THE ASSESSMENT OF POLLUTION IMPACT ON FOREST ECOSYSTEMS USING THE METHOD OF THE INDEX OF GLOBAL POLLUTION

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Abstract

The method of the index of global pollution is used to assess the environmental health state at a given time, considering the quality of 3 or more environmental factors (water, soil, air, flora, population, etc.). In order to evaluate the impact of pollution on forest health, in this study, the method of the index of global pollution was applied to a site located in a forest ecosystem from North Romania. The environmental factors assessed were soil, air and forest health. For the soil state assessment, the soil pH and concentrations of K, Ca, Mg in soil solution were analysed. The air pollution state was estimated using the parameters of the precipitation water and for the state of forest health, the defoliation degree and the concentrations of nutrients in needles were evaluated. The calculation of the index of global pollution, as a relation between the ideal and the real state of the ecosystem alowed the evaluation of the impact of pollution on the studied forest ecosytem for the period 1998-2001.

1. Introduction

Researches concerning the complex phenomenon of „forest decline" were launched beginning with 1980 in order to explain the possible causes. On the basis of the results obtained, most of the specialists considered that the decline was determined by the conjugated action of more stress factors, biotic and abiotic (Manion, 1981; Ulrich & Matzner, 1983; Mc Laughlin, 1985; Landmann, 1991; Hanneberg, 1993). Pollution was considered as one of the main factors determining „forest decline".

In order to evaluate the impact of pollution on forest ecosystems, the method of the index of global pollution was considered useful (Macoveanu, 2003).

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This method makes possible the assessment of the health or pollution state of the environment and the quantitative interpretation of this state using an indicator (index of global pollution, I_{GP}) defined as a ratio between the ideal value and the real value at a given moment of some indicators considered specific for the environmental factors analysed. The method consists of synthetic evaluations, based on quality indicators for each environmental factor and their further correlation using a graphical representation. Thus, for each environmental factor and for the environment health, evaluation grades are established , on the scale 1-10, considering the levels of quality indicators as imposed by national or/and european standards. The 10 grade represent the natural state of the environment unaffected by human activities and the 1 grade represent an irreversible situation and seriously degradeted state for the environmental factor analysed.

Generally, the evaluation of the environment quality for a certain site and at a given moment is possible by estimation the state of each considered environmental factor: air, water, soil, flora, population etc. Each factor can be characterized using quality indicators specific for the assessment of the pollution degree and for which exists accepted levels. Depending on the values of these indicators, the evaluation grade is estimated, considering the evaluation scale.

In this study the method of the index of global pollution was used in order to assess the impact of pollution on a forest ecosystem located in North Romania, in the montain Rarau.

2.. Materials and method

For the studied forest ecosystem, three environmental factors were evaluated by the method of the index of global pollution: air, soil and forest health.

Air quality was assessed using quality indicators of precipitation waters, considering that the precipitation droplets wash - out the gases and /or particles of pollutants from the atmosphere.

Soil quality was estimated on the basis of results obtained for soil pH and the mean values of the concentrations of some nutrient elements in soil solution.

The measurements of the parameters of precipitation waters, soil and soil solution were made on samples colleted in the site Rarau (table 1). The

analysis were performed at the chemistry laboratory of the Forest Research Station Campulung Moldovenesc, Romania.

In order to evaluate the forest health for the studied ecosystem, the results concerning the defoliation degree and the concentrations of some nutrient elements in spruce needles were analysed. The measurements were made in the framework of ICP Forests, but in another subprogrammes of research (Badea, 2002; Bolea, 1998). Observations concerning the defoliation degree were made at the site Rarau - spruce (Table 1). The needles analysed were collected from trees located in U.P. I, u.a. 94 C.

The characteristics of sites and stands where measurements have been made are presented in table 1.

Table 1

The characteristics of sites and stands where measures were performed (Barbu, 1997; Badea, 2002)

Site name	U.P.	u.a.	Geographical coordinates		Altitude (m)	Consistency	Age (ani)
			Latitude	Longitude			
Rarau	I	89B	25° 32'11"	47° 28'34"	1100	0,8	70
Rarau - spruce	I	94N	25° 33'51"	47° 26'54"	1400	0,8	57

Precipitation samples were collected during the vegetation period using two collectors consisted of gutters, with a reception area of 0,1 m^2, twice every month (on 1st and 16).

During the cold season (november-march), when precipitations collected were usually snow, we used two collectors made of polyethilene bags, each of them with a cylinder reception area of 0.0093 m^2 (within the period 1998-2000) and 0.028 m^2 in 2001 (Barbu, 1997; 2000). Samples were collected once every month, on the 1st day.

The volume of the sample collected with each collector was measured and then samples were mixed in order to obtain a mean sample, which was transported to the laboratory for analysis.

For soil solution, gutters lysimeters fixed in the soil profile at different depths were used (Barbu, 1997).

The soil samples for which the pH was determined had been collected from the site Rarau at 18.09.2001, from a soil profile dug close to the profile where soil solution was collected. The pH was measured in a soil solution prepared with 20 g soil and 50 ml distillated water for each sample.

The methods of analysis for the parameters of precipitation and soil solution samples recommended by ICP Forests and those used in the laboratory of the Research Station Campulung Moldovenesc are presented in table2.

The mineral ion fluxes were calculated according to:

$$\text{Ion flux } Q = \frac{\sum Pi * Ci}{100} \text{ , where}$$

Flux of ion Q = quantity of ion Q, expressed în kg/ha/year
P_i = quantity of precipitation, in mm
Ci = concentration of ion Q, related to period i, expressed in mg/l

Table 2

Methods of analysis for precipitation water

Parameter	Method recommended by ICP Forests (P.C.C., 1994)	Method used in the laaboratory ICAS Campulung Mold.	Source for the ICAS method
Sulphate ion ($S\text{-}SO_4^{2-}$)	-Ion chromatography - Spectrophotometry, the thorin method -Isotope dilution -Potentiometric determination	Spectrophotometry, the thorin method	EMEP, 1996
Nitrate ($N\text{-}NO_3^-$)	- Ion chromatography - Spectrophotometry, e. g. the Griess mehod - Ion selective electrode	Spectrophotometry, the method with sodium salicylate	Rodier, 1984
Ammonium ($N\text{-}NH_4^+$)	- Spectophotometry, e. g. the indophenol method and flow injection analysis (FIA) - Ion selective electrode	Spectrophotometry, the method with Nessler's reactiv	Mănescu et al.., 1994
Base cations: K, Ca, Mg	- Atomic absobtion spectrophotometry - ICP emission spectrophotometry	Atomic absobtion spectrophotometry	EMEP, 1996

The mean annual concentration for the ion Q was calculated as:

Mean concentration of ion Q = $\frac{\sum Pi * Ci}{\sum Pi}$, expressed in mg/l.

3.Results and discussion

The evaluation scale for the environment factor air was established taking in account the following indicators of the precipitation waters: the frequency of the months with acid precipitation (pH<5.6) and mean annual fluxes of some mineral ions considered as pollutants ($S\text{-}SO_4^{2-}$, $N\text{-}NO_3^-$, $N\text{-}NH_4^+$) in bulkdeposition.

Table 3

The evaluation scale for the environmental factor air

Evaluation grade	Frequency of months with acid precipitation (%)	$S\text{-}SO_4^{2-}$ (kg/ha/year)	$N\text{-}NO_3^-$ (kg/ha/year)	$N\text{-}NH_4^+$ (kg/ha/year)
10	<10	<4	<2	<1
6-9	10-50	4-10	2-6	1-4
2-5	51-90	10-20	6-10	4-10
1	>90	>20	>10	>10
Rarau	40	8,6	2,5	5,75

In order to establish the evaluation scale for the sulphate, nitrate and ammonium fluxes, the values obtained at european level between 1998-2001 were used. (Ulrich, 2002; EMEP, 2003).

For the site Rarau, on the basis of the mean annual values of the four indicators considered, we calculated the mean values for the period 1998-2001 (last row in table 3). Considering that the four indicators analysed have the same weight for the evaluation of the factor air, we calculated the arithmetic mean of the grades and we obtained the value 6.

The assessment of the environmental factor soil had been made using an evaluation scale that contains as indicators the soil pH (Vanmechelen et al., 1997) and the concentrations of the main base cations considered as nutrients (Ca^{2+}, Mg^{2+}, K^+) in soil solution. We appreciated that in soil solution, comparing with precipitation water, is more useful to consider the mean concentration than the ion fluxes in order to evaluate the

content of the solution to which trees roots have access. The pH represents the soil acidity and the concentrations of the base cations mentioned have, in addition to the role of nutrient, the capacity of buffering the soil acidity.

Table 4

Evaluation grades for the environmental factor forest soil

Evaluation grade	pH (soil)	Ca (mg/l) (soil solution)	Mg (mg/l) (soil solution)	K (mg/l) (soil solution)
10	>6,0	>8,0	>6,0	>6,0
8-9	5,31-6,0	6,0-8,0	4,0-6,0	4,0-6,0
6-7	4,61-5,3	4,0-6,0	2,0-4,0	2,0-4,0
4-5	3,91-4,6	2,0-4,0	1,0-2,0	1,0-2,0
2-3	3,21-3,9	1,0-2,0	0,5-1,0	0,5-1,0
1	≤3,2	<1,0	<0,5	<0,5
Rarău	5,03	20,80	2,30	2,17

For the elaboration of the evaluation grades for the concentrations of Ca^{2+}, Mg^{2+} and K^{+} in soil solution we used the data available from the specialized literature, concerning the concentrations of these ions in soil solution collected at 10-20 cm depth in the soil profile (Nys, 1987, Ahmed, 1992, Marques, 1996, Boyle, 1997). Values obtained for the site Rarau were used for calculating the evaluation grade, considering that pH contribute with a weight of 50% and the base cations have a total weight of 50% (each cation, 16,67%). We obtained the grade 7 for the environmental factor soil (table 4).

The environment factor forest health was evaluated considering as indicators the defoliation degree for the site Rarau-spruce in 1998 and 1999 (Badea, 1999a) and the content of nutrients in spruce needles at the site Rarau, U.P I, u.a. 94G in 1996 (Bolea, 1998). Even if the needles analysed have been collected two years before the period considered for the other indicators, we appreciated that we can refer to the measurements made in 1996, because the foliar analysis are performed every two years (Programme Coordinating Centres, 1994).

The defoliation degree permit the clasification of trees in classes, according to table 5 (Badea, 1998).

Table 5

Definition of defoliation classes

Defoliation class	Percentage of needles loss	Degree of defoliation
0	0-10	Not defoliated
1	11-25	Slightly defoliated
2	26-60	Moderatly defoliated
3	61-99	Severly defoliated
4	100	Dead

At international level, the intensity of damage on forest is assessed considering the values of the percentage of trees serious defoliated (classes 2-4 of defoliation), as follows: when this percentage is les than 10%, the forests are considered to be „slightly damaged"; when the proportion of the damaged trees has values between 11-20%, the forests are considered "moderately damaged" and when the ratio of the trees included in the defoliation classes 2-4 is grater then 20%, the forests are appreciated as "severely damaged (Badea, 1999b). On the basis of these reasons, we established the evaluation scale containing the evaluation grades correlated with the defoliation degree of the trees (table 6).

For the estimation of the nutrition state of the trees we used the scale with optimal, critical and deficiency levels of major element concentrations in spruce needles(Bonneau et Solberg, 1994, citați de Bolea, 1998).

The evaluation scale for the environment factor forest health is presented in table 6.

Table 6

Evaluation scale for the environmental factor forest health

Grades	% trees in classes 2-4 of damage	Element content (g/kg)				
		N	P	K	Ca	Mg
10	<10	>17	>1,8	>6,5	>2,5	>1,2
8-9	11-20	15,1-17	1,51-1,8	5,31-6,5	2,11-2,5	1,01-1,2
6-7	21-40	13,1-15	1,31-1,5	4,21-5,3	1,71-2,1	0,81-1,0
4-5	41-60	10,1-13	1,11-1,3	3,71-4,2	1,35-1,7	0,71-0,8
2-3	61-80	8-10	0,9-1,1	3,2-3,7	1,0-1,35	0,6-0,7
1	>80	<8	<0,9	<3,2	<1,0	<0,6
Rarău	24,2	9,23	1,16	2,51	8,90	0,81

Considering that the six indicators analysed have the same weight for the evaluation of the factor forest health, we calculated the arithmetic mean of the assessed grades and we obtained the value 5.

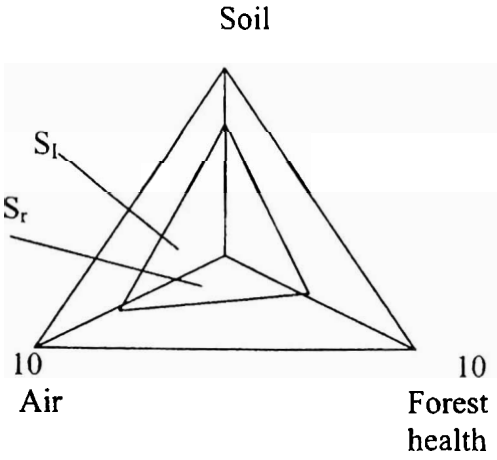
The grades estimated for the three factors of environment analysed were used to elaborate the diagram from figure 1, as a method of simulation of the synergic effect produced by all types of pollution (Macoveanu, 2003).

Table 7

Values of the index of global pollution

Value of the index of global pollution	Effects
$I_{GP} = 1$	Natural environment unaffected by human activities
$1<I_{GP}<2$	Environment modified by human activities within admissible limits
$2<I_{GP}<3$	Environment modified by human activities causing discomfort conditions
$3<I_{GP}<4$	Environment modified by human activities causing distress to life forms
$4<I_{GP}<6$	Environment modified by human activities dangerous for life forms
$I_{GP}>6$	Degraded environment, not proper for life forms

The value of the index of global pollution calculated for the forest ecosystem Rarau allow to estimate that the ecosystem is affected by the human activities, which cause discomfort conditions to the life forms.



S_I = area illustrating the ideal state of the environment

S_r = area illustrating the real state of the environment

$$I_{GP} = \frac{Si}{Sr} = \frac{43,3}{15,59} = 2,79$$

Figure 1. Diagram used to illustrate the calculation of the index of global pollution when three environmental factors are analysed

Conclusions

The method of the index of global pollution that was applied in this study permitted the evaluation of the impact of human activities, including pollution on the forest ecosystem from the mountain Rarau, Romania, within the period 1998-2001. On the basis of the value of this index we estimated that the effect of human activities cause discomfort conditions to the life forms.

Even if this method has the disadvantage that it depends on the experience and the exigency of the evaluator, it has in the same time the advantage that it offers the possibility to evaluate and to compare the state of the same ecosystem at different moments and to estimate its evolution and it also permit to compare the state of more ecosystems for which the same factors and indicators have been analysed

References

1. Ahmed, M., 1992: Rôle du facteur édafique dans le fonctionnement biogéochimique et l'etat de santé de deux pessières vosgiennes. Effet d'un amendement calci-magnésien. These, Universite de Nancy, INRA, Nancy, France, 96-98
2. Badea, O., 1999a: Cercetări privind influența factorilor de stress asupra creşterii arborilor şi arboretelor în cadrul sistemului de monitoring forestier, Referat ştiinţific parţial, Tema A6, Manuscris ICAS Bucureşti
3. Badea, O.,1999b: Optimizarea rețelei naționale de sondaje permanente pentru supravegherea stării de sănătate a pădurilor, Revista pădurilor, Nr.3., 15-21
4. Barbu, 1997: Cercetări privind dinamica depunerilor minerale din atmosferă şi nutriția speciilor de arbori în principalele ecosisteme forestiere, Referat ştiinţific final, Manuscris, ICAS Bucureşti, 12-17
5. Bolea, V., Popescu, E., Vlonga, S., Mandai, M., Man, G., Surdu, A., 1998: Nutrition of Norway spruce in the Romanian Carpathians in 1996 *in* Forest condition monitoring in Romania, (Eds.) Office National des Forêts, Département des Recherches Techniques, ISBN 2-84207-153-0, 49-53
6. Boyle, M.G., Farrell, E.P., Cummins, T., 1997: Intensive monitoring Network-Ireland, FOREM2 Project, University College Dublin, Belfield, Dublin 4, Ireland, 221p.
7. EMEP, 1996: Co-operative Programme for Monitoring and Evaluation of Long Range Transmission of Air Pollutants in Europe. Manual for sampling and chemical analysis.EMEP/CCC-Report 1/95 Norwegian Institute for Air Research Lillestrøm, Norway, (4-1)-(4-34)

8. EMEP, 2003: Status Report 1/03 Part II , *Transboundary acidification and eutrophication and ground level ozone in Europe: Unified EMEP model performance* , Joint CCC & MSC-W Report, emep
9. Hanneberg, P., 1993: Acidification and Air Polution. A brief guide, Swedish Environmental Protection Agency, 86 p.
10. Landmann, G., 1991b: Dépérissement des forêts et pollution atmospherique: mythes et reálités, *Phytoma.* La Defense des vegetaux, No.434, p.62-67.
11. Macoveanu, M, 2003: Metode şi tehnici de evaluare a impactului ecologic, Ed. ECOZONE, Iaşi, 140-148
12. Manion, P., 1981: Tree Disease Concepts. Prentice-Hall, Englewood Cliffs, New Jersey, USA, 399 p.
13. Marques, R., 1996: Dynamique du fonctionnement minéral d'une plantation de Douglas (*Pseudotsuga menziesii* (Mirb.Franco) dans les Monts du Beaujolais (France), These, Ecole Nationale du Génie Rural, des Eaux et des Forêts, INRA Nancy, France, 240 p.
14. Mănescu, S., Cucu, M., Diaconescu, M.L. 1994. Chimia sanitară a mediului, Ed. Medicală, Bucureşti, 145
15. McLaughlin, S.B., 1985: Effects of air pollution on forests – A critical review, *Journal of Air Pollution Control Association*, Vol.35, No.5, 512-534

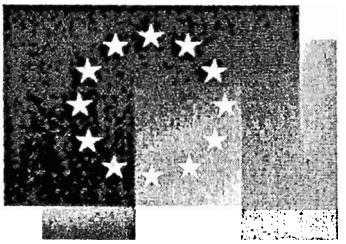
Nys, C., 1987: Fonctionnement du sol d'un ecosysteme forestier: etude des modification dues a la substitution d'une plantation d'epiceas commun (*Picea abies*) a une forêt feuillue mélangée des Ardennes, These, universite de Nancy I, U.E.R., G.S.M, Nancy, France, 137-140

Programme Coordinating Centres (eds.), 1994: International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Programme Coordinating Centres, Hamburg, Prague, 6-7

Vanmechelen, L., Groenemans, R., Van Ranst, E., 1997: *Forest Soil Condition in Europe.* Results of the Large-Scale Soil Survey, Brussels Geneva

Ulrich, E, Coddeville, P., Lanier, M., 2002: Retombées atmosphériques humides en France entre 1993 et 1998, Ed. ADEME, Paris, 6-8, 76-78

Ulrich, B., Matzner, E., 1983: Abiotiche Folge wirkungen der weiträunigen Ausbreitung von Luftverunreiningungen. Luftreinhaltung, Forschungsbericht 10402615 Göttingen.



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