2nd International Workshop on Forest Inventory Statistics

*Proceedings of the workshop organized
by Forest Management Institute of the Czech Republic
in collaboration with
Swiss Federal Institute for Forest, Snow and Landscape
Research WSL*

*Workshop is organized in frame of the Sub-project
CH-003-202: Sharing and Exchange of Methodologies
in National Forest Inventory – NFI exchange*

Kromeriz 24th – 26th May 2016 Czech Republic

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Agenda of the 2nd International Workshop On Forest Inventory Statistics, Kromeriz 24th - 26th May 2016 (version 16th May 2016)

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13:15–13:45	**Berthold Traub**[*]**, Ivo Kohn**[**]**,** *WSL Switzerland, **ÚHÚL Czech Republic: *Processing and analysis of national forest inventory data - insights into the current Swiss and Czech systems*
13:45–14:15	**Karel Drápela**[*]**,** Zdeněk Adamec[*], Radim Adolt[**], * MENDELU Czech Republic, **ÚHÚL Czech Republic: *Individual tree crown projection area models based on data from the National Forest Inventory of the Czech Republic*
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Activities of Forest Management Institute

Jaromír Vašíček

Forest Management Institute Brandys nad Labem, Headquarters , Nábřežní 1326,
250 01 Brandýs nad Labem Czech Republic
vasicek.jaromir@uhul.cz

The Forest Management Institute (FMI) is a government organization established by the Ministry of Agriculture of the Czech Republic (CR) in 1935. The FMI operates as a service of the Ministry of Agriculture for forestry. FMI`s headquarters is situated in Brandýs nad Labem and nine branches are located regionally. Main activities are:

National Forest Inventory (NFI) – the first nationwide statistical forest inventory in the Czech Republic. NFI is based on mathematical-statistical basis, which allows an objective and independent assessment of the actual state and development of forests in the CR. The aim of NFI is to provide comprehensive data both in terms of environmental sustainability and in terms of economic use. The first cycle of the NFI was carried out in 2001–2004, the second one in 2011–2015.

EU Timber Regulation. The FMI is named as an „authorized person" in this field. The aim of this regulation is to prevent illegally harvested timber on the EU market.

Forest Reproductive Material. The FMI is named as an „authorized person" in this field. It performs expert operations and control in the field of forest reproductive material management.

Regional Plans of Forest Development (RPFD) are methodological tool of the state forest policy. According RPFD are recommend principles of forest management especially in creation and approval of Forest Management Plans/Guidelines.

Support of Authorities State Forest Administration and Game Management. It represents professional and technical support to the regional offices of State Forest Administration and Game Management.

Information and Data Centre. The FMI administrates and operates the central databases and archives of forest management and game management.

Expert Opinions. The FMI is enlisted in the list of institutes qualified for expert activities pursuant to § 21 of Act no. 36/1967 Coll., on experts and interpreters, as amended. The FMI elaborates expert opinions for courts, police and state administration.

Forest Management Counselling. The FMI provides counselling for forest owners especially in the financial aids in forestry, legal requirements for the forest management and in activities specified in the FMI Foundation Deed.

Forest pedagogy is focused to children in kindergartens and pupils in primary schools. The FMI carries out events in the forest with the forest wardens about the forest.

The third Italian National Forest Inventory: state of implementation, methodological issues and first results of the survey

Patrizia Gasparini

Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per il Monitoraggio e la Pianificazione Forestale (CREA – Forest Monitoring and Management Research Unit), p.zza Nicolini 6, 38123 Trento, Italy
patrizia.gasparini@crea.gov.it

The current Italian National Forest Inventory (NFI) was established, for the first time, in the year 2001. As it focused on the assessment of forest biomass and carbon content, it was called National Inventory of Forests and forest Carbon pools (INFC). In the 1980s, a first sample-based national inventory had been already conducted using a one-phase systematic sampling, with a 3x3 km grid. INFC adopted, instead, tessellated sampling with a 1x1 km grid, and a three-phase design with a double stratification: the first based on land cover/use classes and the second on forest categories, both classified by administrative regions. The first-phase sample is used to classify the land use/cover by photo-interpretation. The second-phase sub-sample is surveyed in the field to classify definitively the forest cover/use according to FAO definition, to identify the third phase strata and collect information on many qualitative attributes. Finally, the third-phase is used for measurements on trees, regeneration, shrubs and deadwood in a sub-sample of plots. The first INFC cycle (INFC2005) was conducted in the years 2002-2006. During 2013 the second INFC cycle (INFC2015, third Italian NFI) was started. The 301,000 sampling points of the previous cycle were re-classified on digital orthophotos. The land cover/use was assigned to identify the changes occurred between the two cycles. Although the forest area will be estimated definitively after the next field survey, preliminary forest area estimate were calculated. Results confirmed the increase of forest area for all Italian regions. The rate of forest area increase for the period 2005-2015, however, is lower compared to that of the period 1985-2005, approximately 53,790 ha year-1 and 77,960 ha year-1 respectively. As actual cost and time constrains affect the possibility to carry out two distinct field phases, a different sampling strategy should be defined for the upcoming surveys, which are planned to start in 2017. The possibility to carry out both qualitative and quantitative measurements at the same time using different sub-sample is discussed, as far as the opportunity to use the information collected for post-stratification, to identify the sampling strata for INFC2015.

Efforts to improve the National Forest Inventory in Poland

Andrzej Talarczyk

Bureau for Forest Management and Geodesy, Sękocin Stary, ul. Leśników21, 05-090 Raszyn, Poland

andrzej.talarczyk@zarzad.buligl.pl

The NFI in Poland commenced in 2005. The first cycle covered the 2005–2009 period. Since then, the NFI has been performed on a continuous basis, providing a complete and up-to-date set of results every year. The second full inventorying cycle covered the years 2010-2014., the third started in 2015. The NFI in Poland is carried out by the Bureau for Forest Management and Geodesy (Biuro Urządzania Lasu i Geodezji Leśnej), by virtue of a contract with the Directorate-General of the State Forests National Holding.

The primary aim of the National Forest Inventory in Poland is to assess condition of the country's forests of all forms of ownership and any large-scale changes that may be occurring in them. The inventory supplies reliable information on forests, in particular regarding to the species and age structure, health condition and presence of damage, forest site type structure as well as an independent estimation of growing stock, current volume increment and main-use felling volume.

Continuous efforts are undertaken to improve methodology of both calculations and field work. This presentation addresses the issues of sample representativeness, sample size and sampling design of the Polish NFI and their influence on the accuracy of results.

The sampling and estimation methods of the Romanian NFI: an example of two phase sampling with clustered plots

Olivier Bouriaud[1], Gheorghe Marin[2]

[1]National Institute for Research and Development in Forestry, Bulevardul Eroilor nr. 128, Voluntari, Ilfov, Romania
[2]Inventarul forestier național, Bulevardul Eroilor nr. 128, Voluntari, Ilfov, Romania
obouriaud@gmail.com
ghmarin@roifn.ro

The Romanian NFI was initiated in 2006, being the first statistical inventory for this country, conceived as a two-phase sampling. A great majority of the forests are located in mountain, with an often reduced access. The forest vegetation area was expected to be in excess of 7 million ha. The ground sampling, inspired from those implemented in Germany, Austria and Switzerland, was meant to address these difficulties. The first phase consists in photo-interpretation of aerial images on a very dense network. The second phase ground sampling is based on systematic grids of ground plots with a density depending on the relief, thus creating a pre-stratification. Ground plots are constituted of clusters of 4 subplots, subplots are mapped plots of fixed size. The estimation methods are based on two-phase sampling for stratification whereby both pre-stratification and post-stratification are being implemented. The requirements for the reporting imposed to produce not only country-level estimations but also region- and relief-level estimations. The pre-stratification was therefore based on these requirements in order to improve the error estimation and to ensure the additivity at country level.

The National Forest Inventory in the Republic of Bulgaria - a recognized need

Spas M. Todorov

Ministry of Agriculture and Food, Forestry Sector Development Directorate, 1040 Sofia 55 Hristo Botev boulv., Bulgaria
stodorov@mzh.government.bg

The Republic of Bulgaria possesses various natural assets. The forests are between the most valuable. The organized work on forest inventory and forest management was initiated in 1901. During last decades the forest inventory has been conducted by forest stands on forest typological classification basis. Actually, all forest areas are inventoried according to this technology and are managed in accordance with the forest management plans.

Adapting the forest inventory to changing requirements the Ministry of Agriculture and Food aims: 1) to improve the information about the status and dynamic of the forest resources and processes for the national forest policy and sustainable management of the forest sector; 2) to fulfill the requirements for the implementation of national and international commitments concerning the form and accuracy of provided forest statistic data to DG Eurostat/EC, FAO/UN, Forest Europe; 3) to overcome the difficulties with the access to the relevant international programs, projects and funds.

The project for conducting a National forest inventory is increasingly important in order to support the protection of the ecosystems and the sustainable management of the natural resources in Bulgaria through improvement of information about the forests and forest territories. The expected results is the strengthening of the Bulgarian capacity to collect, analyze, disseminate and utilize strategic information required for the planning and development of activities in the forest territories, as well as the monitoring of their implementation, aiming to support Bulgaria's efforts to implement the forest measures under the National Rural Development Program 2014-2020 and the forest sector development. This will be achieved through developing analytical and practical capacity for design and undertaking National Forest Inventories based on modern approaches and international best practices. The project will be realized with consultant support provided by the World Bank and the WSL, Switzerland.

Key words: forest inventory, changing requirements, aims, developing capacity, National Forest Inventory (NFI).

The German NFI - upcoming methodological and technological issues

Susann Klatt

Johann Heinrich von Thünen-Institut, Thünen-Institut für Waldökosysteme,
Alfred-Möller-Straße 1, Haus 41/42, 16225 Eberswalde, Deutschland
susann.klatt@thuenen.de

The German National Forest Inventory (NFI called "Bundeswaldinventur" = BWI) uses a standardized sampling procedure. The German NFI is a large-scale systematic cluster sample, which is assessed every 10 years periodically. The survey focusses not only on the state of forests, but also on changes in forests in the last decade(s). In addition, the NFI is the basis for forest development and timber resource model scenarios. It is a one-phase terrestrial sampling inventory, which uses permanently marked sample points distributed in a 4 km x 4 km quadrangle grid (basic grid), whose resolution has been increased on a regional basis to a 2.83 km x 2.83 km or 2 km x 2 km quadrangle grid at the request of the Federal States. The acceptance of additional densification seems to be continuously strong for the time being.

The fourth National Forest Inventory (NFI 2022) is the third successive survey throughout whole Germany. Complete data for many objects are already available from former surveys 2002 and 2012, from the inventory study 2008, carbon inventory 2017 and several specific inventories in the federal states, which will broaden research possibilities after the forth inventory to time series analysis.

The basic principle for the next inventory concept is, that changes in methodology should only be done where they are necessary. The inventory must respond in a way that it is able to meet new demands of economy, ecology and society. New methodologies need to be downward compatible. Detected errors may not be continued.

Following innovations and technological problems are discussed:
- Further development of the forest development and timber resource model
- Optimization of stand space functions
- Quantitative indicators for structural diversity
- Integration of remote sensing data as additional NFI data (small area estimators, trees outside forest)
- Representative assessment of state forest (national property)
- Change from Bdat to TapeR
- Diameter measurements for stem taper via digital terrestrial photogrammetry
- Regionalization of growth functions for NFI and the forest development

and timber resource model
• Assessment of the FAO definition in addition to the national forest definition

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FAO support to national forest monitoring and the open foris initiative

David Morales-Hidalgo

Forestry Officer. FAO, Rome, Italy.
Food and Agriculture Organization of the United Nations
david.morales@fao.org

FAO has been monitoring the world's forests since 1946, providing a consistent approach to describing the world's forests and how they are changing. The report depends on the quality, and reliability of the country data. As in the last FRA reports, FRA 2015 stresses once again the need to improve the quality of the data. Improving the reporting quality requires countries with good capacities on national forest assessment. Since year 2000, FAO has been providing support to member countries with the aim of strengthen national/institutional capacity for long term forest monitoring. The support has been not just about inventories and accumulating forest data where there was none before through field or remote sensing surveys. Rather, it is a process that aims at long term monitoring on their national forest and tree resources, with a focus on the data analysis for national level decision makers. Currently, the number of countries that have finished their first ever National forest assessment with FAO's support is 18, however there are other 17 close to end in the next two years. Tanzania, Panama, Ecuador, Panama, Comoros Islands had successfully finalized their first round of data collection recently, and Brazil, Bangladesh, Paraguay, Angola, Peru, Bhutan, Chile, Republic of Congo, Ethiopia, Papua New Guinea, Paraguay, Solomon Islands, Uganda, Uzbekistan, Viet Nam and Zambia had started or are almost finishing their data collection. With the aim to provide a better support, FAO had prepared the Voluntary Guidelines on National Forest Monitoring, document that is compiling years of FAO's experience and will serve member countries to strength National Forest Monitoring Systems. FAO support to National Forest Monitoring, had produce a positive impact, and not only in improving forest data, but as well in the use of it. Countries are now more prepare to use the data in their own needs and to attend the international reporting needs, such as SDG, FRA, the 2030 Agenda for Sustainable Development, the Paris Agreement among others. In a complementary effort, FAO is promoting the Open Foris inititative (www.openforis.org), which provides member countries and different users the possibility to share and use free open-source solutions for environmental monitoring.

Repeated application of an upper diameter model

Ambros Berger

Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und
Landschaft, Seckendorff-Gudent-Weg 8, 1131 Wien, Austria
ambros.berger@bfw.gv.at

The Austrian NFI uses the upper diameter D03H at 30% of the tree height. The measurement of this diameter contains a lot of information about the tree stem shape, but since it is an optical measurement, it carries a relatively high uncertainty. It also requires time and effort and consequently is expensive. For this reason, the Austrian NFI employs diameter increment models for most of the sample trees. The model mainly uses the increment of the dbh which is measured on every sample tree in every inventory period. We take a look at the long term effects (over 35 years) of the repeated appli cation of the upper diameter increment model for Norway Spruce.

Domain estimation and poststratication in national forest inventory

Adrian Lanz and Berthold Traub

Swiss Federal Institute for Forest, Snow and Landscape Research WSL
Zürcherstrasse 111, 8903 Birmensdorf, Switzerland
adrian.lanz@wsl.ch
berthold.traub@wsl.ch

Radim Adolt and Jiří Fejfar

Forest Management Institute Brandys nad Labem, National Forest inventory
Methodology and Analysis, Branch Kroměříž, naměstí Míru 498, 767 01 Kroměříž,
Czech Republic, Branch Kromerz
náměstí Míru 498, 767 01 Kroměříž, Czech Republic
adolt.radim@uhul.cz
fejfar.jiri@uhul.cz

The sampling frames of the national forest inventories in Switzerland and the Czech Republic extend over the entire territory of the respective countries, and in both inventories a unique systematic grid denes the distribution of the sample plots for terrestrial data collection. On the other hand are the results not only requested for the entire country, but for various geographical domains of interest, such as administrative units or forest types. The former is an example of a domain of known, the latter of unknown size, and in both
cases we assume a known attribution of plot (centres) to the domains.
In this study, we investigate domain estimation and poststratication under the innite population (or Monte-Carlo) approach to forest inventory. It turns out that the choice of estimator is not clear-cut, but depends case by case on the availability of auxiliary data, the size of the domains of interest and on the distribution of the target variable over the study area. This nding contrast to a certain degree with the requirement for simplicity and transparency in the computation of public statistics, as well as in additivity and therefore compatibility of the estimates in the result tables. The study highlights the theoretical background and gives numerical examples as a basis for identifying optimal solutions in national forest inventory application.

References

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A new variance estimator for spatially restricted sampling designs

Radim Adolt

Forest Management Institute Brandys nad Labem, National Forest Inventory Methodology and Analysis, Branch Kromeriz
náměstí Míru 498, 767 01 Kroměříž, Czech Republic
adolt.radim@uhul.cz

A new design-unbiased estimator of variance of the total estimator has been derived from the continuous Horwitz-Thompson theorem formulated by Cordy (1993). The estimator is derived from the approximation of pair-wise sampling densities by densities corresponding to uniform random sampling in 2D space. On top of this approximation the estimator was adjusted to allow for random sample sizes in the geographical domain of interest, which makes the estimator geographically additive, computationally effective and unbiased unconditionally on realized sample size. The estimator is shown to be almost identical with another one, used by many authors, but justified by different statistical reasoning.

A functional regression model for inventories supported by aerial laser scanner data or photogrammetric point clouds

Steen Magnussen

Canadian Forest Service, Pacific Forestry Centre, 506 Burnside Road West, Victoria, British Columbia, V8Z 1M5, Canada
steen.magnussen@canada.ca

Forest inventories with a probability sampling of a target variable Y and a potentially very large number of auxiliary variables (X) obtained from aerial laser scanner or photogrammetry are faced with the issue of model and variable selection when a model for linking Y to X is formulated. To bypass this step we propose a generic functional regression model (FRM) for use in both a design- and a model-based framework of inference. We demonstrate applications of FRM with inventory data from Germany. The generic FRM achieved results that were comparable to those obtained with more traditional approaches based on model and variable selections. The proposed FRM generates interpretable regression coefficients and enables testing of practically relevant hypotheses regarding estimated models.

The estimation of periodic volume increment from permanent inventories with pps-sampling design

Gerald Kändler and Dominik Cullmann

Forstliche Versuchs - und Forschungsanstalt Abt. Biometrie und Informatik,
Wonnhaldestraße 4, 79100 Freiburg, Deutschland
gerald.kaendler@forst.bwl.de
dominik.cullmann@forst.bwl.de

Periodic volume increment is an essential target variable when analyzing repeated forest inventories. Permanent designs allow the estimation of all components of change which are required for calculating volume increment of a period between two consecutive surveys for any stratum with a sufficient number of permanent samples (i.e. with repeated measurements).

PPS (probability proportional to size) sampling design like angle count sampling (ACS) exhibits a specific feature with sample trees observed on two consecutive occasions as their respective inclusion probabilities at both points in time change due to diameter growth. Thus, different design-based estimators of volume increment may be used. We present the three estimators for volume increment known from literature using the example of the NFI of 2002 and 2012 of Baden-Württemberg. The methodology is explained, including diameter and height growth models which are required for the estimators. Moreover, some problems and challenges associated with the different approaches like the issue of additivity are addressed and discussed.

Processing and analysis of national forest inventory data - the current Swiss and Czech systems

Berthold Traub[1] and Ivo Kohn[2]

[1]Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland
[2]Forest Management Institute Brandys nad Labem,National Forest Inventory Methodology and Analysis, Branch Kromeriz, náměstí Míru 498, 767 01 Kroměříž, Czech Republic
berthold.traub@wsl.ch
kohn.ivo@uhul.cz

The "NFI Exchange project between the Czech and Swiss National Forest Inventories" covers several topics such as inventory statistics as well as technical issues of data processing and analysis software solutions. In our presentation, the Swiss NAtional Forest Inventory Data Analysis System (NAFIDAS) solution and current developments of the Czech NFI evaluation system will be presented with focus on metadata based techniques for efficient data storage and analysis.

The Czech NFI started with a desktop application in the first NFI (2001-2004). The system showed weaknesses in terms of flexibility and transparency and did not support collaboration of NFI experts effectively. In the second NFI (2011-2015), a PostgreSQL database server solution with a Postgis extension has been implemented. After a new DB schema was designed the system has improved strongly but still showed some performance and technological issues.

The Swiss NAFIDAS system is built on ORACLE databases in combination with software applications for statistical analysis and dissemination of results. Key features are a web based access to the system and metadata-controlled data management and data analysis processes. The data warehouse architecture supports internal and external data marts customized by highly sophisticated end-user access tools. Internal users may define, run and publish data analyses by controlled selection of parameters which ensure statistical correct result tables. Public users have access to a comprehensive set of published results via the internet. NAFIDAS has proven to be a very suitable solution for customers using the public website as well as for the internal staff; Performance, availability and transparency has always proven to be highly satisfying.

Topics discussed during the Czech and Swiss NFI-exchange collaboration concentrated on parameterization of estimator calculation and efficient data processing methods. Several techniques proven in the Swiss NAFIDAS system have meanwhile been

implemented in the Czech system. These improvements have already shown positive effects in terms of quality and accessibility about information of Czech forests.

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Individual tree crown projection area models based on data from the National Forest Inventory of the Czech Republic

Karel Drápela[1], Zdeněk Adamec[2], Radim Adolt[3]

[1, 2]Mendel University in Brno, Faculty of Forestry and Wood Technology, Department of Forest Management and Applied Geoinformatics, Czech Republic
[3]Forest Management Institute Brandýs nad Labem, National Forest Inventory Methodology and Analysis, branch Kroměříž, Czech Republic
zdenek.adamec@mendelu.cz (corresponding author)
drapela@mendelu.cz
adolt.radim@uhul.cz

Individual tree crown projection area is an important part of many forest models, e.g. estimation of tree biomass, species composition, canopy or natural regeneration (estimation of seed production). On the basis of Czech National Forest Inventory (CZNFI) data, two groups of models were fitted: (a) for trees with DBH above 7 cm, (b) for trees with DBH below 7 cm. Data were collected on 7772 inventory plots of CZNFI2 network (second period of inventory 2011 – 2015), totally 32 650 trees were measured (22 873 with DBH above 7 cm and 9 777 with DBH below 7 cm, respectively). Models with mixed effects proved the best results for all models. Models of the first group (DBH above 7 cm) were the 2nd order polynomials with centred DBH and IUFRO categories of heights (significant only for spruce, beech and pedunculate oak models) as fixed effects and segment of inventory plot as a random effect. Models of the second group (DBH below 7 cm) were nonlinear Michailoff functions (Michailoff 1943) with tree height, damage of the tree (significant only for spruce, beech, birch, pine and pedunculate oak models) and the type of regeneration (natural or artificial - significant only for larch model) as fixed effects and inventory plot as a random effect. Power weight function was part of all models because of coping with heteroscedasticity. According to AIC values, all models with mixed effects were significantly better compared with global models and heteroscedasticity of residuals was largely removed. Final models will be used for estimation of species composition in CZNFI on the levels of the whole state and selected subregions.
Keywords: heteroscedasticity, IUFRO height classes, Michailoff function, mixed effects model, natural regeneration, polynomial model, tree damage.

Photo: Robert Hruban

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