5 Visions

Peter Brassel, Michael Köhl

5.1 Introduction

The attitude of society towards forests has changed. Today, forests are no longer primarily considered as a source of raw material, but are appreciated as one of the last close-to-nature landscapes. The function of forests as a source for recreation, as protection against erosion, avalanches, rockfall, noise and flooding, as habitat for animals and plants, as well as for the improvement of air and water quality, is rated higher in several different regions of Switzerland than timber production. Just as the demands on the forest have changed, so have the informational needs of society. Inventories contribute decisively in obtaining the information needed in order to allow for sound political decisions. The change of informational needs is reflected, for example, in the main focus of the first and second Swiss NFI. The first Swiss NFI focused clearly on the timber production function, while the focus in the second Swiss NFI changed towards non-wood goods and services.

The demands for inventories are high. They should cost little, and at the same time should satisfy all current informational needs. They should be conducted with the most up-to-date methods and technologies, and should provide scientifically sound estimates of the target parameters (LUND 1998). The translation of the informational needs into suitable methods and attribute catalogs, the evaluation of appropriate sources of data, and the study of the inventory perimeter is a continuous process, which is essential for scientifically sound inventories. Without research, it is not possible to achieve the high standards set for inventories. The development of methods for the third NFI is being conducted in the following four activity fields: 1) Inventory design and statistical methods, 2) survey techniques and attribute catalogs, 3) modeling and prognosis tools, and 4) implementation and extension services.

5.2 Inventory Design and Statistical Methods

The sampling design, the assessment rules, and the statistical analysis methods are the center of any sample based environmental observation. The development of methods must comply with the informational needs, the objectives of the inventory, the availability of suitable data sources and auxiliary information, and it must meet the long-term objectives. Last but not least, it should be compatible with inventories on successive occasions.

In large-scale forest inventories, the further development and changes of methods from one inventory to another is more the rule than the exception. For example, today’s inventory design of the Swedish National Forest Inventory does not have much in common with the first national forest resources assessment conducted in the 1920’s. Their commonality is that both times information was gathered about the forests, and that the terrestrial assessment remained the most important data source.

Methodological changes made it possible to apply the newest development in sampling theory, computer science, and remote sensing in the Swiss NFI, and thus utilized all possibilities to increase the accuracy and to decrease the inventory costs. The savings of variable cost are best realized by reducing relatively expensive components, such as expenses for field assessments. One way of cost reduction is to increase the extensive utilization of remote sensing data. In addition to the introduction of double sampling for stratification, it is conceivable to extend the attribute catalog and the sampling intensity of the aerial photography interpretation. This would render the further reduction of estimation errors and cost possible.

Updating of the existing data sets offers another possibility to reduce expenses. Similar to the increment models, which are used in the second NFI, methods for updating other attributes should be developed and applied. The choice of such an approach to describe changes resulted, for example, in a considerable cost reduction to forest inventories in the United States (HAHN and HANSEN 1983).

The optimization of inventory cost can only consider variable costs that are dependent on sample size and occur during the field survey, aerial photography interpretation, and the map survey. The most important cost factor, which cannot be reduced, however, is the method development itself in a broader sense, due to changing demands. Identifying informational needs and transferring them into measurable attributes, statistical design, evaluation of data sources, and development of feasible assessment methods and programs, software for the database and analysis, interpretation of the results, implementation of the information, infrastructure, and general knowledge about inventories are the indispensable basis for national inventories.

The reduction of the field assessments by employing statistical models for updating stand developments, or by the extensive utilization of remote sensing data, conflicts with the current and future informational needs. Many of them require intensive observations in the forests and on individual trees. For example, monitoring species diversity or regeneration can only be carried out through field assessments.

The objectives of the second Swiss NFI were to provide reliable information on current state and changes for entire Switzerland and the five productive regions. These objectives could be met by a cost-efficient inventory design. By intensifying aerial photo interpretation and employing a double sampling for stratification design, it was possible to reduce the number of field plots by roughly fifty percent and maintain the sampling errors of the first NFI. If results are to be presented for units of reference on a level smaller than the productive region, i.e., cantonal or community level, the sample size of the NFI might not be sufficient to provide results with an adequate reliability, since sampling errors may become too large for decision making.

For the third NFI, the sampling intensity of both aerial and field samples must be evaluated in the scope of the then valid inventory objectives. The NFI-design is, however, open for a local intensification of the sample grids by regionally or locally increasing the number of aerial or terrestrial plots by additional assessments in order to maintain both satisfaction of informational needs and cost-efficiency. Thus, reliable information could be provided for specific regions of interest or hot spots. The assessment and estimation procedures and the analysis software can still be applied in those situations.

In the future, aerial photographs will still be an important data source for the NFI, as long as aerial photographs with complete coverage are available without charge. However, the analysis does not necessarily have to be carried out using an analytical method with aerial photography interpreters, as in the current survey. Developments in the area of digital photogrammetry open up new possibilities for future employment of aerial photographs in obtaining information for the NFI (OESTER and KÖHL 1995). Digital photogrammetry offers the measurement of structural attributes which could replace qualitatively assessed information such as development stage, stand structure, or crown closure.

In the future, remote sensing will gain in importance as an option in obtaining current, up-to-date and geo-referenced data with complete coverage. The utilization of satellite imagery, however, still needs to overcome some obstacles, of which the insufficient classification accuracy of different forest types is the most serious (BODMER 1993; KELLENBERGER 1996). Satellite remote sensing is described in several publications as an ideal method to assess forest resources; the classification accuracy mentioned in these publications are, however, difficult to achieve with the heterogeneous forest structure and topography of Switzerland. Nevertheless, the technology of satellite remote sensing is currently developing so fast that it might be an operational tool at the time of the third NFI. Aerial photography and terrestrial surveys could be supplemented by digital satellite images or by radar (SAR) data. One important field for the application of satellite remote sensing could become the classification of forest areas and the preselection of spots on which field surveys will be conducted.

NFI methods and information are increasingly used for reports at the cantonal level. Some cantons built up on the information provided by the NFI and intensify the sampling grid on the cantonal level. This approach results in a sound information basis for multi-purpose forest planning at the regional level. A side-effect of this synergism is that expensive forest inventories for larger forest enterprises can be replaced, and information on both public and private forests is available. The current NFI-design and the NFI data base management system enables the establishment of an integrated forest information system that combines information assessed on the national, cantonal, regional and even local levels.

The importance of computer science will increase even more in the future. The database should be developed further and optimized. The complexity of the structure and the size of the database will drastically increase with additional inventories. This will increase considerably the access time for joins and queries. Maintaining and optimizing the database will be essential in order to allow the information of the NFI to be widely used. The programs for gathering data directly in the forest and in open fields with a laptop computer must be adjusted to the new technology, operating systems, and interfaces. Software for the data assessment of aerial photographs and satellite images has to be evaluated and further developed. Finally, the analysis software has to be provided.

5.3 Survey Techniques and Attribute Catalog

The survey technique is, and will remain, an essential prerequisite to the NFI. On the one hand, the technique fits in with already existing inventories in order to ensure that results can be compared; on the other hand, it complies with the new needs for information. By translating these needs into measurable and reproducible attributes, one of the most important basics for the entire inventory system is established. Apart from the attributes used today, other ones will be required in the future. These include attributes for the vegetation survey, the soil parameter, the intensive survey of the forest structures in the montane forests to evaluate the protection function, and the extended young growth inventory to evaluate the forest and game problem. Although the number of terrestrial sample plots does not necessarily have to be increased, the surveys on the individual sample plots will be more extensive and intensive, and will require highly qualified field survey equipment.

The recreational space required by humans, and the space needed for animal and plant habitats is not limited to forests alone, but encompasses the entire landscape; especially the extensively used areas. For many problem tasks, it is not possible to evaluate the forest separately from other biotopes (e.g., alpine meadows, pastureland). This requires an expansion of the inventory perimeter to the entire extensively used terrestrial ecosystem.

Up until today, the Swiss forest periodically was surveyed in a ten-year cycle. Apart from the indisputable advantages, this approach has several disadvantages, such as the relatively long period of time that must pass until new attributes can be introduced, or the decrease in the up-to-dateness of the results between two surveys. One alternative to the periodic surveys in a ten-year interval appears to be the permanent survey (Scott *et al.*, 1999, Schreuder *et al.*, 1999). For this, every year a tenth of the inventory quota is assessed either per region or in systematic sub-grids, which cover all of Switzerland every year. If the survey would be conducted per region, it would be possible to publish annual results for the region or canton that was surveyed. However, for the summary of the inventory data in a form comparable to the current result reports, the ten-year survey period would require that the individual tree and sample plot data must be updated too. If the data would not be updated, it would not be possible to determine which "current" state the NFI results would reflect.

The necessity to update the area and tree data for permanent inventories leads inevitably to complex statistical algorithms. A preliminary study conducted during the preparation for the third NFI (SCOTT *et al.*, 1999) showed that the estimation procedures would make it impossible to analyze the NFI data with standardized analysis methods as they are currently used for the NFI. In addition to this, the result tables would not be additive any longer and the results of the NFI analysis would not be intuitively comprehendible.

In the future, the NFI will have to comply with international standards and definitions. Currently, all European countries employ for their own national forest inventories a system of nomenclature and definitions that historically grew out of specific national conditions, but which only partially allow for a comparison between different countries. Several international organizations (EU, UN-ECE, and UN-FAO) are currently attempting to harmonize the most important key parameters for forest inventories and develop mandatory definitions and consequently international standards.

The NFI has been actively involved in the development of a harmonic nomenclature (KÖHL and PÄIVINEN 1996) and will have to comply with the international conventions in the future. However, this should not effect the comparison of the current NFI results with earlier surveys.

5.4 Modeling

The NFI data are suitable as a basis for modeling the forest development and for the derivation of cause and effect relationships. Ecosystems are strongly influenced by their abiotic and biotic environment. The information about the states and the developments in the landscape and in the forest could be combined with relevant environmental data. This could allow for the derivation of hypotheses about cause and effect relationships, and could improve the understanding of the interaction between forest and landscape on the one hand and influence factors on the other.

Since all of the NFI data have a spatial reference, it is easily possible to combine them with geo-referenced environmental data. For the preservation of the biological diversity in ecosystems, it is possible to combine the data with other inventories, for example, the inventory of lowland moors that are of national importance (BROGGI 1990). Apart from the modeling, it is feasible to use different techniques such as conventional analysis systems, GIS, knowledge-based systems, fuzzy techniques, or neural networks within the scope of an environmental system research.

The interest will further shift from a pure account of the current state (first NFI) and the registration of changes (second NFI), to scenarios of future development (third NFI) (e.g., climatic changes). This requires a better understanding of relationships in the ecosystem forest, the impact to the ecosystem, the effects and function of the forest, as well as the instruments used for predictions and for assessing the risk.

An important part of such instruments are models that allow hypotheses to be tested with regard to the cause and effect relationship, and which allow the simulation of future developments of forests and landscapes. These could include statistical models that are derived directly from the NFI data or mechanistic ecosystem models.

Statistical models can be derived directly from the NFI data and provide reliable empirical estimates (e.g., relationships between DBH and tree volume, see Chapter 3.2 or for short to medium-term developments of the forest, see Chapter 3.3).

Mechanistic ecosystem models, by comparison, cannot be directly derived from the NFI data, since they require detailed knowledge on a smaller spatial, temporal, and structural scale. The NFI data provide, nonetheless, an excellent opportunity to initialize, standardize, and validate existing (BUGMANN 1996; LISCHKE *et al.* 1998) and newly developed models (e.g., based on Chapter 3.4), which are built upon the knowledge and assumptions about the processes that take place in the forest system. Such models could then predict long-term changes in the Swiss forest as a reaction to different environmental conditions (for example see LISCHKE 1998) and could test hypotheses about cause and effect relationships. These models will, for example, allow finding areas in which the sustainability would be not ensured under certain environmental scenarios (e.g., continued climate change or increased browsing intensity).

The significance of the raw material wood by itself, the high increase of the timber volume that was determined with the second NFI, and the resulting risk for the sustainability of forest effects have become a high priority in solving the problem of "timber, biomass, and CO_2 sink." The interactions between timber volume, increment, sites, and management (utilization) are crucial to forest effects. The modeling of these forest developments, which depend on management (see utilization scenario in Chapter 3.3), will make it possible to predict the future state of the forest, timber volume, CO_2 sinks, and possibly timber production, as well as to assess the risks involved. Based on such modeling studies, important information can be provided for political decisions.

The NFI provides information to evaluate the forest effects at a national and regional level. The question now is whether the Swiss forest is currently able to fulfill the functions that are demanded of it now as well as in the future. In order to answer this question, more must be known about forest structures and their influence on the forest effects; about stand stability and its development; and about forest regeneration as the basis for the sustainability of the forest effects.

With an increasing number of completed inventory cycles, the NFI will provide data to model changes and the development of forests. The NFI offers the advantage to assess representatively all forest structures in Switzerland in the future and, thereby, allows the derivation of models that are valid over a wide range of values.

Many of the current available models are based on data that reflect only a relatively small part of the entire spectrum of the Swiss forest and are, therefore, only valid for this narrowly defined range. For example, the range of the Swiss yield tables should, strictly speaking, include only approximately 18% of Swiss forest area (KÖHL *et al.* 1995). The data from the NFI offer a possibility to supplement intensive but spatially limited studies, such as researching long-term forest ecosystem areas, and to define the valid scope of these studies.

5.5 Implementation

Utilizing the knowledge, methods, and data of the NFI for local and strategic decisions and for understanding forest ecosystems is an important objective. An active implementation is important for the success of the long-term NFI project. Clarifying future information needs is essential in defining the objectives of subsequent inventories. By building a forest information and communication system, a close link between decision makers on the local, regional cantonal and national level and the NFI will be established. The information and communication system will be engaged in transferring adequate, comprehensive, up-to-date and reliable information and technology between applied forestry, politics, research, teaching, and the NFI.

Future developments will lead to changes, not only in gathering and analyzing the data, but also for the dissemination of the results. The increasing access to the Internet and recent developments such as open GIS or platform independent software tools will open up new possibilities and challanges to make the latest results and special analysis available for a wide audience.

5.6 Conclusions

The NFI has become an instrument that can provide extensive information with respect to the Swiss forest. By applying environmental statistical methods and environmental data processing using the existing NFI data and appropriate links with other databases, the NFI offers an important contribution to environmental analysis. The NFI satisfies, therefore, all prerequisites to become a powerful national forest information and communication system, which provides a sound information background for decision makers in the forestry, environmental and political sector.

5.7 Literature

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