated.

The attributes are described in the sequence in which they are found in the “Manual for Field Surveys in the 1993–1995 inventory” (STIERLIN *et al.* 1994). The number behind the title and the attributes (i.e., Chapter 3) refers to the corresponding chapter in the survey manual.

2.3.3.1 Measuring Sample Plots (Chapter 3)

- *Reference points* (Chapter 3.2) *NFI1=NFI2*
- *Accessibility* (Chapter 3.4) *NFI1≠NFI2*

In the first NFI the reason for the inaccessibility of a sample plot was described with a maximum of a 20 character text. In the second NFI the reason for the inaccessibility of a sample plot was coded with five different code meanings.

- *Sample plot status* (Chapter 3.5) *NFI2*

The sample plot status provides information about if and how the sample plot center was found (using a reference point, with or without surveying) (Table 2).

Table 2. Status of the sample plots for the terrestrial sample plots NFI2.

Code	Code meaning	Number of SP	%
1	Found *	4780	85.8
2	Reconstructed	639	11.5
3	Measured / found *	43	0.8
4	Measured / reconstructed	32	0.6
5	Other RP / found *	7	0.1
6	Other RP / reconstructed	16	0.3
7	Not found	52	0.9
	Total NFI 1-SP	5569	100.0
8	First time surveyed	1008	
	Total	6577	

* Aluminum- pipe in the ground found = 4,830 sample plots out of 5,569 NFI1–SP = 86,7% Key: SP = Sample plot, RP = Reference point

For 85.8% of the permanent sample plots from the first NFI, the team located the sample plots without any measurements, and found the pipe in the ground only with the help of the layout sketch from the first NFI. In 11.5% of the cases, the sample plot was found without measurements; however, the sample plot center had to be reconstructed from the existing permanently marked points because the pipe in the ground had disappeared. All reconstructed sample plot centers were marked with an aluminum tee bar. In all only 1.8% of the first NFI sample plots had to be surveyed in again. In 1.4% of the cases, the same reference points were used as in the first NFI. Only about 0.9% of the sample plots of the first NFI could not be found, since they were not correctly located either in the first or the second NFI. For sample plots which were not found, all of the preset values in the handheld computer were deleted, and the sample plot was newly measured just as in a first survey.

- *Difference in measuring the sample plot* (Chapter 3.6) *NFI2*

This was not systematically measured and could not be analyzed.

2.3.3.2 Forest/Non-Forest Decision (Chapter 4)

- *Forest/non-forest decision and reason* (Chapter 4.8) *NFI1=NFI2*

The decision as to whether a sample plot was within the forest or not was a point decision, which refers only to the sample plot center. In order to detect any changes of the forest area since the first inventory, it was essential that the interpretation be conducted with exactly the same instructions as in the first NFI. The criteria for the forest/non-forest decision were: 1) formulated more precisely; 2) the decision model was made more consistent; 3) the designation of the forest type “brushwood forest” was integrated (STIERLIN *et al.* 1994) (Figure 6).

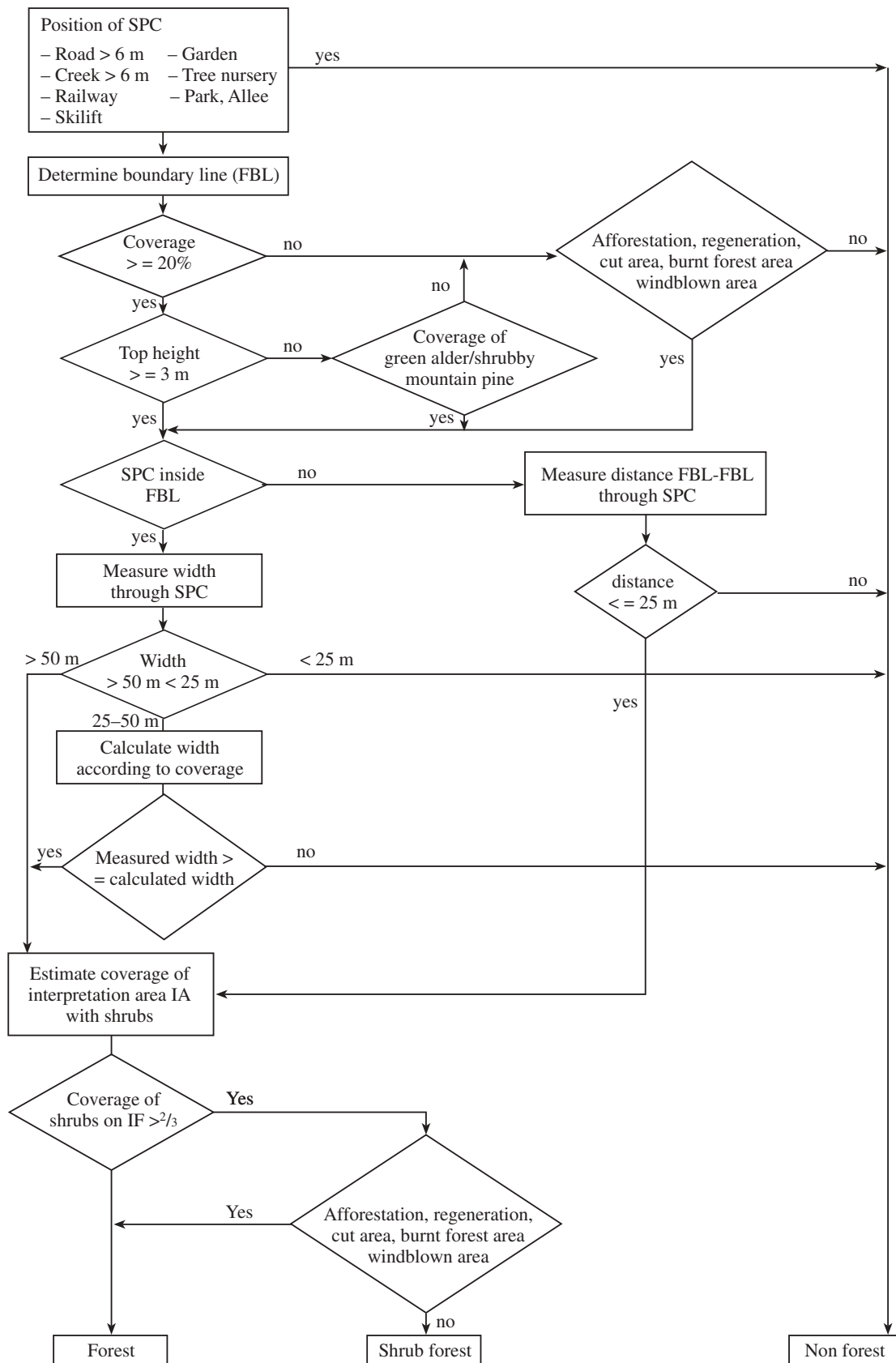
Forest-/ Nonforest - Decision

Figure 6. Forest/non-forest decision according to the NFI.

2.3.3.3 Slope and Sample Plot Radii (Chapter 5)

- *Status of the slope values* (Chapter 5.2) NFI2

For existing sample plots, the slope of the sample plot and the sample plot radii were given. They could not be altered in a subsequent inventory.

- *Slope of the sample plot* (Chapter 5.3) NFI1=NFI2

For new sample plots, the slope gradient was measured in exactly the same way as in the first NFI (ZINGG and BACHOFEN 1988), and the sample plot radii were calculated with the handheld computer (Figure 7).

- *Sign of the slope* (Chapter 5.4) NFI1=NFI2

- *Radii of sample plots* (Chapter 5.5.) NFI1=NFI2

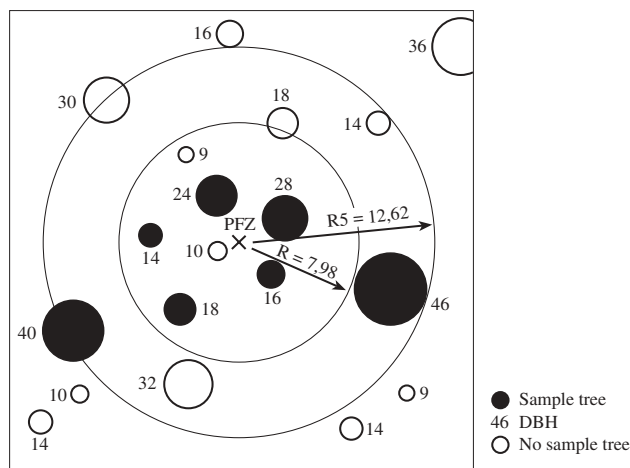


Figure 7. Sample plot radii and sample trees.

2.3.3.4 Permanently Marking of the Sample Plot Center / Situation (Chapter 6)

- *Status of the permanently marked point* (Chapter 6.2) NFI2
- *Azimuth of the permanently marked point* (Chapter 6.3) NFI1=NFI2
- *Distance of the permanently marked point* (Chapter 6.4) NFI1=NFI2
- *Description of the permanently marked point* (Chapter 6.5) NFI1=NFI2

2.3.3.5 Stocking Boundary, Accessibility Boundary, and Forest Edge Survey (Chapter 7)

The forest edge is an important habitat in the transition zone between forest and the open land. During the second NFI, close attention was paid to the ecological aspect of the forest edge. Several new attributes for describing the forest edge were included in the survey, and the forest edge survey was vastly extended. The survey in the first NFI was limited to the quantification of the boundary line between the stocked part of the sample plot at the forest edge and the unstocked part. Measuring this boundary line helped in projecting the stocking of the entire sample plot. Terms such as forest edge, forest boundary line, stocking boundary, accessibility boundary, assessment line, and boundary line are defined in the Manual for Field Surveys (STIERLIN *et al.* 1994). Compared to the first NFI, the area of quantifying a forest edge was extended. In the first NFI, all forest edge lines were measured, which intersected with the 0.05 hectare sample circle. In the second NFI, all forest edges were measured, which intersected a circle of a 25m radius around the sample plot center.

- *Type of boundary* (Chapter 7.2) NFI2
- *Forest edge* (Chapter 7.3) NFI1≠NFI2

The attribute stated whether or not a forest edge was present. This statement was the same in the first, as well as in the second, NFI. However, the definition of the forest edge, that is the stocking boundary, was changed:

- NFI1 forest edge line: Connecting line of all forest edges forming stocking elements with a height of more than 3m.
- NFI2 stocking boundary: Outside tangent (in breast height) on the stems of trees and shrubs with a DBH of 12 cm or more which form the outermost forest edge.

This change was necessary that not two different boundary lines had to be measured: One for the reduction of the sample plot area at the forest edge, and a second one for the forest edge description. If no trees or shrubs with a DBH < 12 cm and over 3m in height were in front of the stocking boundary, the boundary line – according to the NFI1 definition – was the same as in the NFI2 definition. In all the other cases, this resulted in a different boundary line and a different reduction of the sample plot area as in the first NFI. It is advisable for further subsequent inventories to preset the boundary line as the default.

- *Forest edge description* (Chapter 7.4) NFI2

If the conditions were met, the forest edge description took place along the so-called assessment line. The assessment line is a line of 25m to both sides of the inflexion point (see also “boundary line”) along the forest edge. The forest edge was described along this 50m long line with a total of 11 attributes (Figure 8).

- *Boundary line* (Chapter 7.5) NFI1 ≠ NFI2

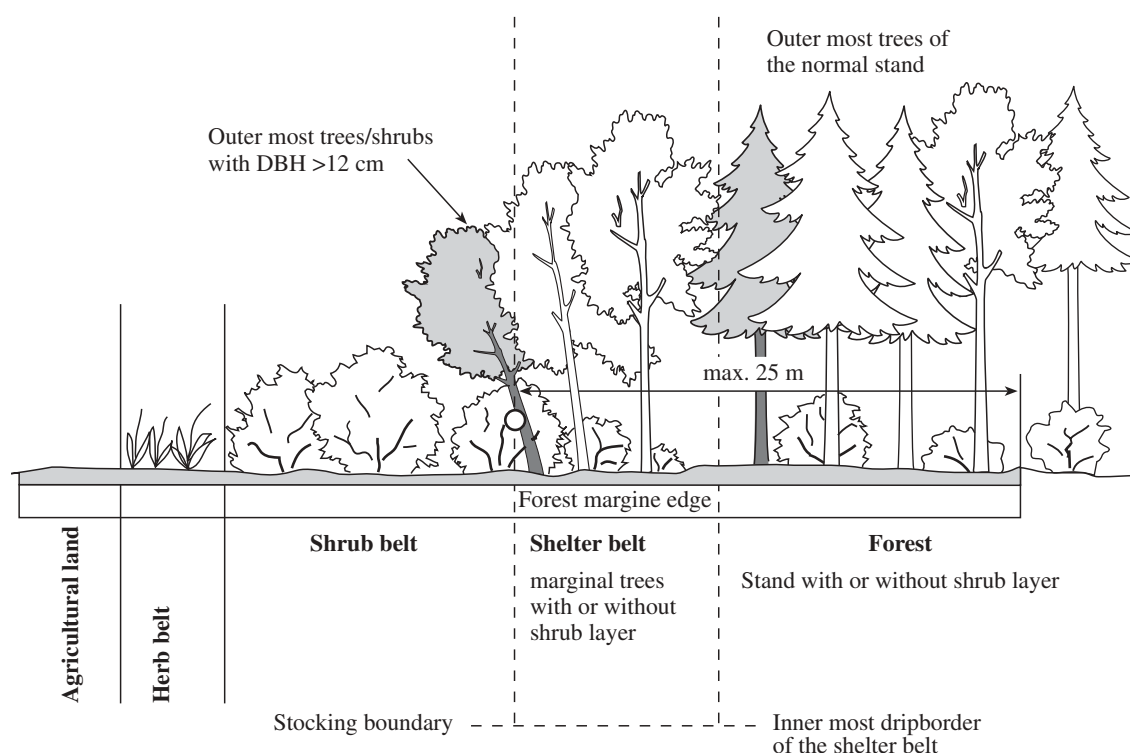


Figure 8. Forest edge in a sectional view.

The boundary line (NFI1: forest edge line; NFI2: stocking boundary) is defined by: 1) an inflexion point, which is chosen on the boundary line; 2) by the distance and azimuth from this inflexion point to the sample plot center; 3) by both azimuths along the boundary line. The way the boundary line was measured in the second NFI was the same as it was in the first NFI, yet the boundary line is defined differently (see above “forest edge”).

- *Location of the sample plot center* (Chapter 7.6) NFI2
- *Forest edge aspect* (Chapter 7.7) NFI2
- *Type of forest edge (vertical)* (Chapter 7.8) NFI2

– Width of forest edge	(Chapter 7.9)	NFI2
– Width of shrub belt	(Chapter 7.10)	NFI2
– Width of herb belt	(Chapter 7.11)	NFI2
– Type of forest edge (horizontal)	(Chapter 7.12)	NFI2
– Forest edge density	(Chapter 7.13)	NFI2
– Forest edge condition	(Chapter 7.14)	NFI2
– Border at forest edge	(Chapter 7.15)	NFI2
– Forest edge surroundings	(Chapter 7.16)	NFI2
– Species at forest edge	(Chapter 7.17)	NFI2

The survey of trees, shrubs, berry shrubs, and climbing plants helped to determine the botanical diversity and to record important habitats for birds and insects. This could also be used as a basis for the aesthetic evaluation. The survey of the species at the forest edge was conducted from outside of the forest. The area proportion for each of the small wood species was estimated from the forest edge profile (vertical projection).

2.3.3.6 Survey of Individual Trees (Chapter 8)

– Tree species	(Chapter 8.5)	NFI1≠NFI2
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For the comprehensive forest edge survey, it was necessary to extend the list of shrubs which had to be measured. This included berry shrubs, herbaceous plants, and climbing plants. In contrast, willows were no longer differentiated.

– Distance of tree from plot center	(Chapter 8.6)	NFI1=NFI2
– Azimuth of tree	(Chapter 8.7)	NFI1=NFI2

Azimuth and distance were used to identify the sample trees of the first NFI. In virtually all of the cases, the sample trees could be identified without any problems. However some difficulties arose, especially for forked stemmed trees. (Should they be considered one tree or two trees?) The decrease in the magnetic declination was another difficulty in identifying the sample trees. Numbering the sample trees with an electronic measurable tree number, for example, should be studied for future inventories.

– Tree status	(Chapter 8.8)	NFI2
– Reason for trees present in 1st assessment not found in 2nd assessment	(Chapter 8.9)	NFI2
– Number of year rings	(Chapter 8.10)	NFI2
– Remarks on special features of sample tree	(Chapter 8.11)	LF11=LF12

The attribute “remarks...” was primarily an auxiliary variable for selecting tariff trees and indicated particular properties of the sample trees (e.g., forked stem, standing dead tree, reserved tree). The comments had to be adjusted to the new survey in the second NFI.

– Reactions to marking of bark in 1st assessment	(Chapter 8.12)	NFI2
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In the first NFI the position at which the DBH was measured was marked with a blazer. The mark was important for subsequent measurements, so that the DBH would be measured at the same stem height. The frequency and the degree of wound reaction to this marking were measured. Table 3 shows that beech is the most sensitive tree species, followed by maple and the other broadleaf trees. In general, it can be concluded that marking the position of the measurement with a blazer does not cause any significant problems (Table 3).

– Diameter at breast height	(Chapter 8.13)	NFI1=NFI2
– Circumference	(Chapter 8.14)	NFI2

As a basis for estimating the precise increment, the stem circumference was measured to the nearest centimeter, in addition to measuring the diameter at breast height with a caliper. It is possible that in subsequent inventories, the DBH will not have to be measured any longer using a caliper.

Table 3. Reaction to marking with a blazer on the sample trees of the first NFI.

Main tree species	No reaction		Slight reaction		Considerable reaction		Total	
	Number	%			Number	%	Number	%
Spruce	20,009	94.2	1,094	5.2	133	0.6	21,236	100
Fir	5,623	95.7	233	4.0	16	0.3	5,872	100
Pine	2,081	96.8	66	3.1	2	0.1	2,149	100
Larch	2,356	98.9	27	1.1	0	–	2,383	100
Cembra pine	432	94.1	22	4.8	5	1.1	459	100
Other conifers	158	98.8	2	1.2	0	–	160	100
Total conifers	30,659	95.0	1,444	4.5	156	0.5	32,259	100
Beech	7,654	80.7	1,483	15.7	344	3.6	9,481	100
Maple	1,335	87.7	151	9.9	36	2.4	1,522	100
Ash	1,483	95.7	62	4.0	5	0.3	1,550	100
Oak	1,050	98.2	15	1.4	4	0.4	1,069	100
Chestnut	867	96.6	28	3.1	3	0.3	898	100
Other broadleaf trees	2,535	92.6	174	6.3	30	1.1	2,739	100
Total broadleaf trees	14,924	86.5	1,913	11.1	422	2.4	17,259	100
All tree species	45,583	92.0	3,357	6.8	578	1.2	49,518	100

Key:	No reaction:	No reaction to the NFI1 blazer mark visible
	Slight reaction:	Small overgrowth or short (up to 20 cm long) Stem parallel cracks in the bark No dead parts of the bark Resin flow
	Considerable reaction:	Large overgrowth (more than 1 cm) Long stem parallel cracks Parts of the bark are dead

– *Crown class* NFI1
 “Crown class” was an attribute used in the first NFI, which was composed of the crown form, crown length and amount of foliage. In the second NFI the “crown length” and “crown form” attributes were measured separately.

– *Crown length* (Chapter 8.15) NFI2
 – *Shape of tree crown* (Chapter 8.16) NFI2

Crown form describes the form and the volume of the crown. For this attribute the survey teams were instructed during training sessions, so that only the really outstanding crowns were classified as a class 1 “round,” and the crowns that were clearly below average were classified as a class 3 “strongly one-sided.” In the second NFI the crowns were assessed with approximately 9% being “round,” 75% as “slightly one-sided,” and 16% as “strongly one-sided.”

– *Layer to which sample tree belongs* (Chapter 8.17) NFI1 ≠ NFI2

For solitary and reserved trees, an additional code known as “no layer membership” was introduced.

– *Social position* (Chapter 8.18) NFI2

We quantified the status of a tree within the stand structure in order to describe the sample tree more precisely. The social status is a useful attribute in closed forests. The social status within selection type forests (plenter forests), mountain forests, or in open forest stands could not be assessed; in these cases the attribute did not have any meaning.

– *Tree damages* (Chapter 8.19) *NFI1≠NFI2*

For the damage assessment of the individual tree, the attributes “pattern of damage” and “extent of damage” from the first NFI were combined and assessed as one attribute. The “cause of damage” was extended from nine different causes in the first NFI to fifteen different causes in the second NFI. Damages during timber harvest were separated into cutting and skidding damage, as well as other human influences. Crown defoliation of less than 50% was no longer recorded in the second NFI. The timber quality attributes “spiral grain growth” and “deformation” were not considered as damages. The pattern of damage – “bumped tree” – in the first NFI was no longer recorded as damaged, but was recorded as a remark “tilted tree.” In the first NFI up to three lines of text could be used for other non-coded damages. The most important damages, such as “dried top” or “missing main branch”, were included in the code list of the second NFI. The additional damage description was dropped. These improvements were important to the survey and also had consequences to the damage analysis and the comparability between both inventories.

– *Data status* (Chapter 8.20) *NFI2*

– *Tariff sample tree selection* (Chapter 8.21) *NFI1≠NFI2*

In the first NFI about 30% of the sample trees, all with an azimuth of less than 150 gon and a DBH of more than 60 cm, were selected as tariff sample trees. During the survey of the second NFI, a random number generator in the handheld computer selected the trees at which the D7 (diameter in 7m height) and the height had to be measured (for approximately 12% of all recorded trees). The selection probability was proportional to the DBH of the sample trees. That is to say, thick trees were selected with a higher probability than small ones (see Chapter 3.2.4).

– *Upper stem diameter in 7m height* (Chapter 8.22) *NFI1=NFI2*
(Figure 9)

– *Tree height* (Chapter 8.23) *NFI1=NFI2*

– *Timber quality of the standing tree* *NFI1*

The attribute “timber quality of the standing tree”, which was measured in the first NFI, was not measured in the second NFI. Changes were not expected, and a second survey of the quality that had the same evaluation criteria might have shown only changes that did not really exist.



Figure 9. Measuring the diameter in 7 meter height with an upper stem calliper (Finnenkluppe).

2.3.3.7 Young Growth Survey (Chapter 9)

The survey methods for the young growth were fundamentally changed. In the first NFI the young growth data were measured in the center of the sample plot in a circle with a 3m radius ($=28 \text{ m}^2$ area). The center of the young growth sample plot was the same as the one for the NFI sample plot. Starting north (0°) and going clockwise, there were up to 30 young growth plants between 30 and 130 cm in height and between 0 to 4 cm DBH counted and described. For the projection, the azimuth to the last plant was determined next. The trees with a DBH between 4 and 12 cm were measured in the entire young growth circle (ZINGG and BACHOFEN 1988). A second survey in the center of the sample plots would have led to incorrect results, since parts of the sample plot were considerably disturbed during the yearly forest damage inventory and the cantonal inventories.

The young growth was measured in the second NFI on two circular young growth plots (“satellites”), which had an area of 14 m^2 each. One of the circles was moved 10m east, while the other was moved 10 m west from the sample plot center (Figure 10). All young growth plants between 10 and 39 cm in height within the young growth satellites on a circle with a 1m radius were measured as class 1. On the entire area of the concentric circles with a radius 2.12m, all plants higher than 40 cm and up to the tally-threshold of 12 cm DBH (Figure 11) were measured.

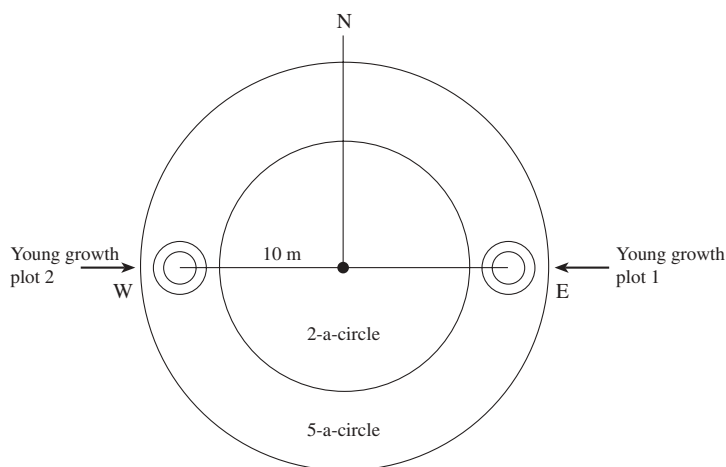


Figure 10. Position of the young growth plots.

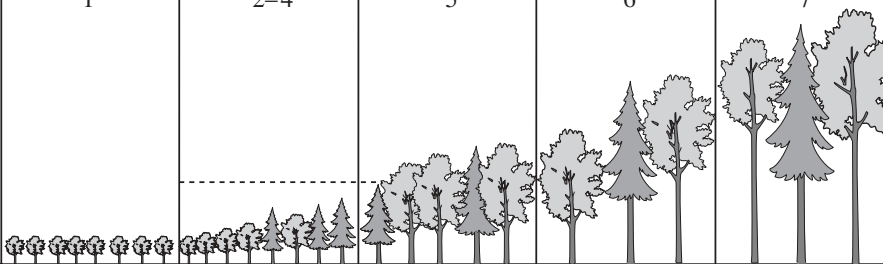
In order to quantify the permissible browsing intensity (EIBERLE 1985) (EIBERLE and NIGG 1983), it was essential to know the yearly browsing caused by hoofed game. Browsing intensity refers to the proportion of terminal shoots browsed per year in percentage to the total number of plants (EIBERLE 1980). In the second NFI young growth plants were registered starting at a height of 10 cm and divided into seven young growth classes. Since the current terminal shoot browsing depended very much on seasonal changes, the browsing event was backdated to the previous year. This was different from the first NFI, which had used current terminal shoots.

– Radii of young growth satellites	(Chapter 9.3)	NFI2
– Satellite position	(Chapter 9.4)	NFI2
– Stage of forest development	(Chapter 9.5)	NFI2
– Crown closure of regeneration	(Chapter 9.6)	NFI2
– Type of regeneration	(Chapter 9.7)	NFI2
– Protective measure	(Chapter 9.8)	NFI2
– Plant counting	(Chapter 9.9)	NFI2
– Species	(Chapter 9.10)	NFI1 ≠ NFI2

For the survey of the young growth data shrubs were also newly measured.

– Young growth size class	(Chapter 9.11)	NFI1 ≠ NFI2
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In the second NFI plants with a height of more than 10 cm were recorded, while the first NFI started at a height of 30 cm. Plants up to 130 cm in height were newly divided into four classes (in the first NFI 1 class).

Class		1	2–4	5	6	7
						
Radius		r small	r large			
Copice shoots		Highest shoot				
Relevant Measure	Height of the terminal bud above the stembase	0,1–0,39 m	> 0,1–1,3 m	>1,3 m	–	–
	Diameter at the DBH measuring position (DBH)	–	–	below 3,9 cm	4–7,9 cm	8–11,9 cm
Measurement instrument		Young Growth-ranging pole		Young Growth-step caliper		

Class 1: 10 cm–39 cm height

Class 2: 40 cm–69 cm height

Class 3: 70 cm–99 cm height

Class 4: 100 cm–129 cm height

Class 5: >130 cm height up to 3.9 cm DBH

Class 6: 4 cm DBH up to 7.9 cm DBH

Class 7: 8 cm DBH up to 11.9 cm DBH

Figure 11. Young Growth Classes.

– *Condition of regeneration* (Chapter 9.12) NF11≠NF12

The condition assessment of the young growth plants in the second NFI were extended by the codes “dry top,” “disease,” “timber harvest,” “damaged,” “lateral shoot browsing,” and “healthy.”

– *Number of plants in class* (Chapter 9.13) NF11≠NF12

– *Closure of regeneration* (Chapter 9.14) NF12

– *Closure of regeneration by main species* (Chapter 9.15) NF12

2.3.3.8 Area Assessment (Chapter 10)

The area assessment refers to an interpretation area of 50 x 50m. Site factors, traces of landslips, rockfall, fire, grazing, and ecological characteristics were assessed.

– *Status aspect and relief* (Chapter 10.2) NF12

For sample plots already existing, the values for aspect and relief were given as default. For new sample plots, both attributes had to be determined.

– *Aspect* (Chapter 10.3) NF11=NF12

– *Relief* (Chapter 10.4) NF11=NF12

– *Traces of landslide* (Chapter 10.5) NF11≠NF12

A distinction was made between landslips due to channel erosion and landslips due to other causes. To be considered as landslide, the extent of its traces had to exceed a minimum threshold.

– *Traces of water erosion* (Chapter 10.6) NF11≠NF12

The assessment of “water erosion” distinguishes between channel erosion, surface erosion, and erosions on slopes. The sum of all partially eroded areas had to be at least 100 m² so that the attribute could be recorded at all.

- *Traces of rockfall* (Chapter 10.7) *NFI1=NFI2*
- *Traces of snow movement* (Chapter 10.8) *NFI1=NFI2*
- *Traces of forest fire* (Chapter 10.9) *NFI1=NFI2*
- *Traces of grazing* (Chapter 10.10) *NFI1≠NFI2*

The attribute grazing was separately recorded by types of grazing (cows, horses, sheep, etc.) and by intensity (current/not current and intensive/extensive).

- *Obstacles* (Chapter 10.11) *NFI1≠NFI2*

The first NFI attribute “limitations for logging” was a combination of obstacles (stumps, stones, etc.) and ground cover. The ground cover was recorded in the second NFI with two attributes: The shrub layer coverage and the berry bush coverage. The obstacles were recorded as a separate attribute. Only obstacles on the interpretation area, which have an influence on the logging, were to be recorded.

- *Limitations for logging* (Chapter 10.12) *NFI1=NFI2*

The second National Forest Inventory also recorded additional indicators to evaluate the forest as a biotope and habitat:

- *Special sites and water bodies* (Chapter 10.13) *NFI2*
- *Heaps of branches* (Chapter 10.14) *NFI2*
- *Stumps* (Chapter 10.15) *NFI2*
- *Standing dead tree* (Chapter 10.16) *NFI2*
- *Patches without vegetation* (Chapter 10.17) *NFI2*
- *Dry stone wall* (Chapter 10.18) *NFI2*
- *Geomorphological objects (small relief)* (Chapter 10.19) *NFI2*
- *Over-utilization and disturbance* (Chapter 10.20) *NFI1≠NFI2*

Within the attribute “over-utilization and disturbance,” seven forms of attributes were distinguished. In the first NFI over-utilization was assessed generally with “existing/not existing”.

- *Recreational facilities* (Chapter 10.21) *NFI2*
- *Type of gap* (Chapter 10.22) *NFI2*

The attributes “removal” and “utilization,” which were itemized under “area based data”, were recorded in the second NFI during the inquiry at the local forest service (see Chapter 2.3.3.11 “Inquiry at the Local Forest Service”).

2.3.3.9 Stand Evaluation

Only the “relevant stand” is evaluated. This means the stand in which the sample plot center is located.

- *Utilization class* (Chapter 11.2) *NFI1≠NFI2*

The segregation of the utilization class was the same as the one for the first NFI, but in the second NFI, for the utilization class A “permanently unstocked forest area,” a stand description for the bordering stand was conducted.

- *Type of forest* (Chapter 11.3) *NFI1≠NFI2*

The types of forest distinguished in the first NFI, like brushwood forest, wooded formation, open forest, and normal forest were reduced to “normal forest” and “open forest”. The brushwood forest was integrated into the forest/non-forest decision, and the forest type wooded formation was completely eliminated, since no statements were possible for this attribute.

- *Stand boundary* (Chapter 11.4) *NFI1=NFI2*

The stand boundary was measured in the first NFI, and the boundary line was surveyed. In the second NFI the survey of the boundary line was dropped, because this type of information had

not been used. It was only assessed with regard to whether a stand boundary intersected with the circular sample plot or not.

- *Origin and management type of forest* (Chapter 11.5) *NFI1=NFI2*
- *Stage of forest development* (Chapter 11.6) *NFI1=NFI2*
- *Stand age* (Chapter 11.7) *NFI1≠NFI2*

The determination of the stand age was conducted as in the first NFI by either counting the annual tree rings on freshly cut stumps, counting branch whorls in young stands, or by estimating the age. In the first NFI the diameter of the counted stumps and the diameter of the heartwood, if present, were recorded. These measurements were dropped in the second NFI.

- *Mixture proportion* (Chapter 11.8) *NFI1=NFI2*
- *Closure* (Chapter 11.9) *NFI1≠NFI2*

The attributes “normal/loosened,” “sparse/open,” and “crowded/normal in groups” had been combined in the first NFI. In the second NFI they were reported separately. Instead of five classes, the attribute was divided into eight classes in the second NFI. The consequence of this change was that the canopy cover density from the first NFI could not be compared with the data of the second NFI.

- *Stand structure (vertical layers)* (Chapter 11.10) *NFI1=NFI2*
- *Type of next silvicultural operation* (Chapter 11.11) *NFI1≠NFI2*

The type of the next silvicultural operation was extended to using the code “mountain forest thinning” and “no silvicultural operation.” The code “sanitation felling” was not recorded any further in the second NFI.

- *Urgency of next silvicultural operation* (Chapter 11.12) *NFI1≠NFI2*

The urgency of the next silvicultural operation referred to the period in which the next type of silvicultural operation, which was reported under the “next silvicultural operation,” had to be completed. The attribute “logging potential” from the first NFI corresponded to the urgency of the next silvicultural operation; whereas, the first NFI only distinguished between “short term” and “long term.”

- *Closure of regeneration* (Chapter 11.13) *NFI2*

This attribute addressed whether the relevant stand had any regeneration growth and what percentage of the area was covered by the regeneration.

- *Type of regeneration* (Chapter 11.14) *NFI1=NFI2*
- *Regeneration protection* (Chapter 11.15) *NFI1≠NFI2*
- *Regeneration* *NFI1*

Three attributes were recorded in the first NFI as “regeneration”: 1) the type of regeneration; 2) the distribution of the regeneration on the interpretation area; 3) the regeneration protection. The type of regeneration and the regeneration protection were adopted as independent attributes without any changes in the second NFI. The regeneration distribution was substituted by the new attribute degree of regeneration coverage.

- *Reserving of standards and advance planting* *NFI1*

This attribute was assessed in the first NFI as an area attribute, which was dropped in the second NFI. However, the comment “reserved tree” was added for the individual tree survey.

- *Closure of shrub layer* (Chapter 11.16) *NFI2*
- *Closure of ground vegetation* (Chapter 11.17) *NFI2*
- *Closure of berry bushes* (Chapter 11.18) *NFI2*
- *Dominant berry bush species* (Chapter 11.19) *NFI2*

2.3.3.10 Stand Stability (Chapter 12)

The stand stability was recorded in the second NFI using the same principles as in the first NFI. On the one hand, all effecting influences at a site (*NFI1* = external influences) were evaluated, and from this the “stress profile” was derived. On the other hand, the resistance of the stand (*NFI1* = stand) was evaluated at the respective site and recorded in a “resistance profile of the stand.” These two profiles gave an overview that was used as the basis for the expert assessment

of the overall stand stability. In contrast to the first NFI, the stability definition in the second NFI was explicitly limited to the mechanical stability of the stand against disturbing effects. The questions of ecological stability, as well as long-term stability, were not considered in the second NFI.

– *Stress profile* (Chapter 12.2) *NFI1 ≠ NFI2*

The NFI1 offered the opportunity to describe openly two other “external influences.” The most frequently mentioned influences, “game” and “human disturbances,” were included in the stress profile of the NFI2.

– *Resistance profile of the stand* (Chapter 12.3) *NFI1 ≠ NFI2*

The assessment criteria “crown length,” “tilted tree,” and “anchorage” were newly included in the resistance profile. The first NFI criteria “suitability for site” and “mixture proportion” was summarized in “tree species.” The attribute “tending status”, assessed in the first NFI, was omitted. The possibility of openly describing the stand characteristics was omitted in the second NFI.

– *Overall assessment of stability* (Chapter 12.4) *NFI1 ≠ NFI2*

Stand stability was more precisely defined in the second NFI as “the probability that large damages or a breakdown will occur during the assessment period of an assessed stand.” The values of the assessment scale from 1 to 10 refer to the probability of the occurrence of large damages: codes 1 and 10 correspond to a 90% and 0% probability, respectively.

2.3.3.11 Inquiry at the Local Forest Service (Chapter 13)

The inquiry at the local forest service was revised. Several new attributes were additionally collected. Since 1985, strong technological developments occurred in timber harvesting. Originally developed in Scandinavia, the forwarder and feller-processor have been increasingly used in Switzerland. In steep terrain the mobile cableway has been more frequently employed and in mountainous regions, which are difficult to access, the helicopter has become an important removal tool. These conditions had to be considered for the implementation of the inquiry. Dividing the timber transport into different removal phases (skidding to the next road and transport to the logging depot) made it possible to calculate the logging expenses more precisely.

– *Utilization* *NFI1*

If any stumps were present on the interpretation area they had to be reported. The local forester was questioned about how many years had passed since a prescribed cut, an improvement cut, or an unregulated felling.

– *Type of last utilization* (Chapter 13.3) *NFI2*

The local forest service was questioned about the type of silvicultural operation since the last NFI.

– *Number of years since last cut* (Chapter 13.4) *NFI1 ≠ NFI2*

If an operation had been performed since the last NFI, the number of years since this operation was asked. If no silvicultural operation had taken place, the NFI data were extrapolated.

For new sample plots, the number of years since the last harvest should have been recorded independently of whether this was done before or after the first NFI. With this information the record would have been complete.

– *Unregulated felling* (Chapter 13.5) *NFI2*

– *Person in charge of last harvest* (Chapter 13.6) *NFI2*

– *Method of harvest* (Chapter 13.7) *NFI2*

– *Pole wood or long wood* (Chapter 13.8) *NFI2*

The manner in which the timber was transported from the sample plot center to the sales location was described, so that for each transport tool used, the destination, distance, and the direction of the transport was recorded. A distinction was made between **removing** the timber

from within the stand to a truck-accessible forest road and **transporting** the timber on the forest road.

- *Place to which timber is skidded after cut* (Chapter 13.9) NFI2
- *Logging distance* (Chapter 13.10) NFI2
- *Timber extraction method* (Chapter 13.11) NFI2
- *Direction of timber transport* (Chapter 13.12) NFI2
- *Limitations to extraction method* (Chapter 13.13) NFI1 ≠ NFI2

The option to record additional limitations in an open text was omitted in the second NFI.

- *Ownership* (Chapter 13.14) NFI1 ≠ NFI2

For all sample plots recorded in the first NFI, the ownership category was kept the same. For new sample plots the ownership category was assessed during the inquiry, but not for brushwood forest or for inaccessible sample plots. The status of the data was, therefore, not homogeneous.

- *Management plan* (Chapter 13.15) NFI2

2.3.4 Data Collection

The data for the field survey of the second NFI were directly recorded with a mobile field computer. The American handheld computer PARAVANT (Figure 12), and the tally software that accompanied it, were used (RÖSLER 1994). Recording the data directly affected, fundamentally, the quality improvement of the data gathered in the forest with respects to completeness and plausibility (see also Chapter 2.8). A special plausibility program checked the measurements and the interpretation codes as to whether they were within the permissible range of values, whether certain attribute combinations were permissible and plausible, and whether the data were completely entered. Furthermore, the device was waterproof and shockproof, so that the survey was more independent from bad weather than with the paper forms, which were used in the first NFI. However, the expenditure was very high for programming, preparation of the preset data and copying them onto ramcards, for the data transfer to the survey teams, and for the return of the recorded data. The direct data collection also limited the flexibility of the field survey, since the preloaded default data could not be transferred without difficulties into another machine. The data collection with mobile field computers was surely advantageous to the second inventory, where data from the first inventory were displayed. For a first survey, the advantages and disadvantages of employing a field computer have to be considered carefully. The data flow tested in the pilot inventory ran smoothly during the three years of field surveys (Figure 13). The ramcards that were used for the data transfer proved a success.



Figure 12. Handheld computer PARAVANT RHC 44.

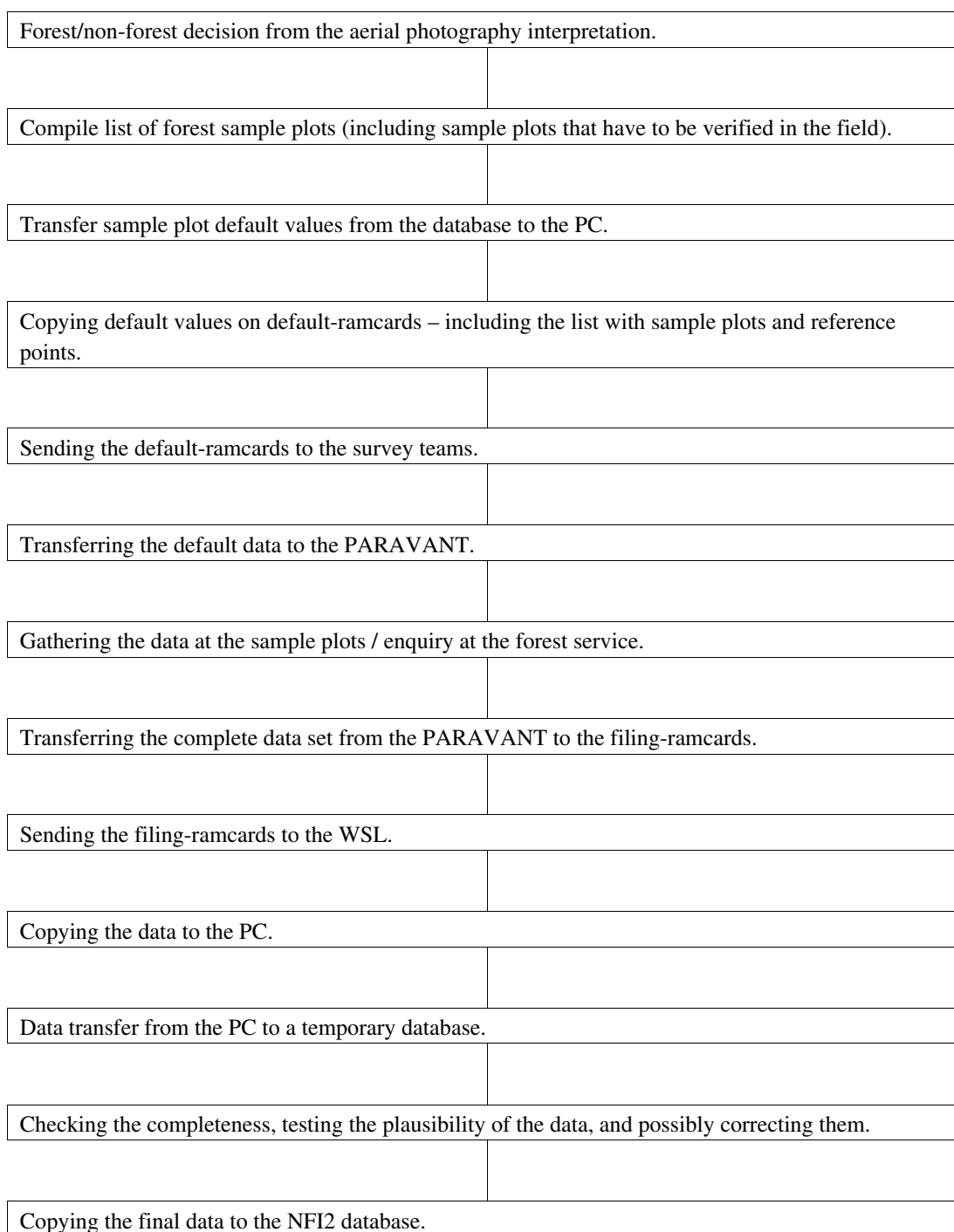


Figure 13. Flow of data for the field survey in the second NFI.

2.3.5 Discussion and Conclusions

2.3.5.1 Future Significance of the Field Survey

Field surveys will play a central role in future inventories. They not only provide reliable data about timber production and the production function of the forest, but also for all other forest functions and, especially, for biodiversity. Many attributes in the forest are measurable and can be evaluated. It is essential that it is made clear before the survey; what the recorded attributes are being used for and what kind of results are possible. Field surveys usually need a lot of qual-

ified personnel and thus, accordingly, a large budget. However, if the costs for measuring a single attribute on a terrestrial sample plot are compared with measuring a single attribute using remote sensing methods, the costs are of the same magnitude.

To find permanently marked sample plots in the forest was, in general, not a difficult task. The methods chosen for marking the sample plots on the ground proved a success and simplified the localization of sample plots tremendously. Whether the blue colored marks on trees and stones influenced the forest manager in his silvicultural decisions could not be proven (see Chapter 2.11). For the survey team, the permanently marked points were very important. They shortened the time for finding the sample plot center significantly. In difficult, undeveloped terrain a simple satellite navigation system (GPS) might be an important tool in the future.

2.3.5.2 Pilot Inventory

It is absolutely essential that a pilot inventory also be analyzed! The pilot inventory for the second NFI established important directions for the survey methodology (Chapter 2.8.2.1), but, unfortunately, it was not possible to analyze it any further. Through this kind of analysis, several mistakes with respects to usability and interpretability could have been discovered and avoided in the second NFI. For example:

- Default data for sample trees: Instead of the data for the first NFI, data from the last (SANA-SILVA) survey were given. As a consequence, the reason for missing trees (harvest or natural death) could not be assessed for approximately 1/3 of all trees which did not exist anymore.
- Dead trees: For the first NFI the condition for recording the dead trees was that the timber could still be merchantable. In the second NFI this condition was dropped. The second NFI had more deadwood than the first NFI. An unknown percentage of this increase was due to the change in the attribute definition. The surveys could have been compared if the dead trees had an additional attribute “timber still merchantable: yes/no.”
- Stocking boundary: see 2.3.3.5.
- Damage type: see 2.3.3.6.
- Canopy cover: see 2.3.3.9.
- Number of years since last silvicultural operation: see 2.3.3.11.

The changes in the way that attributes were recorded caused many problems to the change analysis. Attribute definitions and assessment instructions should, therefore, be changed carefully, and only if absolutely necessary. For most of the cases it is better to record two attributes: one according to the old definition and another according to the new definition; for example, a forest edge line according to the NFI1 definition, and a stocking boundary for the forest edge description in the NFI2.

In the future, a pilot inventory should be completely tested starting with remote sensing through the analysis. The following must be checked in a main test: different survey methods, the usefulness of attributes, the attribute definitions, work flow, materials, machines and equipment, the data gathering and the data transfer, the plausibility of the data, and of course, the analysis concept and the analysis software.

The following should be included in a publication explaining the project: the methods employed, the sampling concept, the experiences from the pilot inventory with respect to remote sensing, the terrestrial survey, the inquiries, the planning, and date of a future inventory and the results of the entire pilot inventory.

2.3.6 Literature

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