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Development of forest inventory methods in multifunctional forest management

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Abstract

The demand for wide range and precise information on forests promotes continuous development of forest inventory methods, owing to the fact that compilation of reliable data is prerequisite not only for improving forest management schedules but also planning land use and natural environment management. In the reality of contemporary forestry, a requirement to improve forest inventory methods stems from obligation to acquire information on broadly understood issues of forestry as well as the protection of nature and environment.

The paper points out to the essential steps, as said by the authors, on the way to the improvement of now used forest inventory methods and calls attention to remote sensing technologies such as ortophotomaps and aerial lidar data.

The revisions proposed concern gathering information on: site conditions, species diversity, forest stock range as well as sample size and work scope on sampling areas. At the same time, in view of surveying the dynamics of forest change, there is recommended the use of permanent observation plots, especially in mountainous forests.

Key words

improvement of forest inventory, inventory accuracy, inventory scope

Introduction

Transformation of contemporary forestry in terms of its capacity and task dimensions calls for forest management directed toward the achievement of multifunctional forest paradigm through ensuring economic, ecological and socio-cultural forest functions. The substance of the case is forest management based on complex assessments of the status, size, structure and spatial distribution of forest stands, as well as evaluation of the effects of anthropogenic and other factors on forests and forest environment. The results of the assessment as such should allow for recognition of the character and extent of divergences between the present and expected forest status along with determination of the directions of future resource development. In order to accomplish these tasks, there is indispensable genuine, complete and trustworthy information on forests. The quality of inventory data determines suitability and usefulness of management plans in forestry and other sectors, e.g. land use planning.

The functions of forest management plans at different organizational levels of Poland's State Forests are as follows (Fuchs et al. 1987):

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1. State Forests (as the whole) – to provide information for planning strategic activities in managed forests as well as to determine forestry economic goals.
2. Regional directorate (RDLP) level – to provide data needed to implement an appropriate strategy of economic activities as well as to monitor the effectiveness of activities.
3. Forest District level – to provide information needed for operational planning and supervision of the production process as well as for monitoring the effects of management treatments.
4. Forest Division level – to provide data needed for carrying out management practices in specific forest stands.

Multifunctional character of forest management plans exceedingly determines the extent and accuracy of information comprised in forest valuation descriptions. The accuracy of the latter is determined by information required at a forest division level.

For the recent 20–30 years, forest inventory range has been subject to comprehensive transformation. Enhancement of forest ecological and socio-cultural dimensions has resulted in including additional aspects into forest inventory. Next to traditional inventory topics (forest stock, increment), there have also been incorporated the attributes such as: distortion, degradation, stability, risk and recreational values (Stępień 1992). Inventory array change is associated with expanding inventory scope as well as progressing measurement and computation technologies. In the vision of a 21st century forestry, the scale and intensity of surveillance must include launching forest information systems, using consistent inventory methods as well as building models of forest growth and development (LOLF-Mittelung 1991; Weimann et al.; 1992; Lipicki 1992).

The State Forest Information System (SILP) implemented in Poland has inspired a new approach to precision and extent of inventory information needed at a forest district level. At the same time, the awareness has been raised that only reliable data (with predictable error) will allow for appropriate interpretation. Furthermore, thanks to the SILP system it has been recognized that for lesser forestry units (stand, age class, forest division) the data gathered has been not as much precise.

Goals, tasks and methods of forest inventory

According to "The Dictionary of Foreign Words" (Kopaliński 1999), the word "inventory" means preparation of a list of stock. A cataloguer is a specialist who prepares the list (register) of some estate assets. In case of forest inventory, the assets listed are elements of forest structure, in other words – forest features. The inventory goal is to gather information on forests as subject to planning forest management and economic activities. The main interests of forest inventory comprise:

– planning collection of information on forest and its resources,
– information gathering,
– evaluation of information collected.

The aforesaid inventory steps are realized within forest management framework.

The aptness of conclusions and decisions (including those economic), taken in forest management processes at some stage in realization of the plan, are reliant upon properly carried out forest inventory and its precision. The tasks of forest inventory include gathering and processing information on:

– natural conditions and biodiversity;
– extent, structure and spatial distribution of tree resources;
– dynamics of tree resource changes;
– the degree of utilization of tree resources in the context of multifunctional forest model.

Forest inventory provides information not only for current planning, but it also constitutes an important monitoring tool (as long as it meets objectiveness criteria). Continuously performed periodical forest inventory allows for gathering information on changes in natural conditions as well as those in biodiversity and tree resources at a global, regional and country level. Furthermore, based on forest inventory results, there can be assessed effects of economic activities in a given forest holding.

In the reality of a modern forest holding, there is the necessity for expanding inventory work scale as well as using innovative technologies along with improved methods of modeling forest growth and expansion. According to Zöhrer (1980), the main reasons behind such requirements are:

– acceleration of global population growth (1820 – 1 billion, 1960 – 3 billion, 1988 – 5 billion, 2012 – 7 billion);
– decrease of global forest area (there annually diminish approximately 5 million ha);
– rapid development of industry and its all consequences (especially in Asia);
– dynamic expansion of agriculture (especially in South America);
– higher standard of living followed by increased demands for productive, protective and infrastructural functions of forests (as predicted, by 2050, the demand for industrial and fuel wood will grow by about 20%).

The scope of information comprised in forest inventory mainly depends on forest geographical position as well as the specifics of long-established management of forest production scale in a given region. In central European countries, with relatively high intensity of forest management activities, the range of needed information on forests is reasonably far-reaching. This concerns three information groups, and namely:
– the area and spatial distribution of inventory objects, e.g. site-soil conditions, vegetation zones, land categories, plant association characteristics;
– volume, structure, status and increment of forest stock;
– forest infrastructure and environmental conditions, with regard to among others: recreation, nature protection, climate, water, pollution and animal damage.

The literature references to forest inventory were published already in the 14th and 15th centuries (Zöhrer 1980). Then, inventory aimed at gathering information in an attempt to organize clear cutting activities in time and space. At that stage of forest inventory development, there was used the measurement method encompassing all elements of a given plant community. Little by little, factual measurements were substituted by visual estimates. In some countries, the latter approach has endured until now. Before sampling techniques were implemented in forestry, the efforts undertaken to decrease inventory labor consumption had contributed to the method based on representative sample plots (fixed area plots). The method (now called estimation-measurement method) was first described at the end of the 1700s (Hartig 1795). The plots were selected by the surveyor, someplace typical for a given stand, and the records obtained (tree species, number and volume) were converted for the whole area under inventory. Hence, this approach is methodologically similar to impartial inventory methods based on random sampling, applied in our time.

Progressive intensification of forest management activities did not add to the significance of the methods based on estimation and measurement. Information (as detailed as possible) on stand soil, site and structure based on visual estimation seemed to be more important than reliable data on growing stock volume and structure. Generally, in Europe, in the 1800s, there were produced meticulous forest maps based on inventories of stand areas, however stand volume and structure were only roughly estimated. In the 1900s, forest inventory methods rapidly developed (Zöhrer 1980). This was possible thank to the implementation of statistical methods along with the progress of aerial photography and electronic calculation methods. In Poland's forestry, computers are commonly used, and IT systems built in recent times substantially enhanced quality of information and its importance in the decision-making processes.

At the present time, the methods of large-scale forest inventory are far and wide applied in Europe. In Poland, the core of a large-scale forest inventory is to promptly compile (with low labor consumption) as much as possible complete information on large areas (e.g. entire country, forest type in a physiographic region, the area administered by Regional Directorate of State Forests). Currently, large-scale forest inventory second cycle is realized, considerably contributing to the enhancement of quality information on the forest status as well as forest change dynamics. It is worth be emphasizing that soon there will be also available data on privately owned forests and forest area augmentation in Poland.

Based on various criteria, forest inventory methods can be divided into a choice of groups. According to Zöhrer (1980), there should be applied the following criteria:
1. Mode of information collection (surveyor's position with regard to a given inventory object).
2. Inventory work technology.
3. Inventory goal.

In addition, there should be also taken into consideration inventory time and extent.

Re 1. With reference to sources, information on forests can be obtained using the following methods:
- ground-based (full, partial traditional, partial novel);
- aerial photography;
- combined (ground-based and aerial).

Re 2. Three basic systems of inventory works can be distinguished based on inventory technology which must take into account the type and character of sampling plots as well as sample collection mode:

System I – with constant sampling plot area (usually 1–5 ars) and variable tree number included in the sample (depends on tree growth stage and DBH).

System II – with variable (unknown) size of sampling plot and variable number of trees included into sampling (relascope sampling).

System III – with variable but known size of sampling area and constant presumed number of trees included into sampling – usually 6 (Prodan 1965). This system is derived from methodology of determination of tree distances.

Re 3. Inventory scope as well as magnitude of obtainable information on forests are determined by inventory goals. Depending on the goal, there are distinguished 6 fundamental inventory categories:
- intercontinental (global);
- large-scale forest inventory;
- land use inventory;
- regional inventory;
- inventory meant for requirements concerning forest management (relatively most operational in Central Europe's countries in terms of the scope and significance of information compiled).

Improvement needs and directions

Progressive advancement of inventory methodology is indispensable and conditionally on the type and precision of required information should be constantly addressed. In Poland, the most important forest inventory issues which need verification and improvement are listed below.

Site conditions

By now, every Poland's forest districts has elaborated soil-habitat assessment reports. These were prepared in different periods of time, thus depending on the instructions then in force, the reports differ in terms of information scope and precision. In view of inevitability of setting up forest management plans with reference to the maximum reduction of risk due to silviculture activities, at some stage in inventory works, there should be also appraised additional (not yet included in soil-habitat surveys) fertile and wet forest sites found in a given forest site type. Owing to the fact that relatively poor habitats (fresh coniferous and mixed coniferous forests) prevail in Poland, documentation of fertile and wet forest patches is of particular importance. Collection of additional data would greatly help foresters to better plan silvicultural activities in a specific stand (at a forest division level), and could be performed either during forest valuation carried out for forest management planning or when appraising site/habitat descriptions or regularly conducted by any concerned forest warden. One way or another, there is a need for formal recommendations on distinguishing additional fertile and wet sites existing in a given forest habitat type.

Species richness

As a result of currently applied rules, forest stand species with low shares are not included into final summaries. The existing formal guidelines recommend preparation of tabulated summaries of age class volumes, lined up according to the factual share of tree species in forest habitat types. The tables consider only species with more than 5% share. Such approach causes "a loss" of various species, factually observed during forest stock assessments and inventory. In view of forest biodiversity safeguarding, there is a necessity to monitor changes in stand species composition of a specific area and to prepare relevant final summaries. We believe that inventory data on all the species found on circular sampling areas should be included in the final summary, regardless of species share. At the same time, there should be revised the manner of presenting stand volumes and areas in keeping with the age class and species richness. Species richness refers to ecological values of forests, and therefore should be denoted more precisely, especially as far as in 2–3 species stands are concerned (after all, e.g.: 9 pines and 1 oak would indicate different species richness level than e.g. 6 pines, 4 oaks).

Forest stock inventory

Bearing in mind the demand for precise information on forest stands which are concurrently utilized and regenerated, i.e. those assigned to distinct regeneration classes, we propose establishment of separate stratum groups, especially because of the increasing contribution and importance of these structures. The same approach should be applied in selection forest stands. In view of efficiency of forest planning processes, increased sample size needed for the implementation of such system will be worthwhile, since more accurate information would allow for improving decision-making processes. In the forest districts with prevailing coniferous sites and pine stands (e.g. Bory Tuchola Forests, Biała Forests, Nadnotecka Forests, Dolnośląskie Forests), there should be considered a possibility of including into forest stock inventory (Stępień and Wieczorek 1990).

Sample size in forest stock inventory

In case of periodical inventory carried out in the areas with especially valuable habitats and exceptional species richness, i.e. those with outstanding biodiversity values, sample size should be enlarged following the decision of the Forest District Techno-Economic Council. The formula for determination of the number of sampling areas provided in Forest Management Guidelines (IUL 2012) is as follows:

$$N = 400 \cdot A/8000 + A/50 + 1000 \cdot p/A$$

where:
- A – overall area of all tree stands under inventory measurements [ha],
- p – overall area of all tree stands with diverse species composition and differentiated vertical structure [ha].

We propose increasing the value of multiplier $1000 \cdot p/A$ in the ratio. This would allow for enhancing information precision and range (e.g. data on deadwood could be included).

Scope of works carried out on sampling areas

An extent of information collected on sampling plots established in intermediate cutting stands should be broadened by inclusion of data on trees selected for felling (Borecki et al. 2006). In case of the latter, there should be considered employment of simplified wood assortment classification, e.g. that which comprises 4 quality classes proposed by Kłapeć et al. (2005). The changes proposed could allow for elaboration of a method for short-term (annual) as well as medium-term plans of intermediate cuttings (Borecki et al. 2006; Wójcik 2013).

Types of sampling areas

The use of permanent sampling plots for evaluation of tree resources and their changes should be deliberated. Permanent plots allow for continuous forest observation and assessment of changes. Higher costs of their initial establishment could be compensated by accuracy and quality of compiled data. Additionally, double sampling of stand resources could be then carried out using remote sensing methods (orthophotomaps, lidar data). If so, the number of sampling areas could be substantially reduced, since these would serve as the source of reference data used in further calculations. The method double sampling of forest stock using both orthophotomaps (Bańkowski and Miścicki 2008) and lidar data has been tested in Poland's conditions.

Highland and mountainous forests

Highland and mountainous forests as well as some multi-age forests situated in lowlands show relatively differentiated structure (in terms of species abundance, space and dimension). Complex structure and shape of such stands are for the most part a result of performed thinning activities (usually stepwise or and selection cutting) along with considerably long forest regeneration periods. Inventory of such forests requires first of all determination of the size and boundaries of the control units, as basic for forest management control and silvicultural planning. The most important inventory task within the control units is description of the parameters for tree distributions and tree volumes in the thickness classes as well as those for evaluation of the status and level of natural regeneration. Fulfillment of this task needs application of the statistical-mathematical inventory system and forest monitoring based on permanent sampling plots – established as several concentric circles for collection of data on main features and parameters of the stand and its regeneration (species, DBH, height, technical quality, and so on). The data collected at an assumed level of precision constitutes the basis for evaluation of the effects of forest management activities performed in a given control unit and support decision-making processes on further development of forest resources in the control unit.

In conclusion, there should be emphasized that due to the importance of inventory data in the economic decision-making process, inventory methods require continuous improvement, especially toward high data reliability. Forest inventory methods need to be constantly adjusted to relentless and unfixed demands for information on forests. The scope of information required has been expanding due to a need for data on forest biodiversity and nature protection. Inventory advancement should be founded on dynamic technological progress, allowing for not only compilation of more and more consistent data, but also – an extension of information scope, in view of practically possible to accept labor consumption during forest inventory works.

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