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 (CUDILIN & 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

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

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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 SO₂ reached as much as 20000 μg 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 develop, 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 develop, 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, Kolv, 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.
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
ČESKA 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 the 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 ugotavljanju poškodovanosti; 0, 1, 2, 3, 4: razredi poškodovanosti)

<table>
<thead>
<tr>
<th>Forest plot / Gospina ploščev</th>
<th>Percentages of trees in damage classes (%) / Odstotek dreves v razredih poškodovanosti (%)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Javor</td>
<td>10.0 0.0 15.0 75.0 0.0</td>
<td>20</td>
</tr>
<tr>
<td>Jelenca</td>
<td>0.0 0.0 0.0 100.0 0.0</td>
<td>3</td>
</tr>
<tr>
<td>Ključevca</td>
<td>0.0 0.0 33.3 33.3 33.3</td>
<td>3</td>
</tr>
<tr>
<td>Gore</td>
<td>0.0 16.7 16.7 61.1 5.5</td>
<td>18</td>
</tr>
<tr>
<td>Kovk</td>
<td>0.0 0.0 33.3 33.3 33.3</td>
<td>3</td>
</tr>
<tr>
<td>Dobovec</td>
<td>11.8 0.0 17.6 70.6 0.0</td>
<td>17</td>
</tr>
<tr>
<td>Marno</td>
<td>0.0 0.0 33.3 66.7 0.0</td>
<td>12</td>
</tr>
<tr>
<td>Ostenk</td>
<td>11.1 0.0 11.1 66.7 11.1</td>
<td>9</td>
</tr>
<tr>
<td>Ravenska</td>
<td>0.0 0.0 0.0 100.0 0.0</td>
<td>3</td>
</tr>
<tr>
<td>Rešje</td>
<td>0.0 0.0 33.3 66.7 0.0</td>
<td>3</td>
</tr>
</tbody>
</table>
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 poskodovanosti razveitve in oigličenosti smrek v Zasavju (češka metoda)

The classification 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 percentages 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.

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 osuših iglic v primarnih in sekundarnih razvejitevih sistemih smrek iz prve skupine
Trees in the first group (Gore-b, Kolv-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.
Graph 4: Green, chlorotic, necrotic and defoliated needles in the primary and secondary branching systems in Norway spruce from the third group

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 kazalec): 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 osuših iglic v primarnih in sekundarnih razvejtvih sistemih smreč iz četrti 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.
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

<table>
<thead>
<tr>
<th>Forest plot / Godna paskev</th>
<th>Slovenian method (% of trees in 2-4 class) / Slovenska metoda (% dreves v razredih 2-4)</th>
<th>Czech method (classification group) / Češka metoda (skupina)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Javor</td>
<td>90.0</td>
<td>damaged trees / poškodovana drevesa</td>
</tr>
<tr>
<td>Jelenca</td>
<td>100.0</td>
<td>extremely damaged trees / zelo močno poškodovana drevesa</td>
</tr>
<tr>
<td>Kluževca</td>
<td>100.0</td>
<td>damaged trees / poškodovana drevesa</td>
</tr>
<tr>
<td>Gore</td>
<td>83.3</td>
<td>/</td>
</tr>
<tr>
<td>Kovk</td>
<td>100.0</td>
<td>/</td>
</tr>
<tr>
<td>Dobovec</td>
<td>88.2</td>
<td>extremely damaged trees / zelo močno poškodovana drevesa</td>
</tr>
<tr>
<td>Marno</td>
<td>100.0</td>
<td>/</td>
</tr>
<tr>
<td>Ostenk</td>
<td>88.9</td>
<td>extremely damaged trees / zelo močno poškodovana drevesa</td>
</tr>
<tr>
<td>Ravenska</td>
<td>100.0</td>
<td>extremely damaged trees / zelo močno poškodovana drevesa</td>
</tr>
<tr>
<td>Retje</td>
<td>100.0</td>
<td>less damaged trees / manj poškodovana drevesa</td>
</tr>
</tbody>
</table>
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 Klučevca 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 extremely 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


Zaradi onesnaženja oslake 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 presvetleve 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,


Slovenska metoda popisa propadanja gozdog (KOVČ et al. 1995) je zasnovana tako, da omogoča sklepanje o povzročitelju poškodovanosti gozdog 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 obvladanja in podstojna drevesa ter opisuje še celo vrsto dodatnih vitalnosti 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 kakost 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.

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, dobline 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 obravnavali 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.


6 REFERENCES

VIRI


