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NORWAY SPRUCE (*Picea abies* (L.) Karst) DAMAGE IN THE ZASAVJE DISTRICT OF SLOVENIA EVALUATED BY TWO METHODS

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Abstract

The Zasavje district has been heavily affected by air pollution due to mining, the presence of a coal-fired power plant, and industry. The extent of forest damage differs according to location because of specific climatic and orographic characteristics. Norway spruce damage was estimated by two methods at 10 locations in the Zasavje district using the Slovenian forestry method for the estimation of forest damage (KOVAČ et al. 1995), and a Czech method for estimation of damage to the branching system and needle loss and discoloration (CUDLIN & CHMELIKOVA 1995). Comparison of the results obtained by the two methods gave similar damage assessments at heavily polluted sites, although the data obtained by the two methods differ due to several environmental parameters. The Czech method did not give as good results as was expected. A possible reason might be that spruce trees in the investigated locations are less damaged than those in the Czech Republic, where the method was developed.

Key words: air pollution, Zasavje, Norway spruce, *Picea abies* (L.), tree damage

POŠKODOVANOST SMREKE (Picea abies (L.) Karst) V ZASAVJU OCENJENA NA OSNOVI DVEH METOD

Izvleček

Zasavje je zaradi rudarjenja, termoelektrarne in bazične industrije že od nekdaj močno onesnaženo. Stopnje poškodovanosti gozdov na posameznih lokacijah v tem območju se razlikujejo zaradi specifičnih klimatskih in orografskih značilnosti. Poškodovanost smreke (Picea abies (L.) Karst) smo ugotavljali na 10 zasavskih lokacijah z dvema metodama: slovensko gozdarsko metodo za ugotavljanje poškodovanosti gozdov (KOVAČ et al. 1995) in češko metodo za ugotavljanje poškodovanosti razvejitve in iglic (CUDLIN / CHMELIKOVA 1995). Na močno onesnaženih točkah so rezultati, ki smo jih dobili z uporabo posameznih metod, podobni, nekoliko se razlikujejo le zaradi nekaterih dejavnikov okolja. Rezultati češke metode so bili slabši od pričakovanj. Razlog bi lahko bilo dejstvo, da so smreke na obravnavanih lokacijah manj poškodovane kot smreke, ki so jih Čehi uporabili pri razvoju omenjene metode.

Ključne besede: onesnaženost zraka, Zasavje, smreka, Picea abies (L.), poškodovanost drevja

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VSEBINA
CONTENTS

1 INTRODUCTION
UVOD

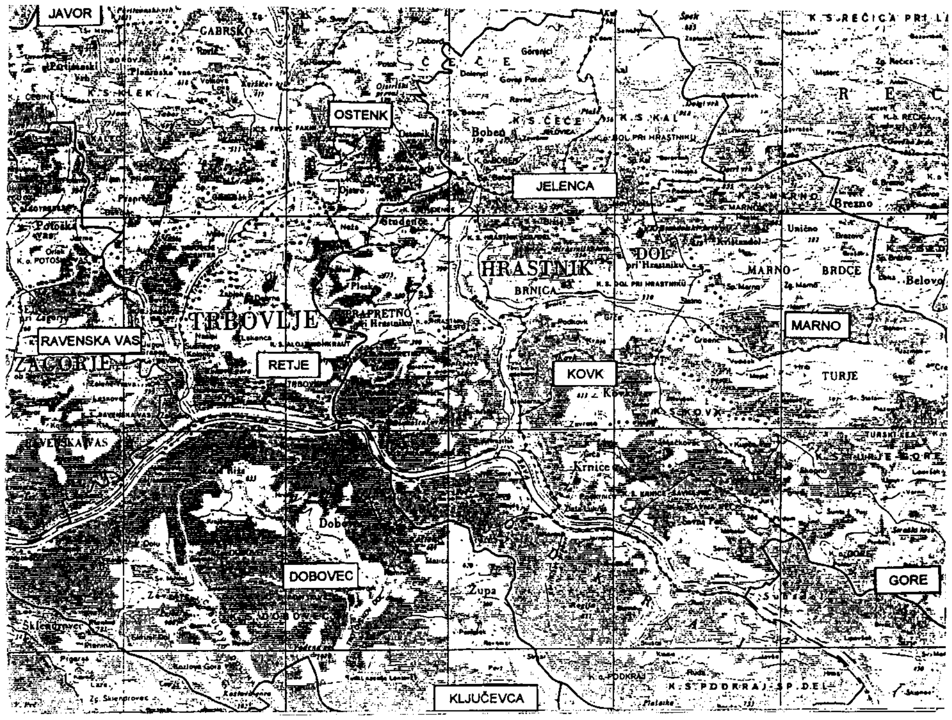
The Zasavje district is situated in the middle of Slovenia. The biggest air pollution source is the thermal power plant in Trbovlje - TET II (125 MW), which was put into operation in 1968. Due to its location in a deep and narrow valley it causes serious air pollution. In the sixties half hourly concentrations of SO_2 reached as much as 20000 $\mu g\ m^{-3}$ at the most exposed localities (PARADIŽ, 1972). Forest decline started at that time in this region. Silver fir died out first and later all conifers disappeared from the most polluted area. The worst affected slopes were almost deforested. This resulted in the threat that slopes would erode and dam the valley of the river Sava, blocking the road and railway. This led to the construction of a 360m high chimney which partly resolved the problems in the valley, but spread air pollution over a much broader area (ŠOLAR 1989, 1991).

Although Norway spruce is not an indigenous tree in this district of Slovenia, it is very common due to forestry practice in the past. After the silver fir, it was the most affected. Typical symptoms of damage were defoliation, chlorotic and necrotic needles, and change in the branching system; these effects were all included in the previous Slovenian method for the assessment of forest decline (ŠOLAR 1989, BELEC 1992). The new Slovenian method for forest decline inventories is described in Kovač et al. (1995). Apart from the well known method for forest decline assessment which was developed by EU countries, and which is predominantly based on tree defoliation, Czech researchers developed a more sophisticated method, based predominantly on changes in the Norway spruce branching system, which is especially convenient for forest decline studies in areas with very high air pollution (CUDLIN & CHMELIKOVA, 1996). This method is based on a visual assessment of the Norway spruce branching system and on the assessment of needle loss and discoloration within the branching systems. When Norway spruce is exposed to very high sulphur dioxide concentrations, the primary branch system usually dies off and secondary branches develope, starting with so-called epicormic sprouts. These develop into the secondary branch system, and later on, when air pollution persists, the secondary system dies off, and tertiary systems develope, and so on (CUDLIN & CHMELIKOVA, 1996).

In our study we tested the application of the Czech method in Zasavje, which represents one of the most polluted regions of Slovenia. We tried to compare the Czech method of forest decline assessment with the Slovenian method to assess any differences in the results. The aim of the study was to compare both estimations of the damage to the Norway spruce, to discover differences in branching disturbance and defoliation level among the experimental plots and to compare the usefulness of both methods.

2 METHODS
METODE

The study was carried out in the autumn of 1995 on ten experimental plots: Javor, Ravenska vas, Ostenk, Jelenca, Retje, Marno, Kovk, Gore, Dobovec and Ključevca. Plots were the same as in the previous studies (ŠOLAR 1989, 1991), differing in the distance from the thermal power plant and their air pollution level (Map 1). On each plot forest damage was assessed by using the Slovenian method for forest decline inventories and three spruce trees were chosen for analyses of macronutrients, pigments and for assessing damage to the branching system by the Czech method. On each plot the damage to the Norway spruce was visually assessed twice: by using the Slovenian method and by using the Czech method and the results gained for each plot were compared.



Picture 1: Experimental plots (ŠOLAR 1989)
Slika 1: Vzorčne ploskve (ŠOLAR 1989)

2.1 SLOVENIAN METHOD
SLOVENSKA METODA

Forest damage on each plot was assessed by using the Slovenian method for forest decline inventories, described in KOVAČ et al. (1995). The method is slightly different from the EU method. First of all it includes the assessment of epiphytic lichen vegetation as an air pollution biomonitoring system, and secondly, in the assessment of tree damage, it includes understory trees and as well as the dominant trees. Apart from this the Slovenian method of forest decline also includes more site and stand characteristics and some additional symptoms of tree damage. The main criteria for the assessment of tree damage are the defoliation of crown, the state of needles according to chlorosis and necrosis, and crown top quality (ŠOLAR 1989). According to this method five levels of tree damage are distinguished: 0 - healthy tree, 1 - slightly damaged tree, 2 - moderately damaged tree, 3 - very damaged tree, 4 - dead tree or unrecoverably damaged tree. On some of the plots chosen in 1988 (ŠOLAR 1989) there were only a few spruce trees. To keep the continuity of the experiment, we decided not to change the experimental plots. Because of that, the samples are smaller than is prescribed by the method, although on each experimental plot all present spruce trees were included in the forest damage assessment.

2.2 CZECH METHOD
ČEŠKA METODA

On each plot three spruce trees, about 60-80 years old, were chosen. These were characteristic and representative of the site, and the upper parts of their crowns were well-lit. Because of the small numbers of convenient spruce trees per plot the sampling of the trees was not completely random. From each tree, one branch about 25 years old was cut off on the sunny site of the crown. The branch was cut to the branching systems according to the Czech method (CUDLIN & CHMELIKOVA 1995, 1996), and the needle damage of each branching system was assessed. As already pointed out, the method is based on the assumption that air pollutants cause disturbances in the branching system of Norway spruce. Trees in clean air have a majority of branches in the normal, primary branch system. With increasing air pollution impact, disturbances in branching appear as well as defoliation. Branches of undamaged spruces are green, with a low level of defoliation. There are few chlorotic and necrotic needles. With increasing air pollution the percentage of needles in the primary branch system decreases, they are more damaged, and the percentage of needles in the secondary or even the tertiary system increases.

Each branch was cut into its branching systems: primary, secondary, tertiary, and rarely quaternary. Within each branching system the percentage of needles was visually assessed according to following:

- percentage of defoliation,
- percentage of necrotic needles (reddish-brownish spots on needles),
- percentage of chlorotic needles (yellowish spots or areas on needles),
- percentage of green (healthy) needles.

In accordance with the statistical analysis of data for defoliation assessment, e.g. the small number of units in samples, high standard deviations and standard errors as a function of the number of experimental units and the variability of the variable, we decided to test the application of the Ward method of clustering for the data evaluation. By the Czech method assessed relative values (percentage of defoliation, percentage of necrotic needles, percentage of chlorotic needles, percentage of green needles) were transformed to absolute ones, which were used as entering variables (Z1, K1, N1, O1, Z2, K2, N2, O2) for cluster analysis.

On the basis of Euclidean distances using the Ward method, trees were divided into five groups. Data were processed by the Statistica for Windows programme. In the corresponding programme material additional information about the clustering method can also be found (Statistica for Windows, 1994). Only data of the primary and secondary branching system were processed. Because of the small samples, the mentioned five groups cannot be numerical described.

3 RESULTS
REZULTATI

3.1 SLOVENIAN METHOD
SLOVENSKA METODA

When using the Slovenian method, the majority of trees were classified as very damaged. The highest percentage of very damaged trees was found at the Ključevca and Kovk sites (Table 1).

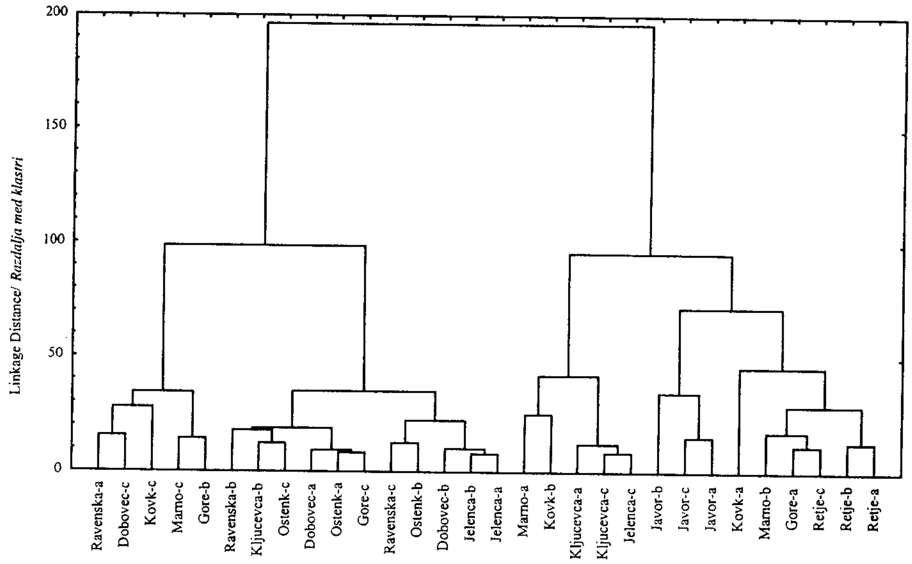
Table 1: Percentages of Norway spruce trees in damage classes; forest decline inventory in Zasavje district in 1995 (n = number of spruce trees present on the plot and included in damage assessment ; 0, 1, 2, 3, 4: damage classes)

Preglednica 1: Odstotki smrek v posameznih razredih poškodovanosti; popis poškodovanosti v letu 1995 (n = število smrek na posameznih ploskvah, zajetih v ugotavljanje poškodovanosti; 0, 1, 2, 3, 4: razredi poškodovanosti)

Forest plot / *Gozdna ploskev*	Percentages of trees in damage classes (%) / *Odstotek dreves v razredih poškodovanosti (%)*					n
	0	1	2	3	4	
Javor	10.0	0.0	15.0	75.0	0.0	20
Jelenca	0.0	0.0	0.0	100.0	0.0	3
Ključevca	0.0	0.0	33.3	33.3	33.3	3
Gore	0.0	16.7	16.7	61.1	5.5	18
Kovk	0.0	0.0	33.3	33.3	33.3	3
Dobovec	11.8	0.0	17.6	70.6	0.0	17
Marno	0.0	0.0	33.3	66.7	0.0	12
Ostenk	11.1	0.0	11.1	66.7	11.1	9
Ravenska	0.0	0.0	0.0	100.0	0.0	3
Retje	0.0	0.0	33.3	66.7	0.0	3

3.2 CZECH METHOD
ČEŠKA METODA

According to the proportions of green, chlorotic, necrotic and defoliated needles in particular branching systems as entering variables (see chapter 2.2) and on the basis of Euclidean distances using the Ward method, trees were divided into five groups (see linkage distance 50 and groups of trees from the left to the right side of the Graph 1).



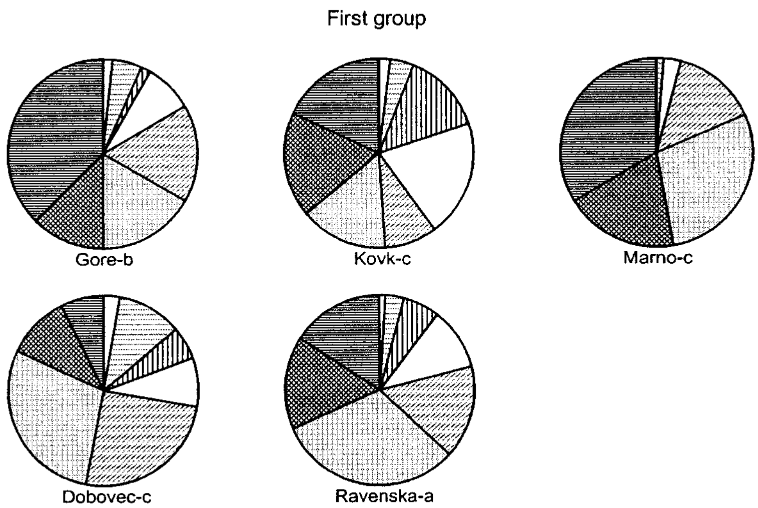
Graph 1: Dendrogram of damage to Norway spruce trees in the Zasavje district based on branching disturbance and needle damage (Czech method)

Grafikon 1: Dendrogram poškodovanosti razvejitve in oigličenosti smrek v Zasavju (češka metoda)

The classificatión into the five groups was done with the programme "Statistica for Windows" by comparison of the percentage of the values of green needles in the primary branching system, chlorotic needles in the primary branching system, necrotic needles in the primary branching system, defoliated needles in the primary branching system, green needles in the secondary branching system, chlorotic needles in the secondary branching system, necrotic needles in the secondary branching system and defoliated needles in the secondary branching system (Graphs 2, 3, 4, 5 and 6). As has already been pointed out, these five groups cannot be numerically described (and according to that, no limit values can be set) and the classification bases only on the comparison of the precentages of the mentioned values.

Legend to Figures 2, 3, 4, 5 and 6 (eight pie-areas; clockwise, starting with pointer on white area):

Z1 - green needles in **primary** branching system,
K1 - chlorotic needles in **primary** branching system,
N1 - necrotic needles in **primary** branching system,
O1 - defoliated needles in **primary** branching system,
Z2 - green needles in **secondary** branching system,
K2 - chlorotic needles in **secondary** branching system,
N2 - necrotic needles in **secondary** branching system,
O2 - defoliated needles in **secondary** branching system.

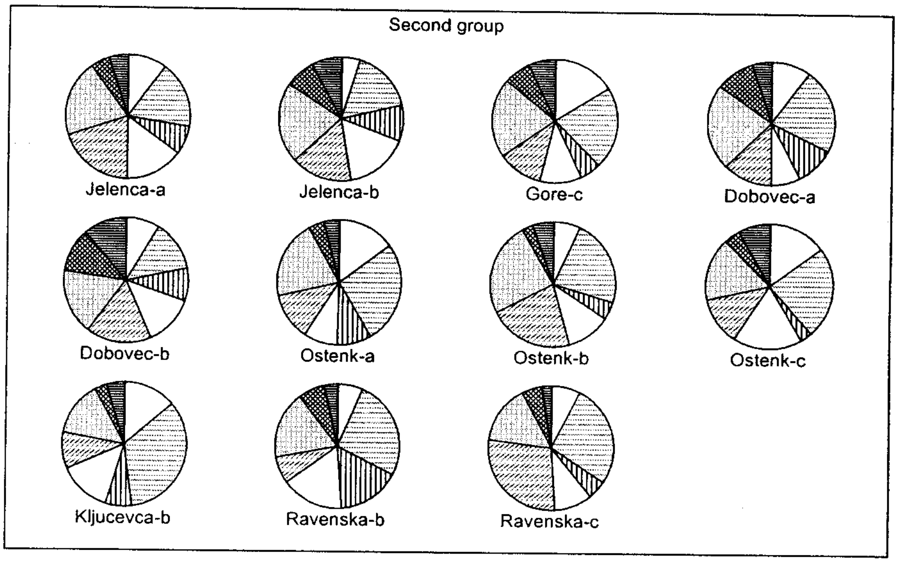


Legend (clockwise): Z1, K1, N1, O1, Z2, K2, N2, O2 / *Legenda (v smeri urnega kazalca): Z1, K1, N1, O1, Z2, K2, N2, O2*

Graph 2: Green, chlorotic, necrotic and defoliated needles in the primary and secondary branching systems in Norway spruce from the first group

Grafikon 2: Deleži zelenih, klorotičnih, nekrotičnih in osutih iglic v primarnih in sekundarnih razvejitvenih sistemih smrek iz prve skupine

Trees in the first group (Gore-b, Kovk-c, Marno-c, Dobovec-c, Ravenska vas-a) are very highly damaged (Graph 2). There are few needles in the primary branching system, and almost all are necrotic. The majority of needles are in the secondary branching system, and even they are highly chlorotic and necrotic.

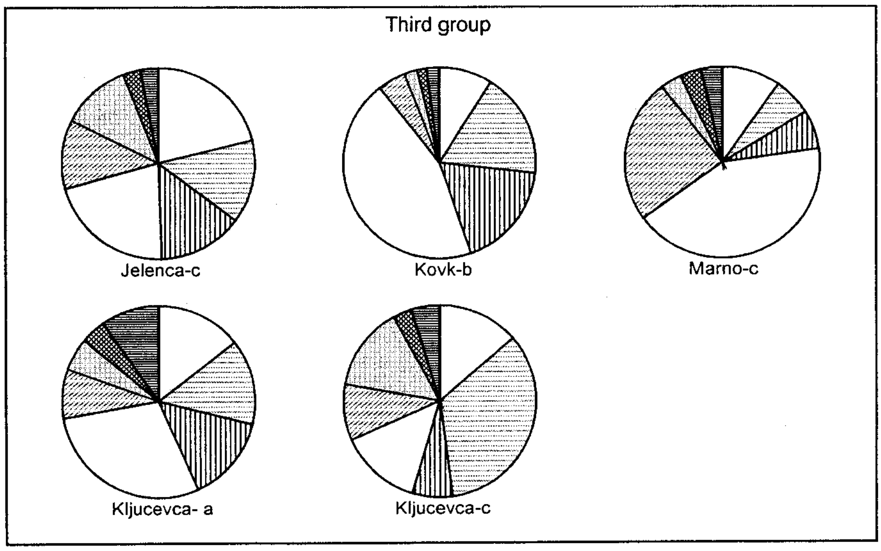


Legend (clockwise): Z1, K1, N1, O1, Z2, K2, N2, O2 / *Legenda (v smeri urnega kazalca): Z1, K1, N1, O1, Z2, K2, N2, O2*

Graph 3: Green, chlorotic, necrotic and defoliated needles in the primary and secondary branching systems in Norway spruce from the second group

Grafikon 3: Deleži zelenih, klorotičnih, nekrotičnih in osutih iglic v primarnih in sekundarnih razvejitvenih sistemih smrek iz druge skupine

In the second group (Graph 3) are very damaged trees. Needles of the primary branching system represent approximately half of all needles. Green needles represent only a small part, while the majority are necrotic and chlorotic needles. Needles of the secondary branching system are green, only the few are chlorotic or necrotic. Defoliation is low.

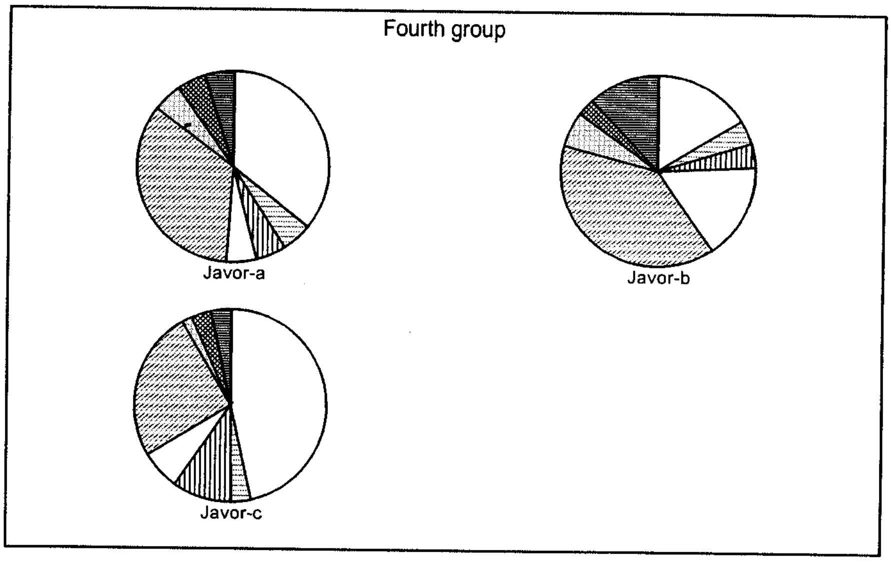


Legend (clockwise): Z1, K1, N1, O1, Z2, K2, N2, O2 / *Legenda (v smeri urnega kazalca): Z1, K1, N1, O1, Z2, K2, N2, O2*

Graph 4: Green, chlorotic, necrotic and defoliated needles in the primary and secondary branching systems in Norway spruce from the third group

Grafikon 4: Deleži zelenih, klorotičnih, nekrotičnih in osutih iglic v primarnih in sekundarnih razvejitvenih sistemih smrek iz tretje skupine

Needles in the primary branching system represent approximately three quarters of all needles in the third group of spruce (Jelenca-c, Kovk-b, Marno-c, Ključevca-a, Ključevca-c). The majority of needles are defoliated, chlorotic and necrotic (Graph 4). The damage level of spruce is medium.

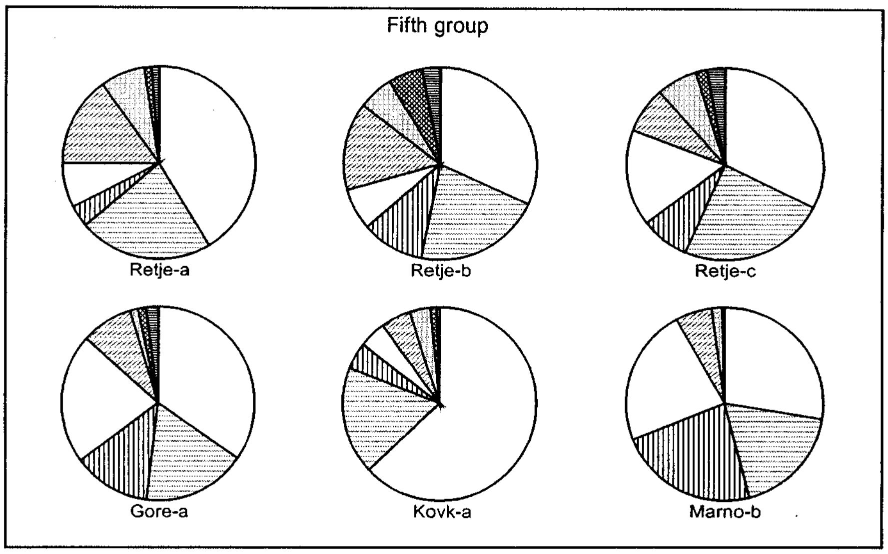


Legend (clockwise): Z1, K1, N1, O1, Z2, K2, N2, O2 / *Legenda (v smeri urnega kazalca): Z1, K1, N1, O1, Z2, K2, N2, O2*

Graph 5: Green, chlorotic, necrotic and defoliated needles in the primary and secondary branching systems in Norway spruce from the fourth group

Grafikon 5: Deleži zelenih, klorotičnih, nekrotičnih in osutih iglic v primarnih in sekundarnih razvejitvenih sistemih smrek iz četrte skupine

In the fourth group of trees (Javor) the needles of the primary branching system represent half of all needles, and almost all are green (Graph 5). Also needles from the secondary branching system are green. Tree damage level is medium.



Legend (clockwise): Z1, K1, N1, O1, Z2, K2, N2, O2 / *Legenda (v smeri urnega kazalca): Z1, K1, N1, O1, Z2, K2, N2, O2*

Graph 6: Green, chlorotic, necrotic and defoliated needles in primary and secondary branching systems in Norway spruce from the fifth group

Grafikon 6: Deleži zelenih, klorotičnih, nekrotičnih in osutih iglic v primarnih in sekundarnih razvejitvenih sistemih smrek iz pete skupine

In the fifth group of trees (Graph 6) needles from the primary branching system represent three quarters of all needles, and the majority are green or chlorotic. Also needles in the secondary branching system in this group are green or slightly chlorotic. Trees in this group are less damaged than trees in the other groups.

3.3 COMPARISON OF THE RESULTS OBTAINED BY THE SLOVENIAN AND CZECH METHODS
PRIMERJAVA REZULTATOV SLOVENSKE IN ČEŠKE METODE

Because of the small samples the Czech method gives us only qualitative results of three damage assessments without numerical values. That is the reason why the comparison of the results of this study can only be descriptive.

Table 2: Comparison of the results of tree damage assessment, obtained by the Slovenian and Czech methods

Preglednica 2: Primerjava rezultatov ugotavljanja poškodovanosti dreves po slovenski in po češki metodi

Forest plot / *Gozdna ploskev*	Slovenian method (% of trees in 2-4 class) / *Slovenska metoda (% dreves v razredih 2-4)*	Czech method (classification group) / *Češka metoda (skupina)*
Javor	90.0	damaged trees / *poškodovana drevesa*
Jelenca	100.0	extremely damaged trees / *zelo močno poškodovana drevesa*
Ključevca	100.0	damaged trees / *poškodovana drevesa*
Gore	83.3	/
Kovk	100.0	/
Dobovec	88.2	extremely damaged trees / *zelo močno poškodovana drevesa*
Marno	100.0	/
Ostenk	88.9	extremely damaged trees / *zelo močno poškodovana drevesa*
Ravenska	100.0	extremely damaged trees / *zelo močno poškodovana drevesa*
Retje	100.0	less damaged trees / *manj poškodovana drevesa*

4 SUMMARY

Comparison of the results of tree damage assessment, obtained by the Czech and Slovenian methods, show similar classes of Norway spruce damage on the investigated sites. When using the Slovenian method, the majority of trees are classified as very damaged. The highest percentage of very damaged trees was found at the Ključevca and Kovk sites (Table 1). When using the Czech method, the most damaged trees were found at the Jelenca, Dobovec, Ostenk and Ravenska vas sites. This difference can be ascribed to the rather late date of the forest inventory using the Slovenian method and to the insufficient number of spruce trees on experimental plots. So, many of the damaged needles fell off, and the assessment of defoliation changed. The study was carried out together with the needle sampling for the pigment analysis, for which autumn is the most suitable time. In the Czech method the main emphasis is on disturbance of the branching system, so the assessment of damage is based more on the impact of long lasting air pollution affecting branch structure, not only on needle condition on which Slovenian and EU methods are predominantly based, and which can change in a shorter time scale.

Assessment of Norway spruce damage by the Czech method looks convenient for forest decline inventories in areas where air pollution impact is high and long lasting, thus causing disturbances in branching. Unfortunately, the method demands the cutting off of the upper branches and the field work is tiring, exacting and time-consuming. Because of the important role of the visual estimation in this method, it is recommended, that the disturbances in branching are assessed only by one researcher, but only about 10 branches per day can be evaluated by one person. With small samples only descriptive results can be obtained. Needle loss and changes to the branching system both reflect well the health, condition, and response of forest trees to environmental stresses, but unfortunately unspecifically. Assessment of forest damage by changes of the branching system looks to be a suitable method in extremely polluted areas. Some sites in the Zasavje district are already so damaged that this method can be used. When the same method was applied in unpolluted areas of the Triglav national park in the Julian Alps, results were hardly reliable (Jurjevčič, 1997).

For general forest decline inventories in the unpolluted or moderately polluted areas the Slovenian method is more convenient and its results give us enough information about the tree damage. Considering time, expense, and human resources, only in extremly polluted areas is the application of Czech method reasonable. For detailed estimation of the results that can be gained by both methods, it would be recommendable to repeat the comparison of the methods including samples with more units. This study gives us a comparison and an evaluation of the suitability of the methods for assessing the forest damage in the polluted areas together with the estimation of variability, which can all be used in an eventual new experimental design.

5 POVZETEK

Zasavje leži v osrčju Slovenije. Bogate premogonosne plasti so tod odkrili že leta 1736. Rudarjenje in razvoj industrije sta prvotno podobo pokrajine močno spremenila. Zasavje je zaznamovano z velikimi dnevnimi kopi, kamnolomi, posedanjem tal, deponijami in onesnaženim okoljem. Največji vir onesnažil v Zasavju je Termoelektrarna Trbovlje (TET). Njeni začetki segajo v leto 1893, 125 MW TET II. pa deluje od leta 1968. V prvem desetletju obratovanja TET II so polurne koncentracije žveplovega dioksida v najbolj izpostavljenih zasavskih krajih dosegale celo 20 000 $\mu g/m^3$ (PARADIŽ 1972). Izgradnja 360 metrov visokega dimnika v letu 1976 je omilila probleme v Savski dolini, prenesla pa je onesnaženje na širše zasavsko območje.

V Sloveniji so gozdarji obsežnejše propadanje gozdov opazili v petdesetih letih, ko so začeli propadati jelovi gozdovi. Načrtno proučevanje propadanja gozdov se je začelo v sedemdesetih letih (ŠOLAR 1976). V letu 1985 je Gozdarski inštitut sestavil raziskovalni program celostnega proučevanja gozdnih ekosistemov Slovenije z ustrezno metodologijo. Istega leta je nastala tudi mreža vzorčnih sestojev za popis propadanja gozdov. Zasavski gozdovi se uvrščajo med najbolj poškodovane slovenske gozdove (ŠOLAR 1989, 1991a,b).

Zaradi onesnaženja oslabele smreke težko uravnavajo ravnotežje med sinteznimi in degradacijskimi procesi. V takšnih razmerah potreba po ohranitvi mladih organov povzroči izgubo starejših letnikov iglic. Včasih zrastejo sekundarni, terciarni ali celo kvartarni poganjki. Tipični znak novodobnih poškodb je presvetlitev krošnje, ker iglice predčasno odpadejo. Navadno odpadajo od spodnjega dela krošnje proti vrhu in od znotraj navzven. Značilna je klorotična pegavost iglic, ki daje krošnji svetlejšo, bledozeleno do rumeno barvo. Število letnikov iglic se zmanjšuje in na zgornji strani vej zrastejo sekundarni poganjki (BELEC 1992).

Poškodovanost smrek v Zasavju smo jeseni 1995 ugotavljali na desetih lokacijah, postavljenih v letu 1988 (ŠOLAR 1989): Javor, Ravenska vas, Ostenk, Jelenca, Retje, Marno, Kovk, Gore, Dobovec, Ključevca (karta 1). Na vsaki lokaciji smo poškodovanost smrek ocenjevali na dva načina: po uveljavljeni slovenski metodi in po takoimenovani češki metodi (CUDLIN / CHMELIKOVA 1995, 1996).

Slovenska metoda popisa propadanja gozdov (KOVAČ et al. 1995) je zasnovana tako, da omogoča sklepanje o povzročitelju poškodovanosti gozdov ter vsebuje drevesno in lišajsko bioindikacijo. Poglavitna razlika med našo in evropsko metodo je v tem, da slovenska metoda, pri vrednotenju poškodovanosti poleg vladajoče plasti upošteva tudi obvladana in podstojna drevesa ter opisuje še celo vrsto dodatnih vitalnostnih znakov dreves in značilnosti rastišča in sestoja. Glavni kriteriji za določitev stopnje poškodovanosti drevesa po slovenski metodi so osutost krošnje, barva in oblika iglic ter kakovost vrha drevesa ali vej, modificiranih glede na znane dejavnike žive in nežive narave. Razlikujemo pet stopenj poškodovanosti (ŠOLAR 1989) (preglednica 1) :
0 - zdravo drevo, 1 - malo poškodovano drevo, 2 - srednje poškodovano drevo, 3 - močno poškodovano drevo, 4 - nepovratno poškodovano in uničeno drevo.

Pri češki metodi smo izbrali po tri, za povprečne okoljske razmere na posamezni ploskvi reprezentativna drevesa, stara med 60 in 80 let, z dobro osvetljenim zgornjim delom krošnje. Z vsakega drevesa smo odrezali po eno, na sončni strani rastočo, okoli petindvajset let staro vejo. Veje smo prenesli na primerno podlago in ocenili poškodbe njihove razvejitve in oigličenosti (CUDLIN / CHMELIKOVA 1995, 1996). Češka metoda temelji na predpostavki, da se zaradi vpliva onesnažil iz zraka pri smreki pojavijo motnje v razvejitvi in oigličenosti vej. Veje nepoškodovanih smrek imajo največji del iglic v primarnem razvejitvenem sistemu. Kloroznih, nekroznih ali celo osutih igic je malo. Z naraščajočim onesnaženjem se odstotek iglic v primarnem sistemu zmanjšuje (in so vse bolj poškodovane), narašča pa odstotek iglic v sekundarnem in terciarnem razvejitvenem sistemu. Posamezne veje smo razdelili na obstoječe razvejitvene sisteme (primarni, sekundarni, terciarni, redko tudi kvartarni). Znotraj posameznega sistema (primarnega, sekundarnega in terciarnega) smo vizualno ocenili, kolikšen odstotek iglic je z vej že odpadel, kolikšen odstotek iglic je nekrotičen; kolikšen odstotek iglic je klorotičen in koliko odstotkov iglic je zelenih. Glede na rezultate statističnih analiz podatkov o osutosti vej, majhno število enot v posameznih vzorcih, visoke ocene standardnih odklonov ter visoke ocene standardne napake, kot funkcije števila poskusnih enot in variabilnosti spremenljivke, smo se odločili, da podatke, dobljene s češko metodo, obdelamo po Wardovi metodi. Ocenjene relativne vrednosti smo pretvorili v absolutne in nato vzorce na osnovi evklidskih razdalj po omenjeni Wardovi metodi s programom Statistica for Windows razdelili v skupine. Pri tem smo obravanavali le veje primarnega in sekundarnega razvejitvenega sistema. Glede na deleže zelenih, kloroznih, nekroznih in osutih iglic v posameznih razvejitvenih sistemih smo smreke razdelili v pet skupin (grafikoni 1, 2, 3, 4, 5 in 6):

- zelo močno poškodovane smreke : 1. skupina,
- močno poškodovane smreke : 2. skupina,
- poškodovane smreke : 3. in 4. skupina,
- manj poškodovane smreke : 5. skupina.

Smreke v prvi skupini (grafikon 2) so zelo močno poškodovane. Iglic v primarnem razvejitvenem sistemu je malo in so večinoma nekrozne ali osute. Večji del iglic se nahaja v sekundarnem razvejitvenem sistemu. Tudi slednje so v veliki meri klorozne, nekrozne ali osute. V drugi skupini (grafikon 3) so močno poškodovane smreke. Iglice primarnega razvejitvenega sistema predstavljajo približno polovico vseh iglic. Zelenih iglic v primarnem sistemu je malo, veliko pa je kloroznih, nekroznih in osutih. Iglice sekundarnega razvejitvenega sistema so zelene ali klorozne, nekroznih in osutih je manj. Iglice primarnega razvejitvenega sistema tretje skupine (grafikon 4) predstavljajo približno tri četrtine vseh iglic in so večinoma klorozne, nekrozne ali osute. Smreke so srednje močno poškodovane. V četrti skupini (grafikon 5) iglice primarnega razvejitvenega sistema predstavljajo približno polovico vseh iglic in so v veliki meri zelene. Tudi v sekundarnem razvejitvenem sistemu predstavljajo zelene iglice večji del iglic. Smreke so srednje poškodovane. Iglice primarnega razvejitvenega sistema pete skupine smrek (grafikon 6) predstavljajo tri četrtine vseh iglic in so večinoma zelene ali klorozne. Tudi v sekundarnem razvejitvenem sistemu predstavljajo zelene ali klorozne iglice večji del iglic. Smreke v tej skupini so manj poškodovane kot smreke iz ostalih skupin.

Rezultati obeh metod (preglednica 2) nam dajejo, kljub nekaterim razlikam, podobno oceno poškodovanosti smrek na posameznih popisnih ploskvah. Slovenska metoda popisa poškodovanosti dreves uvršča večino opazovanih smrek med močno poškodovana drevesa. Največji odstotek dreves v nepovratni poškodovanosti najdemo na Ključevci in na Kovku (preglednica 1). Ob tem moramo upoštevati dejstvo, da smo na ploskvah opazovali manj dreves, kot jih sicer predpisuje metoda, in da je bil letni čas za popise poškodovanosti že dokaj pozen. V okviru tridesetih smrek, ki smo jih obravnavali po češki metodi, lahko kot močno poškodovane označimo smreke z Jelence, Dobovca, Ostenka in Ravenske vasi. Srednje poškodovane so bile smreke na Ključevci in Javorju. Najmanj poškodovane so bile smreke z Retja. Poškodovanosti smrek na ostalih točkah ni bilo mogoče opredeliti. Češka metoda temelji na vizualnem opazovanju poškodovanosti razvejitve in oigličenosti smrek, zato smo lahko, ob omejenem številu vzorčenih dreves s posamezne ploskve, poškodovanost smrek na ploskvah samo okvirno opisali.

Ocenjevanje poškodovanosti oigličenosti in razvejitve vej po češki metodi je dokaj zahtevno in zamudno delo. Premajhni vzorci nam zaradi velike variabilnosti dajejo le okvirne opisne rezultate. Zanesljivejše ocene poškodovanosti smrek po češki metodi bi dobili z večjim številom enot v vzorcih, kar pa je zaradi časovnih in finančnih omejitev težko izvedljivo. Na osnovi dosedanjega dela menimo, da je metoda uporabna kot osnovna ali dopolnilna ocena poškodovanosti smrek na rastiščih z močno in dolgotrajno onesnaženostjo. Za ocenjevanje poškodovanosti gozdov na obsežnejših neonesnaženih ali zmerno onesnaženih območjih pa je prezamudna. Primerjavo obeh metod bi bilo smiselno ponoviti na manjšem številu popisnih ploskev in z večjim številom opazovanih smrek na posameznih ploskvah.

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