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FOREST CONDITION MONITORING: INTENSIVE MONITORING OF AIR POLLUTION IMPACT ON FOREST ECOSYSTEMS AT LEVEL II SAMPLE PLOT KOPAONIK

Radovan NEVENIC[1], Svetlana BILIBAJKIC[1], Tomislav STEFANOVIC[1], Zoran PODUSKA[1], Renata Gagić SERDAR[1], Ilija ĐORĐEVIC[1], Goran ČEŠLJAR[1]

Abstract: *Rational use of different sources of raw nature materials is the primary postulate of the environment conservation. Sustainable development provides the basis for this approach, which in addition to striving for optimization of technological processes, includes the optimum nature protection and prevention of adverse effects of mining sub-product resulting from natural resource exploitation.*

The prosperity of human society through economic growth should be achieved in such a way that its consequences remain limited within the boundaries of the capacity of the environment to accept the loading and avoid permanent disorders. ICP Forests program is implemented in order to prevent specific effects of pollution and the impact of pollutants on forest ecosystems and forest land put under surveillance, through Levels I & II, so as to form a high-quality, usable and functional database on these phenomena, for the territory of the European continent. Level II monitoring of forest vitality is a versatile system of research of many different subjects. Forest ecosystems are highly complex entities characterized by different variation due to continuous activity inherent in biotic and biotic factors.

Evaluation criteria for intensive monitoring are all in compliance so that upon recording and statistical analysis, the obtained data on forest conditions, are easy to compare analytically and logically, providing the basis for a variety of comparative studies. Dedicated sample plots for intensive monitoring of trans- boundary air pollution impacts on forest ecosystems in Serbia – Level II sample plot was established in Kopaonik National Park in 2010, with eleven panels – from 11 separate forestry research areas, grouped according to the research subjects, which methodology is prescribed by ICP Forest Manual.

[1] Institute of Forestry, 11030 Belgrade, Kneza Višeslava 3
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Key words: air pollution, intensive monitoring, database, Serbia

PRAĆENJE UTICAJA AEROZAGAĐENJA NA ŠUMSKE EKOSISTEME - INTENZIVNI MONITORING NA OGLEDNOM POLJU NIVO-A II "KOPAONIK"

Izvod. *Racionalno korišćenje različitih izvora energetskih sirovina primarni je postulat u očuvanju životne sredine. Osnova ovakvog pristupa je održivi razvoj, koji pored težnje ka optimizaciji tehnoloških procesa, uključuje i optimalnu zaštitu prirode, odnosno prevenciju štetnog uticaja nuzprodukata nastalih eksploatacijom resursa iz prirode. Prosperitet ljudskog društva kroz ekonomski rast trebalo bi postići na način da posledice ostanu u granicama mogućnosti okoline da prihvati data opterećenja, i pri tome ne dođe do trajnih poremećaja. ICP forests je program implementiran kako bi se konkretni efekti zagađenja i uticaja polutanata na šumke ekosisteme i šumsko zemljište stavili pod nadzor, i kroz monitoring Nivo-a I i II, formirala kvalitetna, upotrebljiva i funkcionalana baza podataka o ovoj pojavi, na teritoriji Evropskog kontinenta. Monitoring vitalnosti šuma Nivo-a II, predstavlja višenamenski sistem predmetnih istraživanja. Šumski ekosistem, kao izuzetno složen entitet, odlikuju različiti parametri podložni konstatnim varijacijama usled neprestanog i neodvojivog delovanja abiotičkih i biotičkih činilaca. Kriterijumi procene koje intenzivni monitoring podrazumeva, usaglašeni su i tako određeni da se dobijeni podaci o stanju šuma, nakon unosa i statističke obrade analitički i logički lako porede, dajući osnovu za različite komparativne studije. Namenska ogledna površina za intenzivni monitoring uticaja prekograničnog vazdušnog zagađenja na šumske ekosisteme u Srbiji-bioindikacijska tačka Nivo-a II osnovana je u 2010. godini na Kopaoniku, sa deset radnih panela – iz 10 zasebnih stručnih oblasti šumarstva, grupisanih prema predmetu istraživanja, a metodološki propisanim Manual-om ICP-a za šume.*

Ključne reči. aerozagađenje, intenzivni monitoring, baza podataka, Srbija

1. INTRODUCTION

Air pollution created by burning of fossil fuels and industrialization in expansion coupled with the emission of enormous quantities of aerosols in the atmosphere are not characteristic only of large urban and industrial centres. Owing to natural processes of air mass movement, the air pollution does not «recognize» administrative and regional borders. Plants and forest trees as the base of the food chain develop under the conditions that have been altered in this way only up to a certain level of load. In broader zones of large city areas, and further on over huge territories of leading European countries, where excessive pollution and uncontrolled emission of harmful matter was present, massive dieback of forests occurred over the last few decades of the 20th century.

Regardless of whether they are located on the territory of economically developed or developing countries, almost all existing ecosystems on the planet are followed by deposits of large quantities of harmful phytotoxic substances or substances resisting degradation. Harmful matter such as heavy metals (sources include heavy industry and busy traffic arteries) and deposits of nitrogen and sulphur salts, as well as ammonia, were first recognized as direct factors in the following occurrences: dying out of the living world in the immediate surroundings of factories and in water flows into which products of processing were released; indirect influence of pollution emitted into the atmosphere. Toxic matter gets into the nature through subterranean waters or acid rain from great distances. The origin of the pollution appears to be unknown, it is difficult to be directly recognized, the emitter of the pollution remains unidentified or under the jurisdiction of the neighbouring county or state, under «somebody else's» management or responsibility – in plain words, «someone else's» fault. Such occurrences on a massive scale caused decay of forest communities and separation of tree species with stronger resistance to air pollution that survived pushing back more sensitive species. During the 1970s and 1980s, forest dieback on a large scale spread through forests in Central and Western Europe, and became particularly notable in developed European countries.

Developed economy in these countries at the time included a multitude of plants for heavy industry, factories for processing of ores, coal and oil derivatives. Under such cumulative negative anthropogenic influence, the decay of forests in Europe, as extremely sensitive biocenoses and complex ecosystems, was inevitable. Over a period of time that was much too short for adaptation, fir proved to be the most sensitive species and decay of fir forests was the first to start. The political framework – evidence of the awareness of wider scientific and professional public on the escalating problem on the alarming scale, was provided by the Convention on Long-range Trans-boundary Air Pollution (CLRTAP) in 1979, which came into effect in 1983. Monitoring the dieback, first of fir forests and then forests of other coniferous species, slowly became a point of interest for creators of forestry policies in Europe, representing the beginning – awakening of collective awareness on the importance of preservation of forests and at least preventing the entire forest complexes from dying out (Nevenić et al, 2005). The foundation of the manual for continuous coordinated monitoring of forests was laid down at the working session of European Commission for forests in Freiburg in 1984, while in December of the same year the ICP forest program (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests - ICP Forests) held its first meeting. The next step was adoption of the Resolution no. 1 at the Ministerial Conference on Protection of Forests in Europe, which marked the beginning of implementation of Level II, the intensive monitoring programme.

To date, the condition of forests on the territory of Europe have been monitored at about 6,000 points at Level I, and since 1994 at about 800 testing plots separated for intensive monitoring. The assessment of health condition of forests in our country was conducted through assessing the condition of tree crowns on testing plots, bio-indication points of Level 1, when soil testing was performed for about 150 points (chemical and mechanical properties) (Kadović & Knežević, 2004) and chemical content of nutrition of the forest trees was analyzed.

2. METHODOLOGY

In order to preserve the forests through instruments of the politics and changes of laws regulating emissions of harmful matter, a way to stop the decay of forests was recognized. Nonetheless, the existence of the causal connection between air pollution and forest decay may be proven only by means of authoritative and fundamental results of scientific research on a representative sample, according to the methodology designed for this specific task, through continuous intensive monitoring. The next step would be to put the polluters recognized in the wider or general surroundings under control by sanctions if the plants emit harmful matter into the environment without appropriate mandatory protective technology in the form of filters etc.

By setting up testing stations in Kopaonik National Park (2010) and in Fruska Gora last year, Serbia has joined the European network of over 800 Level II points. On the test plot in NP Kopaonik, the operative plan according to methodology for the stipulated assignments commenced immediately upon placement of the wire fence and geodetic survey of each tree on the plot. Level II sample plot in Kopaonik National Park covers an area of 0.5 ha (100 x50 m). During each visit to the plot, every team kept detailed records containing dates of works on continuous measuring or sampling of the materials, in the form of a field journal. A working version of the journal is provided in Table 1.

According to the set distribution plan of the test plots and specification of equipment necessary for conducting the experiment of intensive monitoring of the forest condition, the equipment for following the moist deposition process was set up: collectors passing through the tree crowns, collectors for sampling the depositions pouring down the trees, and collectors gathering forest leaf waste. Soil profiles were dug up and soil samples taken, while herborized material was collected in order to prepare phytocenological surveys from the spring, summer and fall aspects. Within the entire test plot, subplots for customized sampling were distributed and assigned as permanent to the same continuous measuring (3 subplots, 4 sub-fields in the middle one).

Table 1. *Working version of the field journal during the first year upon establishment of the Intensive Monitoring Test Plot – Level 2*

PUBLIC COMPANY "KOPAONIK NATIONAL PARK"				
Sequence	Test plot no. 2 (GJ Samokovska Reka, dept. 75)	Date of field visit	Team members	Type of the measured parameter or sampling
1				
2				
...				
n				

The Level II monitoring program comprised the following parameter groups: crown condition, foliar analyses, soil chemistry, soil solution chemistry, growth and yield, ground vegetation, atmospheric deposition, air quality, meteorology, phenology and forest litterfall. Given that not all monitoring is continuous or annual, numbers of plots in European countries that submit reports vary from one year to the next (ICP Forests, 2010a). Frequency of monitoring the individual parameters is shown in *Table 2*.

Table 2. *Parameters, frequency of survey monitoring intensity for Level II (ICP Forests, 2010a)*

Parameter type	Frequency of sampling
Crown condition	At least annually
Foliar analysis	Every two years
Soil chemistry	Every ten years
Soil solution chemistry	Continuous
Growth and yield	Every five years
Ground vegetation	Every five years
Atmospheric deposition	Continuous
Air quality	Continuous
Ozone injuries	Annually
Meteorology	Continuous
Phenology	Several times a year
Forest litterfall	Continuous

3. RESULTS AND DISCUSION

Assessment of the crown condition: Assessing the crown condition on Level 1 has been practiced at the Institute for Forestry for many years, while the methodology of assessment served as basis for developing and perfecting the intensive monitoring methodological approach (Nevenić et al, 2011). The research in intensive monitoring for assessing the crown condition, as well as for the Level I, focuses on assessment of decolouration, defoliation and detecting the injuries, which are then used to derive the tree condition, crown shadow (damage), crown visibility, fructiferousness of the visible part of the crown, presence of secondary new branches. The trees are marked with permanent markings on the bark, bearing ordinal numbers 1-195, on 3 subplots and within the «buffer» zone (Nevenić et al, 2011). Out of the total number of spruce trees marked for the purpose, 30 spruce trees were selected within the subplot 2.

Sampling and analyses of assimilation organs for testing nutrition of the forest trees: Sampling of the leaves for testing the nutritive condition of forest trees was conducted using five dominant spruce trees. Concentrations of nutritive matter in the assimilation organs had highly notable seasonal variability. For this reason, sampling of spruce needles was carried out in late October, which is the period of stagnation of the vegetation in Kopaonik, when the assimilation organs comprise the representative concentration of nutritive matter. Sampling was conducted from the top third of the trees, where the assimilation organs had developed under favourable light conditions. For the foliar analysis, only one-year needles were selected. The air pollutants are possible to detect by measuring the chemistry and quantity concentrations of certain matter in the plants (their living tissue and litterfall).

Floristic and vegetation research: Study of the ground vegetation was carried out in three aspects: spring, summer and fall. During the first year, floristic and vegetation research was conducted according to the prescribed methodology for data collecting and processing (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests - ICP Forests). Assessment of crown coverage of the present species on the levels of trees, shrubs and ground flora was carried out on 16th September 2010. For this purpose, four square-shaped test plots (10 x 10 m) were set up, covering the total area of 400 m^2 (ICP Forests, 2010a). Positions of the test plots are shown on the as-built plan for the Kopaonik station. In the field, the described plots are visibly marked.

Phenological observations: At Level II sample plot 15 spruce trees (*Picea abies* L.) were selected for phenological observation. Phenophases were observed continuously, in succession, and the following parameters were detected and monitored: budding, change in colour of conifer needles, significant indications of needle or crown damage, other damages (broken branches and trees and uprooted trees), secondary budding and blooming. The aforesaid parameters were monitored in the trees located within the sample plot, starting from the first field visit.

Litterfall sampling and analysis: 15 collector pads for collection of dead organic remnants of forest trees (waste) were placed at the sample plot. The average collection surface area was500 cm^2 per pad and the total collection surface area amounted to 0.75 m^2. In addition to dead organic remnants of spruce trees, those of European rowan were also present in the overall litterfall at the sample plot. During waste collection, of all the waste fractions, only that of spruce needles was collected in the amount sufficient for performance of laboratory analyses in the year 2010, whereas in 2011 European rowan (*Sorbus aucuparia* L.) waste amount collected allowed laboratory analyses as well.

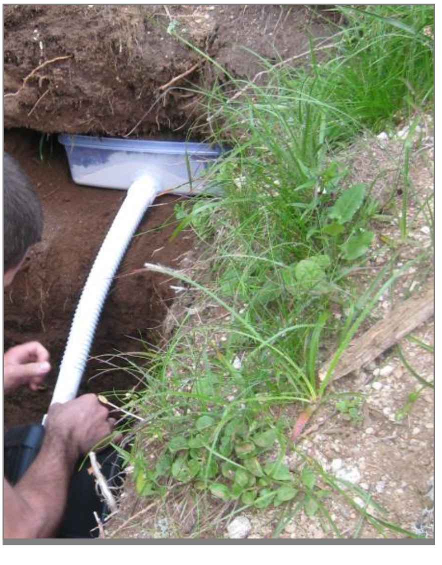
Deposition collection and analysis: According to the planned arrangement of the wet deposition collectors, instruments for deposition process monitoring were placed in positions. They included collectors of precipitation falling through the tree crowns – "Throughfall" (15 pcs.), collectors of deposition sliding down the tree trunks – "Steamflow" (5 pcs.) and snow collectors (3 pcs.), the so-called "Bulk" collectors. Materials used to make the collectors include: wire structures, plastic containers, pipes and mesh PVC canvass. These materials were used according to the concept designs in the manual so that functional equipment was obtained. The iron was protected from corrosion and the containers for precipitation collection were buried into the ground (the soil temperatures prevent evaporation). The elements of the collectors were joined by means of silicone glue to avoid contamination from the environment. At Level II sample plots special attention is paid to wet deposition, particularly deposition affecting the chemistry of the deposit in direct contact with plant organs where air pollutants are retained (ICP Forests, 2010c).

Growth gain and yield determination: Growth gain is defined as periodical tree growth. The primary aim of the growth gain element measurement at the Level II sample plot was to obtain data for each individual tree as well as for the whole sample plot area. At Kopaonik sample plot 28 trees were measured, all of them were spruce trees (*Picea abies* L.*)*. The following elements were measured: tree diameter at breast height (two intersecting diameters, one from the north and the other from the west), tree height and crown height. Based on the measurements of these elements, other parameters relevant to growth gain and yield were calculated: volume per tree and total plot volume. Mortality of the measured trees was also assessed as a descriptive dimension (ICP Forests, 2010a).

Assessment of ozone injury to foliage: There is more and more evidence that the concentrations of ozone (a very unstable highly reactive gas with molecules consisting of three oxygen atoms) measured at different locations in Europe particularly affect deciduous vegetation. This refers to direct, visible damages to the assimilation tissues of leaves and, less frequently, conifer needles, which indirectly reduce development and result in yield decrease (1). Ozone induced injuries affect the usual ability of the plants to resist the impact of both biotic and abiotic environmental factors. As "ozone pollution" produces no consequences detectable by analytical techniques, the only easily measurable evidence at field are visible damages to the conifer needles of spruce, in this case. Although these visible damages lack their common traits, they do have harmful effects on the living plant organs (physiological changes, reduced growth) (2). Based on the results of studies dealing with this problem, field observation and recognition of the typical symptoms turned out to be the major factor in ozone impact assessment. The goal was to collect needles (sampling by means of a sporting rifle or tree climbing and picking) from the selected trees at the experimental plot where sampling is conducted two times during the vegetation period. Conifer needle samples then ought to be categorized as annual and biennial. Upon successful sampling, assessment was conducted: for each of the 5 trees 3 samples in clusters originally coming from three branches. Visible ozone induced damages in conifers are mostly manifest at upper crown parts which are most exposed to the sun, i.e. upper parts of the twigs and needle tips (Nevenić et al. 2011). These numbers (of trees and branches) comprise the minimum amount for relevant sampling (3 branches per tree and 5 trees per quadrat). Evaluation differs significantly for deciduous trees on one hand and conifers on the other. The samples taken at Kopaonik plot belong to the dominant species – spruce. The results need to be confirmed by a validation centre and a special expert team issues a certificate on the findings on the examined species (ozone induced injuries were detected in pines), followed by further monitoring of the same phenomenon. Researchers familiar with the issue and plant protection experts competent to eliminate all the empirically determined damages caused by the usual instigators (mites, insects and fungus fruiting bodies, burns, frost, etc.) are educated for recognition of damages on economically significant species given the increase in ozone concentrations in the atmosphere, which will in future bring now evident climate changes of the magnitude we cannot predict (3).

Soil sampling and analysis: At sample plot on Kopaonik three pedological profiles were opened for the purpose of soil type determination. Out of these profiles samples were taken for chemical analyses by pedological horizons in order to determine soil type according to the World Reference Base for Soil Recourses. The same profiles provided unspoiled soil samples in Kopecky cylinders of 100 cm^3 volume for determination of volume density, specific density, total porosity and water retention at pressure values of 0, -1, -33 and -1500 KPa. Within subplot 1, soil sampling was performed by means of a probe across the total area with uniform average samples by layers of 0-10, 10-20, 20-40, 40-80 cm (ICP Forests, 2010b). Soil samples were chemically analyzed and the results of laboratory sample testing were obtained (physical properties).

Analysis of soil solution chemistry: In addition to groundwater flows, forest soil, as both the starting and ending point for the process of matter and energy circulation in nature, contains basal deposits of pollution from all anthropogenic sources. These substances are accumulated within plant organisms themselves – parts of tree trunks, twigs and assimilation organs, on the surface and inside living plant tissues. In the horizons of the soil are also deposited pollutants dissolved in precipitation, of which rain and snow are quantitatively the most significant. Certain amounts of atmospheric deposits, which rinse assimilation organs, branches and trunks of the trees and are practically "filtered" through the crowns, are collected into special collectors. Analysis of such deposit chemistry is to determine the presence of a certain harmful substance and its concentration per area unit. It is possible to monitor plants' reactions to the impact of such a factor over a course of time, and recognize the connection between the trees' susceptibility to diseases and pests and air pollution. The aim is to derive various conclusions on the forest vitality condition or to prove the undeniable harmful effects on particular species. One of the aims is also to achieve possible differentiation among species in respect to their resistance to such substances and thus favour and promote more resistant woody species in long-term planning of cultivation.



Picture 1.
Gravitational lysimeter below the organic soil layer ~ 18cm (Orig.)

Picture 2.
Installed lysimeter with a collector for soil solution at depth of ~ 25cm (Orig.)

Intensive studies are continuously conducted by installing gravitational lysimeters into the front vertical wall of the existing pedological profiles at defined depths below the organic layer horizon, varying for all three profiles (Picture 1 and Picture 2). Soil solution deposit samples were collected together with other parameter samples for continuous monitoring at experimental plot Kopaonik, and out of all three, one summary sample was made (4). Soil chemistry monitoring in forest ecosystems is aimed at verification of the hypothesis about the depth of soil damage as well as forecast of the future soil development and transformation.

Research and sampling by means of suction soil lysimeters for different layers and sampling from different depths are yet to be conducted at field with appropriate equipment, which will be used in our country for the first time for the purpose of forest soil examination. By means of special pressure modification pumps, which consist of two tubes made of very hard plastic, with different diameters so that one is inserted into the other, an interspace with extremely low air pressure is created - almost a vacuum. Suction lysimeters are inserted into the ground with a steel probe in order to prevent possible damage to the parts of equipment made of fragile materials (ceramics). The ceramic tip, which is in direct contact with the wet ground, due to the differences in osmotic pressures in the wet soil, which may be in solid or colloid state, extracts a sample of the liquid with dissolved matter that reached the given depth in the soil either by deposition or due to groundwater level rising. The aim of this research is to provide results on the origin of harmful substances and the manner and mechanism of their entrance into the forest soil.

Meteorological monitoring: For meteorological monitoring performed in order to obtain information on microclimatic conditions for the year 2010, data provided by Kopaonik automatic weather station, which is situated near the Level II sample plot on Mt. Kopaonik. The location of the weather station ensured representative meteorological data (ICP Forests, 2010a). The following mandatory parameters were monitored during 2010: precipitation (PR), air temperature (AT), relative air humidity (RH), wind speed (WS), wind direction (WD) and solar radiation (SR) from 1 July 2010 to 22 November 2010. Weather stations with special measurement performances were placed beneath the crowns of centennial spruce trees within the sample plot to automatically record and memorize data comparable to the data provided by the Kopaonik synoptic unit. Comparative studies would provide insights into the impact of forest complexes on the parameter values, whether they be measured in the open areas or within thick forest. Such studies would also better define forest capacity to regulate inevitable future climatic changes, i. e. underline the role of forests as man's chief ally in preservation of elementary conditions for survival in a healthier environment.

4. CONCLUSION

For each group of parameters monitored, the ICP Manual for Forests version from May 2010 contains a set of precise instructions for synchronized sampling, various field data collection, measuring equipment installation and guidelines for obtaining valid and useful results as the ultimate goal.

Intensive forest monitoring is conducted by institutions with adequate expert staff. Its particular feature is team work of different background and expertise researchers. Field tasks and laboratory tasks are performed in cycles, which means that each cycle begins with more experience gained (ICP Forests, 2010d). Contrary to the established stereotype that repetitive actions are inflexible, monotonous and compelling, coordination system offers possibilities for introduction of new ideas due to the very dynamics and necessity to monitor changes in nature.

Due to the complexity of combined sciences that study forests as intricate natural units, the obtained insights and results of forest monitoring differ considerably from the approaches applied in research of the properties of an isolated subject and its direct and indirect relations to the environment.

Conclusions are made as feedback information and are based on the system of observed connections and causal relations in many directions. Such multidisciplinary approach provides room for implemented methodology improvement as well as for the enthusiasm to introduce new methods, which typically occurs during continuous forest monitoring at the same locations and experimental sample plots over several years or decades.

The process of obtaining raw field data, which are there entered into worksheets, logs and tables, is followed by their conversion into numerical codes acceptable by the unique IT database. The database with measured parameter data has the same coding system for the whole network of intensive monitoring experimental field stations in Europe, where the same methodology principles are applied in scientific research (Fischer, 2010.)

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