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Structure, development and growth of selection forests at the Granata research site

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Abstract

The Granata research site was established for the study of structure, growth and regeneration of silver fir-European beech single stem selection forest. Three phytocoenological relevés were carried out, all trees ≥5 cm diameter at breast height (d.b.h.) were measured by full callipering, tree growth was analysed for sample trees, regeneration of tree species was registered on 63 sampling plots. In addition, historical data from past forest inventories were studied. In the period from 1952 to 2003, the share of silver fir has decreased from 86% to 26%, the share of Norway spruce increased significantly, whereas the share of beech and sycamore has slightly increased. The current growing stock amounts to 350 m^3 ha^{-1}, with large-size diameter trees (d.b.h. ≥50 cm) representing 51% of total growing stock. The site is divided into 16 stand patches with significant differences in tree species composition and diameter distribution. Regeneration is sufficient with silver fir prevailing in total number of seedlings (42%). 23% of all seedlings are damaged as a result of game browsing.

Key words: Selection forest (Plenterwald), selection system management, stand structure, tree species composition, growth, regeneration, diameter distribution, vitality, *Omphalodo-Fagetum*

Struktura, razvoj in rast prebiralnih gozdov v raziskovalnem objektu Granata

Izvleček

Granata (GGE Logatec, odd. 22) je raziskovalni objekt za študij prebiralnega gozda na rastišču Omphalodo-Fagetum. V objektu so bili opravljeni fitocenološki popisi, sestoje smo izmerili s polno izmero, analizirali smo priraščanje dreves in pomlajevanje drevesnih vrst. Na podlagi zgodovinskih virov smo analizirali razvoj gozdnih sestojev v obdobju 1952–2003. V tem času se je delež jelke v sestojih zmanjšal s 86 % na 26 %, znatno se je povečal delež smreke, opazen je tudi delež bukve in gorskega javorja. Lesna zaloga je 350 m^3 ha^{-1}, delež debelega drevja (d.b.h. ≥ 50 cm) predstavlja 51 % celotne zaloge. Objekt je razdeljen na 16 sestojev, med njimi so opazne razlike v drevesni sestavi in debelinski zgradbi. Pomlajevanje je ustrezno, v pomladku prevladuje jelka (42 %), 23 % vseh mladic v pomladku je poškodovanih zaradi objedanja divjadi.

Ključne besede: *prebiralni gozd, prebiralno gospodarjenje, sestojna zgradba, drevesna sestava, rast, pomlajevanje, debelinska struktura, vitalnost, Omphalodo-Fagetum*

1 Introduction

1 Uvod

Single stem selection (plenter) structure of forest stands is a consequence of human intervention (DIACI 2006, KOTAR 2005); it seldom occurs naturally – sometimes as a development stage in extreme site conditions. Trees of different ages and dimensions in small areas are typical of such a structure. To maintain plenter structure, continuous elimination of upper-storey trees, permanent regeneration of tree species and recruitment of trees from lower to upper-storey needs to be secured. Selection silviculture system has a rich tradition in Slovenia (HUFNAGL 1893, POGAČNIK 1947, TREGUBOV / ČOKL 1957, ČOKL 1959). »Farmer selection system« represents an experience-based principle of forest management taking into account the needs for supply of certain assortments (CENČIČ 2000). A regular selection system was developed in the 1890s by Leopold Hufnagl in the large-estate forests of the Kočevje region; gradually, the silvicultural system was adopted and upgraded with the "Control Method" by Schollmayer in the Snežnik estate forests. After WW2, selection system was the main silvicultural principle and the majority of Slovenian forests were classified as selection forests (Inventarizacija …1947). Eventually, the irregular shelterwood system was adopted (MATIJAŠIĆ / BONČINA 2002) and selection system regressed, partly due to the strong silver fir decline (DIACI / ROŽENBERGAR 2002) and problems with natural regeneration due to browsing. In the 90s, selection

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system was practically omitted. During the last 15 years, the ideas of selection management have been revitalised – on one hand as a result of growing importance of social and environmental functions, and on the other due to adoption of the principle of close-to-nature management (BONČINA 1992, 1994, 2000, BONČINA / DIACI / CENČIČ 2002, CENČIČ 2002, DIACI / ROŽENBERGAR 2002, KOŠIR 2002, KOTAR 2002, 2003, ROBIČ / ACCETTO 2002). Selection management should be adopted as the most rational type of management taking into account site and stand conditions and management goals (BONČINA / DEVJAK 2002). Therefore, knowledge of the structure and functioning of the selection forest is essential. Decision-making in selection forests is based on precise studies of monitoring of stand structure development. It is useful to compare values of stand parameters to the reference values obtained from research sites. Therefore, a network of research sites for studying structure, composition and development of selection forests was established (BONČINA *et al*. 2004); the Granata research site is one of them. The reasons for choosing Granata as a reference site are the following: suitable stand structure; development of forest stands in the last century is well documented; in addition, the size and the location of the research site are suitable, which enables easy conduct of the research and facilitates educational work.

2 Research goals

2 Namen raziskave

Main research goals were the following: to analyse the development of forest stands in the period 1952–2003, to analyse current structure and tree species composition of stands, to survey site conditions and natural regeneration, to asses the growth characteristics of major tree species. Besides, our goal was to contribute to the reaffirmation of selection system in this part of Slovenia. The following hypotheses were tested: i) tree species composition as well as diameter structure of forest stands have significantly changed in the last decades, ii) important differences in site conditions, stand structure and regeneration inside the research site exist despite its small area.

3 Site description

3 Opis objekta

Compartment 22 of the Logatec-Zagora Forest management unit (FMU) has been selected for research site, named Granata. Its area amounts to 18.58 ha and is divided into two sub-compartments. The altitude of the site is 830–900 m a.s.l., bedrock is cretaceous limestone. The following forest communities prevail: *Neckero-Abietetum* (67%), *Omphalodo-Fagetum scopolietosum* (30%) and *Ulmo-Aceretum* (3% of total area) (Gozdnogospodarski načrt ..., 2001). Mean annual precipitation in Hrušica (870 m a.s.l, l.2 km away from the Granata site) is 1837.5 mm with maximum in autumn and minimum in winter. Mean annual temperature is 9.3 ˚C; climatological data comes from Postojna (about 12 km to the south and at 550 m a.s.l.).

There are no significant differences between both sub-compartments considering surface, altitude and forest communities. However, differences in stand structure and tree species composition are notable (Table 1). In both sub-compartments uneven-aged structure prevails: in sub-compartment 22a, selection structure is combined with patches of pole stands, whereas in sub-compartment 22b selection structure is more evident in the southern part; in its northern part, some old growth patches are present.

Table 1: Site and stand characteristics of forests in sub-compartments of the Granata research site

Preglednica 1: *Rastiščne in sestojne značilnosti gozdov v odsekih raziskovalnega objekta Granata*

Characteristics *Značilnosti*	Sub-comp. *Odsek* 22a	Sub-comp. *Odsek* 22b
Area (ha) *Površina (ha)*	12,84	5,74
Forest communities (% of total area) *Gozdne združbe (% površine)*		
Neckero-Abietetum	65%	70%
Omphalodo-Fagetum scopolietosum	30%	30%
Ulmo-Aceretum pseudoplatani	5%	0%
Growing stock ($m^3\,ha^{-1}$) *Lesna zaloga ($m^3\,ha^{-1}$)*	332	390
Tree species composition (% of growing stock) *Drevesna sestava (% lesne zaloge)*		
Picea abies	56.4	38.9
Abies alba	22.4	33.1
Fagus sylvatica	11.2	17.0
Acer pseudoplatanus	6.7	6.5
Sorbus aucuparia	0.3	0.1
Ulmus glabra	0.9	1.1
Fraxinus excelsior	1.2	0.3
Tilia cordata	0.8	2.9

4 Methods

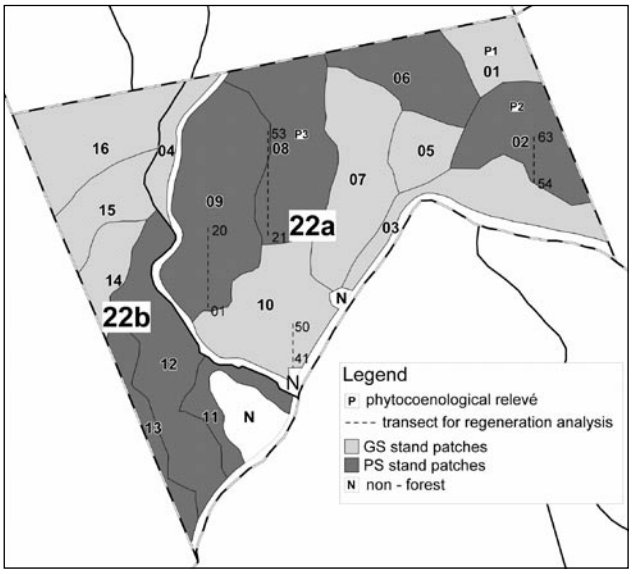
4 Metode dela

The analysis of site conditions

In 22a, three phytocoenological relevés were carried out according to the Central European School of vegetation studying (ROBIČ 2004). Indicator plant values were used for the analysis of site conditions (ELLENBERG 1988); only the presence and transformed estimation of abundance (MAAREL VAN DER 1979) were considered when processing the surveys. The significance of the differences between relevés was tested by the monogram method.

The analysis of forest development

Development of forests was analysed by using the data from past forest management plans on the number of trees for different tree species and diameter classes (Table 2). In different periods inventories collected data for different diameter classes, therefore our analysis was limited to the period from 1952 to 2003 and to A, B, and



Map 1: The map of the Granata research site, divided into sub-compartments, stands with marked locations of phytocoenological relevés and transects of sample plots for regeneration analysis

Karta 1: *Karta raziskovalnega objekta Granata z delitvijo na odseka a in b, vrisanimi sestoji ter lokacijami fitocenoloških popisov in transektov vzorčnih ploskev za analizo pomlajevanja*

C d.b.h. classes. For 1952, there are no exact data for tree species, only the number of trees for conifers (e.g. silver fir) and broadleaved species (e.g. beech), since the share of other tree species was of minor importance at that time. Data from 1983 and 1990 were not used for the analyses due to unsuitable inventory methods used at that time (REŠČIČ 2004). Stand parameters in 2003 were obtained with full callipering in August and September 2003. We used Biolley tariffs ("tarif fixe") for calculating growing stock at the Granata site as well as at other research sites (ČOKL 1961).

The analysis of stand structure

The site was divided into smaller stand units (stand patches) taking into account vertical and horizontal structure of stands and their tree species composition. When delineating patches, we also considered skidding tracks and outstanding natural boundaries such as ridges. Patches were marked in the field; their borders were measured by theodolite. A map of stand patches was produced using Map Info (Map 1). Trees in all 16 stand patches were measured by full callipering. Two major groups of stand patches were defined; patches with single stem selection (plenter) structure (PS) and patches with group selection structure or small patches of developmental stages (GS). Threshold value for full callipering was 5 and 10 cm of d.b.h. in the PS and the GS patches, respectively. When evaluating the vitality of the trees, defoliation, tree damage, presence of epicormic buds, and formation of the crown were considered; trees were ranked using a four grade scale: 1 very vital, 2 medium vital, 3 less vital or unviable and decaying, 4 dead standing trees.

Tree heights for spruce, silver fir and beech were measured; three measurements per each tree species and each 5 cm d.b.h. class were carried out by Suunto clinometer. In total, 126 heights (accuracy: 0.5 m) and d.b.h. (accuracy: 1 cm) of randomly selected trees in the PS patches were measured.

Natural regeneration was systematically analysed on sampling plots (1.5 m x 1.5 m each) along the transect in the selected patches (patches 2, 8, 9 and 10). The direction of all transects was the same (azimuth 0°); the first plot was chosen subjectively, others followed every 5 m (Map 1). In total, 63 sample plots along 4 transects were analysed (20 in the patch 9, 23 in patches 8 and 9, and total 20 in patches 2 and 10). Seedlings (< 5 cm d.b.h.) were assessed per tree species and height classes: 0–19 cm, 20–49 cm, 50–89 cm, 90–129 cm and 130 cm and more. Besides, browsing (current and last year's) was monitored.

Table 2: References for study of stand development at the Granata research site, inventory methods used and diameter classes for which numbers of trees are recorded

Preglednica 2: *Viri za študij razvoja gozdnih sestojev v raziskovalnem objektu Granata, uporabljene inventurne metode in debelinske stopnje, za katere so navedeni podatki o številu drevja.*

References *Viri*	Inventory method *Inventurne metode*	d.b.h. class *Debelinske stopnje*
Gospodarska osnova za dobo 1953–1962 revir Logatec, Nanos, Hrušica	Full callipering *Polna premerba*	10 cm
Gozdnogospodarski načrt gospodarske enote Bukovje 1.1.1963–31.12.1972	Full callipering *Polna premerba*	5 cm
Gozdnogospodarski načrt za gospodarsko enoto Logatec 1.1.1973–31.12.1982	Full callipering *Polna premerba*	5 cm
Gozdnogospodarski načrt za gospodarsko enoto Logatec 1.1.1984–31.12.1993	Bitterlich, Full callipering *Bitterlich, polna premerba*	5 cm
Gozdnogospodarski načrt za gospodarsko enoto Logatec 1.1.1994–31.12.2000	Permanent sampling method *Kontrolna vzorčna metoda*	A, B, C d.b.h. class* *Razširjeni deb. razredi*
Gozdnogospodarski načrt za gospodarsko enoto Logatec-Zagora 1.1.2001–31.12.2010	Permanent sampling method *Kontrolna vzorčna metoda*	A, B, C d.b.h. class* *Razširjeni deb. razredi*

* A d.b.h. class (10–29 cm), B d.b.h. class (30–49), C d.b.h. class (50– cm)

Growth of six trees was analysed in detail (four spruces and two firs). Tree height, diameter of the stump and d.b.h. were measured; sampling stem discs from trees were taken at every 4 m of tree height. The analyses were carried out at the Department of Forestry and Renewable Forest Resources.

FoxPro, Excell and SPSS 14.0 were used for data processing. Differences in diameter distribution of trees between the PS and the GS patches were tested by the Snedecor-Brandt test.

5 Results

5 Rezultati

5.1 Site conditions

5.1 Rastiščne razmere

The research site belongs to Dinaric silver fir-beech forests. The relevé 1 was classified as *Omphalodo-Fagetum* (TREG. 1957) MAR. et. al. 1993 var geogr. *Calamintha grandiflora* SURINA 2002 *mercurialietosum perennis*, the relevé 2 as *Omphalodo-Fagetum* (TREG. 1957) MAR.et. al. 1993 var geogr. *Calamintha grandiflora* SURINA 2002 *hacquetietosum epipactis*], and the relevé 3 as *Omphalodo-Fagetum* (TREG. 1957) MAR.et. al. 1993 var geogr. *Calamintha grandiflora* SURINA 2002 *neckeroetosum crispae*. The site conditions were described using the indicator values of registered plants according to Ellenberg (1988) (ROBIČ 2004):

- Light conditions: half of all plants registered in the relevés 1 and 2 show shadow conditions, indicating well preserved and coherent forest vegetation. In the relevé 3, 20% of all registered plants indicate half-shadow conditions; this might indicate a less preserved forest, or can be interpreted as a result of specific micro-relief - high rockiness and extremely diverse relief.
- Warmth conditions: registered plants in the relevés 1 and 2 indicate merely warm conditions in sub-montane belt, whereas registered plants in the relevé 3 indicate cold conditions in montane belt.
- Continentality: plant species composition indicates subatlantic conditions.
- Water conditions: plants in all three relevés indicate fresh site conditions.
- Reaction: pH reaction is weak in general in all three relevés. Plants indicate slightly acidophilus or/and slightly basic reaction.
- Nitrogen availability: plants of the relevés 1 and 2 indicate richer nitrogen availability compared to those of the relevé 3, where plants indicate moderate nitrogen availability.

5.2 Development of forest stands at the Granata research site

5.2 Razvoj gozdov v raziskovalnem objektu Granata

Stand structure and tree species composition have undergone major changes in the last 50 years. Noticeable changes in growing stock are the result of various intensities of cutting (Table 5). Forests were being over-used until 1983, when growing stock in sub-compartment 22b reached only 150 m^3ha^{-1}. Current high share of light demanding tree species may be a consequence of intense cuttings. The share of silver fir decreased significantly in the analysed period (Table 3), while the share of Norway spruce increased from 25.2% to 50.4% of total growing stock. The share of European beech has increased for 5.3% in the 1963–2003 period. Spruce regenerates naturally; it has never been planted in the region.

Table 3: Tree species composition and growing stock of stands at the research site in the 1952–2003 period

Preglednica 3: *Drevesna sestava in lesna zaloga sestojev raziskovalnega objekta v obdobju 1952–2003*

Year *Leto*	Tree species composition (% growing stock) *Drevesna sestava (% lesne zaloge)*					Growing stock *Lesna zaloga* (m^3 ha^{-1})
	Abies alba	*Picea abies*	*Fagus sylvatica*	Acer *pseudopl. & Ulmus glabra*	Other deciduous *Ostali listavci*	
1952	86.3*	-	13.7**	-	-	257.4
1963	59.8	25.2	7.9	5.7	1.3	311.6
1973	52.2	32.3	7.6	7.6	0.4	294.1
1983	38.5	44.1	8.3	7.5	1.5	212.3
2003	26.1	50.4	13.2	7.6	2.7	349.7

* Conifers in total; ** deciduous in total; - no data
* *Iglavci skupaj; ** listavci skupaj; - ni podatkov*

The d.b.h. structure of the growing stock changed noticeably in the observed period. In the 1952–2003 period, the share of large diameter trees (d.b.h. ≥50 cm) increased from 6.9% to 51.2%, while the share of other trees (10–49 cm) decreased. The proportion of medium-size trees (30–49 cm) decreased by half (Table 4).

Table 4: The structure of growing stock (%) according to d.b.h. classes in the 1952–2003 period

Preglednica 4: *Struktura lesne zaloge (%) sestojev po razširjenih debelinskih razredih v obdobju 1952–2003*

	D.b.h. classes (cm) *Deb. razred (cm)*	Year *Leto*				
		1952	1963	1973	1983	2003
Total *Skupaj*	10–29	31.1	17.6	15.8	16.6	20.9
	30–49	62.1	51.6	48.5	39.6	27.9
	above 50 *nad 50*	6.9	30.8	35.7	43.9	51.2

Table 5: Mean annual cut and volume increment of stands in sub-compartments 22a and 22b in the 1963–2003 period

Preglednica 5: *Povprečni letni posek in prirastek po obdobjih za odsek 22a in 22b v obdobju 1963–2003*

Period *Obdobje*	Mean annual cut *Povprečen letni posek* (m^3ha^{-1})		Increment *Prirastek* (m^3ha^{-1})	
	22a	22b	22a	22b
1963–1972	17.6	7.6	6.3	5.5
1973–1982	8.3	5.9	9.1	8.6
1983–1989	12.4	7.7	-	-
1990–2000	11.7	4.1	-	-
2001–2003	4.4	*	10.4	10.2

* no cut, - no relevant data

5.3 Structural characteristics of forest stands

5.3 Strukturne zančilnosti gozdnih sestojev

Growing stock and tree species composition

Lesna zaloga in drevesna sestava

The Granata research site is characterised by diverse tree species composition; 13 tree species, some of them light demanding, were registered. Apart from sycamore (*Acer pseudoplatanus*) and elm (*Ulmus glabra*), some trees of rowan – *Sorbus aucuparia* (7.5 ha^{-1}), littleleaf linden – *Tilia cordata* (4.7 ha^{-1}), as well as some trees of wild cherry – *Prunus avium*, whitebeam – *Sorbus aria*, goat willow – *Salix caprea* (0.4 ha^{-1} in total) and yew – *Taxus baccata* (0.4 ha^{-1}) are present. Light demanding tree species represent 13.2% and 10.3% of the total number of trees and of the total growing stock, respectively. Conifers prevail, representing 76.5% of the total growing stock; among deciduous trees, (23.5%) beech (13.2% of total growing stock) prevails. The share of silver fir in total growing stock is significantly higher than its share in the total number of trees, indicating old population of silver fir and probable decline of its share in the future.

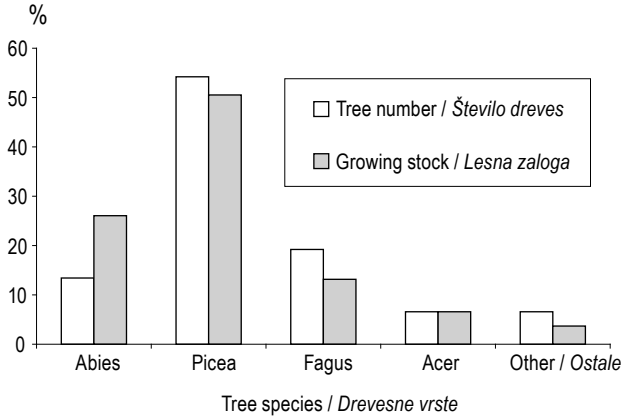


Figure 1: The share of tree species in total number of trees and in growing stock of the stand

Slika 1: *Delež drevesnih vrst v skupnem številu in skupni lesni zalogi sestoja*

Diameter distribution

Debelinska struktura

Diameter distribution of trees is typically J-shaped. Average growing stock is relatively low (350 m^3ha^{-1}) due to the high share of small-diameter trees. The growing stock distribution per d.b.h. classes is unimodal (Fig. 2), and asymmetric in lower d.b.h. classes as a result of the exaggerated regeneration (intense cutting) in the past. The highest growing stock is accumulated in trees with 45–65 cm d.b.h. The share of very large size diameter trees (>90 cm d.b.h.) is high – 2.8 trees per hectare are present. Among large diameter trees, spruces and silver firs prevail.

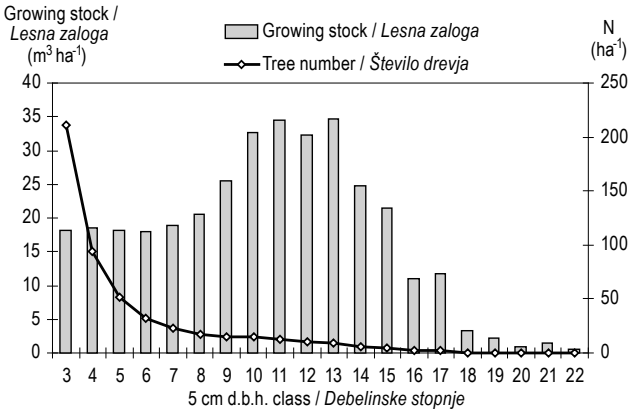


Figure 2: Diameter and growing stock distribution

Slika 2: *Število dreves in lesna zaloga po debelinskih stopnjah*

Vitality

Vitalnost

Generally, vitality of trees is more than satisfactory; 15% of all trees are very vital, 77% normally vital, and only 7% of all trees are less vital or declining. Dead trees represent only 1% of all standing trees. Deciduous trees are more vital compared to conifers, with elm as an exception (5% of elm trees are unvital and additional 7% are dead trees as a result of Dutch elm disease).

Regeneration

Pomlajevanje

For undisturbed functioning of selective forests, continuous regeneration must be secured. Seedling density amounts to 1.291 m^{-2} (Table 6). Silver fir prevails in natural regeneration (42.5%), followed by sycamore (23.9%), spruce (18.0%), rowan (8.2%), beech (4.9%) and elm (2.2%). 59.6% of all seedlings are lower than 20 cm, 23.5% of them were browsed, with elm leading (50.0%), followed by silver fir (28.2%) and sycamore (22.7%). The least browsed tree species is beech (0%).

Table 6: The number of seedlings (N/ar) in height classes and tree species: total number (n) and number of damaged individuals (n')

Preglednica 6: *Število osebkov v pomladku (N/ar) po višinskih razredih in drevesnih vrstah: skupno število (n) in število poškodovanih osebkov (n')*

Height *Višina*	*Picea abies*		*Abies alba*		*Fagus sylvatica*		*Acer pseudopl.*		*Sorbus aucuparia*		*Ulmus glabra*		Total *Skupaj*	
(cm)	n	n'	n	n'	n	n'	n	n'	n	n'	n	n'	n	n'
0–19	9.2	2.1	33.2	9.2	1.4	0	23.2	4.9	8.5	0.7	1.4	1.4	76.9	18.3
20–49	3.5	0.7	11.2	4.9	1.4	0	6.3	1.4	1.4	1.4	1.4	0	25.4	8.5
50–89	4.9	1.4	4.2	1.4	0	0	0	0	0.7	0	0	0	9.9	2.8
90–129	2.8	0	1.4	0	1.4	0	0.7	0	0	0	0	0	6.3	0.0
130 and more *130 in več*	2.8	0	4.9	0	2.1	0	0.7	0.7	0	0	0	0	10.6	0.7
Total *Skupaj*	23.2	4.2	54.9	15.5	6.3	0.0	30.9	7.1	10.6	2.1	2.8	1.4	129.1	30.3

Tree growth

Priraščanje dreves

Height growth of Norway spruce and silver fir with regard to d.b.h. (Fig. 3) is similar, while height growth of beech was more intense until 60 cm d.b.h.; above this size, the height increment diminished considerably. Conifers reach higher top tree heights if compared to beech trees. Top heights for analysed trees amount to 38 m, 43 m and 39 m for spruce (d.b.h.=75 cm), fir (d.b.h.=73 cm) and beech (d.b.h.= 63 cm), respectively.

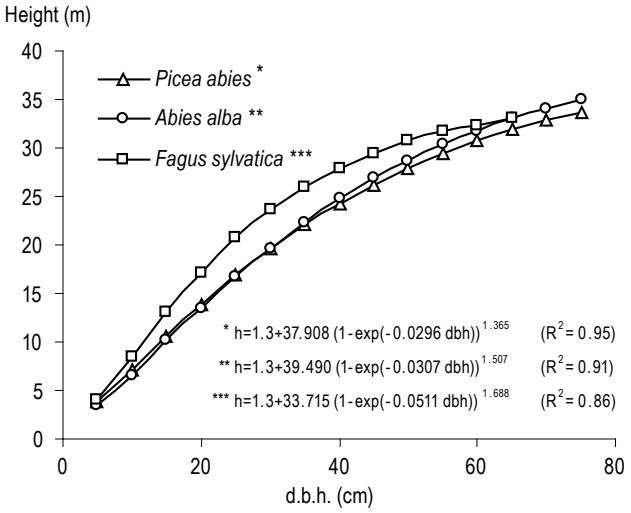


Figure 3: Tree height growth curves for European beech, Norway spruce and silver fir

Slika 3: *Višinska krivulja za bukev, smreko in jelko*

The ages of the analysed firs were 140 and 150 years. The analysed spruces were even younger on average; their growth is more intense with the exception of the spruce C, which shows similar dynamics as the analysed firs. Stem wood analyses show irregular growth of the trees, which might be a result of changing growth conditions in the lifetime of trees. Spruces reached tree height of 10 m at the age of 20 (D) to 46 years (C); firs needed 42 and 47 years to reach the same height (Table 7). Growth of both silver firs was similar despite noticeable distance between them. Annual rings in the core of the fir stems are very narrow, which is a result of suppression growth for approximately 30–35 years, followed by a relatively accelerated growth.

Relatively low ages of the analysed trees and their similar growth indicate that these forest stands have been managed at least for 150 years or even more. This could be a consequence of its location - near the road connecting Ajdovščina and Ljubljana.

Mechanical stability

Mehanska stabilnost

Mechanical stability is of great importance for sustained functioning of selection forests. The mechanical stability of trees is expressed with the ratio between tree height and its d.b.h. At the research site, the mechanical stability of trees is favourable; the ratio of trees calculated per 5 cm d.b.h. classes is lower than the critical value (h/dbh = 85) with an exception of beech trees with 5–9 cm d.b.h., where the ratio amounts to 117, compared to 75 and 69 for spruce and fir, respectively. With increasing tree diameter the ratio decreases, it amounts to 73 and 46 for the trees 10–14 cm d.b.h. and the trees 70–74 cm d.b.h., respectively.

Analysis of horizontal stand structure

Analiza horizontalne strukture

The Granata research site was divided into 16 smaller stand patches (Map 1). The PS patches cover 51% of total area; the rest is covered by GS patches. There are no significant differences in tree species composition between the PS and the GS patches in sub-compartment 22a. On the other hand, tree species composition of patches in sub-compartment 22b is more diverse, with a high share of spruce and low share of silver fir and beech in the PS patches and with a significantly larger proportion of beech and silver fir in GS patches (Table 8).

Table 7: Basic data about the analysed trees in the stem wood analysis

Preglednica 7: *Osnovni podatki o analiziranih drevesih pri debelni analizi*

Tree label *Oznaka drevesa*	Tree species *Drevesna vrsta*	Height *Višina* (m)	d.b.h. *Prsni premer* (cm)	Age (years) *Starost (leta)*	Age needed to rich the height: *Potrebna starost za višino*			
					5 m (years) *(leta)*	10 m (years) *(leta)*	20 m (years) *(leta)*	25 m (years) *(leta)*
A	*Picea abies*	29.7	60.8	122	16	28	72	93
B	*Picea abies*	30.7	51.5	113	13	31	68	79
C	*Picea abies*	28.1	53.7	148	36	46	95	126
D	*Picea abies*	35.0	70.5	111	12	20	36	51
E	*Abies alba*	29.3	60.9	140	34	47	85	113
F	*Abies alba*	31.0	64.8	150	32	42	84	112

Table 8: Tree species composition (% of growing stock) for PS and the GS patches in sub-compartments 22a and 22b and at the entire site

Preglednica 8: *Drevesna sestava (% v lesni zalogi) po sestojnih stratumih (PS in GS) v odsekih 22a in 22b ter v celotnem raziskovalnem objektu*

Stands *Sestoji*	Tree species composition (% in growing stock) *Drevesna sestava (% lesne zaloge)*							
	Picea abies	*Abies alba*	*Fagus sylvatica*	*Acer pseudopl.*	*Sorbus aucuparia*	*Ulmus glabra*	*Fraxinus excelsior*	*Tilia cordata*
PS 22a	56.6	23.3	11.4	6.1	0.2	1.0	0.5	1.0
GS 22a	56.2	21.5	11.0	7.5	0.5	0.7	2.1	0.5
PS 22b	57.6	28.3	4.0	5.9	0.2	1.1	0.1	2.8
GS 22b	14.1	39.5	34.5	7.2	0.0	1.1	0.6	3.0
PS 22	56.9	25.1	8.8	6.0	0.2	1.0	0.3	1.6
GS 22	42.0	27.6	18.9	7.4	0.3	0.8	1.6	1.4
Total	50.4	26.1	13.2	6.6	0.3	0.9	0.9	1.5

The PS patches are characterised by a high growing stock (369–582 m^3ha^{-1}), which is higher if compared to the growing stock of GS patches (Table 9). The d.b.h. structure of growing stock per d.b.h. classes differs significantly between PS patches and GS patches (Snedecor-Brandt test). The portion of large diameter trees (d.b.h. ≥50 cm) in total growing stock is significantly higher in PS patches (43–63%) if compared to the portion of large diameter trees in the GS stands.

For the sustained plenter stand structure, an adequate number of saplings is needed to recruit into higher classes and to replace cut trees (Table 10). A high number of saplings (5–15 cm d.b.h.) is a result of intense cutting in the past. The share of silver fir and sycamore in the total saplings number in sub-compartment 22a is much lower than their share in the total growing stock, which indicates a probable decrease of these species in the future. The share of silver fir is much higher in sub-compartment 22b if compared to the patches in 22a, therefore fir conservation will be more successful in stands of 22a sub-compartment. On the other hand, the share of European beech in the growing stock of the A d.b.h. class is higher if compared to its share in the total growing stock, which indicates an increase of this species in total growing stock in the future.

Table 9: Growing stock structure (%) for A, B, C d.b.h. classes, and testing differences in the distribution of tree numbers per A, B, C d.b.h. classes between selection stands and small scale-uneven stands using Snedecor-Brandt test

Preglednica 9: *Struktura lesne zaloge (%) po razširjenih debelinskih razredih in testiranje razlik v porazdelitvi števila dreves po razširjenih debelinskih razredih med prebiralnimi in malopovršinsko raznomernimi sestoji s Snedecor-Brandtovim testom*

Unit	Growing stock (%) *Lesna zaloga (%)*			Total *Skupaj*	Area *Površina* (ha)	Snedecor-Brandt test*
	A	B	C			Calculated χ^2 *Izračunani* χ^2
PS 22a	13.9	28.1	58.0	367.9	6.51	50.41^{***}
GS 22a	30.9	29.1	40.0	304.2	6.15	
PS 22b	23.5	26.3	50.1	451.7	2.83	7.46^{*}
GS 22b	15.5	26.9	57.6	337.9	2.83	
PS 22	17.2	27.5	55.3	393.3	9.34	16.62^{***}
GS 22	25.7	28.4	46.0	314.8	8.98	
Total 22 *Skupaj 22*	20.9	27.9	51.2	354.6	18.32	

Table 10: Tree species composition of saplings (5–14 cm d.b.h.) in selection stands

Preglednica 10: *Delež števila dreves (%) v 2. in 3. debelinski stopnji po drevesnih vrstah v sestojih s prebiralno zgradbo*

Stand patch *Sestoj*	Sub-comp *Odsek*	The share of tree species (%) in total sapling (5–14 cm d.b.h.) number *Delež (%) drevesnih vrst v 2. in 3. debelinski stopnji*								Number of trees (N/ha) *Število dreves (N/ha)*	
		Picea abies	*Abies alba*	*Fagus sylvat.*	*Acer pseudo.*	*Sorbus aucup.*	*Ulmus glabra*	*Frax. excels.*	*Tilia cord.*	5–9 cm d.b.h. *2. deb. st.*	10–14 cm d.b.h. *3. deb. st.*
2	22a	67.7	3.4	22.4	0.7	2.4	1.9	1.2	0.2	216.0	116.0
6	22a	73.1	4.8	12.5	0.6	1.9	4.5	1.0	1.6	180.4	98.2
8	22a	56.8	5.6	24.0	1.3	4.9	3.0	4.1	0.3	335.4	186.3
9	22a	39.1	8.6	31.8	7.7	3.5	7.9	0.1	1.3	240.6	140.2
11	22b	31.8	19.6	10.9	20.9	4.8	5.8	1.9	4.2	371.4	263.3
12	22b	51.8	11.6	17.6	9.0	3.7	5.2	0.2	0.8	391.8	261.4
13	22b	41.7	8.3	27.0	7.0	6.1	10.0	0.0	0.0	278.0	182.0
Average *Poprečje*		52.6	8.0	22.6	5.6	3.7	5.2	1.2	1.0	286.5	173.1

In sub-compartment 22b, tree species composition of saplings is almost identical to that of total growing stock, therefore larger changes of tree species composition in the future are not expected. Quite considerable differences in tree species composition of saplings and small diameter trees between both sub-compartments might be a result of different site conditions and different silvicultural treatment in the past.

6 Discussion

6 Razprava

The results from the Granata research site enable a comparison of the structure and composition with results from other research sites and with reference values. The diameter distribution of trees was one of the key stand parameters for describing plenter stand structure. It was also used to define the optimal selection forest structure (also named "ideal" or "normal"); the curve was, similarly, named optimal, ideal or normal (BACHOFEN 1999, FRANÇOIS 1938, HANEWINKEL 1999, LIOCOURT 1989, MEYER 1933, SCHÜTZ 1989). Mitscherlich has justifiably claimed that several optimal diameter distributions are possible, the decision being dependant on the forest management goal (KOTAR 2002). Accordingly, he defined intervals for the number of trees per hectare and d.b.h. classes; 100–700 trees in A d.b.h. class (7–24 cm), 50–300 trees in B d.b.h. class (25–49 cm) and up to 70 trees in the C d.b.h. class (50 cm and more) (MITSCHERLICH 1952, 1961). The diameter distribution of trees at the Granata research site fits this model, with 357, 87 and 45 trees per hectare in the A, B and C d.b.h. class, respectively. The diameter distributions of trees in 16 patches fit this model (with the exception of patch 10) although all patches were not defined as plenter forest.

The results from the site can be compared to similar reference sites (Table 11). Data indicate significant differences in diameter distribution between the research sites. Possible reasons may lie in different site conditions (ROBIČ 2004), different tree species composition of plenter stands, and differences in past silvicultural treatment. The Granata research site is an example of a site characterised by lower growing stock and high number of small- and large-diameter trees. The discrepancy between the number of small- and large-diameter trees and low growing stock can be explained with patches of pole stands as a result of former intense cuttings, whereas on the other hand several large-diameter trees were left untouched due to good increment and vitality. The comparison of diameter distribution of trees between stands in similar site conditions (Granata, Draga and Sibirija) shows similarity for number of trees in lower as well as in higher d.b.h. classes. However, at the Granata site the number of middle sized trees is much lower, and, as consequence, growing stock is lower as well.

Stand structure at the Meja Dolina and Palikovec research sites was not classified as plenter structure, but it is nevertheless uneven. Comparison to the Mitscherlich model shows a surplus of large diameter trees (C d.b.h. class) at both research sites, and a deficit of small diameter trees (A d.b.h. class) at the Palikovec research site. At both sites, forests are intended to be gradually transformed into selection plenter stands.

With the exception of the Palikovec and Meja Dolina sites, the number of trees per ha at all other research sites amounts to 310–505, whereas growing stock is 283–441 m^3ha^{-1}. The tree number of the lowest d.b.h. class still measured during forest inventory (10–15 cm) is an important indicator of undisturbed functioning of selection forest as it shows appropriate recruitment of saplings into upperstorey. This number varies between 96 and 141 at other research sites, but is too high (171 ha^{-1}) at the Granata site as a consequence of intense past cutting. At the Meja Dolina and Palikovec research sites, the number of saplings is too low, indicating inappropriate selection structure.

The distribution of growing stock per A, B, C d.b.h. classes is a common and useful indicator for monitoring

Table 11: Number of trees per ha for d.b.h. classes and total growing stock (m^3ha^{-1}) at the analysed research sites in Slovenia (Bončina *et al.* 2004)

Preglednica 11: *Število dreves na hektar po debelinskih stopnjah in skupna lesna zaloga (m^3/ha) v analiziranih raziskovalnih objektih po Sloveniji (Bončina et al. 2004)*

D.b.h. class. *Deb. stop.*	Draga*	Sibirija*	Lazar*	Smolar*	Sgerm*	Marinšek*	Meja dolina*	Palikovec*	Granata*
3	128	113.3	94	133.6	141.0	97.6	50.5	24.9	211.5
4	91	70.8	31	74.0	83.4	57.6	25.9	3.0	94.2
5	73	48.7	26	32.5	48.2	36.0	11.0	0.3	51.2
6	43	35.9	16	25.6	28.9	41.6	7.0	0.3	32.1
7	34	30.5	23	18.2	21.2	28.0	10.0	9.1	22.7
8	29	24.6	21	21.7	16.8	41.6	13.6	21.6	16.8
9	25	21.4	22	29.6	16.8	39.2	26.6	39.8	15.3
10	29	18.8	22	28.0	9.6	37.6	27.9	39.8	15.2
11	14	14.1	19	20.0	10.3	27.2	31.6	34.7	12.8
12	16	14.1	13	13.5	7.4	10.4	31.2	25.2	9.8
13	8	9.9	12	13.0	6.5	6.4	18.9	10.3	8.8
14	7	6.0	6	3.1	5.8	0.8	9.6	3.3	5.4
15	3	4.9	3	1.7	2.4		4.7	0.6	4.0
16 and up *16 in več*	4	3.3	2	1.7	2.8		2.3	0.6	4.6
Total *Skupaj*	504	416.3	310	416.2	401.1	424.0	270.8	213.5	504.5
Growing stock (m^3ha^{-1}) *Lesna zaloga (m^3ha^{-1})*	440.8	389.5	357.8	385.9	282.7	412.2	491.5	427.5	345.9

* References / *Viri*:
Draga (BONČINA 1992), Sibirija (POJE 2001), Lazar (DOLINAR 2002), Smolar (KUNSTEK / BONČINA 2004), Sgerm (SKLEDAR 2002), Marinšek (GLUK 2003), Meja dolina in Palikovec (BONČINA *et al.* 2004).
** Current growing stock at the sites is higher, as growing stock of the trees with the d.b.h. above 80 cm was calculated with the tariff for the d.b.h. class 75–80 cm.
** *Prikazana lesna zaloga objektov je nekoliko manjša od dejanske, saj smo lesno zalogo dreves s prsnim premerom nad 80 cm obračunali s tarifo za 16. debelinsko stopnjo.*

the development of plenter stand structure. At the Granata research site, the distribution of growing stock per A (10–29 cm), B (30–49 cm), C (50 cm an up) d.b.h. classes is the following: 21%, 28% and 51% of total growing stock, respectively.

The share of large-diameter trees (C-class) differs between research sites; it amounts to over 45% in stands with high growing stock (>300 m^3ha^{-1}). Kotar (2002) defined model values of growing stock structure per A, B, C classes for plenter forests at *Omphalodo-Fagetum festucetosum* site: A - 20%, B - 35%, C - 45%. According to the research carried out in forests with appropriate selection structure, a portion of 40–50% of the large-diameter trees in the selection forests is recommended (BONČINA *et al*. 2004). A higher share of large-diameter trees and consequently a higher growing stock would lead to the regression of the number of small-diameter trees, and continuous recruitment of saplings into higher d.b.h. classes would be hindered.

The Granata research site is characterised by a high share of Norway spruce (56%), which is the highest share if compared to other research sites. This is partly a result of extreme site conditions where spruce regenerates successfully, as well as of silver fir decline and its replacement by Norway spruce.

The regeneration density at the Granata site exceeds minimum standards (reference values) about number of natural regeneration, securing successful functioning of selection forest (DUC 1991, SCHÜTZ 1989, 2001). Silver fir regenerates successfully, it prevails in the regeneration. The situation differs from other research sites, where an increasing portion of beech in total natural regeneration is noticed. At the Granata site, a significant share of sycamore was registered; this indicates an important niche of this species in the Dinaric fir-beech forests. Besides, its economic value is considerably high.

Successful regeneration of rowan at the Granata research site is unique among research sites for plenter forests in Slovenia, indicating lower browsing pressure by large herbivores. They could hinder or even stop natural regeneration, making a selection system use impossible. The average browsing of all tree species seedlings amounts to 23.5%, which is similar to browsing pressure at the Palikovec (29%) and Sgerm (21%) research sites. At the Granata site, seedlings of silver fir are less browsed (28%) than at the Palikovec (43%) and Meja dolina (43%) sites.

The values of stand parameters from the Granata research site are useful as reference values for evaluating structure of selection forests in similar site conditions. Plenter forests in Slovenia cover 4% of the total forest area; the target value is ca. 15–20% of the whole forest area (BONČINA *et al*. 2004). The selection system was slightly neglected in the region around the Granata research site during the last decades. We hope that the research will contribute to a more favoured use of selection system in forest management. The research results indicate dynamic nature of selection forests, since diameter structure and tree species composition have changed significantly in the last decades (GAŠPERŠIČ 1967, BONČINA / DIACI / GAŠPERŠIČ 2003). Therefore, determining of strict models and/or rigid silvicultural goals is not appropriate. Permanent monitoring of stand structure of plenter stand structure is needed to enable us to take appropriate decisions for the future forest management.

A population of silver fir is becoming older in Slovenian forests; its share in total growing stock has been decreasing permanently (FICKO / BONČINA 2006). The current diameter distribution of silver fir at the Granata research site indicates the decreasing of fir portion in total growing stock. However, results on natural regeneration indicate possible reaffirmation of fir in the future stand development, as silver fir dominates in total seedling number (46%).

The research shows a patchy horizontal stand structure; different types of stand patches were found at the Granata research site. Something similar was established in and reported from other research sites, predominantly in the Dinaric silver fir-beech forests (BONČINA *et al*. 2004). Therefore, elements of selection system and irregular shelterwood system should be combined at small spatial scale when silviculture activities are taken, presenting a challenge for silviculturists.

Enlarging the area of selection stands is an important challenge for the future silviculture in the region; the selection system has some advantages compared to other silviculture systems: the smaller amount of cost silvicultural measures is needed, greater possibilities for high quality wood production, plenter structure is suitable for extreme site conditions, improving protection function, it also contribute to favourable habitat conditions, it is resistant against natural hazards, etc. Some of these characteristics might be of great importance in the conditions of global climate changes, ensuring stable functioning of forests.

7 Povzetek

V raziskovalnem objektu Granata smo opravili fitocenološke popise, polno premerbo, analizo vitalnosti, pomlajevanja, debelne analize in izmero višin glavnih drevesnih vrst. S pomočjo obstoječih gozdnogospodarskih načrtov je bila opravljena tudi analiza razvoja gozdov za obdobje med letoma 1952 in 2003. Iz analize razvoja gozdov je razvidno, da se je delež jelke v lesni zalogi močno zmanjšal (s 86,3 % leta 1952 na 26,1 % leta 2003), tako da se bo trend zmanjševanja zaradi neugodne debelinske strukture jelke najverjetneje nadaljeval. V preučevanem obdobju se je močno spremenila tudi debelinska struktura, kajti današnji delež debelega drevja (51,2 % leta 2003) je mnogo večji, kot je bil ta v preteklosti (6,9 % leta 1952). Pri opravljanju polne premerbe smo objekt razdelili na sestoje, v okviru katerih smo ločeno zbirali podatke o premeru in vitalnosti posameznih drevesnih vrst. Površina objekta je 18,58 ha, povprečno število dreves je 504,5 dreves/ha, lesna zaloga 349,7 m^3ha^{-1}. Vitalnost drevesnih vrst je zadovoljiva, saj je slabo vitalnih ali odmirajočih dreves le 7 %. Najmanj vitalna sta brest in jelka, najvitalnejša pa je bukev. Pri analizi pomladka smo ugotovili prevlado pomladka jelke, ki pa je z 28,2 % poškodovanostjo med najbolj objedenimi v objektu. Debelna analiza dreves kaže, da so drevesa zgornjega položaja razmeroma mlada in da je bilo obdobje zastrte rasti relativno kratko. To kaže na intenzivno gospodarjenje z gozdovi v preteklosti. Posek v zadnjih desetletjih je bil pretiran in je sprožil obilno pomlajevanje, število tankega drevja zato presega vrednosti, ki so sicer značilne za prebiralne gozdove. Med sestoji in deli sestojev so opazne razlike; razlike med sestoji z izrazitejšo prebiralno zgradbo in med drugimi raznomernimi sestoji smo statistično potrdili. Razlike so opazne predvsem v debelinskih strukturi sestojev, manj pa v drevesni sestavi. Raziskovalni objekt Granata lahko v primerjavi z drugimi raziskovalnimi objekti v Sloveniji uvrstimo med objekte z nižjo lesno zalogo in z velikim številom najtanjšega ter najdebelejšega drevja.

Glede na rastiščne razmere, drevesno sestavo, zgradbo sestojev in prednosti, ki jih ponuja prebiralno gospodarjenje, je smiselno ohranjati in izboljševati prebiralno zgradbo gozdov v raziskovalnem objektu in njegovi širši okolici.

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