FOREST CROWN CONDITION AND MONITORING DEPOSITED MATTER IN GORSKI KOTAR AREA IN CROATIA

BORIS VRBEK, IVAN PILAŠ, TOMISLAV DUBRAVAC, NENAD POTOČIĆ, IVAN SELETKOVIĆ, MILAN PERNEK

Forest Research Institute, Jastrebarsko Cvjetno naselje 41, HR–10450 Jastrebarsko, Croatia; borisv@sumins.hr


Monitoring the state of crown damage in 2004 in the Republic of Croatia showed a further increase in the percentage of significant tree damage of all species. The amount of damage to all species, in particular Silver fir, in the Gorski Kotar region, is worrying: Silver fir with 88.4% of significant damage is in a very poor condition and beech is also of poor vitality with 20.1% significantly damaged trees. This high percentage of significant damage in the investigated area is a consequence of intensive dieback of fir. Monitoring of precipitation and liquid phase of the soil is also carried out on the experimental plot in the same area. Data show that the annual deposition of NOx for Gorski Kotar amounts to approximately 16–18 kg.ha⁻¹. In the same way the investigated plot received approximately 8 kg.ha⁻¹ chloride and about 9 kg.ha⁻¹ sulphur. On average the lysimeters had a higher content of sedimentary substances than the values registered in the funnels under the tree-crowns. This data points at the reason for lower pH values in lysimetric samples. Accumulation of deposit substances on the soil surface and further transport through the soil profile into seepage and ground water is evident. Deposited matters effect the soil and the quality of seepage water.

Keywords: Crown damage, deposition, lysimeters, Gorski Kotar, Croatia

1. Introduction
Constant acidification of the soil by dry and wet deposition results in secondary consequences, such as solubility of heavy toxic metals, nutritive substances and their transformation into liquid phase (soil solution) which further progresses into ground water. In such cases, in particular climatic conditions and regions, it is necessary to know the quality and quantity of water which moves through particular forest ecosystems towards the ground water, which is in most cases used for water supply. These problems were investigated in Germany by BRECHTEL & VUKOREP (1991), LEHNARDT and BRECHTEL (1983), in Croatia by VRBEK & PILAŠ (2001), VRBEK (1993). Constant acidification and deposition input is especially important in the case of soils which have a lower buffer capacity (e.g. soils on acid-dystric parent materials) reported by ULRICH (1982), BALZS et al. (1992). A large number of authors consider that acidification of forest soils is directly connected to the lowering of pH-values and increased concentration of Al³⁺ in soil solution is the most responsible factor for damage and dieback of forests in many regions.

2. Research area
The investigation was carried out in the Gorski Kotar area and experimental plot in „Risnjak“ National Park (NP), which covers an area of 6 400 ha. During the 1930s Prof. I. Horvat, a botanist, began a cycle of scientific investigations at "Risnjak", initially alone and later with numerous coworkers. Following his proposal "Risnjak" was proclaimed a national park on 15th September 1953. He substantiated his proposal by indicating the basic characteristics of "Risnjak": "On "Risnjak" there is a large number of natural phenomena in a small area. In addition "Risnjak" has in the past been spared from the influence of management, so that its natural vegetation features have remained almost unchanged, and if changed by the occasional
influence of management, it will be possible to relatively quickly establish its natural state”. The specificity of the natural values is conditioned the collision of the climatic characteristics of the Mediterranean and continental climate. Here, 30 plant communities can be found, of which 14 forest communities were classified with characteristic zonal distribution. According to VUKELIĆ (1985) the region of Risnjak is largely covered by a forest community of beech and fir (\textit{Abieti-Fagetum dinaricum} Treg. 1957), and sub-Alpine beech forest with coltsfoot (\textit{Homogyno sylvestris-Fagetum sylvaticae}, Ht. 1938/Borph. 1963), fir forest with reed grass (\textit{Caladmagrostio-Abietetum} Ht. 1950), fir forest with hard fern (\textit{Blechno-Abietetum} Ht. 1950), mountain spruce forest with aremonia (\textit{Aremonio-Picetum} Ht. 1938), sub-Alpine spruce forest with common tway blade (\textit{Listero-Piceetum abietis} /Ht. 1938/ Fuk. 1969), mugho pine with mountain honey suckle (\textit{Lonicero borbacianae-Pinetum mugi} /Ht. 1938/ Borh. 1963). A major part of the park is covered by forest, and the rest consists of meadows, grassplots and rocks. The highest altitude in the park is 1528 m, (Veliki Risnjak) and the lowest 676 m (Leska valley). According to Vrbek (1992) limestone and dolomite rocks prevail, while the most frequent soil type is cambic soil on limestone and dolomite (cambisols). The tree composition on the plot is: \textit{Abies alba}, 3.4., \textit{Fagus sylvatica} 2.2., \textit{Acer pseudoplatanus}+ and \textit{Acer Campestre}+.

3. Materials and methods
Crown condition assessment were performed according to ICP-Forest (Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution in forest – PCC 2004). According to DUBRAVAC \textit{et al.} (2004) horizontal crown projections of all trees were recorded on the basis of which the sum of the crown projections per ha in absolute and relative values, are not covered by crowns, mean projection and mean diameter were calculated. The horizontal projections of crowns in the field, recorded in this way, were used for digitalisation of the crowns in the \textit{MicroStation} programme \textit{IRAS B} application and datapool then transferred into the \textit{AutoCAD} 2000 programme format dwg, in order to simplify the method of presentation. On the basis of the digital model and the measured sizes in the field (tree heights and stem lengths, length and width of crowns) a three-dimensional digital dynamics model of the stand was produced (programme \textit{CorelDraw}).
In order to monitor the possibility of natural reforestation on the sub-plot, the structure and number of young growth, including a shrub layer on an area of 360 m² (three strips, 2×60 m in size), was recorded and classified into height-age classes. In 1998, a permanent experimental plot, 100×100 m in size, was established, on which all trees larger than 8 cm in diameter were numbered and basic measurement data recorded. The experiment was repeated in 2003. The crown projections were digitalised and on the basis of the measured values (tree height and stem length, and the length and width of crowns), a three-dimensional digital dynamics model of a stand was produced. For the purpose of investigating the possibility of natural reforestation, records were made of the structure and number of young growth, as well as the shrub layer, on a sample area of 360 m², and classification made in height-age classes. Monitoring of precipitation and soil solution in lysimeters is also carried out on the experimental plot in the Gorski Kotar region. Plots are provided with rain-gauges for measuring amounts of precipitation and with funnels for sampling of water (sedimentation of dry and wet deposition) as recommended by the ICP method (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forest). Rain-gauges and funnels are laid out in diagonal distribution in 9 units, each in a sub-plot area 30×30 m in size. At a control spot, without the influence of vegetation, bulks and rain gauges were set up in a random distribution or circle. A zero-tension lysimeter was installed at a depth of 10–20 cm for measurement of seepage water (percolate) in order to establish the quality. Sets of three rain-gauges and three bulks were set up in the control areas, outside the influence of vegetation, i.e. in an open space. All instruments are washed out before installation on plots by 10% nitrogen acid and also several times by redistilled water. Liquid sampling was carried out once or, if required, several times at month. Acidity and conductivity of liquids were measured directly on the field, immediately after sampling. Chemical composition of liquids was determined in the State Hydro-meteorological Institute. The following ions were
determined: Chloride (Cl\textsuperscript{-}), sulphate (SO\textsubscript{4}\textsuperscript{2-}), ammonium (NH\textsubscript{4}\textsuperscript{+}), nitrate (NO\textsubscript{3}\textsuperscript{-}), sodium (Na\textsuperscript{+}), potassium (K\textsuperscript{+}), calcium (Ca\textsuperscript{2+}), magnesium (Mg\textsuperscript{2+}). Standard or common analytical methods were used for determination of small quantities of substances in waters and precipitation: spectrophotometry (Spectrophotometer Perkin Elmer Lambda-1) was used for determining SO\textsubscript{4}\textsuperscript{2-}, NO\textsubscript{3}\textsuperscript{-}; the method of ionselective electrodes (ORION- Microprocessor ionanalyser, Model 901 for determining NH\textsuperscript{4+} and Cl\textsuperscript{-}), while metal ions (sodium, potassium, calcium and magnesium) were determined by atomic absorptive spectrophotometry (Atomic spect. Perkin Elmer, Model 603). pH and electric conductivity in \(\mu\)S.cm\textsuperscript{-1} were measured in the field. Methods are described in WMO (1974), Standard Methods (1975) and MOHLER & JACOB (1975).

Figure 3. Deposition monitoring on research plot.

4. Results and discussion
Crown condition of Silver fir in Gorski Kotar region for the period 1998–2004 (POTOČIĆ & SELETKOVIC 2004) is stable at a very high percentage of trees damaged more than 25% (moderately to severely damaged trees).

Figure 4. Crown condition of Silver fir in Gorski Kotar region, period 1998–2004.
The damage to all species, in particular Silver fir, in the Gorski Kotar region, is in increase: Silver fir with 88.4% of significant damage is in a very poor condition and beech is also of poor vitality with 20.1% significantly damaged trees. This high percentage of significant damage in the investigated area is a consequence of intensive dieback of fir. The distribution of the number of trees indicates the entire absence of fir of the smallest diameter degrees, and also the lack of medium diameter trees. With the increase of diameter breast height this difference disappears in the medium diameter trees (55 cm) and above this diameter an excessive number of large diameter trees is present. This confirms the fact that for several decades the accession (influx) of the fir from natural regeneration has failed to occur, what, as a consequence, can be observed in the change of tree species. The results of measurements of numbers and quality of young growth during the years of monitoring do not guarantee the further course of the anticipated normal process of nature reforestation, what is the fundamental objective of reforestation and maintenance of forest sustainability.

Table 1. Average annual concentration of anions and cations in mg.l⁻¹ and pH and conductivity values during the year 2004.

<table>
<thead>
<tr>
<th>NP Risnjak</th>
<th>No. samples</th>
<th>pH</th>
<th>Conduct. µS.cm⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/dm³</td>
<td>mg.l⁻¹</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Bulk (Open space)</td>
<td>7</td>
<td>1.44</td>
<td>0.77</td>
</tr>
<tr>
<td>Funnels (Throughfall)</td>
<td>7</td>
<td>1.52</td>
<td>1.87</td>
</tr>
<tr>
<td>Soil solution (Lysimeter)</td>
<td>7</td>
<td>1.90</td>
<td>6.05</td>
</tr>
</tbody>
</table>

Measurements of precipitation and soil solution on research plot in Gorski Kotar area are monitored now 6 years (from 1999) in the beech and fir forest community. Table 1 present average annual concentration of anions and cations in mg.l⁻¹ of dry and wet deposition and lysimeter measurements. Total amounts of cations and anions in mg.l⁻¹ determined in funnels under the crown cover (throughfall) and in lysometric water are, as a rule, higher than on control locations (bulks), where the impact of vegetation is excluded. Depending on the buffer soil capacity minor or major damage to the soil may occur, which is then manifested on the increment of volume of wood. These results are in concord with researches of Brechtle (1989), Van Breemen et al. (1983, 1988), who established a major role of forest cover in the
fact that the total of deposited matter is always higher under the forest cover than on control locations.

Average value of pH of liquids from the open space is 5.22 and under the crowns 5.07. The lowest of the average pH values was observed in the soil solution pH (lysimetric samples) – 4.21. Differences, according to Brechtel & Vukorep (1991), with regard to deposition within forest ecosystems compared to the control, can be explained by the fact that as a rule the deposition of sulphur in the form of sulphate under forest ecosystems is higher than in an open space. During the last thirty years in Europe the input of nitrogen increased from 3 – 4 kg.ha\(^{-1}\) per year to 10 – 20 kg.ha\(^{-1}\) per year. According to data by Komlenović et al. (1988) input of nitrogen from 10 to 40 kg.ha\(^{-1}\) per year represents critical loading of the forest ecosystem. Surplus of nitrogen stimulates the growth of foliage mass and slows down the processes of lignification and unfavourably influences the development of the root system and micorisis. This leads to disruption in nutrition and lowering of plant resistance to drought and lower temperatures (Komlenović et al. 1988). Flückiger & Braun (1993), in their investigations in Swiss forests of beech and Norway spruce, measured deposition amounts from 10 to 12 kg.ha\(^{-1}\).year\(^{-1}\) N (NH\(_4^+\)-N) in lowland parts and in sub-Alpine regions from 13 to 20 kg.ha\(^{-1}\) year\(^{-1}\) N. In our forest stands of beech and fir these values are higher and amount to approximately 25 kg.ha\(^{-1}\).year\(^{-1}\). For northern Italy, Ugolini et al. (1993) reported sedimentation of nitrogen from 10 to 14 kg.ha\(^{-1}\).year\(^{-1}\) up to 20 kg.ha\(^{-1}\).year\(^{-1}\), depending on the sampling site (geographic region, height above sea level, exposition, etc). Investigating similar problems in Denmark, Nguyen et al. (1990) stated that precipitation was unevenly present on the measuring sites, as a result of varied transportation of SO\(_2\) and NO\(_x\) by wind transportation, clouds, etc. Namely, the force of the rain, as well as the size of the raindrops, is important. The main causes of acidification of wet deposition in Europe are sulphuric (H\(_2\)SO\(_4\)) and nitric (HNO\(_3\)) acids. Transformation of NO\(_x\) into HNO\(_3\) is faster than transformation of SO\(_2\) into H\(_2\)SO\(_4\).

The needs of this forest ecosystem for the intake of nitrogen by dry and wet deposition are satisfied up to 100%, what can have positive, but also negative consequences, on the growth and development of the forest. For the purpose of comparison, Simonić (1996) reported deposition of sulphur in the open area of 13 kg.ha\(^{-1}\) and in a beech stand it was 22 kg.ha\(^{-1}\) in the area of steam power station "Šošanj". In a culture of Norway spruce it was amounted to 33 kg.ha\(^{-1}\) of sulphur. Data from Lesnijak & Rajh-Alatić (1993) show sulphur deposition between 28 and 36 kg.ha\(^{-1}\) in urban areas (non forest areas), while for nitrogen it was 15 kg.ha\(^{-1}\). For the Alpine regions of Austria, in the open space, Smidt (1993) cited values of 7 to 15 kg.ha\(^{-1}\) of sulphur and 7 to 17.5 kg.ha\(^{-1}\) of nitrogen, while at the same time Führer (1993) in Hungary reported 16 kg.ha\(^{-1}\) for sulphur and 12.5 kg.ha\(^{-1}\) for nitrogenous substances. In Croatia regional data vary with regard to forest community, height above sea level, exposure of the plot on which sampling took place, etc. Thus, Komlenović et al. (1988) for Lividraga in Gorski Kotar reported 23.77 kg.ha\(^{-1}\) for sulphur (SO\(_4^2-\)S) and the total of 27.87 kg.ha\(^{-1}\) nitrogen (NO\(_3^−\)-N + NH\(_4^+\)-N). According to the latest data, which were collected during 1999 (Vrbešk & Pilas 2001), the amount of sulphur (SO\(_4^2-\)S) amounted to 5.2 kg.ha\(^{-1}\) in the lowland forest ecosystems of Peduncled oak and Common hornbeam up to 27.5 kg.ha\(^{-1}\) in the area of Zagreb, 28.0 kg.ha\(^{-1}\) in the Zavižan region on Velebit and 50.2 kg.ha\(^{-1}\) in the area of Gorski Kotar. The leaching of Ca and K from foliage is also considerably increased. From the data on the control measurement site, total amounts of cations and anions are regularly smaller than the data under the tree crowns and still less in relation to the lysimetric liquid samples.
5. Conclusions
The investigation results of the stand structure and measurements of the number and quality of young growth during the years of monitoring show that the expected normal process of natural reforestation is questionable. The continued stability of natural reforestation is the basic condition for permanent and stable structure in the process of preserving biological diversity and the basic objective with regard to maintaining permanent natural self-regeneration.

While the very poor condition of Silver fir is a long-standing problem for ecology and management of Croatian beech and fir forests, the deteriorating condition of Common beech is likely to become the real challenge for the future.

Data show that the average annual intake of nitrogenous compounds for the NP "Risnjak" and Gorski Kotar area amounts to approximately 16–18 kg.ha\(^{-1}\), 8 kg.ha\(^{-1}\) of chloride and 9 kg.ha\(^{-1}\) of sulphur. On average the lysimeters samples had a larger content of atmospheric deposition compounds than the values registered in samples under tree crowns. This data indicates the reason for the support findings of lower pH values in the lysimetric samples. Accumulation of deposited compounds on the soil surface and further transportation through the soil profile into seepage water is evident. Sedimentary materials from atmosphere influence the soil and quality of seepage water. The majority of pH values measured in the samples are acidic. By lysimetric pedology it is easy to establish the degree of soil acidification due to dry and wet sedimentation and to estimate soil buffering capacity. Thus, the type of forest cover is an important factor.

References