A Comparison of Periodic versus Permanent Surveys

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Abstract.—Extensive forest surveys can be periodic or permanent, regional or national, can include midcycle updates or not, or use partial replacement of plots or not. Fifty-two combinations of these and other factors were evaluated, not solely on a statistical basis, but also on their perceived ability to meet various design and customer objectives. These criteria include survey cost, precision and reliability of the results, reporting and customer satisfaction, simplicity, and flexibility. Based on this evaluation of permanent and periodic surveys, we recommend that planners compare their current periodic design to a permanent national design, a permanent regional design, and each of the two with a midcycle update.

The objectives of forest surveys can differ considerably, so various sampling designs and assessment methods are applied. Comprehensive and sensitive monitoring of forest condition is needed to assess environmental effects on forest ecosystems and to ensure the sustainability of those ecosystems. Forest inventories carried out on one single occasion are justified only in rare cases, such as reconnaissance surveys. Monitoring forests demands repetitive assessments over time and remeasurement of sample plots and sample trees.

The time period between assessments and the allocation of sample plots are two important issues in monitoring. Statistical designs for sampling on successive occasions, such as Continuous Forest Inventory (CFI) or Sampling with Partial Replacement (SPR), have been described in the framework of periodic assessments with sampling occasions following, for example, the management planning cycle. The advantage of periodic assessments is the common point in time to which the inventory results can be related.

In extensive surveys, the periodicity of assessments has some major disadvantages: the number of staff members is substantially higher during the field assessment periods, within an inventory cycle there are periods with both very high and very low workloads, expertise can be lost due to the unevenly distributed tasks, and the annual budget is not constant. The organization of periodic assessments has to be flexible to the varying tasks to be accomplished within each year.

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From an organizational point of view, permanent assessments are superior to periodic assessments; in the former, a (constant) proportion of the total number of sample plots is visited each year. Many national forest inventory systems including those in Austria, Finland, France, Sweden, and the US have adopted permanent surveys (table 1). In some countries, the assessment of the annual proportion of plots is conducted region by region (e.g., Sweden and France); in others an annual subsample covering the whole country is taken (e.g., Austria) (EC 1997).

The classical sampling and estimation methods, which have been developed mainly for periodic assessments, have to be adjusted for permanent surveys. One major consequence of applying a permanent survey system is the necessity to update the plot and tree data assessed in different years to one common point in time. This can be done by modifying the CFI and SPR procedures, by introducing estimation methods such as the Kalman filter or Mixed Estimator (ME), which can incorporate updating and projections using growth functions.

The objective of this paper is to present and compare design alternatives for permanent and periodic surveys. This study was initiated by the Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland, to evaluate design alternatives for the third Swiss National Forest Inventory (NFI). We therefore present the evaluation of design alternatives for the example of the Swiss NFI.

SAMPLING METHODS

Many sampling design options exist for both periodic and permanent forest surveys. For each of these designs, there are several possible estimators. Each of these combinations has different cost-effectiveness, level of complexity, and utility. There are three primary sampling methods used in extensive (large-scale) forest surveys.

Table 1.—*Mode of surveying for several European national forest inventories*

Country	Time since first inventory (years)	Inventory period	Assessment scheme	Regional or partial assessments
Austria	30	1986-1990	continuous	fraction of entire area
Finland	70	continuous	by regions	(5-year cycle)
France	20/ 30*	1980-1993	continuous	by region (10-12 year cycle)
Germany	-	1986-1990	periodic	
Italy	-	1985	periodic	
Norway	70	1986-1993 since 1994	continuous continuous	by region fraction of entire area
Sweden	70	1988-1993	continuous	fraction of entire area
Switzerland	10/30*	1983-1985 1993-1995	periodic periodic	

* for some limited areas

Continuous Forest Inventory

The permanent observation of forests has a long tradition, but sample-based forest surveys are a rather recent concept. Stott (1947) introduced a design for sampling on successive occasions called Continuous Forest Inventory. CFI uses a set of permanent sample plots, which are established at the first occasion and remeasured at each successive occasion. CFI plots are selected either randomly or systematically. Plots are monumented, so that they can be measured on future occasions. Estimates are easily obtained with CFI and are particularly good for change estimation. The estimation procedures are simple and results are easy to understand. Additive tables are obtained, where independent estimates of cell values sum up to the row and column totals. Even for more than two occasions, the estimation procedures are clear.

Sampling with Partial Replacement

Sampling with Partial Replacement was introduced into forestry by Ware and Cunia (1962) based on work by Patterson (1950). At the first occasion, assessment and estimation procedures are the same as with CFI. At the second occasion, only a portion of the plots established at the first occasion are remeasured and a set of new plots is added. The remeasured plots are used to develop regression relationships to update all unremeasured plots. A second estimator is based on the new plots. Both estimates are combined and result in more precise estimates of current values than does CFI (Scott 1984). The emphasis can be altered between the estimation of current values and change detection by adjusting the proportion of new and remeasured plots; thus SPR is simultaneously cost-effective for estimates of current values and net change in those values.

Scott (1986) described many of the problems encountered with SPR. One of the major disadvantages is the complexity of the design arising from the number of plot types, which increases geometrically with the number of occasions. The complex estimation procedures become very unwieldy for more than two occasions. SPR estimators can be applied to independently estimate individual row and column cells of tables, as well as row and column totals. However, data developed in this way are not additive; cells will not sum to row and column totals.

Double Sampling

SPR and CFI were originally described as single-phase inventory systems using only field assessments. The desire to increase the cost-efficiency of surveys has led to the development of design alternatives that combine field measurements with auxiliary information mainly obtained by remote sensing techniques. Double-sampling designs include information from two different assessment levels. Double sampling for stratification is a derivative of stratified sampling and is used when the stratum sizes are unknown. To estimate the stratum sizes, a large first-phase sample is drawn. On each of these sampling units, only the stratum in which it falls is recorded. The stratum sizes are estimated as the number of first-phase sampling units falling within each stratum. In forest surveys, aerial photographs are often used to locate and classify the first-phase sample. This stratification on photos can usually be done at a fraction of the cost of ground observation.

Double sampling for stratification can be used to increase the cost-efficiency of sampling on successive occasions. Köhl (1994) describes the sampling design of the second Swiss national forest inventory, which is a combination of SPR and double sampling for stratification and uses CFI-type estimators for current values and change. Scott and Köhl (1994) give estimates for SPR and stratification for up to three occasions and discuss the complexity of estimation.

Periodic Survey Designs

Most countries started with a periodic survey system and have already conducted several cycles of their national forest inventories (NFI). Periodic survey designs are characterized by field assessments conducted across the whole country once every cycle. In spite of the fact that the measurement usually requires more than 1 year to complete, the information is regarded as relating to a single point in time. In Europe, countries such as Germany, Switzerland, and Italy are practicing periodic surveys, while Switzerland is one of the very few countries that has a permanent NFI setup, but it is still applying a periodic survey design.

Permanent Survey Designs

Among the countries having a permanent NFI setup and applying a permanent inventory system are Austria, Finland, Sweden, and the US. The following brief description of their inventory systems is intended to give insight into the multitude of applied inventory systems.

In Finland, a permanent survey design with regional assessments was implemented. The eighth inventory cycle was conducted between 1986 and 1994. Only temporary plots were measured until 1992. Since then permanent plots are being established, so that in the inventory regions of North Finland, 20 percent of the sample plots are permanent. No updating techniques are applied to derive current forest resource results. Estimates of change are obtained by comparing total values and means of two successive occasions as well as analyzing increment cores. In 1990, a special investigation was carried out. Plot data were updated to a common point in time by combining modeling techniques for estimating increment and natural loss, with information on removals from auxiliary sources. In the forest health monitoring program, 3,000 plots distributed over the entire country were assessed twice (1986 and 1990) and were being remeasured a third time in 1995. However, they are not used for updating purposes in the scope of the forest resource assessment.

Permanent surveys with annual national assessments are carried out in Austria and Sweden. The Austrian national forest inventory shifted in 1980 from a 10-year cycle to a 5-year cycle. One-fifth of the entire set of plots is assessed annually at the national level. Due to the short inventory cycle, no updating is applied. To ensure consistency in the estimates of net change, plots are remeasured at approximately the same point during the growing season. Before 1980, estimates for increment were obtained by the analysis of increment cores. Since then, change is estimated by comparing data from two successive occasions.

The Swedish national forest survey established the first permanent clusters between 1983 and 1987 and remeasured them for the first time between 1988 and 1992. During the remeasurement period, temporary plots were also measured. The number of permanent and temporary plots was equal each year. In 1993, budget cuts forced the shift from a 5-year to a 10-year remeasurement cycle. However, the number of temporary plots measured each year will be the same as in the inventory period between 1988 and 1992. When results for the entire country are estimated, the changes observed on permanent plots are used to update the older data from temporary plots. Changes are computed by a mixed approach. On permanent plots, the differences between two occasions are taken to calculate net change; on temporary plots, growth is estimated by the analysis of tree ring cores. For long-term timber forecasts, the so called Hügin system is applied, in which trees from temporary plots are updated using matching trees from remeasured plots.

In the US, the Forest Inventory and Analysis (FIA) units of the USDA Forest Service have been conducting permanent regional surveys since the 1940's. These surveys are typically conducted on a state-by-state basis within each region on a cycle of 5 to 15 years. Although some units have used SPR, most plots are permanent. Double sampling for stratification is used at each measurement using current aerial photography. Most units do not update values between occasions, but midcycle update surveys (Scott 1979) have been conducted in special cases. For national assessments, various techniques have been used to update the estimates to a common date.

The USDA Forest Service and the Environmental Protection Agency, in cooperation with other agencies and states, have been conducting the Forest Health Monitoring (FHM) program since 1990. The purpose of the program is to provide a mechanism for detecting widespread change in forest ecosystems due to human and natural disturbances. The design uses a fixed grid across the entire US, with one ground plot every 62,500 ha. However, one-fourth of the grid is measured each year with the rest of the grid being measured in the succeeding years. Thus, plots are remeasured on a 4-year cycle. This interpenetrating or rolling survey design is expected to provide precise estimates of change after the first 4 years.

There is a strong interest in the US in providing forest resource data more frequently than is currently provided by FIA but with more detail than can be provided by FHM. Research is being conducted by the North Central and Southern FIA units on sampling a portion of all states each year and combining this with remotely sensed data to provide timely estimates with adequate levels of detail annually.

ESTIMATION METHODS

Many methods exist for developing estimates from a sample design. Simple means and variances are appropriate for the CFI design. Typically, the more complex regression estimators are used for SPR, but the CFI estimators can also be applied. This results in a loss of precision but a gain in simplicity.

One way to improve estimates in successive surveys is to use the Kalman Filter (Kalman 1960). It was developed for time-series data and adapted for forest surveys by Dixon and Howitt (1979). They showed that it simplifies to the SPR estimator when no control information was used, or any prior information. It is a recursive estimator, in that the estimates at time t are developed by first estimating values at time 2 based on time 1, then time 3 based on time 2, etc.

A related method is the Mixed Estimator (Theil 1971). The regression or Generalized Least Squares (GLS) approach is used for the sample data. When prior information in the form of growth models is available, then using them can improve the sample-based estimates. The sample data and the model predictions are then set in a single estimation framework to provide more precise resource estimates (Van Deusen 1996).

One of the difficulties with each of the estimators, except the CFI estimator, is the lack of additivity of tables. By this, we mean that if the estimators are applied to each cell in a table and to the table margins, the rows and columns will not sum to the margins. Although this results in precise estimates for each cell independently, users do not like or understand this characteristic (Scott 1986). A method of addressing this problem was introduced by Schreuder *et al.* (1988). However, a more direct and simple means is needed for large-scale, repetitive surveys.

UPDATING AND PROJECTION USING GROWTH FUNCTIONS

Users of forest resource data want precise estimates frequently. One method of providing this information frequently is to update the survey data without further field sampling.

One simple alternative for producing estimates for succeeding years after a survey is to use the same results without modification. However, this results in estimates with some (unknown) bias. If the survey results were precise to begin with, then the mean squared error (bias squared plus variance) may be preferable to other alternatives. A second approach is to update the data based on past rates of change, such as using the SPR regression estimators to predict future change. A third approach is to use growth and yield models. Both of the modeling alternatives introduce prediction errors and, perhaps, model errors if the model is not applicable to the survey data. This holds especially true if growth of uneven-aged mixed species stands has to be modeled.

Growth and yield models are typically developed for commercial tree species to predict individual tree or stand growth and standing volume at some point in the near future. Some models have been developed for survey applications, rather than forest management planning. One such model is TWIGS (Belcher *et al.* 1982), which was initially developed in the Central United States using both inventory and silvicultural research data. In this way, all tree species present in the region can be modeled. Prediction intervals are usually 1, 5, or 10 years. Many models also have components to predict mortality and ingrowth, and can be used to manipulate harvest levels. Hansen (1990) used TWIGS to update unremeasured plots in an undisturbed stratum, which was then combined with a complete remeasurement of the disturbed stratum.

In forest resource surveys, there is at least as much interest in the rates of change as in the current values. Although net change between surveys is helpful, ingrowth, accretion (survivor growth), mortality, and harvest levels provide a more useful picture. While temporary surveys can provide estimates of net change, only remeasured plots can provide estimates of the components of change. Van Deusen (1989) has described the estimation of these components in an SPR context.

DESIGN CRITERIA

A host of possible alternatives are available in the planning of an extensive inventory on successive occasions. From the viewpoint of the inventory planner, the design alternatives include several sample selection rules, sample sizes, and the use of additional information, e.g., from maps or aerial photographs. We identified seven characteristic properties of possible sampling alternatives. Those properties form the framework within which the most appropriate alternative is to be found.

1. **Mode of inventory**. An inventory can be permanent or periodic.
2. **Allocation of sample plots**. A permanent inventory means that part of the entire sample is surveyed annually. These samples can be distributed over the entire nation or by region.
3. **Subsample**. In addition to the annual survey of one region or the entire nation, other subsamples could be surveyed. In regional surveys, for example, a national subsample could be surveyed annually.
4. **Several subsamples**. Just as one network of plots can be allocated nationally or regionally with a specified remeasurement period, a second network can be established that has a different combination of allocation rule and measurement period. For example, one annually surveyed sample plot network could be used for the estimation of some few key attributes. And a second network, including larger sample sizes, could be surveyed at intervals of several years, which serves for interim reports at the national level.
5. **Mode of inventory for the subsamples**. Each subnetwork can be surveyed annually or periodically.
6. **Allocation of the subsamples**. Each subnetwork can be surveyed at a regional or national level.
7. **Permanent samples or partial replacement of samples**. Each network or subnetwork can be based either exclusively on permanent inventories or on replacing some plots with new ones.

The specified seven design properties were combined to determine possible sampling alternatives for both periodic and permanent survey designs in the scope of the third Swiss NFI. Figure 1 shows the possible combinations of the seven design properties as well as the resulting sampling alternatives. Some of the possible combinations are not practicable and are not shown.

COMPARISON FACTORS

To select the optimal design among the alternatives, clear evaluation criteria have to be given that involve a variety of perspectives, such as statistical, logistical, economic, and political information needs. Precision, cost, and cost-efficiency are three well-known evaluation criteria. For each alternative, there exists an optimal combination of sample sizes, which can be defined in one of two ways: minimizing the cost for a fixed precision level, or minimizing variance for a fixed cost. To compare different design alternatives, they must either reflect the same amount of cost or result in the same level of precision. However, the evaluation should not be based on cost-efficiency alone, but should involve other criteria. Beside costs, the criteria are accuracy and reliability, customer satisfaction, simplicity, and flexibility. Projection and updating issues have a decisive impact on the survey design and should be included in the evaluation process.

The suitability of the various design alternatives can be investigated with respect to the comparison factors described above. To clarify the evaluation process, the possible design alternatives given in figure 1, i.e., the sampling design alternatives for the third Swiss NFI, are used.

Costs of the Inventory and Organization

Permanent inventories are preferred to periodic ones based on their even budgets over time. Startup costs are reduced and the experience of the staff is maintained, which results in increased productivity. Permanent regional surveys are preferable, because the field appraisals and (unproductive) travel is concentrated in a smaller area. Subsamples raise the complexity of the procedure and reduce the productivity, especially if they are spread over the whole country. If plots are well monumented, productivity is also increased if only permanent samples are used. In view of the inventory costs and the organization, a permanent, annual, regional survey without subsamples with no replacment seems to be the most suitable alternative (fig. 1, alternative 48).

Accuracy and Reliability

No inventory is beneficial unless it is accurate (low bias and small sampling errors) and reliable (procedural and computational errors are avoided and the survey regarded as trustworthy). Permanent surveys are preferred because expertise is retained. Regional surveys without subsets are preferred, because their simplicity makes them more reliable. Some design alternatives may necessitate the development of growth models to update the values of previously measured sample plots to the current time, which can greatly improve precision. However, this dependence makes the estimation procedures more sophisticated and may lead to reduced reliability. Some sample plans are more robust against the occurrence of errors than others, e.g., methods that replace old sample plots by new ones, avoiding reliance on a single unrepresentative sample. However, using complex SPR estimators with them may come at the cost of reliability, because their regression estimators can be influenced by outliers. A permanent NFI with annual, regional surveys without subsamples, but with the replacement of permanent samples by new samples, seems to be the most appropriate alternative for accuracy and reliability (fig. 1, alternative 47).

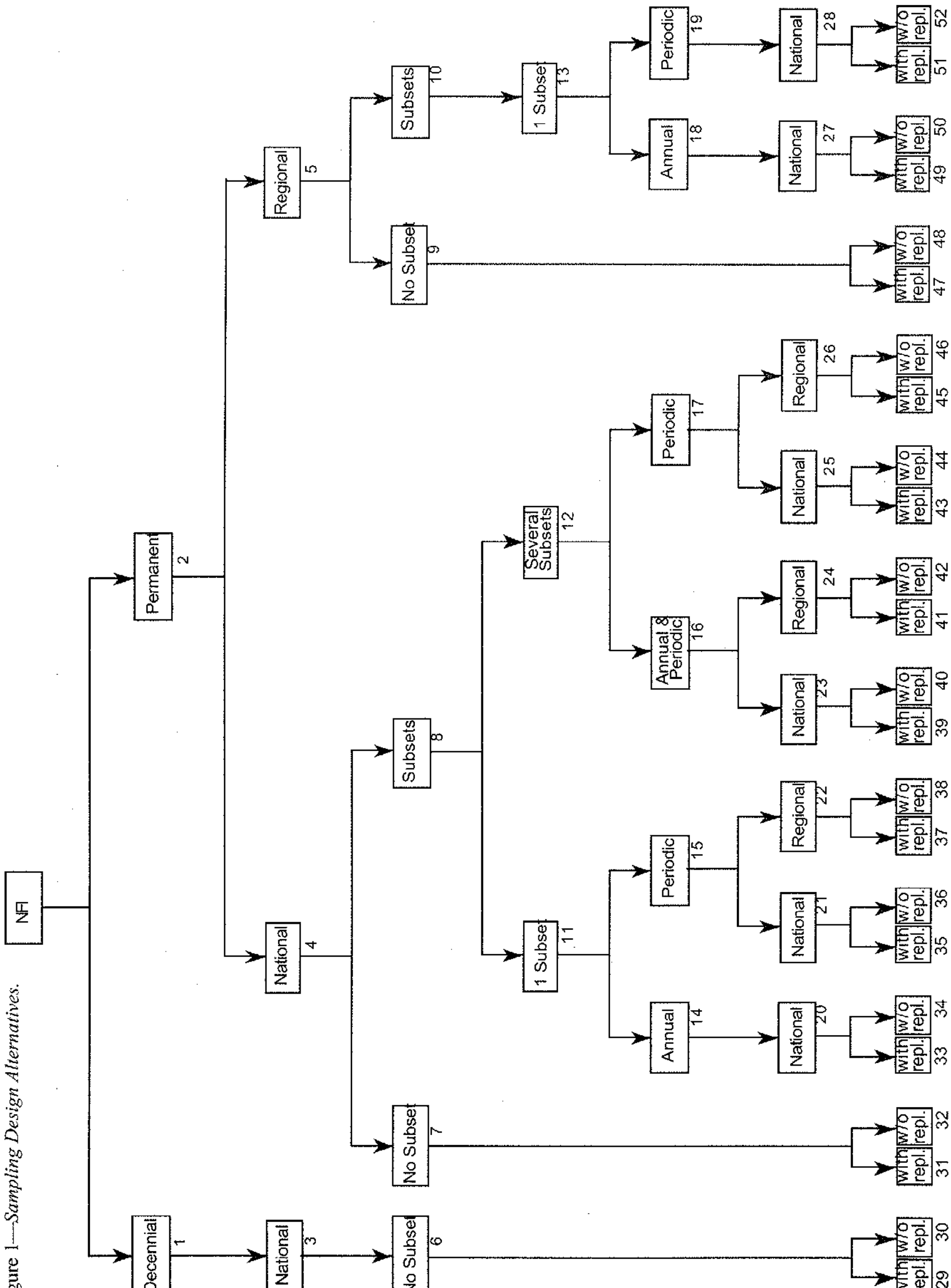

Figure 1—*Sampling Design Alternatives.*

Publication of the Results and User Satisfaction

A main drawback of periodic inventories is the long time between reports. However, annual reports in permanent national inventories may be too frequent and too imprecise. Permanent regional surveys permit periodic reports at regional and national levels, thus meeting the needs of local and national user groups. Efficient and unbiased estimates can be generated for each cell in a table, but some designs lead to estimators that do not add to the estimate of the table total. Many users will not see such tables as credible. Complete remeasurement is preferred, because it provides better estimates of change and is easier to understand. Three designs that perform well in this category:

permanent regional survey with periodic national reports (fig. 1, alternative 52)
permanent national survey with periodic national reports (fig. 1, alternative 21)
permanent national survey with periodic regional reports (fig. 1, alternative 22)

The key is to provide analytical results periodically and at both the regional and national levels, accomplished through the use of subsamples. This result differs greatly from that for the other factors.

Simplicity and Plausibility

Either a periodic inventory at a national level or a permanent inventory at a regional level are to be favored for reasons of simplicity and plausibility. Subsamples should be avoided. The simple CFI estimation procedures can be used both at national and regional levels. The exclusive use of permanent samples promotes the simplicity and plausibility of the inventory design. The preferred method is a CFI design at the regional or national level (fig. 1, alternatives 1 and 48).

Flexibility

Permanent inventory methods are more flexible than periodic ones, because changes and additions to the list of attributes to be assessed are possible each year. Regional surveys can be adapted to the regional (local) requirements. Subsets can provide opportunities to be flexible, but there are disadvantages due to the added complexity. Thus, a permanent, regional inventory without subsamples is preferred for flexibility (fig. 1, alternative 9).

FOUR SELECTED INVENTORY ALTERNATIVES

In summary and in consideration of the advantages and drawbacks of the design alternatives to be favored under various aspects, it becomes obvious that a permanent, regional survey without subsamples and with the exclusive use of permanent sample plots (fig. 1, alternative 48) is preferable to the other design alternatives. If, however, individual comparative factors are weighted stronger than others, other design alternatives might be more suitable for the third Swiss NFI. Hence, four design alternatives are described in the following. Each of the four alternatives can be implemented with or without the replacement of sample plots.

Alternative 1: Periodic National Survey

This design alternative corresponds to the current Swiss NFI design. Sample plots spread over the whole country are assessed once during the inventory cycle (at present 10 years) (fig. 1, alternative 29 or 30). Each measurement requires 3 years to complete. Subsamples are not used.

The design lacks constancy in its annual budget, so it ranks poorly in cost. Due to its simplicity, the design is easy to understand, leads to additive tables, and allows for regional or national survey results. The evaluation procedures are clear even after several measurement cycles, and the design is regarded as reliable and robust. Disadvantages are that the experience gained by the staff, especially that of the surveying crew and computer scientists, is lost between surveys. New attributes can be added only every decade, and the production of interim reports is not possible. The actual design of the NFI is a design of contradictions. For many aspects, it ranks at the top, but for costs, flexibility, and continuity of the efforts, it has clear deficiencies.

Alternative 2: Permanent Regional Survey

The permanent regional survey is much the same design as the periodic national survey, but the country is divided into regions, each containing approximately 1/10 of the samples of the second Swiss NFI. This is accomplished by combining cantons, i.e., federal states. Ideally, the survey of each region can be concluded within 1 year. Hence, the inventory cycle for the national survey corresponds to the current 10-year cycle. Subsamples are not used; however, the forest damage survey could be used for interim reports. In figure 1, the procedure corresponds to alternative 47 (with replacement) or alternative 48 (exclusively permanent sample plots).

The method is efficient and appears to have relatively simple estimation procedures and a favorable cost structure. It leads to reliable results with low estimation errors and can easily be adapted to regional peculiarities and demands. Regional events, such as wind damage, can be readily assessed with this design. It seems to be less favorable, however, for national purposes. The time between surveys is still long (10 years) for an individual region. Changes to the attributes likewise requires 10 years to complete at the national level. Thus, this alternative is especially suitable to meet regional information demands. But for most of the questions raised nationally, this concept is less appropriate.

Alternative 3: Permanent National Survey with a Periodic National Update

The third alternative differs considerably from the two alternatives already introduced. A fixed percentage of all sample plots of the NFI is surveyed each year. If a 10-year cycle is used, 10 percent of the samples would be measured each year. These samples will be spread over the country, forming 10 different sample sets that will be surveyed independently of one another. Every year new estimates of the current status and change can be calculated. However, the low number of sample plots measured in the current year results in relatively high sampling errors. A subsample that is more often assessed, e.g., every 5 years, could be used to improve the statistical properties of the design. The more frequently assessed subsample could be used to update the rest of the plots to a common date and would facilitate national reports of higher estimation accuracy. Thus, the method corresponds to a variation of SPR but increases the complexity of the survey accordingly (Scott 1986, Köhl 1994) (fig. 1, alternative 36). New samples can be added (fig. 1, alternative 35) without greatly increasing the complexity of the procedure.

With this alternative, new attributes are easily and rapidly introduced. The distribution of the effort is nearly constant. Because national results are more frequent, the expected satisfaction of the users is greater than in the first or second alternative. However, travel costs are comparatively high, since samples are surveyed in the entire country each year. Because the estimation procedures are very complex due to the need to develop and use a growth model for updating, the evaluations are not easily understood, the tables are not additive, and it is doubtful whether the available samples and funding will achieve the accuracy of the first and second alternatives. And, it is difficult to change the inventory cycle in this procedure or to concentrate the sampling network on a specific region of interest.

Alternative 4: Permanent Regional Inventory with National Updates

With the Permanent Regional Inventory with National Updates design, one region is surveyed each year. After several years, instead of measuring one region, a group of samples distributed over the whole country are surveyed. Thus, the number of regions is reduced by the number of times during the cycle a national update is performed. In a 10-year inventory cycle with a national update every 5 years, the country would need to be divided into eight regions. By means of the national subsubsample, the regional surveys are updated to a common year. Thus, it is possible to produce results at a national level during the update years. Because this is an SPR design, it includes all the disadvantages and the complexity of partial replacement of plots. This procedure is shown in figure 1 as alternative 51 (with new samples) or alternative 52 (exclusively permanent samples).

The design proves to be cost efficient for estimating regional and national results. During the years when the national network is surveyed, the cost efficiency drops because of the higher travel costs. The calculation of regional results does not require any updating, hence the design is not very complex here. The evaluation of national results becomes complex, however, and results in nonadditive tables. To introduce new attributes at a national level requires a comparatively long time. This design has not been found to be distinctly superior or inferior to other design alternatives.

UPDATING OF THE INVENTORY DATA

Some of the design alternatives require updating inventory data to a common date. Updating procedures are based on projection models that can predict the current state. This implies the prediction of the individual tree history: ingrowth, mortality, cut, or survivor tree. Likewise, the increment of each survivor tree must be estimated.

The field measurement period for almost all national inventories in Europe covers several years. The necessity of relating the inventory data to a common date depends greatly on the field period. The problem of a common date is handled differently among countries. The field measurement period of the first German national forest inventory lasted from 1985 to 1990. The inventory data refer to a reference date, but the assessed data were not updated. Thus, indication of a reference date seems to be rather questionable, and is unjustifiable from a methodical point of view. The Swiss NFI does not specify a date that all data refer to. Until now, the inventory period consisting of several years has been generally accepted and the wish for a reference date has never been expressed by users.

The Swedish NFI provides results for 5-year periods. Since 1981, annual reports have been published that generally rely on data surveyed over the past 5 years. An updating of data is not performed at the national level (Söderberg 1986). A special technique of updating is used for regional estimates of the long-term use potential. The Hügin System substitutes recent data from comparable trees for missing data for unremeasured trees.

The STEMS projection system (Belcher *et al.* 1982) is used by the North Central Forest Inventory and Analysis unit in the United States. STEMS has much of the functionality of a growth and yield model but was developed for prediction of inventory data. It can be regarded as a regional model that can be applied to all tree species--not just to the commercial ones. However, it is not as accurate as forest growth models, because site and stand history data are missing or not as reliable as with long-term forest growth plots.

CONCLUSIONS

The combination of the specified seven properties of sample designs leads to many possible design alternatives for the forest inventories on successive occasions. The most appropriate design has to be selected on the basis of clear objective criteria. Depending on the weighting of the decision factors, different alternatives may be selected. Therefore, a robust, cost-effective design that meets most requirements should be selected. If the design is changed, additional efforts must be made to alter the estimation and publication procedures. Likewise, the impacts of an increase in the complexity of the design should not be underestimated.

In the search for an optimal inventory design and the appropriate estimation procedures, the increased requests for information on the non-productive functions of the forests should not be overlooked. Examples include criteria and indicators that quantify the sustainability and functions of the forest, or assessments of the protective function of forests. In general, these characteristics cannot be directly measured, rather they are recorded via definitions or deduced via models. Since objective data are not collected for this new group of characteristics, complex inventory designs make their inclusion more difficult.

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