

CONSISTENCY OF STAND DENSITY ESTIMATES AND THEIR VARIABILITY IN FOREST INVENTORIES IN SLOVENIA

KONSISTENTNOST OCEN SESTOJNIH GOSTOT IN NJIHOVA VARIABILNOST V GOZDNIH INVENTURAH NA SLOVENSKEM

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ABSTRACT

The national estimates of forest resources in Slovenia are based on data aggregation from forest inventories conducted in forest management units of Slovenia Forest Service (SFS) and on the parallel forest inventory established within the Forest and Forest Ecosystem Condition Survey (FECS) as a continuation of international forest monitoring programme. Since the difference in sampling design and temporal dynamics of data collection is of key importance for inventories at the level of forest management units compared to large-area forest inventories, the consistency of stand densities was checked in both concepts. Comparing growing stock estimates in FECS on the systematic 4-km grid of sampling plots from SFS forest management planning, no overall significant differences in temporally comparable periods have been detected. We propose a basis enabling consistent estimates of structural forest characteristics at the national level for the process of forest inventory harmonization in Slovenia.

Key words: forest inventories, sampling grids, stand densities, forest site types, Slovenia

IZVLEČEK

V Sloveniji so ocene o gozdnih virih na ravni države sestavljene iz podatkov gozdnih inventur v gozdnogospodarskih enotah Zavoda za gozdove Slovenije (ZGS) in vzporedne gozdne inventure, ki je bila zasnovana v sklopu Monitoringa gozdov in gozdnih ekosistemov – popis MGGE Gozdarskega inštituta Slovenije. Ker je za inventure na ravni gozdnogospodarskih enot v primerjavi s konceptom nacionalnih gozdnih inventur ključna razlika v zasnovi vzorčenja in časovni dinamiki zbiranja podatkov, smo preverili konsistentnost sestojnih gostot, ki jih ocenjujemo v obeh sklopih gozdnih inventur. S primerjavo lesnih zalog, ocenjenih v popisu MGGE in na prilagojeni sistematični 4-km vzorčni mreži vzorčnih ploskev gozdnogospodarskega načrtovanja ZGS, nismo odkrili značilnih razlik v časovno primerljivih obdobjih. Za proces harmonizacije gozdnih inventur na Slovenskem predlagamo izhodišča, po katerih bo mogoče usklajeno ocenjevati strukturne značilnosti gozdov na ravni države.

Ključne besede: gozdne inventure, vzorčne mreže, sestojne gostote, gozdni rastiščni tipi, Slovenija

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1 INTRODUCTION

1 UVOD

In Slovenia, forest resources are being monitored using two concepts of survey; forest management planning conducted in 233 forest managements units (ZGS, 2013a) and the Forest and Forest Ecosystem Condition Survey (FECS) modified and improved after the Forest Condition Monitoring established within the framework of the UN-ECE International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) operating under the UNECE Convention on Long-range Transboundary Air Pollution - CLRTAP (UN-ECE, 1979). The national estimates are still based on aggregation of data from forest management units and their forest management planning system and from parallel Forest and Forest Ecosystem Condition Survey (Kušar et al., 2010). The traditional forest resource assessment based on

stand-level inventories and designed in similar way as in many Eastern European countries for management planning purposes, was improved with the control sampling method, and the continuous forest inventory has been performed in all forest management units since the end of the 20th century (Regulation..., 1998). By introducing continuous forest inventory with a 10-year cycle, different forest management units are completed in different years and are thus not enabling the annual estimates of the forests at the regional or national level.

On the other hand, the process of national forest inventory (NFI) development is still running, although the first concept of large-scale forest inventory in Slovenia was established in 1985 (Kovač et al., 2014), when the monitoring of forest decline and forest condition started within the International Co-operative Programme on Assessment and Monitoring of Air Pollu-

tion Effects on Forests under the CLRTAP. Among EU countries, different approaches and relations between Forest Condition Monitoring and NFI were implemented in the last few decades (Gasparini et al., 2012; Kovač et al., 2014). As reported by Chirici et al. (2010), the ICP Forests Level I grid was integrated in most of the countries into the NFI in such a way that its grid represents a subsample of the NFI grid (e.g. Austria, Bavaria in Germany, Finland, Poland, Sweden). In the second group of countries, the integration process of both networks was under study (Baden-Wuerttemberg in Germany, Flanders in Belgium, Denmark, Estonia, Iceland, Italy, Latvia, Romania), whereas in the third group of countries no relationship or planning of integration was expected (most German countries, Wallonia in Belgium, Bulgaria, Netherlands, United Kingdom, Spain, Slovakia). The ICP Forests monitoring in Slovenia was modified to ensure representative sampling units and to enable the change detection in forests. In addition to the cluster of four sampling plots with a fixed number of trees (6-tree sample plot; Prodan, 1968), hidden concentric permanent plots (200 and 600 m²) were established as the main sampling units at a 50 m distance west to the previous four cluster samples. The systematic grid spacing for permanent plots remains the 4 x 4 km distance between plots (Kušar et al., 2010).

On the basis of the results of forest condition monitoring in Slovenia, deviations from the forest resources estimations, which originate from forest management planning (FMP), have often been shown. The latter were acquired as an aggregation of estimations from forest inventories designed for FMP purposes in forest management units. According to the estimations for 2000 (Hočevar et al., 2006), differences in growing stock volume between the abovementioned surveys (FMP and FECS) at the national level amounted to 12%, in the forest condition monitoring of 1995 they were whole 36% higher than the estimations in the forest management units' plans (Hočevar, 1997). Such high differences in growing stock volume estimations before introduction of control sampling method and continuous forest inventory in FMP were also a consequence of poor data quality, above all in economically less important forests, where the method of standwise inventory based on visual assessment of the growing stock prevailed. We should also take into account the warnings about the special feature of the concept (ZGS, 2013b) saying the data from forest management planning do not show accurate growing stock volume changes by individual years, but reflect 10-year changes in forest management units for which FMP were made in individual years. Estimation of growing

stock volume as an average of the past 10-year period and estimation for the calculation into the year 2010, which is by 10% higher than this average, are also presented in the synthesis of data and estimations for regional forest management plans (ZGS, 2012).

Forest management planning has a long tradition in providing information on forest resources, but gathering data and information has always been subordinated to the level of the forest management units, where statistical evaluation of their reliability (Regulation ..., 1998) is stipulated for the information of forest sources. At higher levels – forest management regions or at the national level – such reliability estimation could not be performed due to the inconsistency arising from sampling design in forest management units and intertwining of concepts of sample inventory and standwise inventory based on visual assessment in economically less important forests (Kovač et al., 2004). According to the provisions of the Regulation ..., (1998) and Rules on forest management plans ..., (2010), it was possible to perform standwise inventory of growing stocks in forests on sites with average production potential lower than 4 m³/ha yearly and in forest management classes comprising forests with very low quality trees and low growing stock.

A key difference between the inventories at the level of forest management units compared to the concept of the national forest inventories (Tomppo et al., 2010) is in the temporal dynamics of data gathering and spatial distribution of sampling plots in individual inventory years. In the majority of the European countries (Lawrence et al., 2010), national inventories were carried out in several successive years (three to five years) and unified estimates on forest resources for whole country performed. In those rare countries that have not yet designed national inventories, former data aggregation form of stand-level inventories originally designed for management planning purposes has been kept (Tomppo et al., 2010). Given the renewal of forest management plans, a tenth of forest management units are comprised in the forest resources estimate in Slovenia annually; every year in other geographically separated areas. Estimations of forest resources at the national level thus relate to the whole ten-year period and present an estimate of an average of such a ten-year period (ZGS, 2013b). Such method of data collection is not comparable to panelled inventory systems, where the sampling grid is systematically divided into panels with rotating panels being measured on an annual basis (Reams et al., 2005). In USA (McRoberts et al., 2010), the plots have been systematically assigned across the entire country to five groups called panels

so that no adjacent plots are assigned to the same panel and measurement of all plots in a panel in a state is completed before measurement of plots in a subsequent panel is initiated.

Panel inventory system has been presented to point at the duality of inventory systems in Slovenia and to find possibilities for an eventual connection between the two forest inventories. Gasparini et al. (2012) stressed the obvious disadvantages of having two monitoring systems at the national level (NFI and Forest Condition Monitoring) – costs, possible inconsistency of information and potential loss of representativeness in relation to change in the target population. A similar judgment was also made regarding the duality of inventory systems in Slovenia (Hočevar et al., 2006; Hladnik and Žižek Kulovec, 2012). Taking into account a large number of permanent sampling plots in individual forest management units within the framework of the FECS, it has also been possible to report only at the national level, since the 4 x 4 km sampling grid on the entire surface area of Slovenia (20,273 km²) comprises less than 800 sampling plots in forests (Kušar et al., 2010), which is not enough to estimate parameters on forest resources at the level of individual Slovenian regions in detail. Changes of both systems should occur in the coming years, since the limitations of financial assets have already required the first work intensity reduction (ZGS, 2013a). Within the framework of the already performed adaptations of the FECS, it has not been possible to ensure the monitoring of all indicators (Japelj and Hočevar, 2008) required by national and international conventions and processes (e.g. Global Forest Resources Assessment, Global Biodiversity Assessment, Ministerial Conference on the Protection of Forests in Europe, Kyoto Protocol).

The objectives of this study are to:

- compare the estimates of forest resources on the basis of the FECS versus permanent sample survey plots for the forest management planning (FMP) in forest management units in Slovenia;
- recommend the starting points and evaluate the possibilities for harmonization between FECS and FMP survey;
- investigate the consistency of forest resources estimates on the basis of diverse spatial distribution of systematic sampling grids and inventory frequency of permanent sampling plots within the framework of the FECS;
- estimate current variability of stand densities and feasibility of stratifying the inventory data by strata formed as forest site types at the national level.

2 MATERIALS AND METHODS

2 MATERIALI IN METODE

In accordance with the international concept of Forest Condition Monitoring in Slovenia, a 16 x 16 km systematic grid of sample plots for annual reports and a 4 x 4 km sampling grid for the estimation of forest decline in 5- to 10-year periods were designed. The system of hidden concentric permanent plots was checked on the orthophoto to ensure the sampling units at a distance of 50 m west to the previous four cluster samples on 4 x 4 km sampling grid were placed on the total forest area. In 2012, we eliminated deficiencies in systematic sampling grid originating in less accurate placement of the initial clusters on the 4 x 4 km sampling grid. The inaccessible sampling plots (14 plots) were estimated based on interpretation of aerial images using a digital stereoplotter and estimations conducted in standwise inventory by the Slovenia Forest Service (ZGS, 2014).

For a comparison with sample plots from FMP of the Slovenian Forest Service we determined the nearest SFS permanent sampling plot for the points of the kilometre grid located in the forest (12,379 points). In the next step, we selected the sampling plots that were spatially congruent with the ones in the 4 x 4 km grid from the databases. These were used for comparing stand densities estimated in the FECS and in the concept of forest management planning by SFS. Separately we compared the stand basal area on four 4 x 4 km sampling grids formed from the basic kilometre grid and fitted within the already established sampling grid of the FECS. Through the comparison we wanted to estimate possibilities for establishing a system of forest inventory, comparable to panel system in national inventories. For stand density comparison we applied data on permanent sampling plots from the last decade, measured until 2010 before the renewal of regional forest management plans of SFS. The oldest data of 1998 and 1999 were gathered in two forest management units, the most recent ones of 2010 in three units. Between 2000 and 2009, they were gathered annually in the area of 19 to 27 forest management units. At the national level, we compared the estimates on average values of stand densities on the basis of sampling plots harmonized on the 4 x 4 km grid for forest inventories by the FECS of 2007 and 2012 and FMP in the ten-year period by 2010.

We performed estimation for every sampling plot, determining its forest site type in line with the new typology of Slovenian forest sites (Kutnar et al., 2012). Based on each plot's geolocation we gathered the infor-

mation on forest communities from SFS digital databases of forest compartments. Information on forest communities were code of the name of forest community, its share and area in the compartment. Based on dominant forest community in the compartment, the sampling plots were allocated to forest site types strata. For estimating conditions of diverse forest groups at the national level we applied the typology of Slovenian forest site types according to ecological and vegetation conditions, developed on the basis of ecological and floristic similarity of forest plant communities, which represent the key basis for the forest management and silvicultural planning in Slovenia (Kutnar et al., 2012). On the basis of unified treatment of forest associations at the national level, it is possible to ensure estimation on diverse forest groups that could have been compared only on individual forest management regions until now.

Having only few permanent research plots in Slovenia (Hladnik and Skvarča, 2009), where the development of forest stands has been kept under observation continuously, we have no national comparable reference values on stand structures for the most important forest site types at our disposal. Methodical work began with determining site productivity (Kotar, 2005); Slovak yield tables (Halaj et al., 1987) represented the starting point for forming the tables, adjusted and used in Slovenia. On the basis of these tables and estimates on site indices for individual tree species and forest associations (Kotar, 2005) we compared relative stand densities (RD) as a quantification of the current stand density for each plot to stand

density index (SDI) observed in fully stocked pure or nearly pure even-aged stands. The SDI by Reineke (1933; cit. Pretzsch and Biber, 2005) is based on the relationship between quadratic mean diameter d and the number of stems N per unit area:

$$N = a d^{-1.605}$$

The relationship can be presented on the ln-ln scale (Figure 2) as a straight line with intercept $a' = \ln(a)$ and slope -1.605.

The SDI has been proposed also as a technique for estimating relative density of forests at large scales where uneven-aged and mixed species stands are typical (USDA, 2005; Woodall et al., 2006). The SDI by Reineke describes the density of stands with quadratic mean diameter d and number of trees per hectare N by calculating the number of stems related to mean diameter of 25 cm:

$$SDI = N \cdot (25/d)^{-1.605}$$

or by summation method for the uneven-aged stands (Woodall et al., 2006):

$$SDI = \sum \text{tph}_i (\text{DBH}_i/25)^{1.6}$$

where DBH_i is the midpoint of the i th diameter class and tph_i is the number of trees per hectare in the i th diameter class. Woodall et al. (2005) reported that SDI has been infrequently applied in mixed species stands

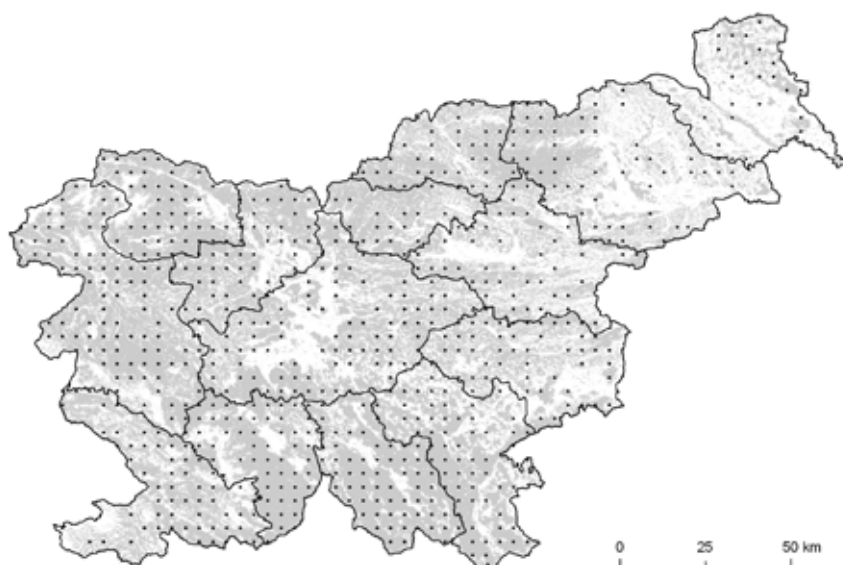


Fig. 1: Sampling grid (4 x 4 km) of FECS in 2012 on the map of forests and regional units of the Slovenia Forest Service (Source: Slovenia Forest Service (ZGS, 2014), Slovenian Forestry Institute)

Slika 1: Vzorčna mreža (4 x 4 km) popisa MGGE v letu 2012 na karti gozdov in območnih enot Zavoda za gozdove Slovenije (Vir: Zavod za gozdove Slovenije (2014), Gozdarski inštitut Slovenije)

due to the lack of available SDI_{max} 's for the multitude of tree species mixtures. Although SDI was originally developed for even-aged stands, it was proposed as a tool for stocking control in uneven-aged stands.

We applied a similar approach for estimating SDI on permanent sampling plots to enable at least a rough comparison of stand densities in Slovenian predominantly uneven-aged mixed stands. On the basis of the data on permanent sampling plots, we did not estimate maximum densities and compare them to potential table ones; SDI was used for the estimation of stand density variability according to individual forest site types. We estimated SDI for research plots on area of the uneven-aged fir-beech forests (Kobal and Hladnik, 2009) according to both procedures to present the development of these stands in the past 50 years (Figure 2). According to individual 10-year periods, SDI calculated using summation method was by 4 to 8% lower than calculation according to the procedure foreseen for pure even-aged stands. In the 50-year period we have estimated SDI between 700 and 860 on the research plot with predominant fir, between 600 and 770 on the plot with predominant beech, and between 730 and 930 on the plot with predominant spruce (Figure 2).

From the adapted table values for beech stands (Kotar, 2003) with site indices estimated according to forest site units (Kotar, 2005), we have estimated SDI

values from 789 to 746 for the development of a beech stand from pole stand to old timber and for higher productivity level values between 885 in 827 (SI_{100} 28, 2nd and 3rd yield level). In montane spruce stands of an equal site index, values between 879 and 975 and between 1007 and 1105 have been estimated. These values are comparable to the values we have derived from data on research plots at Pokljuka by Čokl (1971) and presented after their last measurement (Hladnik and Skvarča, 2009). In 50 years of development of three Pokljuka research plots (Figure 2), SDI values exceed table values for montane forests (Halaj et al., 1987). For a comparison with the development of stands where extensive (high) thinnings took place, we have presented SDI estimates derived from Swiss yield tables (Badoux, 1969). Comparative SDI values are lower and range from 612 in pole stand to 515 in old timber (SI_{50} 18) and between 664 and 588 (SI_{50} 16) as well as 693 and 624 (SI_{50} 18) for spruce.

3 RESULTS

3 REZULTATI

Data on trees on permanent sampling plots, collected by the Slovenia Forest Service, show large differences in average growing stocks at the national level, which would be estimated on the basis of sampling plots, measured according to individual years

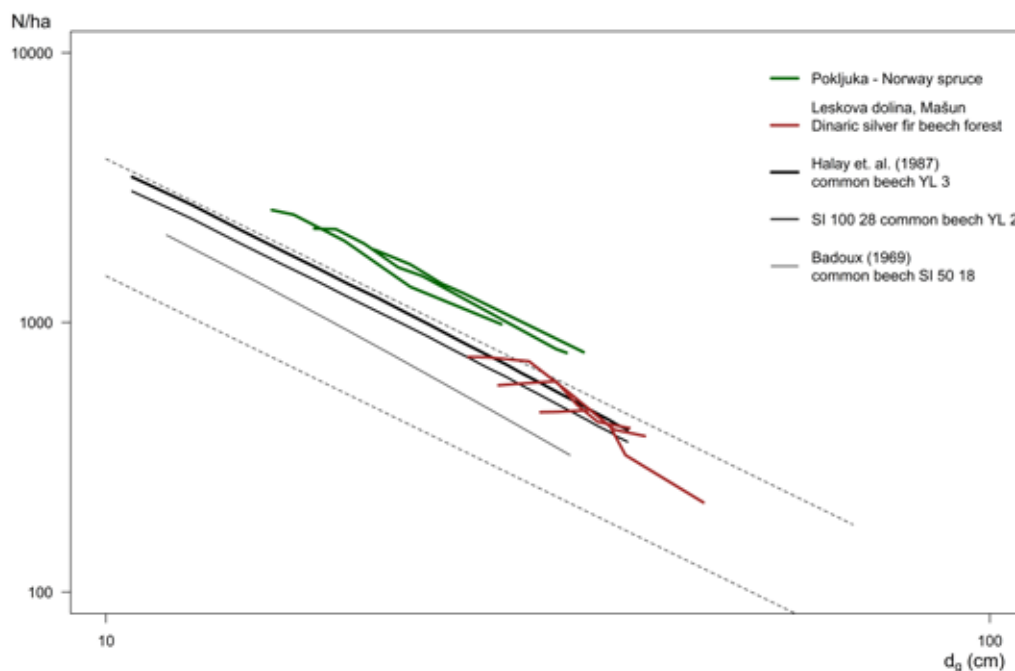


Fig. 2: $\ln(N)$ - $\ln(d)$ relationship for the survey plots on the selected Slovenian forest sites (Hladnik and Skvarča, 2009; Kobal and Hladnik, 2009) and comparison with the data derived from yield tables (Halaj et al., 1987; Badoux, 1969), often used for comparison of stand densities in Slovenia

Slika 2: Razmerje med logaritmi števila dreves in srednjetelemeljnih premerov na izbranih raziskovalnih ploskvah v Sloveniji (Hladnik in Skvarča, 2009; Kobal in Hladnik, 2009) in primerjava s podatki iz tablic donosov (Halaj et al., 1987; Badoux, 1969), ki jih uporabljamo na Slovenskem za primerjavo sestojnih gostot

(Figure 3). The majority was acquired in 2005, when the median for a year of measurements on permanent sampling plots was also set.

The lowest growing stock according to estimation was in colinar-submontane forests (Figure 5), typical for Karst and Murska Sobota regional units. In the Karst regional unit, 69% of sampling plots belong to the class of thermophilous broad-leaf forests with the lowest growing stock estimation, and in Murska Sobota 10 of 22 sampling plots belong to forests of *Carpinus betulus* with *Quercus petraea* on silicate bedrock.

Using the FECS data, we estimated significant increase of the growing stock volume and basal area in the five-year period (Table 1). We found no significant difference between growing stocks for the temporally closest estimates by FECS of 2007 and SFS forest management planning inventory in the ten-year period.

Despite consistency of estimates on the basis of permanent sampling plots from forest management planning (Figure 4), caution is needed in connecting sampling plots from diverse monitoring programmes in Slovenia. We have assessed that representativeness of sampling plots on 16 x 16 km sapling grid, which were placed 50 m west to the cluster of four annually remeasured plots of the UNECE forest condition monitoring, could be questionable. In 2007, the estimates of stand basal area and growing stock on 42 sampling plots differed significantly ($P < 0.05$) from those on

other sampling plots of the 4-km grid. The estimates of an average basal area exceeded the estimates on the 4-km sampling grid by 5.3 m²/ha and the estimates of growing stock exceeded the ones on the same grid by 58.7 m³/ha. In 2012, the differences in stand density were no longer significant. A more detailed comparison revealing potential factors and causes according to individual forest site type strata or stages of development of forest stands was not carried out due to small sample size and high variability of stand parameters.

At the national level it has been possible to estimate structural differences only for a part of forest site types, which were encompassed by the 4-km sampling grid in 2012. Comparison of forest groups with regard to site and vegetation characteristics shows big differences in stand density among vegetation units and variability of stand density above all in colinar-submontane forests on carbonate and mixed carbonate-silicate rocks (Figure 5, Table 2). In addition to the lowest growing stock, the highest SDI variability has been estimated in thermophilous broad-leaf forests. In montane-altimontane forests on carbonate and mixed carbonate-silicate rocks, division into two subgroups is of key importance. The first one is composed of alpine (46% sampling plots), prealpine (25%) and predinaric montane beech (25%), and the second one of fir-beech on carbonate and mixed carbonate-silicate rocks (75%), prealpine-dinaric fir beech (14%) and prealpine fir-beech (12%). Differences

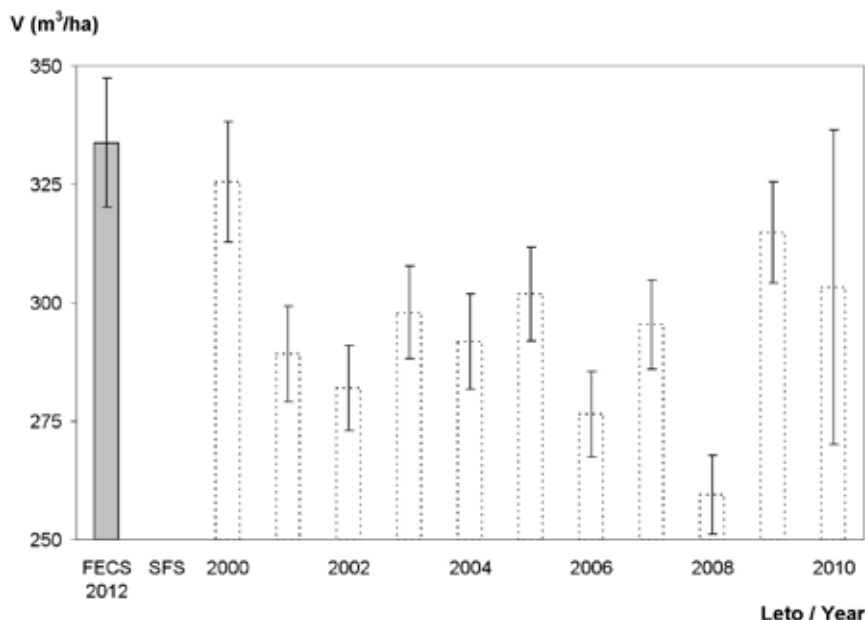


Fig. 3: Estimates of average growing stock with 95% confidence intervals - on 4 x 4 km sampling grid of the FECS in 2012 and on 1x1 km grid of permanent sampling plots of forest management planning (SFS). For SFS sampling plots, we also estimated average values according to individual years when measured.

Slika 3: Ocene lesnih zalog z intervalnimi vrednostmi pri 5 % verjetnosti pomote - na 4 x 4 km vzorčni mreži popisa MGGE v letu 2012 ter 1x1 km mreži stalnih vzorčnih ploskev gozdnogospodarskega načrtovanja ZGS (SFS). Za vzorčne ploskve ZGS smo ocenili povprečne vrednosti tudi po posameznih letih, ko so bile izmerjene.

Table 1: Comparison of stand densities for sampling plots on the harmonized 4 x 4 km sampling grid estimated within the framework of the FECS and SFS forest management planning (* Paired samples t - test and unpaired for panels, $P < 0.05$)

		FECS 2012	FECS 2007	SFS
No. of plots / Št. ploskev		760	751	738
Growing stock / Lesna zaloga (m ³ /ha)		333.7 *	313.6	300.0
Coefficient of variation / KV (%)		57.4	58.9	57.8
Basal area / Temeljnica (m ² /ha)		32.0 *	30.4 *	28.6
Coefficient of variation / KV (%)		47.7	49.0	49.2
SDI	Average / Povprečje	633 *	604	584
	Percentile 50 th	616	591	591
	75 th	790	759	741

Preglednica 1: Primerjava sestojnih gostot za vzorčne ploskve na usklajeni vzorčni mreži 4 x 4 km, ocenjenih v okviru popisa MGGE in gozdnogospodarskega načrtovanja ZGS (SFS) (* t - test za odvisne vzorce in neodvisne za primerjavo panelno oblikovanih inventur, $P < 0,05$)

in stand density for forest site types on silicate rocks are smaller, but estimation sample in 2012 was too small for experiencing statistical validation of these differences.

The highest stand densities were estimated in submontane-montane forest on sites of acidophilous beech (*Fagus sylvatica* forests on silicate bedrock) and forest sites of fir with fern (forests of *Abies alba* on silicate bedrock) (Figure 5, Table 2). In addition to highest growing stock, the highest SDIs were estimated in these site types, but besides high variability of stand density. For stands on acidophilous beech and acidophilous beech-sessile oak sites, we estimated that SDI did not achieve stand densities characteristic for Swiss tables of beech stands with high thinning on a quarter

of the sampling plots. Such lower SDI values were estimated on one-third of sampling plots on beech site types (Colinar - submontane *Fagus sylvatica* forests) on carbonate and mixed carbonate-silicate rocks.

In uneven-aged fir-beech stands, for which we have no comparable table reference estimates, we did not achieve SDI values estimated as the lowest in the 50-year development on research plots (Figure 2) on 42% of sampling plots. At the same time, values of the 75th SDI percentile reached values adopted on research plots as optimal values for fir-beech forests. On forest site types of other beech forests, 75th percentiles reach SDI values comparable to table values for even-aged low-thinning stands.

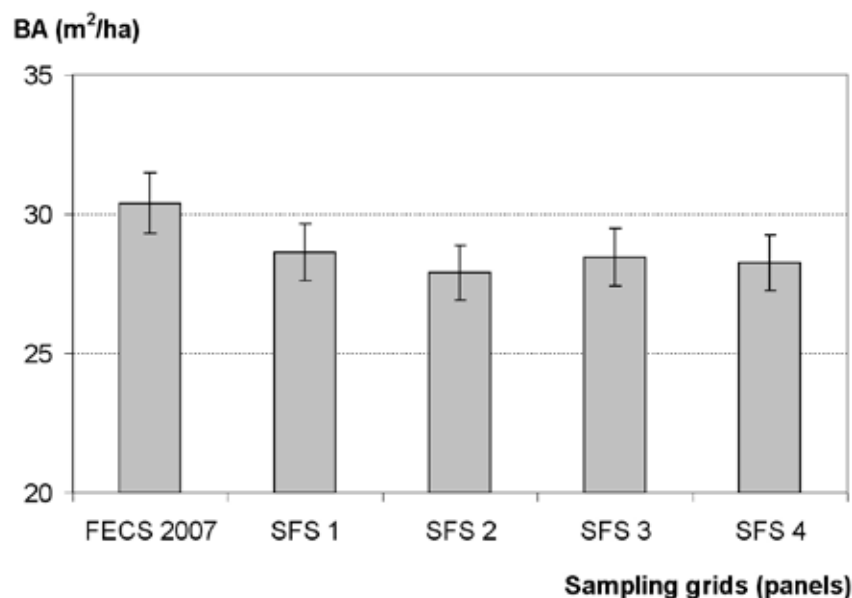


Fig. 4: Comparison of estimates of SFS and FECS stand basal area on 4 x 4 km sampling grids, designed on the basis of the basic systematic kilometre sampling grid

Slika 4: Primerjava ocen sestojne temeljnice ZGS in popisa MGGE na 4 x 4 km vzorčnih mrežah, oblikovanih iz osnovne sistematične kilometrske vzorčne mreže

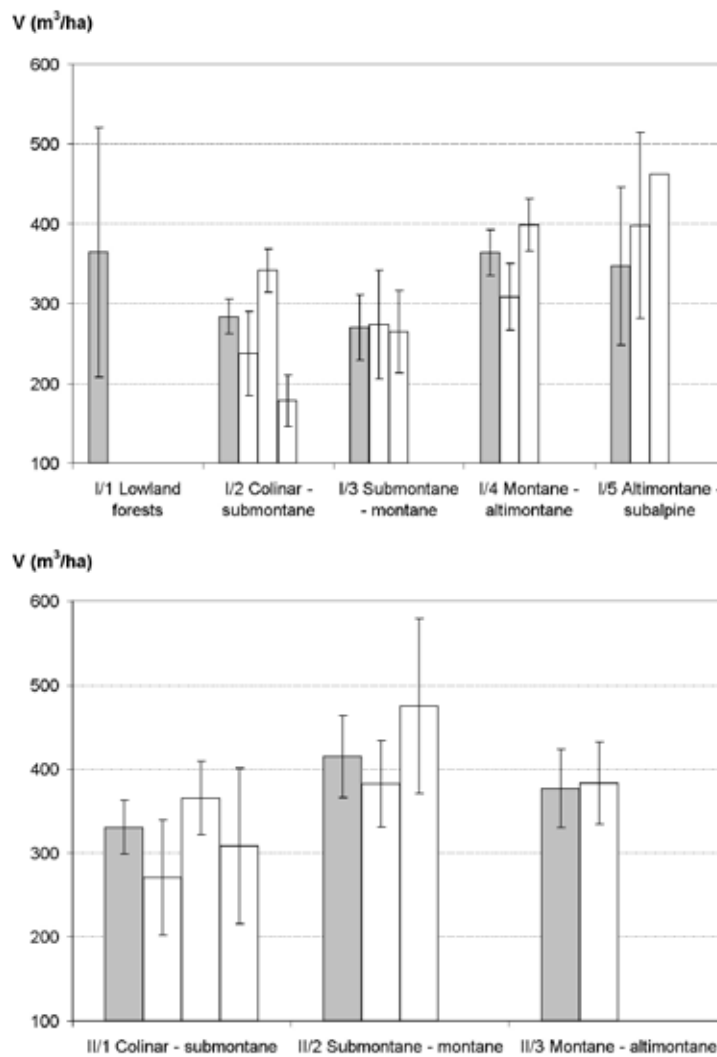


Fig. 5: Estimates of average growing stock in the year 2012 with 95% confidence intervals by groups of selected forest site types and selected vegetation units defined by ecological and floristic similarity of forest plant communities

Slika 5: Ocene lesnih zalog v letu 2012 z intervalnimi vrednostmi pri 95%-intervalu zaupanja po skupinah gozdnih rastiščnih tipov in izbranih vegetacijskih enotah, ki jih opredeljujejo gozdne združbe

- a) I Forest site types on carbonate and mixed carbonate-silicate rocks
 - I Gozdni rastiščni tipi na karbonatnih in mešanih karbonatno-silikatnih kamninah
 - b) II Forest site types on silicate rocks
 - II Gozdni rastiščni tipi na silikatnih kamninah
-
- I/ 1 Lowland forests on carbonate and mixed carbonate-silicate bedrock
 - I/ 2.1 Forests of *Carpinus betulus*, and of *Quercus petraea* on carbonate and mixed bedrock
 - 2.2 Colinar-submontane *Fagus sylvatica* forests on carbonate and mixed bedrock
 - 2.3 Forests and woodlands of thermophilous broadleaves
 - 3.1 Non-thermophilous *Fagus sylvatica* forests
 - 3.2 Thermophilous *Fagus sylvatica* forests
 - 4.1 Montane-altimontane forests of *Fagus sylvatica* on carbonate and mixed bedrock
 - 4.2 Forests of *Fagus sylvatica* with *Abies alba* on carbonate and mixed bedrock
 - 5.1 Altimontane-subalpine forests of *Fagus sylvatica* on carbonate and mixed bedrock
 - 5.2 Altimontane-subalpine forests of *Picea abies* on carbonate and mixed bedrock
 - II/1.1 Forests of *Carpinus betulus* with *Quercus petraea* on silicate bedrock
 - 1.2 Colinar-submontane forests of *Fagus sylvatica* with *Quercus petraea* on silicate bedrock
 - 1.3 Acidophilous *Pinus sylvestris* forests
 - 2.1 Submontane-montane *Fagus sylvatica* forests on silicate bedrock
 - 2.3 Submontane-montane forests of *Abies alba* on silicate bedrock
 - 3.1 Montane-altimontane *Fagus sylvatica* forests on silicate bedrock

Table 2: Comparison of growing stock volume and stand density variability for the selected forest site types on 4 x 4 km sampling grid, estimated within the framework of FECS in 2012 (N – number of sample plots, VOL – growing stock volume, BA – basal area, SDI – stand density index)

Preglednica 2: Primerjava lesnih zalog in variabilnosti sestojnih gostot za izbrane gozdne rastiščne tipe na vzorčni mreži 4 x 4 km, ocenjenih v okviru popisa MGGE leta 2012 (N – število vzorčnih ploskev, VOL – lesna zaloga, BA – temeljnica, SDI – indeks gostote sestoja)

Forest site type Code	N	VOL (m ³ /ha)	Coefficient of variation (%)			Percentiles SDI	
			VOL	BA	SDI	50 th	75 th
2.1 54. (041)	24	249.2	54	51	52	459	584
2.2 551 (072)	79	340.3	45	42	45	594	807
2.2 554 (131)	40	358.5	45	39	35	675	798
2.3 565 (275)	38	164.8	77	66	62	466	761
4.1 634 (083)	32	304.8	83	53	45	629	776
4.2 641 (161)	78	388.8	41	33	32	615	745
1.1 711 (042)	26	270.1	45	39	31	618	726
1.2 731 (132)	25	381.3	42	40	43	627	767
1.3 731 (144)	25	400.7	47	35	33	680	791
2.1 751 (151)	52	382.1	48	42	41	639	856
2.3 771 (202)	26	495.5	54	49	44	751	910
3.1 781 (141)	45	365.4	46	44	42	660	809

54. Predinarsko-dinarsko / Predalpsko / Predpanonsko gradnovno belogabrovje
Pre-Dinaric-Dinaric / Pre-Alpine / Pre-Pannonian forests of *Carpinus betulus* with *Quercus petraea*
- 551 Predinarsko-dinarsko podgorsko bukovje
Pre-Dinaric-Dinaric submontane forests of *Fagus sylvatica*
- 554 Gradnovno bukovje na izpranih tleh
Forests of *Fagus sylvatica* with *Quercus petraea*, on luvisols
- 565 Primorsko hrastovje in črnogabrovje na apnencu
Littoral forests of *Quercus sp.* and of *Ostrya carpinifolia* on limestone
- 634 Alpsko bukovje s črnim telohom
Alpine forests of *Fagus sylvatica* with *Helleborus niger*
- 641 Dinarsko jelovo bukovje
Dinaric forests of *Fagus sylvatica* with *Abies alba*
- 711 Kisloljubno gradnovno belogabrovje
Acidophilous forests of *Carpinus betulus* with *Quercus petraea*
- 731 Kisloljubno gradnovno bukovje
Acidophilous forests of *Fagus sylvatica* with *Carpinus betulus*
- 751 Kisloljubno bukovje z rebrenjačo
Acidophilous forests of *Fagus sylvatica* with *Blechnum spicant*
- 771 Jelovje s praprotni
Forests of *Abies alba* with ferns
- 781 Kisloljubno gorsko-zgornjegorsko bukovje z belkasto bekico
Acidophilous montane-altimontane forests of *Fagus sylvatica* with *Luzula luzuloides*

4 DISCUSSION AND CONCLUSIONS

4 RAZPRAVA IN ZAKLJUČKI

Comparing growing stocks estimated in FECS and on the adapted 4-km sampling grid of SFS forest management planning sampling plots, we discovered no overall significant differences in temporally comparable periods (Table 1). Forestry practitioners took into account the basic kilometre sampling grid in the design of forest inventories for individual forest management

units, therefore we had estimated beforehand (Hladnik and Žižek Kulovec, 2012) that 70% of sampling plots from forest management planning had been consistent with this systematic sampling grid.

However, shaping the basic design of national forest inventory in Slovenia, it is not acceptable just to connect two inventory systems and to transform a part of permanent sampling plots of FMP into panel system, which would ensure a large enough number of sam-

pling plots, estimation of sampling error according to individual time periods of forest resources reporting and estimation of trends in forest development. We have presented such system since an observation has been issued in the report on harmonization of national forest inventories (Lawrence et al., 2010) that many countries conduct periodic inventories in which a complete inventory is completed in few years and they are increasingly moving toward annual or rolling inventories, in which some 10-20% of plots are measured each year. In a 5-year panel inventory, 20% of all plots are measured each year, thus enabling a complete sample of each state every year. Individual panels can yield information about variations that occur within a measurement cycle, as well as long term cycles and trends (Patterson and Reams, 2005). Combining the panels, the estimates of the mean of the forest attributes at the current point in time are obtained using several estimation strategies as, for example, the moving average and temporally indifferent method (Patterson and Reams, 2005), nearest neighbour imputation methods (Eskelson et al., 2009). Such monitoring concept is efficient because the panels enable greater flexibility since they can be combined in various ways and connected with other annual ancillary data. With multi-annual cycles of data collection, sufficient large samples for estimation according to individual strata at the national level and, at the same time, reduction of variance through stratification can be ensured. Panel inventory system does not offer a solution for the current method of data collection on the level of forest management units, where the shortage of assets for a repeated measurement of permanent sampling plots has risen. Thus even the density of sampling grid has been reduced in some regional SFS units (ZGS, 2013a).

To ensure unbiased estimators, inconspicuousness or at least possibly small visible markings on trees of sampling plots while planning the sampling grid in the field work are desired. If the permanent sampling plots are marked in such a way that operative forestry experts can notice them during their work, the representativity of these plots can become questionable. The marked sample plots could have influenced the forest service in a way that stands with visible sample plots were managed differently than other stands or were excluded from any kind of forest activity. The potential loss of representativeness was expected due to the clearly labelled or marked trees of FCM plots in the field (Gasparini et al., 2012). In Germany, the sample grid of NFI is shifted relative to the grid of the forest health inventory because the latter is openly marked and the silvicultural influences on the grid were ex-

pected. The sampling grid of the forest health inventory and the forest soil inventory was moved a few hundred metres away from the NFI (Polley et al., 2010). The 50-m distance west to the previous four cluster samples on the 16-km sampling grid in Slovenia was probably too little to ensure low perceptibility of the new concentric plots in the stands, where tree decline estimations had started 30 years ago and were repeated in annual cycles (Hočevár et al., 2002).

Warnings about representativeness of the sampling plots are especially important in Slovenia, where we can hardly expect forestry practitioners not to recognize the sampling plots' locations they notice at intense planning and field work, forest management or silvicultural planning or even when marking the trees for logging operations on the total forest area, irrespective of forest ownership. A discussion about differences in harvest quantity given by district foresters in their evidences for the ten-year period and estimates from permanent sampling plots also took place among forestry experts in Slovenia (Bončina et al., 2010). In some SFS regional units, the concept of continuous forest inventory has started 40 years ago (Grilc, 1972) and the trees on sampling plots were after four or in most Slovenian forest at least two measurement repetitions heavily marked at breast height, where the tree diameter was measured.

The great variety in sampling design for forest management planning in forest management units in Slovenia (Pisek, 2010) makes simple summarisations and assessment difficult, similar to problems in the presentation of sampling designs during the harmonisation process in European national forest inventories (Lawrence et al., 2010). The forest area represented by NFI field sample plots in EU countries varies from 50 ha (Belgium, Luxembourg, Iceland) to 178 ha in Austria, 205 ha in Germany, 449 ha in France, 900 ha in Norway and 1,310 ha in Italy - selected as examples of diverse sampling designs. Due to a long delay of the establishing national forest inventory in Slovenia, we have come to the point when we can report on the basis of the 4-km sampling grid, where every sampling plot represents an area of 1,600 ha. However, at the level of forest management units we can no longer support such high density of sampling grids where 95 % of the entire sampling plots number represented an area of up to 12.5 ha (Pisek, 2010).

At interpretations of data on forest areas it has been estimated for the first time in the last fifty years that forest cover in Slovenia decreased (ZGS, 2011), but it was impossible to infer a reliable estimate of a potential trend, since after two successive reports an

increase of forest cover was evaluated again in 2012 (ZGS, 2013b). According to the foresters' evidences, the deforested area was almost 10 times smaller in the last 10-year period than indicated by the data collected in agricultural sector (Nastran and Žižek Kulovec, 2014). The majority of discrepancies occurred due to different interpretation of the otherwise unchanged condition in nature. Harmonization of criteria for land use and land cover determination in agriculture and in forestry will have to be carried out together with continuation of harmonization of forest inventories taking place in individual SFS regional units and FECS at the national level. One of the key mechanisms for such a harmonization process is the typology of Slovenian forest sites (Kutnar et al., 2012). Although it is intended primarily for operative use in forestry for forest management planning, due to the indicated connections with the existing systems of forest vegetation and its hierarchical concept, we have used it for the estimation of stand densities and their variability according to forest site types.

Considering coefficients of variation for growing stock, estimated between 40% and 50% (Table 2), 70 to 100 sampling plots would be needed for desirable precision (10%) of the estimates for individual forest site types – four times the number of plots in the FECS. Proposal on design of 19 main site groups, which were proposed for creating operative forest management classes on the basis of detailed forest site typology (Kutnar et al., 2012), is also the basis for forest development estimation within the framework of potential national forest inventory in Slovenia. Considering the current forest management models leaning against foreign or adapted yield tables (Veselič and Pisek, 2009), estimates of reference stand densities could be formed on the basis of sampling plots and suggested forest site typology. We have indicated them by estimating SDI according to selected forest communities (Table 2). Considering current researches on site index and site productivity in Slovenian forests (Kotar, 2005), we could complement these researches, by increasing the number of sampling plots, and continue estimating maximum stand densities in mixed species and uneven-aged stands on the basis of the technique for estimating the 99th percentile as the maximum observed SDI (Woodall et al., 2005). The 99th percentile is used to eliminate extreme outliers in a large estimation sample; therefore such a methodology has not been carried out in the FECS yet. In the first step, we compared the estimated SDI values on sampling plots with the values derived from the adapted yield tables. Pretzsch and Biber (2005) re-evaluated this rule on 28 fully

stocked pure stands of common beech, Norway spruce, Scots pine and common oak in Germany that date back to the year 1870. They showed that except for Scots pine, the allometric coefficients deviate significantly and close-to-significantly from the coefficient -1.605 . Shaw (2006) reported that some investigators have determined the relative density slope should be more or less than 1.6, while others have found no evidence that the slope should differ from Reineke's.

Similar as in forest management model analysis on the basis of yield tables (Veselič and Pisek, 2009), on the level of sampling plots we also estimated the share of understocked sampling plots with too low density or, respectively, we reached indirect conclusions about the share of blanks and gaps on sampling plots. We will be able to get an objective estimate about shares of blanks and gaps, if we introduce estimation of surface area shares of individual tree species and stages of development of forest stands on individual sampling plots within the framework of forest inventories harmonization in Slovenia. For example, in the framework of national inventories, the stratifications of forest area based on field assessment of the 1/10-shares of the forest plot covered by the species, the age classes and the growth classes are used. In a similar way, the share of blanks and gaps is included in the assessment (Gschwantner et al., 2010). Such estimation method will cause new inconsistencies in estimating structural forest characteristics in Slovenia, since they have been estimated on the basis of data aggregation from the level of forest site types to the level of forest management regions and to the national level up to now. We therefore propose harmonization process focused on the search for connections between the present models and indicators used in standwise forest inventories for forest management planning and indicators suggested within the framework of national forest inventories in European countries.

5 POVZETEK

5 SUMMARY

Na državni ravni ocenjujemo gozdne vire na podlagi dveh konceptov gozdnih inventur - v gozdnogospodarskih enotah Zavoda za gozdove Slovenije in na podlagi monitoringa gozdov in stanja gozdnih ekosistemov (MGGE), ki je bil izpeljan iz mednarodnega programa monitoringa stanja gozdov (Forest Condition Monitoring / ICP Forests). Ocene o gozdnih virih pridobivamo na podlagi agregiranja podatkov iz gozdnogospodarskih enot in gozdnogospodarskega načrtovanja ter vzporednega popisa MGGE. Po gozdnogospodarskih enotah potekajo gozdne inventure v 10-letnih ciklih,

vsako leto v desetini teh enot. Tak način zbiranja podatkov ni primerljiv s panelnim inventurnim sistemom (Reams et al., 2005), v katerem je sistematična mreža vzorčnih ploskev razdeljena v posamezne skupine, imenovane paneli. Te premikajo tako, da je vsak panel na celotni površini države izmerjen v posameznem letu. V ZDA so na primer vzorčne ploskve sistematično razporejene v pet panelov, v petletnem obdobju je na celotni površini ZDA letno izmerjenih 20 % vzorčnih ploskev, kar vsako leto zagotovi vzorčno oceno na ravni celotne države (McRoberts et al., 2010). Opisani panelni inventurni sistem ne ponuja rešitve za dosednji način zbiranja podatkov na ravni gozdnogospodarskih enot, v katerih je v zadnjih letih začelo primanjkovati sredstev za ponovno merjenje stalnih vzorčnih ploskev, tako da so na nekaterih območjih enotah ZGS zmanjšali gostoto mreže vzorčnih ploskev (ZGS, 2013a).

Pred morebitnim spreminjanjem in povezovanjem obeh inventurnih sistemov smo želeli preveriti:

- kakšna so izhodišča in možnosti za primerjavo ocen o gozdnih virih na podlagi popisa MGGE in gozdnogospodarskega načrtovanja v gozdnogospodarskih enotah Slovenije,
- kakšna je konsistentnost ocenjevanja gozdnih virov na podlagi različne razmestitve sistematičnih vzorčnih mrež in pogostosti popisovanja stalnih vzorčnih ploskev v okviru popisa MGGE,
- kakšna je variabilnost sestojnih gostot in kakšna je možnost stratificiranja inventurnih podatkov po stratumih, oblikovanih v tipologiji gozdnih rastišč na ravni države (Kutnar et al., 2012).

Za primerjavo z vzorčnimi ploskvami iz gozdnogospodarskega načrtovanja Zavoda za gozdove Slovenije smo sprva preverili skladnost kilometrske vzorčne mreže z mrežami stalnih vzorčnih ploskev na Slovenskem, nato pa za tiste kilometrske kvadrate, v katerih smo določili gozdne zaplate ali prostorske enote gozdne matice, iskali najbližjo stalno vzorčno ploskev (Hladnik in Žižek Kulovec, 2012). V naslednjem koraku smo iz zbirke podatkov izluščili vzorčne ploskve, ki so bile prostorsko skladne s tistimi na 4 x 4 km mreži. Te smo uporabili za primerjavo sestojnih gostot, ocenjenih v popisu MGGE in v sklopu gozdnogospodarskega načrtovanja ZGS. Za oceno stanja različnih skupin gozdov na ravni države smo uporabili tipologijo gozdnih rastišč Slovenije, ki temelji na ekološki in floristični podobnosti gozdnih rastlinskih združb (Kutnar et al., 2012). Na ravni države smo primerjali ocene o povprečnih vrednostih sestojnih gostot na podlagi vzorčnih ploskev, ki smo jih uskladili na mreži 4 x 4 km za gozdne inventure popisa MGGE iz let 2007 in 2012 ter

gozdnogospodarskega načrtovanja v desetletnem obdobju do leta 2010. S podatki popisa MGGE smo v petletnem obdobju ocenili značilno povišanje neto lesnih zalog in temeljnice (preglednica 1). Za časovno najbližji oceni lesnih zalog MGGE iz leta 2007 in gozdnogospodarskega načrtovanja ZGS v desetletnem obdobju nismo odkrili značilnih razlik.

Na ravni države je bilo mogoče presojati o strukturnih razlikah le za del gozdnih rastiščnih tipov, ki so bili v letu 2012 zajeti s 4-km vzorčno mrežo. Največje sestojne gostote smo ocenili v podgorsko-gorskih gozdovih na rastiščih kisloljubnega bukovja ter jelovja s praprotni (slika 5, preglednica 2). Ob visokih lesnih zalogah so bili v teh rastiščnih tipih ocenjeni najvišji SDI, vendar ob visoki variabilnosti sestojnih gostot. Za sestojne na rastiščih kisloljubnega bukovja ter kisloljubnega gradnovega bukovja smo ocenili, da na četrtini vzorčnih ploskev SDI ne doseže sestojnih gostot, značilnih za švicarske tablice bukovih sestojev z visokim redčenjem. Na rastiščnih tipih bukovja na karbonatnih in mešanih kamninah (predinarsko-dinarsko podgorsko bukovje) smo take nižje vrednosti SDI ocenili na tretjini vzorčnih ploskev. V raznodobnih jelovo bukovih sestojih, za katere nimamo primerljivih tabličnih referenčnih ocen, na 42 % vzorčnih ploskev nismo dosegli vrednosti SDI, ki so bile kot najnižje ocenjene v 50-letnem razvoju na raziskovalnih ploskvah (slika 2). Hkrati so na tem gozdnem rastiščnem tipu vrednosti 75 percentila SDI dosegle vrednosti, privzete na raziskovalnih ploskvah kot optimalne v jelovo bukovih gozdovih. Na gozdnih rastiščnih tipih drugih bukovih gozdov dosegajo 75 percentili vrednosti SDI, ki so primerljive s tabličnimi vrednostmi enodobnih nizko redčenih sestojev.

Ob koeficientih variacije za lesno zalogo, ocenjenih med 40% in 50 % (preglednica 2), bi za ocenjevanje posameznih gozdnih rastiščnih tipov na državni ravni potrebovali 70 do 100 vzorčnih ploskev – štirikrat večje število vzorčnih ploskev kot v dosedanjem popisu MGGE. Pri morebitnem oblikovanju zasnove nacionalne gozdne inventure v Sloveniji ni sprejemljivo zgolj povezati dveh inventurnih sistemov in del stalnih vzorčnih ploskev gozdnogospodarskega načrtovanja preoblikovati v panelni sistem, s katerim bi zagotovili dovolj veliko število vzorčnih ploskev, statistično ocenjevanje po posameznih časovnih obdobjih poročanja o gozdnih virih in ocenjevanje trendov v razvoju gozdov. Za zagotovitev zanesljivih ocen je treba ob načrtovanju vzorčne mreže pri terenskem delu paziti na neopaznost ali vsaj čim manjšo opaznost vzorčnih ploskev v gozdnih sestojih. Vsaj izkušnje in ocene iz 16-km vzorčne mreže za letno poročanje o stanju gozdov na

Slovenskem opozarjajo na morebitno izgubo reprezentativnosti stalnih vzorčnih ploskev v gozdnih sestojih, če so označene ali obiskovane tako pogosto, da jih pri svojem delu lahko opazijo tudi operativni gozdarski strokovnjaki.

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