Reliability and Efficiency of Lithuanian National Forest Inventory Sampling Design and Results

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Kuliešis, A., Kasperavičius, A. 2004. Reliability and Efficiency of Lithuanian National Forest Inventory Sampling Design and Results. *Baltic Forestry,* 10 (1): 27–35.

The main task of the research is to estimate the efficiency of applied sampling design of Lithuanian national forest inventory (NFI) and to examine the reliability of NFI data. The research was based on the data of Lithuanian NFI permanent sample plots established and measured during 1998–2000 in forest land of Lithuania and generalized NFI data of 1998–2002, as well as generalized standwise forest inventory (SFI) data updated to 2002.

As a result of the study, it was determined, that growing stock volume variation in large forest tracts responds to plot size changes 2–3 times weaker as compared to the changes in plot volume variation in homogeneous stands. The coefficient of the growing stock variation of all stands decreases from 74.2% to 55.7% with increasing sample plot size from 100 to 500 m^2. By applying peculiarities of the dependence of tree volume variation and time consumption variation on plot size, an optimal 500 m^2 plot size was ascertained, allowing to reduce total labour consumption for all inventory object by about 35% as compared to 100 m^2 size plots. Optimization of plot size and their grouping ensures balance between time consumption for driving – walking and direct operations in the plot, as one of the most important features of sampling design optimality. Approximately 1.08 sample plot or its sector from the same tract falls into stand groups homogenous by forest type, age and site index class. Estimation of the growing stock variance in stands homogenous by forest type, age and site index class has shown that diversity loss of investigated object, while allocating sample plots in tracts, is insignificant.

Data of NFI are based on direct and highly precise measurements. The comparison of sampling and standwise forest inventory results has shown, that NFI is reliable and the results are of known precision. NFI is more operative and it allows to reveal most changes efficiently and significantly earlier, as compared to SFI. Sampling forest inventory of 1998–2002 allowed to estimate the area of all Lithuanian forests with ±1.1%, while growing stock volume with ±1.5% standard error, to reveal forest land area changes 8 years earlier than by SFI. The main reason for underestimation of the growing stock volume, increment, mean height, age and stocking level of stands according to SFI lies in non progressive and limited technologies, methods and standards, used by SFI.

Key words: sampling forest inventory, sampling design, time consumption, efficiency, representativeness, data reliability.

Introduction

For many years the main source of information about forests in Lithuania was standwise forest inventory (SFI), which guaranteed the flow of information for a detailed and effective short term planning, organization of forestry on a certain territory. Many quite important characteristics of forests, such as wood increment, mortality, growth balance and allowable cut, tree damages cannot be reliably ascertained by applying previous methods. Lithuanian forest inventory faced many problems after the appearance of private forest sector with very small holdings. Without essential changes in existing inventory methods and technologies used at present, it is impossible to obtain sufficiently precise information needed to ascertain changes in the state of forests, to perform strategic planning and assessment at the level of the whole country. These circumstances have led to the organization of the national forest inventory (NFI) based on sampling method.

The Lithuanian NFI, based on the repeatedly measured permanent sample plots, was started in 1998 (Kuliešis, Kasperavičius 1998, Kuliešis 1999). The aim of the inventory is to carry out a complex and reliable monitoring of natural forest resources for an efficient assessment of the main forest parameters in the country or its regions.

The design of inventory is a systematic cluster sampling with a random start. The estimation of the efficiency of NFI sampling design, optimisation and improvement of its parameters, analysis and estimation reliability of inventory results of the first five years are the main objectives of our research. In order to create an optimal sampling design for Lithuanian forest inventory, to carry out the inventory with minimal labour expenditures under a defined accuracy, it is necessary to optimize the size of sample plots (Shiver, Borders 1996), their construction (Söderberg 1997, Brasell *et al.* 2001, *Estonian*…, 2002), joining into groups – tracts (Ranneby 1979).

In order to solve the main tasks of the research it was necessary: to estimate the variance of growing stock in the sample plots of different size, to estimate the efficiency of the NFI sampling design according to the analysis of time consumption necessary for field operations, to optimise the size of permanent sample plot, to estimate the influence of clustering of plots on the representation of forest diversity, bias of the mean and the variance of estimated parameters, to compare the main characteristics and its accuracies, estimated by NFI and SFI data.

Research materials and methods

The research was based on the data of NFI permanent sample plots established and measured during 1998 – 2000 in forest land of Lithuania and generalized NFI data of 1998 – 2002.

In order to estimate the efficiency of NFI sampling design, we examined the optimality of sampling design parameters: sample plot size, clustering of plots, and size of the cluster. The optimal sample plot size was investigated analysing the variability of the growing stock in sample plots of various sizes and time expenditures required for the establishment and measurement of such plots. The variability of growing stock was estimated analysing the coefficient of variation of growing stock in sample plots of various sizes. It was tested according to Fairfield Smith's empirical "law" (Smith 1938). The regularities of the growing stock variation were analysed using the entire scale of variability of natural conditions in Lithuanian forests. The time consumption for fulfilling different operations in the NFI field works was determined using the time photography method. The effectiveness of the sampling design was estimated under the analysis of multiple relations between direct and indirect time consumption in the sample plot and tract. The optimal size of a sample plot was ascertained minimising the total cost (total time consumption) required for carrying out inventory with a predefined accuracy. The representativeness of the applied sampling design was estimated analysing the mean and the variance of the growing stock, comparing the results from clustered plots versus the individually allocated plots. Various versions of individually allocated plots were used.

Results of NFI of 1998 – 2002 were compared with the data of forest resources assessment in 01.01.2002, made on the base of SFI data. The accuracy of NFI data was estimated by the standard deviation. For the estimation of systematic deviations of SFI data in various periods, total growth balance method and forest cuttings statistics were used (Kuliešis 1989, 1993, 2003).

Results

Variation of the growing stock volume in the forests of inventory area

The estimation of the growing stock volume variance in sample plots is very important both for proving optimal sampling design of forest inventory and for ascertaining spatial forest structure as one of the most important factors of forest sustainability, stability and productivity (Freese 1961, Lindgren 1984). The most important and, unfortunately, least investigated are regularities of growing stock variation in stands associations covering a large scale variability of natural conditions.

The variance of growing stock volume per 1 hectare in all Lithuanian forests on average is 19,014 (m^3/ha)^2. In conventional terms it means a sufficiently high variation, equal to 60 – 65%. The greatest variance was estimated in the least homogeneous aspen, oak and spruce stands, the lowest being in grey alder and pine stands (Kasperavičius, Kuliešis 2001a).

The dependence of the growing stock volume variation on forest type, stand age, stocking level, site humidity and fertility level as well as site index was determined (Table 1). The most stable stands with even spatial structure and the least growing stock variation are those from 40 to 110 years of age, 0.7 – 0.9 stocking level, growing in medium or higher site index conditions (Kasperavičius, Kuliešis 2001b). The most even spatial structure is characteristic of pine and grey alder stands. The coefficient of growing stock variation (CV_q, %) of all stands decreased from 74.2 % to 55.7 % when the sample plot size (q) increased from 100 to 500 m^2 (Table 1).

According to the Fairfield Smith's law (Smith 1938), which can be re-expressed as: $CV_q = kq^{-b}$ (where: k, b – regression coefficients to be estimated), the average value of regression coefficient b is equal to 0.18 (Table 1). The higher the regression coefficient b, the more decreases CV_q following a corresponding increase in sample plot size. Volume variation coefficients of separate stands in most cases are lower, while the way of their changes, depending on sample plot size, is more pronounced as compared to the corresponding characteristics of entire forest tracts. During the study it was ascertained, that the influence of sample plot size changes on the change of tree volume per plot variation coefficient in homogeneous stand communities (b=0.18) is twice less than in separate stands (b=0.33–0.45). These results allow to essentially specify sampling design of inventories in large forest areas and forecast a predefined assessment accuracy of the main variables.

Table 1. Range of growing stock volume (I and II storey) variation coefficients in sample plots and the values of coefficient *b* in Lithuanian forests under increasing sample plot area from 100 to 500 m²

Stand parameter	Coefficient of variation, %, Sample plot size, m² 100	500	Coefficient *b*	Stand parameter	Coefficient of variation, %, Sample plot size, m² 100	500	Coefficient *b*
Forest type				***Site index (H_{AB})***			
Pine	65.8	48.6	0.19	≤16.5	99.1	72.7	0.19
Spruce	76.1	57.8	0.17	16.6 – 19.5	71.9	56.1	0.15
Birch	75.8	60.6	0.14	19.6 – 22.5	75.0	56.1	0.18
Aspen	72.9	51.9	0.21	22.6 – 25.5	65.4	47.7	0.20
Black alder	66.7	55.4	0.12	25.6 – 28.5	65.5	46.5	0.21
White alder	63.3	51.4	0.13	28.6 – 31.5	68.6	48.1	0.22
Ash	81.7	55.7	0.24	31.6 – 34.5	68.1	51.0	0.18
Oak	88.2	54.3	0.30	>34.5	71.2	55.1	0.16
Site humidity				***Age***			
Slopes of normal	75.6	53.4	0.22	≤20	123.8	102.0	0.12
Normal	67.8	47.9	0.22	21 – 40	70.8	55.0	0.16
Temporarily overmoistured	73.3	55.6	0.17	41 – 60	58.1	40.8	0.22
Constantly overmoistured	75.5	59.6	0.15	61 – 80	62.7	41.6	0.26
Drained peatland	72.8	60.8	0.11	81 – 100	64.5	41.4	0.28
Peatland	82.8	70.7	0.10	101 – 120	61.6	42.5	0.23
Site fertility				>120	76.6	52.7	0.23
Very poor	72.5	59.8	0.12	***Stocking level***			
Poor	65.0	48.1	0.19	≤0.30	161.2	119.9	0.18
Fertile	73.7	57.2	0.16	0.31 – 0.50	103.4	58.3	0.36
Very fertile	79.1	55.8	0.22	0.51 – 0.70	73.4	44.2	0.32
Especially fertile	96.1	58.8	0.31	0.71 – 0.90	56.1	39.2	0.22
All stands	**74.2**	**55.7**	**0.18**	> 0.90	54.5	41.0	0.18

Time consumption for NFI measurements

The efficiency of sampling design was estimated analysing multiple relations between direct and indirect time consumption for work operations carried out in the sample plot and tract, the dependence of time consumption for carrying out different operations on the characteristics of measured objects and their quantities was ascertained.

According to the time consumption required for carrying out different operations in a tract and sample plot (Figure 1), time consumption structure in a full tract and in a tract with different numbers of sample plots in each of them was constructed (Figure 2).

Approximately a half of all time is required for driving and walking to the object and another half – for direct measurements in the plot. Time consumption for direct measurements in the sample plots varies from 34 to 63 % in the Lithuanian NFI sampling design depending on the number of sample plots per tract (Figure 2).

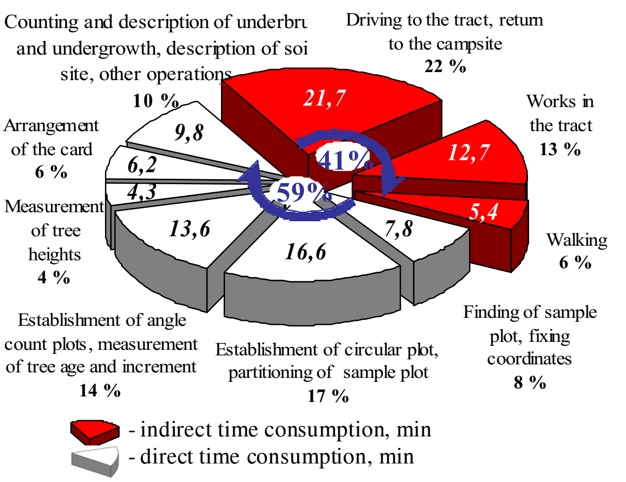

Figure 1. Time consumption, required for singling out and measuring permanent sample plots in Lithuanian forests (3 surveyors)

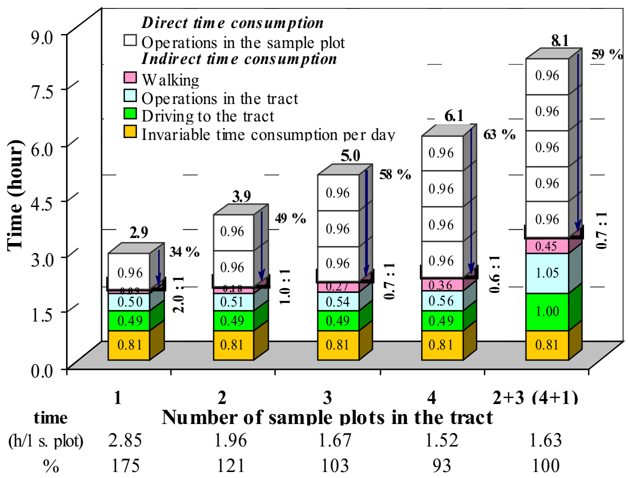

Figure 2. Dependence of time consumption, required to measure tract on the number of sample plots in the tract (3 surveyors)

The share of time consumption for direct measurements in the plot increase due to an increasing number of plots per tract. The average number of plots per tract for all Lithuanian NFI is 2.8. The equality between the time consumed for direct measurements and time for preparation to measure is mostly desirable and, according to Zeide research results (Zeide 1980), is the sign of optimal forest inventory design.

Time consumption for measuring a sample plot in Lithuanian forests by a crew of three members increases almost by 3.1 min for each 100 m² with increasing sample plot size from 100 m² to 500 m² (Figure 3).

Estimation of an optimal sample plot size

The range of optimal plot sizes ensuring the lowest inventory cost in different forest types varies from 500 m² up to 600 m² depending on stand structure. The estimated optimal plot size for the inventory of all Lithuanian forests is equal to 514 m² (Fig. 4). The increase of sample plot size from 100 m² to 500 m² enabled us to reduce the total cost of the inventory of Lithuanian forests by about 33 – 39 %.

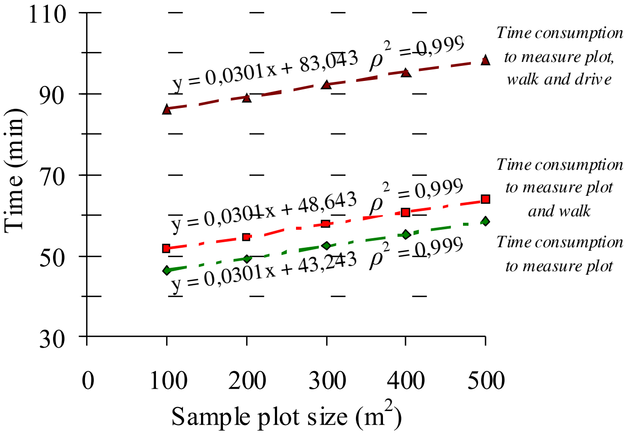

Figure 3. Dependence of time consumption to measure a plot on the plot size

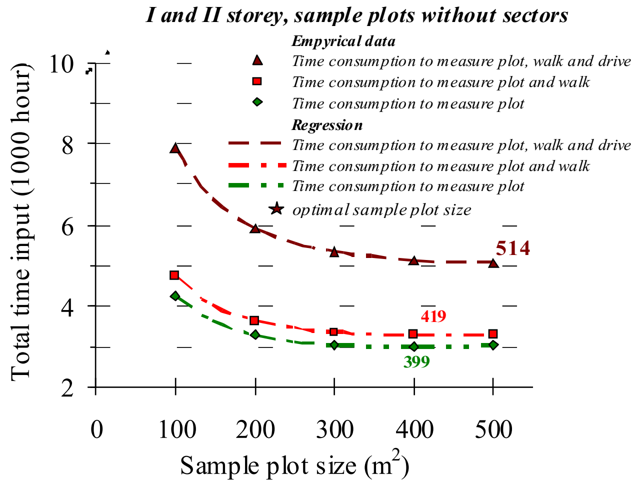

Figure 4. Dependence of time consumption to inventory an object on plot size

The representativeness of inventory design

The aim of grouping of sample plots in tracts is to reduce inventory costs, increase labour productivity by collecting possibly more information. On the other hand, grouping of sample plots may influence the representation of the forest diversity, bias the mean variance of estimated parameters. We have examined the influence of clustering of plots on sampling, representativeness and reliability of inventory data.

Grouping of sample plots of NFI is mostly expressed in pine stands because of their greatest concentration in larger tracts. One of the main characteristics, showing the concentration of sample units or their distribution, is the number of plots or their sectors falling per group of stands singled out according to the same indication (Table 2).

The greatest number of sample units per tract falls in pine stands – 2.47, then follow spruce – 1.46 and birch stands – 1.43. Under smaller groups of stands, i.e. having divided stands by age classes and site indexes, mean number of plots and sectors falling per tract decreases up to less than 1.15 sample units per tract (Table 2).

For all Lithuanian forests approximately 1.08 sample plot or its sector from the same tract fall into the aggregation of stands homogeneous by forest type, age (differences less than 20 years) and site index class (height differences less than 3 metres) (Table 2). The estimation of the growing stock volume variance in stands homogeneous by forest type, age and site index class has shown that losses in diversity of the investigated object while allocating sample plots in tracts by four are insignificant. The introduced sampling design with clusters of four sample plots reduces the variance of the growing stock only by 1 – 2 % for all tree species. Results of this analysis allow to interpret the sampling design of the Lithuanian NFI as a sampling design with individually allocated sample plots.

An essential improvement of the effectiveness of the Lithuanian NFI started in 1998, when compared with the previous forest inventories was ensured reduction in the number of sample plots in a tract down to four, the distance between sample plots was increased to 250 meters and the sample plot size was enlarged fixing it at 500 m². The increased precision of allocating sample plots using GPS receivers and dividing sample plots into sectors according to actual for-

Table 2 Average number of sample plots or its sectors falling in the group of stands of ascertained indications in the tract

Indications	Tree species								
	Pine	Spruce	Birch	Aspen	Black alder	White alder	Oak	Ash	Total
	Number of sample plots, sectors								
Forest type	2.47	1.46	1.43	1.33	1.25	1.25	1.12	1.25	1.59
Forest type, age class (20 years)	1.53	1.14	1.19	1.15	1.10	1.14	1.05	1.03	1.25
Forest type, site index class (3 meters)	1.31	1.10	1.11	1.09	1.04	1.09	1.00	1.01	1.15
Forest type, age class (20 years), site index class (3 meters)	1.15	1.05	1.07	1.05	1.01	1.07	1.00	1.00	1.08

est distribution by forest types has improved the objectiveness and reliability of the NFI data. All these measures allowed to increase the efficiency of the sampling design and reduce time consumption eliminating less informative data.

Comparison of NFI and SFI data

For comparison NFI data over a five year (1998 – 2002) period and SFI data updated to January 1, 2002 were used.

Forest land area

In 2002 NFI inventoried 2084.2 thous. ha of forest land area, i.e. by 50 thous. ha more as compared with SFI. In 1998 this difference comprised more than 100 thous. ha. The reason for differences in forest land areas between NFI and SFI in 1998 and 2002 was the data of SFI obtained 10-15 years ago on 85% of the country's territory in 1998, while only 35% in 2002. The existence of not inventoried before areas of forest land, in size 5 – 6% of the total forest area, was confirmed by SFI, starting with 1995, i.e. after the enactment of the Forest Law (1994). Using the definitions of the Forest Law (1994), during 1995 – 2002 for the first time by SFI were inventoried 63 thous. ha or 5% of new forests. It is expected, that during 2003 – 2006 on the remaining territory of the country there will be inventoried at least 40 – 50 thous. ha of a new forest area. Forest land area corresponding to the definition of the Forest Law by NFI was inventoried in 1998, i.e. 8 years earlier than by SFI. Remeasurements of permanent plots allow to estimate appearing new forests on average 4 thous. ha per year on the territory.

Total Lithuanian forest land area of 2.084 mill. ha by NFI was estimated with the standard error (probability 0.683) of 1.1%. Forest land areas of 10 thous. ha and more in size, using Lithuanian NFI sampling design can be estimated with the standard error of 20% and less. The NFI data sufficiently precisely represent the areas of all forest groups, forest types, ownerships and other categories (Table 3).

Differences in the distribution of forest land area of II-IV groups, estimated by NFI and standwise forest inventory do not exceed 0.1–0.3%. By NFI there was inventoried 5.5% less area of spruce stands, by 2.6% less area of pine stands, 3.5% greater area of aspen and 2.9% that of black alder stands (Table 3). Among the main reasons for the differences in forest type areas were indicated damages caused by draught, wind and *Ips typographus* during 1992–1996 in spruce stands (Karazija *et al.* 1996), the appearance of new stands, mainly of soft broadleaved species, that have not been

Table 3. Comparison of areas, estimated by NFI and SFI

Area category		SFI	NFI	NFI-SFI
		area, %		
Forest land area	I group	1.1	1.2	+0.1
	II group	12.1	11.8	-0.3
	III group	15.3	15.4	+0.1
	IV group	71.5	71.6	+0.1
Forest land area covered by	pine	36.7	34.1	-2.6
	spruce	23.1	17.6	-5.5
	birch	20.0	19.9	-0.1
	aspen	2.8	6.3	+3.5
	black alder	6.0	8.9	+2.9
	grey alder	6.2	6.9	+0.7
	oak	1.8	2.5	+0.7
	ash	2.7	2.4	-0.3
	other	0.8	1.5	+0.7

completely inventoried by standwise inventory up to this time. There was also the methodical reason for estimation of prevailing species during NFI and SFI. New SFI rules were introduced in 2003, according to which these differences were eliminated.

The analysis of forest land area estimations by NFI and SFI has shown, that real changes in the total forest land area and its distribution by smaller units for the whole country can be disclosed by NFI 8 years earlier as compared to SFI.

Growing stock volume and other characteristics

During 1998–2002, by NFI in Lithuanian forests there were inventoried 456.7 mill. m^3 of the growing stock volume with the standard error ± 1.5% (probability 0.683). It is by 17% more as compared to SFI data. What are the reasons for this difference? The first reason is by 50 thous. ha larger forest land area inventoried by NFI. The other reasons will be revealed analyzing and comparing NFI and SFI data (Table 4).

The growing stock volume per 1 ha during SFI on average is underestimated by 14%. Almost one half of ascertained differences are caused by small trees, usually not inventoried by SFI. As a result of NFI and SFI data analysis, it was determined that small trees up to 10 cm in middle-aged and older stands as well as small trees in the second storey on average comprise 15 – 17 m^3/ha and are not inventoried by SFI. This volume is close to that of the second storey trees inventoried by NFI (Table 4). During NFI the II storey was based on the corresponding height differences of trees, while during SFI the II storey, having not reached stocking level of 0.3, most frequently is not recorded. Underestimation of the growing stock volume according to SFI by 2 m^3/ha can be explained in decreased volume by 25 % in grey alder volume tables. Besides that, NFI data of 1998 – 2002 are adequate to the middle of the year 2000, while SFI data of January 1, 2002, according to the practice of updating, are adequate to the middle of 1999. This difference in time corresponds in the decrease

Table 4. Comparison of growing stock volume and other characteristics, estimated by SFI and NFI in Lithuanian forests, depending on ownership

Indices	State forests		Private and others		All forests		Differences, % $\frac{SFI - NFI}{NFI} \cdot 100$		
	SFI	NFI	SFI	NFI	SFI	NFI	state	private and others	all forests
Growing stock volume, m³/ha	201	234	189	223	195	227	-14	-15	-14
from them of II storey		19		11		14			
Stands of pine	235	269	222	261	229	265	-13	-15	-14
spruce	175	209	213	228	191	217	-16	-7	-12
birch	179	208	159	194	168	200	-14	-18	-16
aspen	230	284	203	263	216	274	-19	-23	-21
black alder	203	215	182	212	192	213	-6	-14	-10
grey alder	108	121	116	163	115	157	-11	-29	-27
oak	202	235	176	218	189	226	-14	-19	-16
ash	154	160	169	222	161	190	-4	-24	-15
Growing stock volume of mature stands, m³/ha	279	334	221	270	251	304	-16	-18	-17
Annual gross increment, m³/ha	5.8	7.4	6.5	8.7	6.1	8.0	-22	-25	-24
from them of II storey		0.8		0.6		0.7			
Age of stands I storey, years	56	55	50	47	53	51	+2	+6	+4
Stocking level of stands I storey	0.72	0.71	0.71	0.76	0.71	0.74	+1	-7	-4
Site index	25.0	27.0	25.6	26.5	25.3	26.8	-7	-4	-6

of the growing stock volume, estimated by SFI by 5 m³/ha. In this way, unexplained remains the difference between NFI and SFI data constituting 4 – 5 % of the total growing stock volume. It can be described by a systematic deviation – typical error of subjective inventory methods used by SFI. The volume of mature stands during SFI is underestimated to a slightly greater degree than that of all stands (Table 4). The mechanism of stand volume underestimation during SFI is partially revealed comparing other parameters. Average age of stands during SFI inventory is increased by 4%, stocking level is reduced by 4%, site index is reduced by 6%. Taking into account, that during SFI age is increased, while site index is reduced, it is possible to state, that the mean heights of stands are reduced more than by 6%.

Therefore, the main reasons for volume reduction during SFI lie in the reduction of stand stocking level and even more in the reduction of the mean height of stands. Very often lower requirements were applied on the precision of SFI in private forests, which lead to greater deviations in the volume of all stands (15% in private and 14% in state forests), in the volume of mature stands (18% and 16%) and especially in the age of trees (6% and 2%) in these forests.

The mean annual increment during SFI is underestimated to a greater extent than the growing stock volume. This is mostly influenced, besides, in one direction, by the reduction of the growing stock volume (60%) of the whole difference and site index as well as overestimation of the age of trees influencing increment percentage reduction and the remaining part (40 %) of increment difference between NFI and SFI data. In state forests the mean annual volume increment is underestimated by 22%, meanwhile in private by 25%.

The greatest volume differences according to SFI and NFI data ascertained in aspen (-21%), oak (-16%) and ash (-15%) stands may be explained by very complicated conditions for ocular inventory, high volume variability in groups of these stands (Антанайтис *et al*. 1975). Volume differences ascertained in grey alder stands (-27%) are due to reduced values of form factors used for a long time in SFI. The least differences in the volume are determined in coniferous and black alder stands that are most simple for inventory. Greater volume differences were determined in private as compared to state forests.

The accuracy of SFI data in Lithuania were analysed earlier too (Кулешис 1971, Антанайтис *et al.* 1975, Kuliešis *et al.* 1976, Kuliešis 1989) and similar results were obtained. Seeking to estimate reliability of the results, the balance of the volume increment and its accumulation in the stands of state forests in 1958–1999 was done (Kuliešis 1993, 2003). For this purpose SFI data on the growing stock volume, increment, its accumulation in stands and timber volume, removed by final and intermediate cuttings, was used.

The results of this analysis have shown underestimation of the growing stock volume during SFI on average by 20% for the first 20 years and by about 8–14% for the last 20 year period. Adjusted by the increment balance method, SFI data completely correspond to the NFI data (Figure 5).

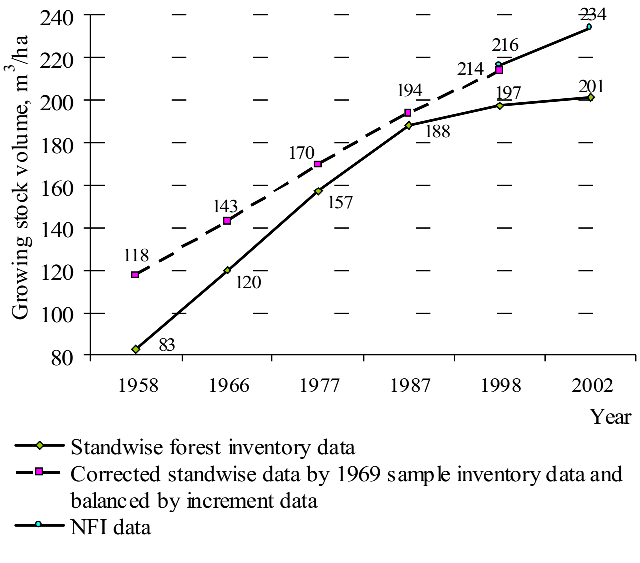

Figure 5. Estimation of biasness of the growing stock volume in Lithuanian state forests

Underestimation of the increment by 10–25% during 1967–1987 was compensated using biased standard – increment tables (Kuliešis 1989). Stand yield model, applied in the nowadays SFI practice, showed an underestimation of increment approximately by 6% as compared with NFI data (Fig. 6). The necessity of yield model correction should be verified in the future by using remeasurement data of permanent plots.

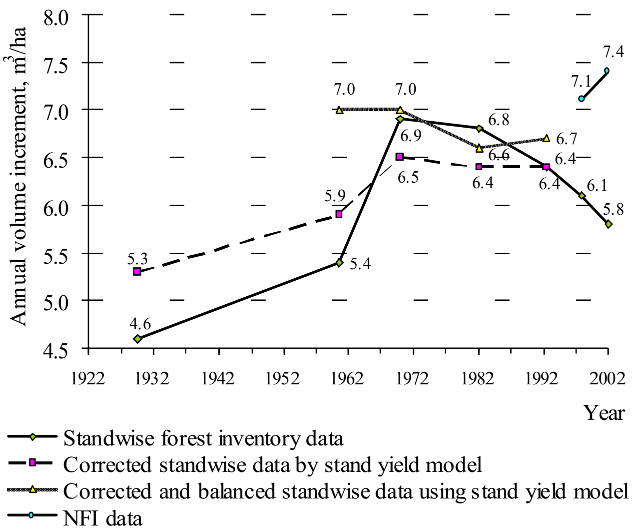

Figure 6. Estimation of biasness of the annual volume increment in Lithuanian state forests

According to the measurements of NFI permanent sample plots in 1998–2002, a preliminary growing stock volume increment balance was made. The growing stock volume in 1998–2002 was estimated every year as a mean of the analysed period. In this way, volume change by 4 m^3, i.e. from 224 m^3/ha in 1998–2000 (on average in the year 1999) to 228 m^3/ha in 1998–2002 (on average in the year 2000) is attributable to the period of 1 year. It can be said, that in this period annually on average 4.0 m^3/ha of wood was accumulated in all Lithuanian forests.

According to the measurement data of NFI permanent plots in 1997–2001, annually by all cuttings 3.5 m^3/ha of stems overbark were felled. Based on the results (Kuliešis 1999) of 5 repeated measurements in permanent plots of the Dubrava forest over 20 years, it is possible to state, that in Lithuanian forests 0.3 m^3/ha of stem volume is naturally lost or remains unused. Such a sum of volumes of felled trees (3.5 m^3/ha), accumulated in stands (4.0 m^3/ha) and dead trees (0.5 m^3/ha), ascertained during a single NFI in 1998–2002, is very close to volume increment – 8.0 m^3/ha estimated at the same time. The growing stock volume increment balance in Lithuanian forests will be essentially specified after repeated measurement of permanent sample plots and will serve as the basis for a motivated efficiency estimation of forest growing and use.

The data on temporary sample plots, measured in 2003, confirmed the validity of the data estimated in permanent plots. It was determined, that differences in growing stock volume (t=0.44), annual increment (t=0.27) and forest land area (t=0.24) estimations, made on permanent and temporary plots, are not significant.

Conclusions

1. Tree volume variation in large homogenous forest stand communities responds to plot size changes 2 – 3 times weaker as compared to the changes in plot volume variation in individual homogeneous stands.

2. 500 – 600 m^2 plot size was ascertained as optimal, allowing to reduce total labour consumption for the whole inventory object by 33 – 39 % as compared to 100 m^2 size plots.

3. Optimization of plot size and their grouping ensures the balance between time consumption for driving – walking and direct operations in the plot as one of the most important features of sampling design optimality.

4. Reduction of the number of plots per tract down to 4, increasing of the distance between plots up to 250 m guarantee every sample plot or its sector to fall into a stand different by site, prevailing tree species or age and maximal (even 98 – 99 %) representation of object diversity. This allows to state, that Lithuanian NFI sampling design is very close to the sampling design with allocation of individual sample plots.

5. NFI by sampling method of 1998–2002 allowed to estimate the area of all Lithuanian forests with ±1.1%, while the growing stock volume with ±1.5% standard error (probability 0.683), to reveal all changes efficiently and significantly earlier (8 years) than by SFI.

6. Tendencies in SFI to exclude small trees, especially of second storey, to reduce mean stand heights, stocking levels, to increase stand ages were revealed, in the consequence of which the growing stock volumes and volume increments were underestimated, especially in more complicated for inventory stands, also growing in private and reserved for restitution forests.

7. In Lithuanian forests by 17% greater wood resources were ascertained, especially of softwood deciduous species, an intensive wood increment accumulation, moderate forest use approaching the limit of one half of volume increment shows an immense potential of forests solving economical, social and environmental tasks in the country.

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Received 10 February 2004

ЭФФЕКТИВНОСТЬ ВЫБОРОЧНОЙ СХЕМЫ И ДОСТОВЕРНОСТЬ РЕЗУЛЬТАТОВ НАЦИОНАЛЬНОЙ ЛЕСОИНВЕНТАРИЗАЦИИ ЛИТВЫ

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Резюме

Основной целью исследования является оценка достоверности и эффективности выборочной схемы национальной лесоинвентаризации (НЛИ), применяемой в Литве с 1998 г., а также результатов первых пяти лет. Для исследования использованы данные постоянных учётных площадок, обмеренных в течение 1998–2000 г.г., обобщённые данные НЛИ Литвы 1998–2002 г.г., а также данные учёта лесного фонда, основанные на актуализации к 2002 г. банка данных повыдельной лесоинвентаризации (ПЛИ).

В результате исследования установлено, что зависимость изменчивости запаса на больших лесных площадях от величины площадок выражается в 2-3 раза менее значительной степени по сравнению с той же зависимостью в гомогенных древостоях. Коэффициент вариации запаса стволовой древесины на больших лесных площадях уменьшается от 74,2% до 55,7% с увеличением величины площадок от 100 до 500м^2. Путем анализа затрат для инвентаризации объекта с определённой точностью установлена оптимальная величина выборочной площадки, равна 500м^2. Площадки оптимальной величины позволяют снизить затраты для объекта инвентаризации на 35% по сравнению с площадками величиной в 100м^2. Оптимизация величины площадок учёта и их группирование по 4 позволило достичь равновесия затрат времени на переезды – переходы с затратами для учёта деревьев на площадке, как одного из показателей оптимальности схемы выборки. Сведение количества учётных площадок определённого тракта в группе древостоев, гомогенных по отношению преобладающей породы, возраста и класса бонитета к минимуму (1,08) гарантирует максимальную репрезентативность разнообразия всего объекта и даёт основу для утверждения, что используемая схема выборки близка к схеме с равномерным одиночным размещением учётных площадок на объекте.

Данные НЛИ, основанные на непосредственных, высокоточных измерениях, являются известной точности и достоверности, гораздо более оперативными по сравнению с данными ПЛИ. Площадь лесов Литвы во время НЛИ 1998–2002 г.г. была оценена со стандартной ошибкой ± 1.1%, а общий стволовой запас – со стандартной ошибкой ±1.5%. Основные изменения в лесах Литвы были выявлены на 8 лет раньше по сравнению с ПЛИ. Выявлены тенденции занижения запасов и прироста по запасу, средних высот, полнот и увеличения возраста ПЛИ объяснены как результат недоучета мелких деревьев, а также несовершенства и ограниченности применяемой технологии, методов и нормативов повыдельной лесоинвентаризации.

Ключевые слова: выборочная лесоинвентаризация, затраты времени, схема выборки, её эффективность, оптимальность и репрезентативность, достоверность данных.