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SILVER FIR (*Abies alba* Mill.) DISTRIBUTION IN SLOVENIAN FORESTS

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Abstract

We analysed the characteristics of silver fir (*Abies alba* Mill.) occurrence and distribution in Slovenia using databases of the Slovenian Forest Service (SFS). Silver fir is the third most widely distributed tree species in Slovenia, occurring in approximately 40 % of total forest area, but abundantly in less than 10 %. Its share in total growing stock varies between separate forest management regions. It is more abundant in the Dinaric and part of the Pre-alpine phytogeographic regions. The highest share in total growing stock reaches at altitudes between 800 m and 1000 m above sea level, forests with silver fir cover the most extensive surface in the altitude belt from 1000 to 1200 m. Silver fir occurs abundantly in 11 syntaxes. Between them, silver fir-beech forests (*Abieti-Fagetum dinaricum* TREG. 57, syn.: *Omphalodo-Fagetum* (TREG.57 corr. PUNC.80) MAR et al. 93) strongly prevail, followed by fir forests with fern (*Dryopterido-Abietetum* KOŠ.65, syn.: *Galio rotundifolii-Abietetum* BARTSCH.40). Silver fir diameter distribution considerably varies between separate forest management regions. The regions with the highest share of silver fir (Postojna, Kočevje) dominate also in having large diameter silver fir trees, whereas in other regions (e.g. Nazarje, Kranj, Maribor) small diameter silver fir trees are prevalent. Developmental stage structure shows that in forest stands with silver fir there is a higher share of timber phase, stands in regeneration, youth stands and selective forests. Considering regeneration we can conclude, that more intensive decreasing trend in silver fir share is expected in the Dinaric phytogeographic region than in northern parts of Slovenia. Successful regeneration due to lower red deer population and balanced stem diameter structure with higher proportion of small diameter trees promise easier conservation of silver fir in northern parts.

Key words: Abies alba, area, forest stand structure, forest vegetation, altitude, Slovenia.

RAZŠIRJENOST JELKE (Abies alba MILL.) V SLOVENSKIH GOZDOVIH

Izvleček

S podatki o gozdnih fondih Slovenije 2003 Zavoda za gozdove Slovenije smo analizirali značilnosti pojavljanja in razširjenosti jelke v Sloveniji. Jelka je tretja najpogostejša drevesna vrsta v Sloveniji, pojavlja se na kakih 40 % površine gozdov, obilneje pa na manj kot 10 %. Njen delež po gozdnogospodarskih območjih močno variira, obilneje se pojavlja na dinarskem in delu predalpskega fitogeografskega območja. Najvišji delež v lesni zalogi doseže v gozdovih na nadmorski višini 800-1000 m, površinsko pa so gozdovi z jelko najbolj razširjeni v nadmorskem pasu 1000-1200 m. Jelka se obilneje pojavlja v 11sintaksonih. Močno prevladujejo dinarska jelova bukovja, tem sledijo jelovja s praprotmi. Debelinska struktura jelke je med območji zelo različna. Območja z najvišjim deležem jelke (Postojnsko, Kočevsko) zbujajo pozornost tudi glede debelega lesa, nasprotno je v drugih območjih (Nazarje, Kranj, Maribor) razmeroma velik delež tankega drevja jelke. V sestojih z jelko je spremenjenost drevesne sestave v povprečju manjša kot na celotni površini gozdov. Struktura gozdov z jelko po razvojnih fazah kaže, da je v primerjavi z vsemi gozdovi tu več debeljakov, pomlajencev, prebiralnega gozda in mladovja. Upoštevajoč pomlajevanje lahko zaključimo, da se v dinarskem delu na splošno nakazuje bolj izrazit trend zmanjševanja deleža jelke v gozdovih kot v severnih območjih (Maribor, Nazarje). Uspešnejše pomlajevanje zaradi manj jelenjadi, ugodnejša debelinska struktura z relativno večjim deležem tanjšega drevja jelke obeta verjetno uspešnejše ohranjanje jelke v teh gozdovih.

Ključne besede: jelka, areal, struktura gozdnih sestojev, gozdna vegetacija, nadmorska višina, Slovenija

INTRODUCTION
UVOD

Forests ecosystems are dynamic and complex systems, their structure is complicated and changing in time. Forest stands are described with forest structure and composition. Tree species composition is an important information about forest stands and therefore about the entire forest biocoenosis. Composition of forests is changing due to natural and anthropogenic influences (BONČINA et al. 2003b). It is often hard to distinguish between them, as they can act mutually, directly and indirectly. By its »nature«, tree species composition is not static. The composition of climax communities can fluctuate; Whittaker (1973) has already described it as a complex of possible stationary situations that climax coenosis could

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achieve…. Current state of forests as well as tree species composition in stands is the result of past development and somehow a record of all previous influences (GAŠPERŠIČ, 1995; ŠERCELJ, 1996). For close to- nature and ecosystem forestry we should recognize developmental processes in forests and understand the reasons for them. This is the base for better prognosticating and managing of forests in the future. The population of silver fir (*Abies alba* Mill.) is changing significantly in its natural range and is therefore also the subject of our research.

For understanding changes of tree species composition we need data for past periods. Spatial units for studying forest development are different: in forest management planning process, this is usually forest management unit or forest management class, for which we have chronological data on forest stands in decennia as well as data on forest management itself (cutting, silvicultural works, protection works, etc.). Despite forest management planning has a rich and long tradition in Slovenia and although forests had been inventoried at the level of basic inventory units many times, no comprehensive analysis of actual state of forest stands in Slovenia has been made yet. State and developmental analysis are often limited to certain smaller areas; a minor analysis has been made about the present state and development of forests at the national level. Neither have we made a detailed analysis of the occurrence and distribution of tree species depending on site conditions, which are indirectly described with potential forest vegetation (syntaxes), forest management and other factors.

In the past, studies of spatial distribution and characteristics of tree species were limited to certain tree species and their specific properties (ACCETTO, 1995; PAVLE et al. 1996; PIŠKUR 1999; KADUNC 2003) or to certain areas, study objects or specific vegetation communities (HLADNIK, 1991; PISKERNIK 1993, DIACI 1994, DAKSKOBLER 1995, BRUS 1998, CENČIČ 2000, BONČINA et al. 2003a, BRUS / LONGAUER 1995b). Many researchers (e.g. BRUS 1995a, HORVAT-MAROLT / KRAMER, 1982) have dealt with morphological and dendrological aspects of tree species, or minor tree species (KOTAR, 1995, ROBIČ 1995, KOTAR/BRUS, 1999). Basic literature about tree species and silviculture in Slovenia (REMIC 1975, MLINŠEK 1991, DIACI 2001a,b, BRUS, 2004) includes some parts that relate to species distribution, but is mostly applicable for study purposes of forest ecology and silviculture. REMIC (1975) showed spatial distribution of some dominant tree species in Slovenia; a more descriptive survey is in BRUS (2004).

In the chair of forest management planning we decided to do a research into the occurrence and distribution of tree species in Slovenia, using comprehensive data of the Slovenian Forest Service (SFS).

The first occurrence and distribution analysis was made for silver fir. There are many reasons for that: silver fir is one of the most important tree species in Slovenia from the silvicultural and management point of view (PRELC et al. 1993). Its share in total growing stock decreased in the past decades due to intensive fir decline (MLINŠEK, 1964, BRINAR 1974). In the chair of forest management planning we also finished research project (BONČINA et al. 2004) about selection forests in Slovenia, where fir as one of the key tree species in this type of forests was also the subject of our analyses.

Information from the entire forest area in Slovenia is gathered in the Forest Information System (FIS), managed by the Slovenian Forest Service. FIS gives the most complete overview of the forests' tree species composition. Data on tree species are shown for various inventory and planning units and are reviewed continuously. For the preparation of forest management unit plan, a detailed inventory of forest stands is carried out at two levels: measurements on permanent sampling plots and forest stand description. The quality of the data acquired in this way is in its detail: data are presented for relatively small areas (forest sub-compartment) that measure only 16 ha on average. At the level of forest sub-compartments, other important ecological parameters are also collected, such as incline, altitudes, exposition, etc.). The extensive SFS's databases has not been fully used for research purposes so far, except for the altitudinal research of structure, composition and silviculture of Slovenian forests according to stand and site conditions by Bončina et al. (2001).

METHODS
METODE

We analysed data of Slovenian forests at the level of forest sub-compartments. Three basic databases in FIS were used for the study regarding the occurrence and distribution of tree species:

- database of general information of sub-compartments and forest sites (sub-compartment denotation, Gauss-Krüger coordinates, altitude range of sub-compartment, incline, forest sites),
- database of growing stock and increments of tree species in sub-compartment (for all registered tree species in forests),
- database of developmental stages in sub-compartment (area of certain stage in sub-compartment).

There are approximately 72.000 sub-compartments (records) in the database. For the time of research, vector layer of sub-compartments in FIS was available only for the year 2001. Therefore it was not possible to show graphically all numeric results from 2003 in vector layer of sub-compartment from 2001. In the 2001-2003 period came to the union of certain sub-compartments or even management units. We achieved 93 % connection between numeric results of research from 2003 database with vector layer of sub-compartments from 2001. 7 % of the forest surface or 41.148 ha could not be correctly shown in pictures, even though the entire forest area was analysed.

As we were interested in the characteristics of silver fir distribution, we put growing stock of silver fir in sub-compartment higher than nil as a selection criterion. We previously omitted all records with obvious errors. To present the distribution of silver fir in phytogeographic regions, we used the original division from Wraber (1969), which is still much in use due to its practicability and general application.

In each sub-compartment, up to three vegetation communities are described. Their denomination between management regions is harmonized at the level of associations. In the analysis, we strictly use denomination of forest vegetation communities as used in FIS even when names are invalid, additionally quoting currently valid names using cross-reference index made by Robič (2003). We analysed distribution of silver fir in vegetation communities by using prevailing association in each sub-compartment. Furthermore, we fused all associations where fir occurred into various site groups by methodology prepared by Veselič and Robič (2001). As fir can occur in various associations in range from less than 1 % to more then 50 % of total growing stock, we decided to take into further consideration only associations, where fir exceeded 20 % in growing stock. Tree species composition of a certain forest association at the national level is the average of tree species composition of all sub-compartments with identical association in the management region. We placed forest communities with higher fir share (above 20 %) into the following site groups (VESELIČ and ROBIČ, 2001):

- Silver fir and spruce forests on skeleton ground (*Neckero-Abietetum* TREG.62*, Festuco- Abietetum, Asplenio-Picetum* KUOCH.54).
- Silver fir forests with fern (*Dryopterido-Abietetum* KOŠ.65, syn.: *Galio rotundifolii-Abietetum* BART-SCH.40*)*.
- Silver fir forests on non-carbonate ground (*Bazzanio-Abietetum* M.WRAB.(53)58 *Luzulo-Abietetum, syn:. Luzulo albidae-Abietetum* OBERD.57 var. geogr. *Hieracium rotundatum* KOŠ.94).
- Beech-fir forests on carbonates of sub-mountain zone (*Clematido-Abietetum* syn.*: Omphalodo-Fagetum asaretosum*, syn.: *Abieti-Fagetum dinaricum* TREG.57 *clematidetosum* TREG.60*)*
- Dinaric fir-beech forest in freezing ravines (*Lycopodio-Abietetum*, syn.: *Omphalodo-Fagetum lycopodietosum*, syn.: *Abieti-Fagetum dinaricum* TREG.57 *lycopodietosum* TREG.57)
- Dinaric fir-beech forests on well-formed and deep ground (*Abieti-Fagetum dinaricum, syn.: Omphalodo-Fagetum* (TREG.57 *corr*. PUNC.80)MAR *et al.* 93)
- Maple forests, ash forests and elm forests (*Carici remotae-Fraxinetum* W.KOCH 26 ex FABER 36*, Ulmo-Aceretum pseudoplatani BERGER 22*).

When analysing tree species composition alteration of forests where silver fir was present, 4 classes according to the classification system by SFS were established:

- natural tree composition is not modified (max. 30 %),
- natural tree composition is modified (from 31 to max. 70 %),
- natural tree composition is strongly modified (from 71 to max. 90 %),
- natural tree composition is altered (over 90 %).

The result of primary preparation and processing of databases was only a single database with around 27.000 forest

sub-compartments, in which silver fir is present. This primary database was further processed and analysed by Fox Pro 2.6, Microsoft Excel 2003 and SPSS 13.0 for Windows computer programmes. Maps were prepared with Map Info Professional 7.8.

For showing trends in Slovenia and in some other European countries, we used different written sources, SFS's older databases, as well as accessible national inventories from foreign countries.

RESULTS
REZULTATI

SHARE OF SILVER FIR IN THE FORESTS' TREE SPECIES COMPOSITION
DELEŽ JELKE V DREVESNI SESTAVI GOZDOV

Total growing stock (GS) in Slovenia encompasses **285,738,349** m^3 or 247 m^3/ha, **22,654,306** m^3 of which (or 19 m^3/ha or 7,9 % of total growing stock) goes to silver fir. In terms of abundance, silver fir holds the third position after spruce (32,3 %) and beech (31,5 %) and before sessile oak (6,3 %), red pine (4,7 %), sycamore maple (2,6 %), hornbeam (2,6 %), chestnut (1,8 %), hop hornbeam (1,1 %), turkey oak (1,0 %) and many other minor tree species that contributes less than 1 % to the growing stock. Because of the heterogeneity of the national forests silver fir growing stock funds vary considerably from the average between separate forest management regions (Table 2); it is abundant in the forest management regions (FMR) of Postojna (71 m^3/ha), Kočevje (53 m^3/ha) and Maribor (28 m^3/ha).

HORIZONTAL DISTRIBUTION
HORIZONTALNA RAZŠIRJENOST

Silver fir is present on approximately 40 % of the total forest area in Slovenia (Table 1, Figure 1), considering all forest sub-compartments in which silver fir is noticed. If we limit ourselves to only those sub-compartments in which silver fir share is higher than a quarter of the total growing stock in it, such forests cover only 9,3 % of the total forest area (Table 1, Figure 1). Most outstanding FMRs in which silver is abundant (more than 25 % of the total growing stock volume) are Postojna, Kočevje and Maribor (Table 2). Forest stands with the share of silver fir higher than 50 % represent only 3 % of all forests. Only 4,400 ha forest stands could be described as "fir stands", which means that fir share in such stands is higher than 75 % of the total growing stock.

Mixed stands with share of fir higher than 25 % are relatively infrequent in FMR of Bled, Nazarje and Kranj, even though they would be expected considering site conditions. It is understandable that forest stands with share of silver fir higher than 25 % of GS could virtually not be found in FMRs of Murska Sobota, Kras and Brežice (Table 2, Figure 1). These three FMRs lie predominantly in sub-Pannonian and sub-Mediterranean phytogeographic regions, in which silver fir could not be found at all. The review of distribution of silver fir in phytogeographic regions shows that it occurs abundantly in the Dinaric phytogeographic region and in part of the pre-Alpine phytogeographic region (Figure 2).

Table 1: Forest area in Slovenia in view of silver fir share in total growing stock of stands

Preglednica 1: Površina gozdov v Sloveniji glede na delež jelke v lesni zalogi

Silver fir share in total growing stock (%)	Forest area (ha)	Share of total forest area (%)
Delež jelke v lesni zalogi sestojev (%)	*Površina (ha)*	*Delež površine gozdov (%)*
0	692984	59,8
≤0,5 %	44407	3,8
0,51-1,00	45800	4,0
1,01-2,00	47350	4,0
2,01-5,00	70834	6,1
5,01-10,00	65779	5,7
10,01-25,00	83715	7,2
25,01-50,00	72637	6,3
50,01-75,00	30565	2,6
75,01-100,00	4403	0,4
Total	1158473	100

OCCURRENCE OF SILVER FIR ALONG THE ALTITUDE GRADIENT
POJAVLJANJE JELKE GLEDE NA GRADIENT NADMORSKE VIŠINE

The occurrence of silver fir was analysed according to 200-metre altitude belts. It is present from 0 to 1800 m above

Table 2: Forest area in FMRs in view of silver fir share in total growing stock of stands

Preglednica 2: Površine gozdov po gozdnogospodarskih območjih glede na delež jelke v lesni zalogi gozdnih sestojev

FMR	Forest area with silver fir share higher than 25 % of GS (ha)	Share of total FMR area (%)			
		Silver fir share in total growing stock (%)			
		0 %	≤25 %	>25 %	Total
GGO	Površina sestojev z deležem jelke v LZ nad 25 % (ha)	Odstotek celotne površine območja (%)			
		Odstotek jelke v lesni zalogi sestojev (%)			
		0 %	≤ 25 %	>25 %	Skupaj
Tolmin	6356	70,8	24,7	4,6	100
Bled	54	23,4	76,6	0,1	100
Kranj	4330	44,8	49,3	6,0	100
Ljubljana	13669	62,9	27,5	9,6	100
Postojna	30497	23,6	36,6	39,8	100
Kočevje	25032	43,0	30,2	26,8	100
Novo mesto	7513	62,4	29,8	7,9	100
Brežice	394	90,7	8,7	0,6	100
Celje	1221	63,8	34,6	1,6	100
Nazarje	2629	44,7	50,0	5,4	100
Sl. Gradec	2734	64,8	30,7	4,6	100
Maribor	13123	51,5	34,9	13,7	100
M. Sobota	0	99,2	0,8	0,0	100
Kras	50	96,9	3,1	0,1	100
Total	107605	59,8	30,9	9,3	100

sea level (a.s.l.), but its share (abundance) in forest stands is considerably various (Table 3); it is abundant in the altitude range from 600 to 1200 m; within that, it reaches the maximum in the altitude belt from 800 to 1000 m a.s.l., where it represents 18 % of total growing stock of all forests within this belt.

Forest area structure along the altitude gradient (Figure 3) shows that most Slovenian forests lie within the altitude belt from 400 to 600 a.s.l., the majority of them within 200-800 m a.s.l. Forest area structure along the altitude gradient is different where silver fir is present; with most of the forests with silver fir lying within 600-800 m belt (Figure 3). More informative is the relationship between the area of forests with silver fir and total forest area in certain altitude belt. Forests where silver fir is registered cover more than 50 % of total forest area in the altitude belt from 800 to 1400 m a.s.l. Considering the area distribution, silver fir is widespread within the altitude belt from 1000 to 1200 m, where it grows on more than 70 % of the forest area (Figure 3).

Let us take a look at the distribution of forests, where share of silver fir in total growing stock is higher than 25 %. Absolutely and relatively, such forests are distributed mainly in the 800-1000 m belt; the second place in view of the share of such forests in total forest area of the belt is held by the 1000-1200 m belt, and the third by 601-800 m belt. Forests with silver fir share higher than 25 % could also be found in the 400-600 m belt, whereas they are rare or could even not be found at all other altitudes (Figure 3).

Forests are changing along the altitude gradient due to various natural conditions as well as different human impacts. This could be illustrated by growing stock changing; the mean growing stock of stands increases until 1200 m a.s.l., then it decreases. In all altitude belts, forests with silver fir have higher mean growing stock values than all forests in the same belt; the higher silver fir share the higher mean growing stock volume (Table 3). The most obvious difference is at lower altitudes (below 800 m), while higher differences are less significant. Results also indicate that silver fir generally occurs in well preserved forests and/or predominantly older developmental stages (Figure 6, Table 5). Differences could partially be explained with high site productivity of silver fir and silver fir-beech sites.

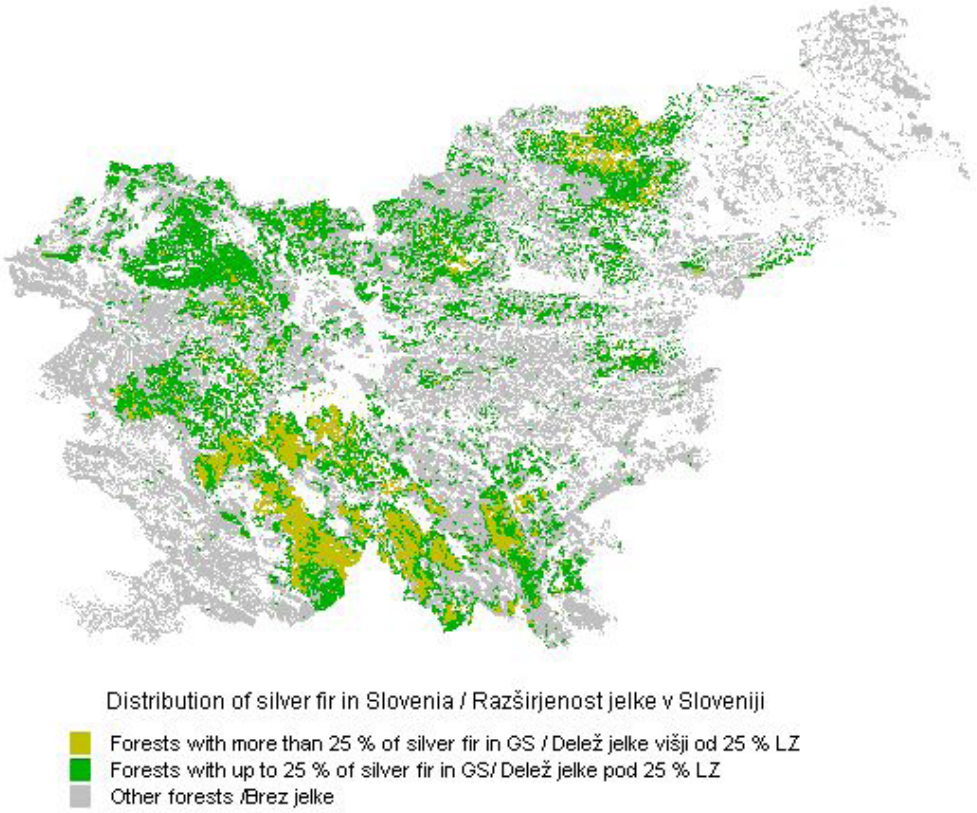

Fig. 1: Distribution of silver fir (*Abies alba* Mill.) in Slovenia. Areas where share of silver fir in total growing stock is higher than 25 % are coloured yellow, green are areas with silver fir share up to 25 %. Basic spatial unit is forest sub-compartment (average size 16 ha, N= 72,074).

Slika 1: Razširjenost jelke (Abies alba Mill.) v Sloveniji. Rumeno so prikazane površine z deležem jelke nad 25 % celotne lesne zaloge v odseku, zeleno površine z deležem jelke do 25 %. Osnovna prostorska enota je odsek (povprečna površina 16 ha, N=72074)

Table 3: Comparison of mean growing stock volume of stands per altitudes and silver fir shares

Preglednica 3: Primerjava povprečnih lesnih zalog sestojev po nadmorskih višinah in deležih jelke

Altitude (m)	Share of silver fir in GS (%)	Mean GS of all stands (m^3/ha)	Mean GS of stands without silver fir (m^3/ha)	Mean GS of stands with silver fir (m^3/ha)	Mean GS with silver fir share		
					> 25 % of GS	> 50 % of GS	> 75 % of GS
Nadmorska višina (m)	*Delež jelke v LZ sestojev (%)*	*Povprečna LZ vseh sestojev (m^3/ha)*	*Povprečna LZ sestojev brez jelke (m^3/ha)*	*Povprečna LZ sestojev z jelko (m^3/ha)*	*Povprečna LZ sestojev (m^3/ha) z deležem jelke*		
					> 25 % LZ	*> 50 % LZ*	*> 75 % LZ*
0-200	2,4	186	174	260	351	386	402
201-400	1,5	224	216	267	324	378	436
401-600	5,2	240	219	283	306	321	325
601-800	11,0	249	213	285	312	313	277
801-1000	17,8	284	232	312	338	344	339
1001-1200	13,0	301	245	321	327	301	264
1201-1400	3,7	293	251	318	301	270	315
1401-1600	1,7	225	211	239	521	0	0
1601-1800	1,6	81	81	111	0	0	0
1801-2000	1,5	40	3	58	0	0	0
2000-	0,0	0,7	0,7	0	0	0	0
Mean/Povp.	7,9	247	215	293	322	328	312

Note: Forest area with silver fir under 400 m a.s.l. and above 1400 m a.s.l. is small (Figure 3). There are also errors possible in database, which have greater impact in smaller areas.

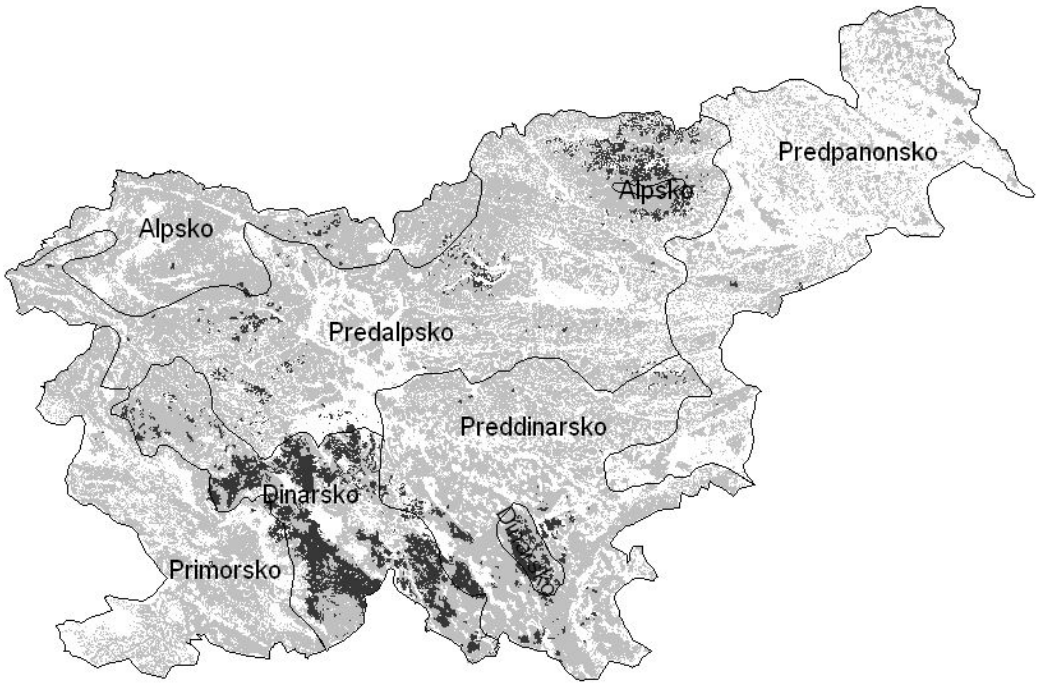

Fig. 2: Distribution of silver fir (*Abies alba* Mill.) in phytogeographic regions. (Only sub-compartments with share of silver fir higher than 25 % of total growing stock are shown.)

Slika 2: Razširjenost jelke (Abies alba Mill.) po fitogeografskih območjih. Prikazani so le odseki, v katerih jelka preseže 25 % lesne zaloge.

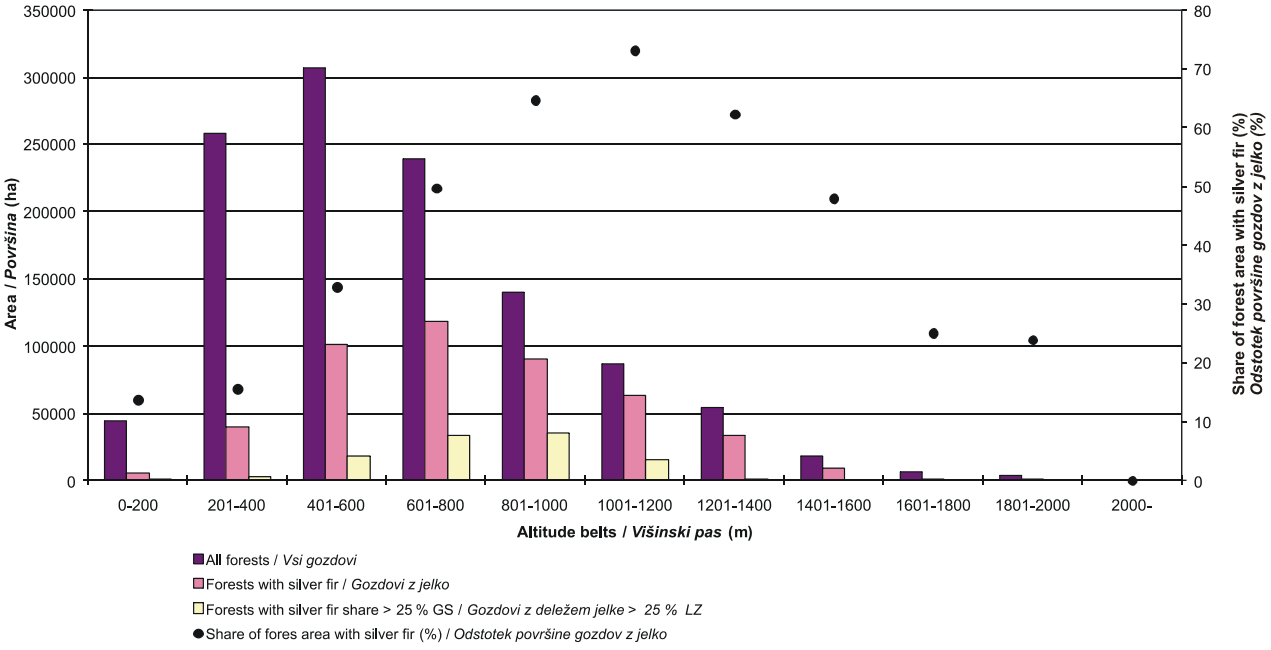

Fig. 3: Forest area along the altitude gradient and silver fir share in total growing stock

Slika 3: Površine gozdov po nadmorskih višinah in deležih jelke v lesni zalogi

DISTRIBUTION OF SILVER FIR IN FOREST VEGETATION COMMUNITIES

RAZŠIRJENOST JELKE V GOZDNIH ZDRUŽBAH

Despite generalisation in the analysis of silver fir distribution in forest vegetation communities, which is indispensable for the national level (check methods), the results are important for understanding silver fir distribution. Silver fir occurs in 75 syntaxes of total 96 described at the phytocenological level of association. Its abundance in associations varies considerably; from less than 0.5 % (in alder forests for example) to more than 50 % (in silver fir forests) of GS of forest stands. If we limit to forest vegetation communities in whose stands silver fir share exceeds 20 % of GS (Figure 4, Figure 5), we get a total area of 108.680 ha, contributed by the following site groups:

- 68 % (73,405 ha) Dinaric fir-beech forests on well-formed and deep ground (*Abieti-Fagetum dinaricum, syn.: Omphalodo-Fagetum* (TREG.57 *corr*. PUNC.80)MAR *et al.* 93), which is around 94 % of total area of the vegetation community in Slovenia,
- 22 % (23,592 ha) silver fir forests with fern (*Dryopteri-do-Abietetum* KOŠ.65, syn.: *Galio rotundifolii-Abietetum* BARTSCH.40*)*, which is around 96 % of total area of the vegetation community in Slovenia,
- 5 % (5,441 ha) silver fir forests on non-carbonate ground (with associations *Bazzanio-Abietetum* M.WRAB. (53)58, *Luzulo-Abietetum, syn:. Luzulo albidae-Abietetum* OBERD.57 var. geogr. *Hieracium rotundatum* KOŠ.94), which is around 76 % of total area of both two vegetation communities in Slovenia,
- 4 % (3,842 ha) of beech-fir forests on carbonates of sub-mountain zone (*Clematido-Abietetum* syn.*: Omphalodo-Fagetum asaretosum*, syn.: *Abieti-Fagetum dinaricum* TREG.57 *clematidetosum* TREG.60*)*, which is around 93 % of total area of vegetation community in Slovenia,
- 1 % (1,538 ha) silver fir and spruce forests on skeleton ground (*Neckero-Abietetum* TREG.62*, Festuco- Abietetum, Asplenio-Picetum* KUOCH.54), which is around 99 % of total area of all three vegetation communities in Slovenia,
- 1 % (634 ha) Dinaric fir-beech forest in freezing ravines (*Lycopodio-Abietetum*, syn.: *Omphalodo-Fagetum lycopodietosum*, syn.: *Abieti-Fagetum dinaricum* TREG.57 *lycopodietosum* TREG.57), which is around 92 % of total area of the vegetation community in Slovenia,

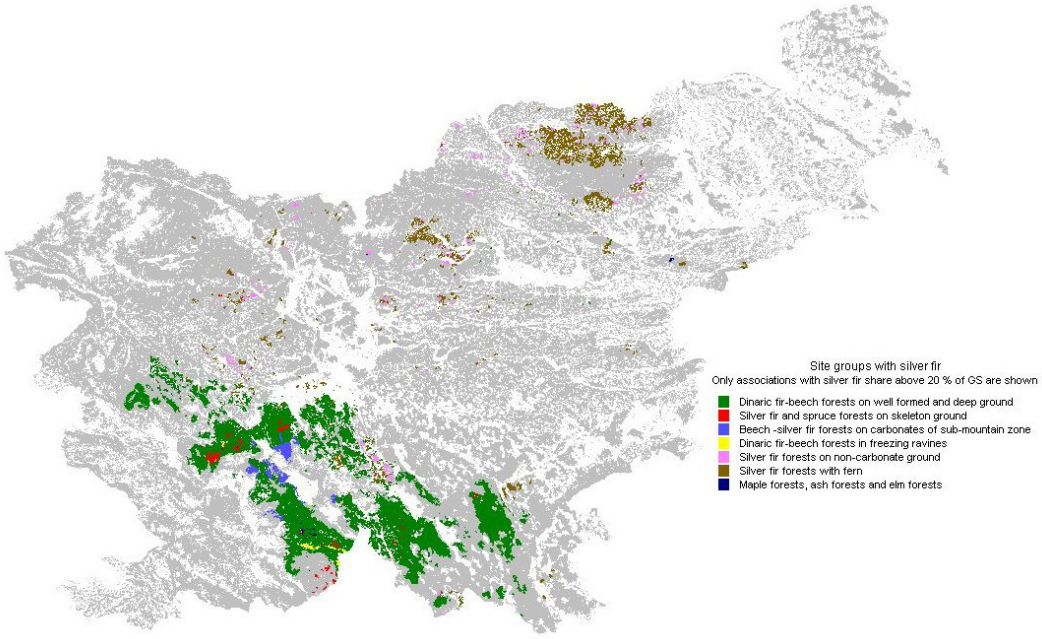

Fig. 4: Distribution of silver fir in forest vegetation communities (with only those forests shown where silver fir exceeds 20 % of GS of stands).

Slika 4: Razširjenost jelke v gozdnih združbah (prikazani so le gozdovi z združbami, v katerih jelka presega 20 % lesne zaloge sestojev).

- less than 1 % (226 ha) maple forests, ash forests and elm forests (*Carici remotae-Fraxinetum* W.KOCH 26 ex FABER 36*, Ulmo-Aceretum pseudoplatani BERGER 22*), which is around 61 % of total area of both vegetation communities in Slovenia.

Two major site groups where silver fir is abundant could be formed from forest vegetation communities described above:

1. Dinaric silver fir-beech forests and
2. silver fir forests with fern and silver fir forests on non-carbonate ground.

STAND CHARACTERISTICS OF FORESTS WITH SILVER FIR

SESTOJNE ZNAČILNOSTI GOZDOV Z JELKO

Stem diameter structure of stands

Debelinska struktura lesne zaloge

Diameter structure of stands is important stand attribute, for it enables us to forecast developmental trends for tree species. There are significant differences in abundance of silver fir between FMRs, as well as in its diameter structure (Table 4). The differences between areas are small in the middle diameter class (B), but noticeable in the share of large diameter (C class) and small diameter (A class) silver fir trees. If we limit ourselves to the FMRs, where GS of silver fir exceeds 5 % of total GS, we can conclude the following:

- Regarding large diameter silver fir trees, two FMRs could be exposed: Postojna and Kočevje, where GS of silver fir trees with stem diameter above 50 cm presents around 42 % of total GS of silver fir. The third position is held by Ljubljana FMR with more than 32 % of GS of silver fir in C class. In both FMRs of Postojna and Kočevje (which both lie predominantly in the Dinaric phytogeographic region), very few small diameter silver fir trees are present, which forecasts a decrease of silver fir share in total GS in these areas in the future.
- In some FMRs, such as Nazarje, Kranj, Maribor (Table 4), there is relative high share of small diameter silver fir trees, which is more prosperous for its conservation in the future.

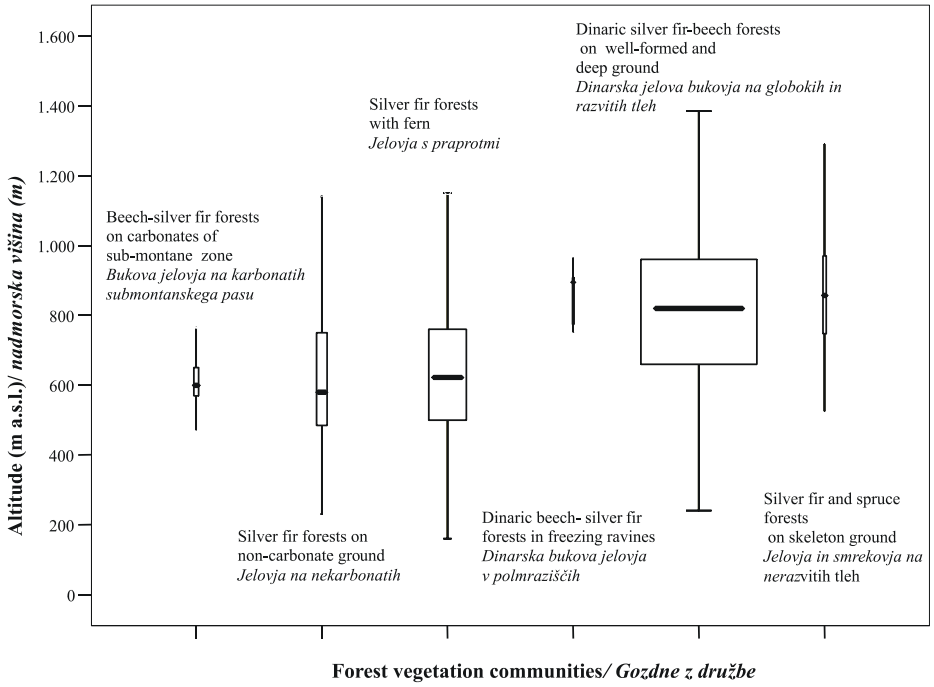

Fig. 5: Altitude distribution of most common site groups with silver fir (with the width of the bar proportional to the commonness of the site group)

Slika 5: Višinska razporeditev najpogostejših rastiščnih podskupin z jelko (širina okvirja je sorazmerna pogostnosti rastiščne podskupine)

Table 4: Characteristics of growing stock structure and increment of silver fir in the forest management regions (FMRs)

Preglednica 4: Značilnosti strukture lesne zaloge in prirastka jelke po gozdnogospodarskih območjih

FMR	GS of all stands (m^3/ha)	GS of silver fir (m^3/ha)	Share of silver fir in GS (%)	Share of GS of silver fir in diameter class (%)			Share of silver fir in total increment (%)
				<30 cm	30-50 cm	≥50 cm	
GGO	*Skupna LZ vseh sestojev (m^3/ha)*	*LZ jelke (m^3/ha)*	*Delež jelke v LZ sestojev (%)*	*Delež lesne zaloge jelke v razširjenem deb. razredu (%)*			*Delež jelke v skupnem prirastku (%)*
				<30 cm	*30-50 cm*	*≥50 cm*	
Postojna	241	71	30	14,1	43,6	42,3	20
Kočevje	289	53	18	13,3	44,7	42,1	14
Maribor	296	28	10	21,3	50,7	28,0	9
Ljubljana	236	16	7	18,0	49,7	32,2	4
Novo mesto	245	17	7	21,5	48,4	30,1	6
Kranj	300	18	6	23,1	55,1	21,8	5
Nazarje	285	16	6	32,2	56,4	11,4	5
Tolmin	198	10	5	20,4	50,0	29,6	3
Sl. Gradec	310	13	4	25,9	49,6	24,5	3
Bled	256	10	4	27,7	50,9	21,4	4
Celje	251	7	3	38,3	50,3	11,4	2
Brežice	253	2	< 1	22,9	47,5	29,6	< 1
Kras	126	< 1	< 1	56,5	34,1	9,4	< 1
M. Sobota	218	< 1	< 1	51,9	44,3	3,8	< 1
Total	247	19	7,9	27,6	48,2	24,1	6,0

Alteration of tree species composition and presence of silver fir

Ohranjenost drevesne sestave in prisotnost jelke

According to the analysis, we claim that silver fir could be found in well preserved forests; in detail further conclusions could be made as well:

- Forests with silver fir are classified as well preserved (51 % of the area) and modified (37 %), whereas only a minor part of forests with silver fir is classified as strongly modified or altered (Figure 6). High share of well preserved forests (66 %), where silver fir exceeds 25 % in total GS of the stands, could be explained with huge and predominating areas of Dinaric silver fir-beech forests. The slightly smaller share of well preserved forests, where silver fir exceeds 75 % of total GS, may be explained as a result of human impact on tree species composition in the past, when silver fir was strongly favoured to beech.

The proportion of developmental stages

Razmerje razvojnih faz

Forest structure with regard to developmental stages, stand types and stand shapes reveals previous forest management practice. We were interested whether share of silver fir is equal in different stands.

In Slovenia, timber phase (36 % of the entire forest area), thicker pole phase (34 %), regeneration phase (8 %), thinner pole phase (6 %) and youth stands (6 %) prevail. There are fewer other stand forms, such as coppice (4.5 %), selective forests (2 %) and early succession forests (3 %).

If we compare these values to forests with higher silver fir share (more than 25 % of GS of stands), interesting differences are established (Table 5):

- There are more timber and regeneration phases, youth stands and selective forests in stands where silver fir is present. The majority of selective forests with silver fir are located in FMRs of Maribor, Nazarje and Kočevje, where approximately 19 % of all stands with silver fir are described as selective forests. The highest share of timber phase

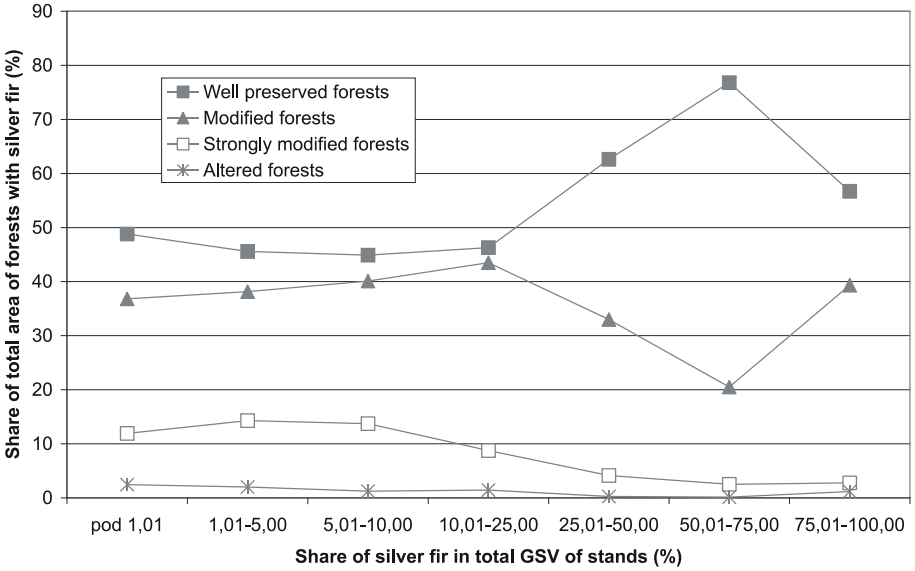

Fig. 6: Forest area structure (%) with regard to natural tree composition and share of silver fir in total GS of stands

Slika 6: Struktura površine gozdov (%) po razredih ohranjenosti naravne drevesne sestave gozdov glede na delež jelke v lesni zalogi gozdnih sestojev

in forests with silver fir has been established in FMRs Slovenj Gradec (64%), Kranj (58 %) and Ljubljana (51 %).

- Higher share of selective forests in forests with silver fir is understandable, considering that silver fir is one of the basic tree species in selective forests.
- In sub-compartments, which were classified as silver fir forests, there are relatively more regeneration phases and youth stands.

CHANGES OF SILVER FIR SHARE IN SLOVENIAN AND EUROPEAN FORESTS

SPREMINJANJE DELEŽA JELKE V GOZDOVIH SLOVENIJE IN EVROPE

Regression of silver fir distribution in Europe began centuries ago (HORNDASCH, 1993), whereas in Slovenia the die-back process raised concern in the 1960s and 1970s (BATIČ, 1997). The first interpretations of silver fir decline causes were based on the hypothesis that fir dies particularly on the periphery of its natural range (RUBNER 1953; DANNECKER 1955), which had been earlier accepted by some Slovenian foresters as well. In his field visit report on silver fir stands in Šoštanj community Miklavžič claimed that causes for die-back were of "periphery nature" (HOČEVAR, 1959). Later on, the explanations for silver fir decline (BRINAR, 1964, 1974) were based on changes in climate extremes, or saw fir decline as a result of incorrect silvicultural treatments in the past or unsuitable sites (MLINŠEK, 1964). Increment analysis for silver fir in the Dinaric phytogeographic region from the 1960-1995 period showed that increment depression was reached between 1976 and 1986. After that year diameter and height increment increased (LEVANIČ, 1997), as well as vitality (PRELC et al.1993). Changes of share of silver fir are also influenced by diameter distribution of forests and difficulties in regeneration in the Dinaric phytogeographic region (BONČINA, 1996; JARNI et al. 2004) whereas silver fir regenerates successfully out of Dinaric silver fir-beech forests and silver fir forests (BONČINA et al. 2003a; KUNSTEK, 2004). Slovenian forest data show a decreasing trend of silver fir share (Table 6). From the first forest inventory in 1946, which also shows situation in forests before World War II (NOVAK, 1951, BLAZNIK et al., 1970), to 2003 (SFS, 1991, 2001, 2004), silver fir share has decreased from 19.4 % to 7.9 % of total GS in Slovenia. It is obvious that the total area of stands, in which silver fir is fundamental or prevailing tree species, has decreased (Table 7).

In Europe, silver fir share has decreased as well, with fir becoming less abundant. In the last 150 years, its northern border moved south. In the northern part of Bavaria (Franken), the share of silver fir in growing stock decreased from

Table 5: Developmental stages and stand forms in forests with silver fir share above 25 % of total GS

Preglednica 5: Razvojne faze, oblike sestojev v gozdovih z deležem jelke, večjim od 25 % skupne lesne zaloge sestojev

Develop. phase *Raz. faz.*		Youth stands *Mlad.*	Pole phase *Drg.*	Timber phase *Deb.*	Stands in regen. *Poml.*	Select. forests *Preb. gozd*	Copp. *Panj.*	Early succ. *Grm.*	Total *Skup.*
All forests	*Vsi gozdovi*	6,4	12,2	35,7	8,0	2,3	4,5	3,7	100
Forests with silver fir share > 25 %	*Gozd. z delež. jelke >25 %*	7,5	10,5	39,9	15,3	8,2	0,0	0,3	100
FMR Postojna	*GGO Postojna*	10,0	14,1	27,2	17,3	0,0	0,0	0,0	100
FMR Kočevje	*GGO Kočevje*	4,9	7,8	45,4	9,1	19,0	0,0	0,7	100
FMR Maribor	*GGO Maribor*	5,0	6,2	31,4	10,8	19,3	0,0	0,2	100

80 % in the 17th century to 3 % in the 19th century, in other parts of Bavaria from 12 % in 1860 to merely 3 % nowadays (BRINKMANN, 1997; BWI2, 2004). The reasons for silver fir decrease in central European countries are versatile, complex and not clarified as yet (HORNDASCH, 1993, KRAMMER, 1992). HOLZAPFEL (1960) sees a complex of diseases on silver fir as a main reason for decline on its northern range, very likely are also influences of climate changes in the entire silver fir natural range (SENN / SUTER, 2003, ZENELLI et al. 2004). In the areas where ungulate herbivore populations have high density, browsing of silver fir in youth stands retards successful regeneration (OTT, 1989), even though SENN /SUTER (2003) believe that many researches (i.e. OTT, 1989; MOTTA, 1996) of the impacts of browsing ungulates on silver fir regeneration in central European countries overestimate its importance. As a matter of fact, although there are insufficient data on shares of silver fir for the central European regions we could not exclude human indirect impact on fir regeneration with forest management methods (BURGA /HUSSENDÖRFER, 2001). Clear cutting as well as contemptuous treatment of silver fir as unfavourable tree species to spruce due to its wood characteristics, large scale spruce planting in the greatest part of silver fir natural range (GRODZIŃSKA / SZAREK-ŁUKASZEWSKA, 1997; SENN / SUTTER, 2003) shoved silver fir aside. In mountain forests of Switzerland (silver fir has greatest abundance between 800 and 1000 m a.s.l.), spruce was used in planting owing to the higher prices of its wood. Apart from this, silvi-

Table 6: Share of silver fir in total GS and annual felling of fir in Slovenian forests

Preglednica 6: Delež jelke v skupni lesni zalogi gozdov Slovenije in posek

Year	*Leto*	1946[3]	1990[4]	1995	1996	1997	1998	1999	2000	2001	2002	2003
Silver fir share (% GS)	*Delež jelke (% LZ)*	19,4	11,9				9,1	9,0	8,5	8,3	8,2	7,9
Annual felling of silver fir (m^3/ha)	*Letni posek jelke (m^3/ha)*			0,31	0,25	0,28	0,26	0,23	0,25	0,26	0,29	0,25

Table 7: Forest area structure (in %) with regard to share of silver fir (%) in stands during 1964 and 2003

Preglednica 7: Struktura površine gozdov z jelko (%) glede na delež jelke (%) v sestojih v letu 1964 in 2003.

	Share of total area with silver fir (%)	
Share of silver fir in stands (%)	Mlinšek (1964)	SFS (2004)
	Delež površine gozdov z jelko (%)	
Delež jelke v sestojih (%)	Mlinšek (1964)	ZGS (2004)
≤ 1 %	16,5	19,4
1,1 – 10,0 %	19,8	39,5
10,1 < 40,0 %	25,4	28,5
40,1 < 90,0 %	36,3	12,5
≥90 %	2,0	0,0

[3] Source: First inventory of forests, 1946,

[4] Source: SFS, Slovenian Forest Service, 1991-2004

cultural systems, ownership and local demands influenced the current share of silver fir and alteration of natural tree composition. Brändli (1996) reports that in Switzerland silver fir is best preserved in selective forests, where it reaches from 17 to 22 % in stem number (trees with more than 12 cm in d.b.h.).

In Switzerland, silver fir is present in 15 % of the total forest area or 180,000 ha, which is considerably more than in other European countries. Its share in total growing stock encompasses 14.6 % (LFI, 1999). In Germany, silver fir share in GS is 2.4 %, but considering their natural range, regional shares are more relevant: e.g. in Baden-Wuertemberg, silver fir reaches 10.5 % in GS (BWI2, 2004).

In Austria, silver fir share has decreased from the 1990s to nowadays from 4.7 % to 4.4 % of the total growing stock (ÖFI, 1990; OWI, 1996, 2002).

For Slovakia, Korpel (1985) and Krammer (1985) reported on a decrease of areas of forests with silver fir from 11 % of all forests in 1920 to 5.8 % in 1980. Until 1994, areas of forests with silver fir furthermore decreased to 5.0 % (NOVOTNY et al. 1994, cit. after OSZLÁNYI, 1997), whereas the latest reports show 4.2 % share (Forest in Slovakia, 2002).

In Croatia, silver fir forests and with silver fir mixed forests represent 10.6 % of total forest area or 220,126 ha. As in other European countries, decreasing trend for silver fir is also noticeable; its share in growing stock decreased from 1986 to 1996 from 11.5 % to 9.4 % (PRPIĆ, 2001).

TREND PREDICTION IN SLOVENIA
OCENA TRENDOV V SLOVENIJI

If we consider diameter structure of silver fir (Table 4), particularly in forest management areas where silver fir share is considerably high, and the presence of silver fir in youth stands (BONČINA et al. 2003a) as well as present amount of sanitary felling (SFS, 2005), we could expect further decrease of silver fir share in the ensuing few years. The future share depends mainly on vitality and regeneration of silver fir.

DISCUSSION
RAZPRAVA

There has been no detailed information on distribution of tree species in Slovenia so far. This was also mentioned by Mlinšek (1964), when he made an analysis of silver fir distribution in Slovenia while studying silver fir decline. At that time, the distribution was analysed at the level of cadastral communities for five regions, which were set in order to contain larger silver fir areas in them. The regions did not consider borders of forest management regions, therefore summary results from 1964 are not easily comparable with current ones. The analysis was not focused on silver fir distribution characteristics, but Mlinšek reports that there were approximately 300,000 ha of silver fir forests in Slovenia or around 32 % of total forest area of that period. Analysis from 2003 shows that there are 465,000 ha of forests with silver fir or 40 % of total forest area.

Generally speaking, silver fir is a tree species of mountain zone, although it also occurs above and below it, depending on edaphic or mezzo-climatic factors. The highest altitude is reached on the extreme rocky sites, which may already be covered with protective forests (ZUPANČIČ, 1992). The research confirmed that silver fir stands are common between 800 and 1400 m a.s.l., distinctly between 1000 and 1200 m. We must underline, however, that we are speaking about mean altitudes of forest sub-compartments. The share of silver fir in growing stock is highest in the altitude belt from 800 to 1000 m, where silver fir contributes 18 % to total growing stock in it.

Silver fir occurs also in sub-Pannonian hills (Haloze) and at some localities at Slovenske gorice. It does not occur in the lower Karst and lowlands of sub-Pannonian Slovenia. It goes down to downy oak stands near Pivka in the coastal region of Slovenia (PISKERNIK, 1985). It occurs abundantly only in its climatic zone optimum and edaphically or mezzo-climatically conditioned areas.

Comparing the tree species composition alteration in stands with different silver fir share, we can establish that there are more well-preserved forests where silver fir share is higher than 25 % of GS but less than 75 %. Considering tree species composition of silver fir-beech forests as dominant site group with silver fir share of 35.4 % of GS, we can conclude, that wide areas of these forests contribute most to the high naturalness of the forests. Close-to nature management has long tradition here (BONČINA et al 2003a, 2003b).

Zupančič (1992) believes that silver fir is by far the most sensitive central European tree species to any disturbing hu-

man influences. The research confirms that silver fir share is generally higher in forests with better preserved tree species composition; an exception are pure silver fir stands (>75 % of GS), which are distributed mainly in Postojna FMR, where silver fir share has strongly increased through silvicultural actions.

Stands with prevailing silver fir (above 50 % in GS) cover only 3 % of total forest area, whereas 30 % of total forest area cover the stands where silver fir share is lower than 25 % of GS. It is interesting that wide areas of such stands lie within the regions that were, or still are, characterized by unnatural high percentage of spruce. For example, in FMR Bled, we find silver fir in three quarters of the total area, but analyses show that in most stands silver fir share is lower than 0.5 %. FMR Bled has the highest percentage of surface area with minimal silver fir share (below 0.5 %). Previous management is the main reason for the modified tree species composition, although there are wide areas of sites, where silver fir could be expected in a higher share. Silver fir is widely present in low percentage also in Nazarje and Kranj FMR; it occurs sparsely in approximately half of both regions.

Generally speaking, at the national level silver fir occurs most often in two larger site groups:

- In silver fir-beech forests on deep and well developed ground, consisting of association *Abieti-Fagetum dinaricum, syn.: Omphalodo-Fagetum* (TREG.57 *corr*. PUNC.80) MAR *et al*. 93): 67 % of all forests with significant silver fir share are phytocoenologically characterised as *Abieti-Fagetum dinaricum*.
- In silver fir forests with fern, consisting of associations *Dryopterido-Abietetum* KOŠ.65, syn.: *Galio rotundifolii-Abietetum* BARTSCH.40: 21 % of all forests with silver fir lie in that site group. Closely related to this site group is also group of silver fir forests on non-carbonate ground *(i.e. Bazzanio-Abietetum* M.WRAB.(53)58 and *Luzulo-Abietetum, syn:. Luzulo albidae-Abietetum* OBERD.57 var. geogr. *Hieracium rotundatum* KOŠ.94), which cover 5 % of all forests where silver fir exceeds 20 % in GS of associations.

Forests of first site stratum could be found mainly in FMRs of Postojna and Kočevje, forests of second site in FMR Maribor, Nazarje for example. If we consider current characteristics of distribution of silver fir in both strata (occurrence, abundance, diameter distribution) and recent research results of characteristics of regeneration and ungulate browsing impact (BONČINA et al 2003a, JARNI et al. 2004), we can conclude that in the Dinaric phytogeographic region a more distinctive decreasing trend of silver fir share is expected than in the northern parts (Maribor, Nazarje), where regeneration is often more successful and browsing damage lesser. Current diameter distribution in these areas with relative higher percentage of small diameter trees promises easier and better regeneration or at least easier preservation of silver fir (BONČINA et al. 2003a; KUNSTEK 2004).

CONCLUSION
ZAKLJUČEK

Forest information System (FIS) managed by the Slovenian Forest Service (SFS) is applicable to show distribution of tree species in Slovenia. Further activities should be focused on:

- analyses of ecological parameters, which (could) influence the current state and development of forests,
- analyses of development of forests, where uniform database about forests in different time periods is attempted to be restored,
- analyses of data from permanent sampling plots, which is going to supplement research at the sub-compartment level.

ACKNOWLEDGEMENTS
ZAHVALA

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SUMMARY

We analysed the characteristics of the silver fir occurrence and distribution in Slovenia using the Forest Information System (FIS). The share of silver fir in Slovenia and other countries, where silver fir is naturally distributed, has been decreasing for many decades. Silver fir is now present in

around 40 % of the total forest area in Slovenia. Abundantly (share in GS>25 %) it occurs in Postojna, Kočevje and Maribor FMRs, in lower share although in large areas in Bled, Nazarje and Ljubljana FMRs. Silver fir could virtually not be found in Murska Sobota and Sezana FMRs. The distribution of silver fir in phytogeographic regions shows that it occurs abundantly in the Dinaric phytogeographic region and in part of the pre-Alpine region. It was registered in the altitude range from 0 to 1800 m a.s.l.; the highest share in growing stock it reaches in the 800-1000 m belt, where constituting 18 % of total growing stock within it.

Surface structure according to altitude belts shows that the majority of Slovenian forests lie within altitude belt from 400 to 600 m a.s.l., that the majority of forests, where silver fir is present, are situated within altitude belt from 1000-1200 m, in which more than 70 % of forest land is covered by forests with silver fir.

Silver fir occurs in 75 syntaxa of the 96 described in forests at the level of association, abundantly (share in GS>20 %) in 11 syntaxa. Considering only those associations in which silver fir is abundant, we can form two main strata:

1. Dinaric silver fir-beech forests (68 %),
2. silver fir forests with fern and silver fir forests on non-carbonate ground (27 %).

We found out that there is a big difference in the amount of large and small diameter trees between forest management regions, that tree species composition is less altered in forests with silver fir in comparison with all forests, and that there is a higher share of timber and regeneration phases, selective forests and saplings. If we consider previous analyses of regeneration, we can conclude that in the Dinaric phytogeographic region a more intensive decreasing trend of silver fir share is indicated than in northern areas (Maribor, Nazarje), where regeneration is often more successful and browsing damage lesser. Current diameter distribution in these areas promises easier regeneration or at least preservation of silver fir.

POVZETEK

Z uporabo gozdarskega informacijskega sistema smo analizirali značilnosti pojavljanja in razširjenosti jelke v Sloveniji. Delež jelke se v Sloveniji tako kot v drugih državah njenega naravnega areala zmanjšuje že vrsto desetletij. Jelka je danes evidentirana na okrog 40 % površine slovenskih gozdov, obilneje (delež v LZ>25 %) se pojavlja na postojnskem, kočevskem in mariborskem gozdnogospodarskem območju, v manjšem deležu, vendar na velikih površinah, pa tudi na blejskem, nazarskem in ljubljanskem območju. Jelke skoraj ne najdemo v murskosoboškem in sežanskem območju. Prikaz razširjenosti jelke po fitogeografskih območjih kaže, da se jelka obilneje pojavlja v dinarskem fitogeografskem območju in delu predalpskega območja. Jelko smo evidentirali v pasu od 0 do 1800 m, najvišji delež v lesni zalogi doseže v pasu 800-1000 m, kjer sestavlja okrog 18 % celotne lesne zaloge gozdov tega pasu.

Površinska struktura gozdov po pasovih nadmorske višine kaže, da največ gozdov v Sloveniji leži v pasu 400-600 m, največ gozdov,v katerih je evidentirana jelka, pa v pasu 600-800 m. Iz relativnega razmerja med površino gozdov z jelko v nekem pasu in celotno površino gozdov tega pasu vidimo, da je relativno največ gozdov z jelko v pasu 1000-1200 m, kjer jo najdemo na več kot 70 % površine vseh gozdov tega pasu.

Jelka se pojavi v 75 sintaksonih od skupno 96 opisanih na ravni asociacije, obilneje (nad 20 % v LZ) pa v 11 sintaksonih Če upoštevamo samo tiste, v katerih se jelka obilneje pojavlja, lahko iz teh oblikujemo dva glavna rastiščna stratuma:

(1) dinarski jelovo-bukovi gozdovi (68 %) in
(2) jelovja s praprotmi in jelovja na nekarbonatnih kameninah (27 %).

Ugotovili smo, da obstajajo velike razlike v količini debelega in tankega drevja jelke po območjih, v gozdovih z jelko je ohranjenost drevesne sestave višja v primerjavi z vsemi gozdovi, višji je tudi delež debeljakov, pomlajencev, prebiralnega gozda ter mladovja. Upoštevajoč predhodne analize pomlajevanja lahko zaključimo, da se v dinarskem območju na splošno nakazuje bolj izrazit trend zmanjševanja deleža jelke v gozdovih kot v severnih območjih (Maribor, Nazarje), kjer je pomlajevanje pogosto bolj uspešno, poškodbe zaradi jelenjadi manjše, sedanja debelinska struktura z relativno večjim deležem tanjšega drevja jelke pa takšna, da obeta lažje ali vsaj uspešnejše ohranjanje jelke v gozdovih.

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