2.8 Criteria and Provisions for Quality Assurance

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Data about the development and state of the Swiss forest were the main products of the National Forest Inventory. It was therefore imperative to care about the quality of data and to spare no effort to collect the best possible data, independent of the type of survey or source. The process of data quality assurance can be roughly divided into three steps: prevention of inaccurate data recording, routine quality control during the data gathering, and data verification before the analysis. All preparation work fell under prevention of inaccurate data recording. For example, the verification and documentation of methods and standards, the planning of the data collection, selection and calibration of working equipment and measuring instruments, evaluation of a suitable computer to collect the data, recruiting of qualified personnel, etc.

During the data collection it was important to ensure that the data were complete, the standards were kept consistent, and that the working equipment and measuring instruments were in good working order. The control surveys, the instruction and training of the survey teams, and periodically visiting the survey teams in the field all helped to meet this goal. Before the data were analyzed they had to be checked to see if they were complete and plausible.

2.8.1 Quality Criteria

What makes out "good data"? The data of the National Forest Inventory should comply with the following quality criteria:

- Precision
- Agreement with the true value
- Completeness
- Comparability
- Plausibility
- Homogeneity
- Representativeness
- Reproducibility

2.8.1.1 Precision

The precision of measurements depends on the measuring instruments and scale as well as on how the measurement is conducted. The field survey of the NFI used relatively simple measuring instruments. Despite this, high precisions were achieved. The precision of the measurements was documented in detail with the control survey (see Chapter 2.9).

The precision of attributes, which are not measured but appraised or estimated, is difficult to characterize. By far, most of the NFI data were categorical variables on a nominal or ordinal scale. The control survey showed the level of agreement and deviation between the first survey and the control survey. These measures characterize the precision of the qualitative data.

2.8.1.2 Agreement with the True Value

The data measured in the NFI need to agree with the true value, whereby the true value for categorical as well as continuous data was always unknown. The analysis of the control survey (see Chapter 2.9) gave details about the agreement between the measurements. The agreement for most of the continuous data between the first survey and the control survey was good. In the NFI great importance was attached to the fact that the assessments of the survey teams corresponded with the standards set in the Manual for Field Surveys (STIERLIN *et al.* 1994).

2.8.1.3 Completeness

The data collected in the forest or from other sources must be complete, because only a complete data set makes a complete analysis possible. For this, the exact definition of the attribute catalog was essential. The attribute catalog had to be kept consistent throughout the entire duration of the survey. Appending additional variables will inevitably lead to an incomplete data set.

2.8.1.4 Comparability

The data from different teams, different seasons, and different regions had to be comparable with each other. The survey attributes had to be defined in such a way that seasonal or geographical differences did not occur. The survey teams had to be trained so that the measurements of different teams were comparable.

2.8.1.5 Plausibility

The data measured in the NFI need to be plausible; that is all measurement values had to be within the defined value range and no inadmissible codes could be used. The attribute combinations had to be meaningful and admissible.

2.8.1.6 Homogeneity

Under homogeneity of the data, the comparability of the first NFI with the second NFI was understood. The data of the second NFI had to be identical to the data from the first survey. Above all, the following three factors were involved:
– The measurements had to be comparable
– The attribute definitions had to agree
– The assessment of qualitative attributes had to be the same as in the first NFI

Caution was therefore advised where new measuring instruments were used (new or more precise measuring instruments do not give better measurements in every case).

The instructions and repeated training of the survey teams played an important role in imparting the standards of the first NFI.

2.8.1.7 Representativeness

The representativeness addresses the degree of concordance between the NFI data and the reality. The systematic sample plot grid of the NFI and the selection procedure of the trees on the sample plots were chosen and verified so that the representativeness of the inventory was guaranteed. Certain sample plots could become “visible” and threaten the representativeness, because the sample plots were visited every year for the last ten years (particularly the sample plots of the national and cantonal forest damage inventory) and because of the points that were permanently marked. The representativeness of the permanent NFI sample plots was verified by measuring additional, new sample plots (see Chapter 2.1 and 2.11).

2.8.1.8 Reproducibility

The measurements or the assessments of qualitative characteristics must be reproducible. This means that different measurements or assessments of the same objects have to produce the same results. Measurements were easy to reproduce, as long as the measurement instructions were observed and the same measuring instruments were being used. The assessment of categorical attributes was more difficult to reproduce and required a high degree of training and control of the survey teams.

2.8.2 Measures to Assure Quality

2.8.2.1 Survey Preparation and Planning

Projects of the magnitude of a National Forest Inventory require careful preparation and planning. A precisely defined method and a clear sampling design were fundamental prerequisites for the success of the National Forest Inventory. With the chosen sample design, the Swiss forest was representatively covered. The methods of the second NFI were tested in 1992 in a pilot inventory in the five regions: Jura, Plateau, Pre-Alps, Alps, and Southern Alps (BRÄNDLI 1992). During that time, the main objective was to check the attribute catalog and to test the inventory manual (STIERLIN *et al.* 1994) with respect to its practicality and consistency. The flow of work and the survey equipment were checked and optimized. The data collection with the field computers, as well as the flow of data between the WSL and the survey teams, had to be newly developed. In the pilot study, the application of the aerial photographs was tested for the forest/non-forest delineation and as an aid to assist the survey teams in locating the sample plots. Since the pilot inventory was not analyzed for the most part due to time constraints, the usefulness of the assessed attributes could unfortunately not be verified.

The planning of the survey was of great importance. The aerial photography interpretation had to be coordinated with the field survey, since the completed aerial photography interpretation was a prerequisite for supplying the survey teams with default values. The field survey was planned in three stages: 1993, 1994, and 1995 (STIERLIN 1993). For each stage the survey teams were assigned different forest districts as survey units. Care was taken that only one team would work in one forest district. The timely order of the field surveys were scheduled in such a way that they started at lower elevations in spring, continued into the mountainous areas in midsummer and returned back to the lower elevation regions during autumn (Chapter 2.3).

The "human" factor played an important role in assuring the data quality. The selection of the team leader (forest engineer) and his assistant (forester or forest warden) was also important to the working climate and to conducting the field surveys without any problems. The survey personnel were selected carefully. The relatively large amount of time spent on recruiting the field personnel was worthwhile. Problems with the personnel were virtually non-existent and the staff members were motivated until the last day of the field survey. The contact between the board at the WSL and the survey teams in the field was an important quality component. The survey teams were able to count on the necessary support of the board at any time.

In the "Manual for Field Surveys of the 1993–1995 Inventory" (STIERLIN *et al.* 1994), the standard methods for the field survey of the second NFI were documented. The definitions and working routines described in it were binding for the survey teams. This set the standard for the terrestrial survey of sample plots and for inquiries at the forest service. For each attribute, a description of the goal and the intended purpose illustrated the significance of its recording. The exact definition of the assessed attributes and the exact measuring instructions or the descriptions of the procedures were important prerequisites for the reproducibility of the measurements and the evaluation.

2.8.2.2 Instruction and Training of the Survey Personnel

At the beginning of the field survey of a particular survey stage, the field teams were introduced to the work and intensively trained. The survey methods and working techniques were taught in the training courses. The survey teams were instructed in the operation of the handheld computer and the measuring instruments. Another important goal of these training courses was the teaching of estimation standards for the qualitative attributes. The board established the assessment standards so that these corresponded with the values of the first NFI. The survey teams had to adopt these standards.

At irregular intervals (at the beginning of the field survey more frequently than at the end of the survey period), so called "training days" were conducted. On each of the training days, a specific topic was taken up and taught. The participation was mandatory for all survey teams. The board selected the training objects and set the standards. The results from the survey teams

were compared to these standards with the help of a special analysis program. The board and survey teams discussed afterwards the exercises for each particular object. The evaluation of identical objects under the same conditions and the discussion that followed regarding the standards and discrepancies were of central importance for the homogeneity, the reproducibility, the comparability of data, as well as to ensure that the assessments were in agreement with the "true" value and the standards set.

2.8.2.3 Carrying out the Field Survey

Complete default values are an important prerequisite for a complete survey in subsequent inventories. For example, a sample plot could only be measured if the data for that particular plot were available on the field computer. The application of field computers ensured the completeness of the data collected in the forest and in the inquiry at the local forest service. The field computer checked the data input as to whether all of the relevant survey fields contained a value. If not, an error message was displayed (RÖSLER 1994).

The motivation of the survey team to do a good job was crucial for the data quality. Therefore, it was important to create good working conditions. An appropriate wage and expense reimbursement was as important as good equipment for the teams and support from the board. In the second NFI an hourly wage and per diem base expense was used. Essential components of the team's equipment were a reliable, spacious vehicle; suitably robust equipment which was rugged enough to keep up with the daily work in often very difficult terrain; all of the necessary documents and maps required; and a mobile phone that ensured contact with the survey teams.

The following measurements were taken at the terrestrial sample plot: The diameter at breast height (DBH) and the stem girth were measured precisely to the full centimeter and rounded off to the next centimeter (STIERLIN *et al.* 1994) with a caliper and a tape-measure (with centimeter marks) respectively. The diameter in 7 m heights was measured exactly to the nearest centimeter with the upper stem caliper; 0.5 to 0.9 cm were rounded up and 0.1 to 0.4 were rounded off. The upper stem caliper was so called "self-rounding." The tree height was measured with the "Christen" dendrometer to the nearest meter. The "Christen" dendrometer was self-rounding. Azimuths and slopes were measured to the full gon (0-399) and to the full percentages respectively. In order to warrant exact measurements, the measuring instruments had to be calibrated before they were used. During the field survey the measuring instruments had to be checked periodically and newly calibrated when necessary. For the DBH measurement, the height of 1.3 m above ground and the measurement direction of the caliper were essential for the precision of the measurement. The girth measurement was independent of the measurement direction and more accurate results were achieved if it was used correctly. Difficulties of the girth measurements that were encountered were a sagging measuring tape (especially for very big trees) and reading the wrong meter.

2.8.2.4 Control Survey

About 11% of the sample plots recorded in the second NFI were measured a second time by a control team. The goal of the control survey was the verification of the work quality, guaranteeing the data quality and data consistency, detection of systematic deviations, as well as determining the variation range of the terrestrially measured attributes. The control survey was an independent second survey of a sample plot, which had already been recorded by the regular survey team. For the analysis of the NFI results, the first survey was used in any case. No corrections of the first survey were made on the basis of the control survey. The sample plots that were to be controlled were chosen at random. The tariff sample trees that were chosen by the first survey team were also used and measured again by the control team. The results of the control team (see Chapter 2.9) pointed out difficulties in the assessment of individual attributes. These attributes were then especially emphasized during the "training days".

2.8.2.5 Plausibility Examination of the Raw Data

The possibilities that errors occur in the data are almost unlimited. It was, therefore, absolutely essential that the collected data were checked with respect to their plausibility before they were analyzed. A first and very important plausibility check was already being conducted during the data collection in the forest. The field computer checked the measured value and the codes to ensure that they were within the range of admissible values. In addition, certain attribute combinations were checked to see if they were admissible and plausible.

The plausibility examination in the office was just as important. The analysis of the minimum, maximum, and distribution of the data for each individual attribute pointed to values which were not plausible. For example, the remains of all trees that were recorded in the first NFI had to be checked to reliably know which trees were still living, which were cut, and which ones were new. The plausibility examination of the field computer did not discover all measured values that were not plausible. For instance, recording the wrong meter while measuring the girth, creating typing errors, and entering unreasonable but admissible codes were not discovered. A large portion of these errors were found and eliminated in the office with a plausibility examination. Continuous values, for example, were compared with the data from the first NFI and, thereby, gross errors were discovered. Certainly the expenditures for programming and executing the plausibility checks should not be underestimated.

2.8.3 Literature

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