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IMPACT OF POLLUTED GASSES FROM THERMAL POWER PLANT IN ŠOŠTANJ, SLOVENIA, ON FOREST ENVIRONMENT: A BRIEF EXPERTISE ON CAUSE-CONSEQUENCE RELATIONSHIP IN FOREST DECLINE STUDIES CARRIED OUT ON THE INSTITUTE FOR FOREST AND WOOD ECONOMY

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Air pollution, connected with types of industry and energy production is one of the major ecological problems in Slovenia. It has been known for longer period that emission of sulphur compounds in nowadays levels from above mentioned sources situated in different parts of Slovenia will not be acceptable any longer in this part of Europe. Approximately at the same time Slovenia faced with the first spell of forest decline phenomena which was in greater part correctly classified as a consequence of air pollution. That led to strong ecological movement which influenced decision makers in Slovenian politics and economy to accept quite famous "Slovenian ecological project", guided by the people from the Slovenian Ministry for the Environment. First targets of that projects were actions to clean up the most polluted areas like major towns (Ljubljana, Trbovlje, Maribor) and also the biggest Slovenian air pollution source, the Thermal Power Plant (TPP) in Šoštanj.

In the activities connected with efforts for getting money for desulfurisation devices and changes in energy supply it was necessary to obtain an assessment of losses due to several influences of air pollution on nature, man and its activities. In the case of desulfurisation of power units in TPP Šoštanj it was necessary to justify the need of desulfurisation of unit five after decision about cleaning up the unit four had been already accepted. First calculations of eventual losses due to still persisting air pollution from unit five were done by experts from World Bank exclusively on data about wood increment losses. When calculations were rather low, and not justifying the investment in desulfurisation the leaders of Slovenian ecological project decided to invite research group from the forestry institute to provide data from their more "ecosystematic" oriented studies. The following brief expertise is very short summary of data obtained by several investigations dealing with air pollution impacts on forests in the surroundings of TPP in Šoštanje and elsewhere in Slovenia. First meeting about preparation of that expertise was in late October 1993 between group from forestry institute and Slovenian ecological project. Later on when we met also with representatives of World Bank we agreed that our group can provide data considering following topics which were not properly treated earlier:

1. Comments on already used increment studies with additional data on wood stocks, growing potentials, sanitary cuttings and stand age structure of affected area.
2. Comments on non timber losses like ecosystem and water functions of forests.
3. Data about the extension of the polluted area obtained by forest die-back inventories
4. Data about measured pollution with sulphur compounds on the basis of spruce needle analysis.
5. Data about eventual recorded losses in agriculture and recreation activities.
6. Data about public opinion considering air pollution, forest decline and sanation of pollution sources.
7. Scenario about the forest development under persisting air pollution.

Items 1 and 2 are discussed in the article from M. KOVAČ, item 3 in parts from D. JURC and F. BATIČ, item 4 by J: KALAN and the rest by D.JURC and F: BATIČ.

I.

THE INFLUENCE OF EMISSIONS FROM THE ŠOŠTANJ THERMAL POWER PLANT ON FOREST VEGETATION - COMMENTS OF INCREMENTS STUDIES AND SOME FOREST ECOSYSTEM FUNCTIONS

Marko KOVAČ

1 INTRODUCTION

Studying relationships between various factors of forest development seems to be one of the most intricated fields of the scientific research in forestry. Mainly, because a growth of trees and stands does not depend only on one certain factor but on various genetic, ecological and climatic conditions, as well as on human interventions in the forest. These may be either beneficial and do reflect the perspective development of forest stands, or harmful, with series of negative effects upon the environment, and are usually seen as an air, water and soil pollution, as a destruction (extinction) of plant and animal species and finally as a destruction of ecosystems. Due to the problematic' complexity, the article is divided into more thematic parts. The first one presents general conditions of the Slovenian forests, the second briefly describes characteristics of the Slovenian stands with a stress upon analysis of the sustained yield, the third part continues with a detailed summary of the research work dealing with growth problematics in the ŠTPP imission area, and finally, the last part gives some recommendations that concern an urgent need of improving ecological conditions in the ŠTPP surrounding area. This part is based on a short survey of the forest multipurpose functions.

2 GENERAL CONDITIONS OF THE SLOVENIAN FORESTS (area, ownership, management system)

Forests are the most characteristic element of the Slovenian landscape, covering more than 50% (1.071.151 ha; IGLG 1990) of the national territory. In the last century the forest area has grown for more than 20% (ŽUMER 1976), mainly because of industrialisation and deagrarization processes, that advanced overgrowing of the uncultivated agriculture land. Almost two thirds of the forest land is in private ownership, in the very near future this percentage will even raise due to the process of reprivatization.

A forest management, based on the principle of sustained yield has a long tradition in Slovenia. As a basic forestry discipline has been known for more then a century, thus today's thoroughly modernised concept includes rich past experiences as well as modern pro-natural silvicultural techniques. The aim of pro-natural managing is a preservation of forest reproduction capabilities, an improvement of its condition and an enforcement of non-production forest role. A protection function seems to be of extreme importance, because 34% of all forests cover moderately steep terrains (slope 20-35%) and almost 40% very steep terrains, with slopes larger than 35% (ANKO, GOLOB, SMOLEJ 1985).

Today's forest conditions depend very much on managing measures in the past, which were not always pleasant. Results of inconvenient treatment (*exaggerated consideration of the maximal land rent was promoting artificial planting of spruce on unfavourable sites, therefore natural tree species compositions have been severely damaged*) are therefore still seen in most national forests. Clear-cuttings, half a century ago well known management system, have been also given up (such managing is regulated by law) and foresters have widely accepted a group-graded rotation system, characterised by mosaic-like dispersed measures of tending and regeneration. Though a strategy of forest regeneration is based for a long time on natural regeneration, the introduction of spruce (because of simple breeding) has been continuing up to now. As late as in the last decade (when some vast catastrophes appeared) some more interest and effort is dedicated to natural and artificial forest regeneration with site-appropriate species, especially with broadleaves.

Damages of trees and stands are frequent in most Slovenian forests. Up to 1985, until emphasising the process of forest decline, were treated in a context of the following groups:

- damages caused by abiotic factors (mostly by climatic conditions) such as windfalls, snowfalls, icebreaks,
- damages caused by biotic factors (fungi, insect calamities, big game grazing),
- damages caused by inconvenient treatment with the forest (road engineering, cutting, logging),
- damages caused by unknown factors (e.g. fir decline),
- damages caused by emissions and imissions (local pollutants in Koroška, Gorenjska, Štajerska, Zasavje).

Most of these damages have been registered in the forestry information system (FIS), while damages caused by imissions have been always researched separately (ŠOLAR 1986). Almost in the middle of the eighties, when health conditions of our forests became more questionable, a monitoring system based on the permanent sampling plots was designed and carried out. This periodical inventory is still in force and is the most important source of forest health information. More about assessment of forest damage carried out through forest die-back inventories is presented in the article of D.JURC , a part of this expertise.

3 CHARACTERISTICS OF THE SLOVENIAN STANDS

3.1 Site and stand typology

By taking into consideration the data about natural potential vegetation, it's easy to find out, that Slovenia is the land of broadleaves. Almost 73% of forest land should be covered by deciduous trees (54.3% with beech), 14.1% by conifers and the rest by mixed forests of beech and fir (KOŠIR 1976). The proof that this is not so and that a man has severely modified (if not exchanged) forest tree compositions can be seen in the following tables.

Table 1: Areal distribution of stand developmental phases (age classes) (KOVAČ 1992)

phase/age class	area / ha	area %	GS m^3/ha
young growth (incl. trees with dbh<10cm)	107.770.00	10.1	52
pole wood	451.110.00	42.1	180
old growth	236.670.00	22.1	295
old growth in regeneration	64.440.00	6.0	273
selection forests	44.440.00	4.1	213
other (coppice, degraded forests)	126.110.00	11.8	76
undefined	40.611.00	3.8	-

legend: GS = growing stock

Table 2: Forest types in Slovenia (LEVANIČ 1990)

forest type	area/ha	area/ %
pure broadleaves - brdl.>90%	308.609.00	28.9
mixed broadleaves/con. - brdl.>50%	269.528.00	25.3
pure conifers - con.>90%	195.407.00	18.3
mixed conifers/brdl. - con.>90%	293.785.00	27.5
pure spruce stands - spruce>75%	163.064.00	15.3
pure fir stands - fir >75%	18.866.00	1.8
pure beech stands - beech>75%	156.326.00	14.6
Slovenia - total	1.067.329.00	100.0

Table 3: Forest structure - tree species frequency (GOLOB, ČAS, AZAROV 1990, LEVANIČ 1990)

percentage of tree species %	conifers				broadleaves			
	spruce	fir	pines	other	beech	oak	nobles	other
in appearance[1]	25.2	6.7	7.2	0.8	31.9	8.5	4.3	15.4
in volume[2]	35.2	11.1	no data	8.1	26.9	8.6	2.8	7.3

legend: 1=density (particular species/all species); 2=percentage in volume

The spatial distribution of forest types is various. With a reference to data of the large-scale forest inventory, broadleaved forests cover mostly eastern and extremely western parts of Slovenia, the central part is quite equilibrated with all forest types, while the coniferous forests are dominant on the north and north-west territory. Predominant species are spruce and beech. The former is some kind of pioneer and is much more widely spread than is determined by natural sites. Its growing stock is increasing towards higher elevations. In comparison with spruce, beech has a very wide ecological amplitude, therefore is equally distributed (with the volume) in all elevation levels (GOLOB, ČAS, AZAROV 1990). The third very important tree species is fir, which has either the role of a "stand builder" or is only mixed in the stand.

Important information about stand conditions are shown in table 1. The sustained yield of the national forests has been endangered for some time due to the low percentages of old growths, while the percentages of young and mid-aged forests are too high. Quite a large trouble do represent forests in regeneration which are extensively grazed by big game and because of questionable prosperity of certain tree species (fir, spruce).

3.2 Development of the stands

The average growing stock is 193 m^3/ha. More than 47% of the total volume belongs to trees, having DBH (diameter at breast height) smaller or equal to 30 cm (see also Table 1; age classes distribution), about 43% to trees with the DBH ranging from 30-50 cm, and only about 10% of the total volume is in the third (wider) diameter class. The growing stock has been in increase since extensive cuttings after the world war II. The increment of the absolute growing stock is estimated to be 7.5% in ten years, while the average, calculated to one hectare is about 5.0 m^3/ha/year. Annual cuttings reach 3.3. million m^3 and exploit about 72% of the annual increment (see table 4).

Table 4: Growing stock and increment in Slovenia and forest enterprises (MIKULIČ 1990)

Spatial unit	GS m^3/ha	index GS/ha	GS.con %	GS.brdl %	GS 1-3 %	GS 3-5 %	avg.DBH cm	I_v.con %	I_v.brdl %
F.E. Tolmin	146	1.028	30.6	69.4	58.0	34.3	20.8	2.2	2.4
F.E. Bled	237	1.035	77.9	22.1	34.7	49.9	25.6	2.2	2.3
F.E. Kranj	227	1.086	67.0	33.0	41.2	49.1	24.3	2.4	2.3
F.E. Ljubljana	186	1.005	50.6	49.4	48.8	44.2	22.8	2.4	2.4
F.E. Postojna	212	1.029	58.9	41.1	35.4	46.7	25.6	2.3	3.2
F.E. Kočevje	240	1.076	48.1	51.9	35.3	46.8	25.4	2.4	3.0
F.E. N. Mesto	201	1.086	29.6	70.4	52.1	39.4	21.9	3.0	2.8
F.E. Brežice	157	1.098	19.2	80.8	58.6	35.6	20.9	2.9	2.9
F.E. Celje	198	1.048	41.6	58.4	54.3	41.5	22.2	2.7	2.7
F.E. Nazarje	238	1.067	81.2	18.8	44.8	47.7	23.9	2.2	2.0
F.E. S. Gradec	255	1.032	88.0	12.0	43.2	47.7	23.9	2.5	2.7
F.E. Maribor	223	1.018	53.8	46.2	43.0	46.8	23.8	2.3	2.7
F.E. M. Sobota	147	1.043	33.9	66.1	62.4	32.6	20.6	2.4	2.8
F.E. Kras	79	1.274	30.7	69.3	84.4	15.1	18.6	3.6	3.5
Slovenia	193	1.043	52.1	47.9	47.1	43.1	22.7	2.4	2.7

legend: GS = growing stock; index = 1990/1980; con = conifers; brdl = broadleaves; 1-3 = diameter from 10-30 cm ; 3-5 = diameter from 30 -50 cm; avg. DBH = average diameter at breast height; I_v = volume increment (GS_{90}-GS_{80}/ GS_{90});

3.3 Forest damages

A complete record about area damages is missing. For orientation are cited some data from FIS (GOLOB, ČAS, AZAROV 1990) which show the affected areas of a certain cause of damage. Percentages are not necessary cumulative, therefore each of them represents the part of forest land endangered by a separate cause.

Table 5: Areas (in % of the total forest area) under a certain cause of damage (GOLOB, ČAS, AZAROV 1990)

CAUSE OF DAMAGE				
diseases	insects	wildlife grazing	windfall	snowfall
4.6	1.1	4.1	2.2	4.4
CAUSE OF DAMAGE				
icebreak	forest work	imissions	unknown reason	wildlife/fir decline
5.4	1.8	2.8	3.4	1.9

Indirect damages caused by natural disasters are growing increasingly. They are commonly repeating every 2-5 years (average 3.4 years) in such a cycle that the moderate disaster is followed by the catastrophic one. The extent of damages is increasing by the exponential function, therefore approximately 1 million m^3 of wood is estimated to be damaged in 1995 (ŽGAJNAR 1991).

Table 6: Average volume (in m^3) of damaged wood, caused by natural catastrophes

PERIOD				
1955-1964	1965-1974	1975-1984	1985-1988	1989-2000
43.000.00 m^3	152.600.00 m^3	270.700.00 m^3	476.700.00 m^3	1.000.000.00 m^3 ??

Most damages are caused by ice-breaks (47%), snowfalls (39%) and windfalls (24%). In the past, natural disasters were causing about 5% of annual cutting, in the period from 1975-1984 the percentage was raised to 8%, while in the period from 1985-1988 damages are already exceeding 13%. Besides natural disasters caused by climatic conditions, forests are occasionally endangered by insect calamities (bark beetle and others), as was an example in the summer 1993.

Increasing extent of damages in the last years has not been studied in details yet; however, many signs do show that catastrophic events are not the only reason (*area under their influence has not been considerably enlarged*), but we should also count a forest decline (a loss of vitality) as a possible cause. Extent of damages, caused by natural disasters, is in very close connection with a loss of vitality and with weakening of self-preservation mechanisms. Both mentioned factors are backwards related to vast climatic and ecological changes (such as droughts, air and soil pollution) and nevertheless to forest management measures. The apparent cycle is therefore closed and results in the increasing extent of irregular fellings that reached about 20% of the total annual cutting before 1980, and exceed 28% since 1986 (AHAČIČ 1993).

4 ASSESSMENT OF FOREST DEVELOPMENT IN THE IMISSION AREA OF THE ŠTPP

A wider imission area of the ŠTPP (forest enterprises of Nazarje and Slovenj Gradec) with the total area of 157.824 ha encompasses the central part of northern Slovenia. It is enclosed by water basins of the river Drava (with affluents Meža, Mislinja and many torrents) and by upper flow of the river Sava with subsidiary river Savinja, affluents Paka, and Dreta and torrents. Though these two mentioned regions do not actually gravitate to each other, they do have many similar characteristics such as large relief variation, high proportion of forested land (Slovenj Gradec 66.5%, Nazarje 65.8%), similar development until the world war II (autarkic agriculture on enclosures, forestry, mining, coaling), and in the last years similar ecological problems, caused by industrialisation (ironing, mining, energy supply). Impacts result in forest decline of the wider forest region, they do probably affect agriculture (*although they are mostly unknown*) and already high vulnerability of the landscape.

Forests of both enterprises were severely affected by many mankind activities. The growing industrialisation in the middle of the 18ht century (ironworks, glassworks) has strongly affected the structure and tree composition of stands. Beech, some time ago predominant species was severely cut out (partially exterminated) due to high needs of firing, and was replaced by spruce which was economically more interesting. The study, carried out few years ago (GOLOB, ČAS, AZAROV 1990, p. 100-101) describes these forests as follows:" In the region of Nazarje Alpine forests are the most frequent. Almost 7500 ha of spruce forests have growing stocks (GS) larger than 200m^3/ha and about 7000 ha of forest land is covered by spruce forests, having GS lower than 200 m^3/ha. There is also more than 5000 ha of mixed forests with spruce as a major species. In the sub alpine region is more than 8000 ha of mixed forests, primarily consisting of spruce, beech and fir. In the hilly terrains mixed forests with predominant spruce prevail (almost 5500 ha). In the eastern part of the Saleska valley is about 1500 ha of mixed forests with very low GS.

In the region of Slovenj Gradec conifers are even more predominant. Alpine forests have a bit lower percentage than in the region of Nazarje. About 7500 ha of spruce forests have GS higher than 200 m^3/ha and nearly the same area is covered by spruce forests with low GS. More than 500 ha is covered by mixed forests in which spruce is a predominant species, while mixed forests with predominant beech have the smaller area (about 300 ha) and lower GS. In the sub alpine region (in the region of enclosures) more than 8000 ha of land is covered by mixed forests in which spruce is absolutely predominant species. In the hilly terrains are most frequent spruce forests (almost 6500 ha) with very high GS, but mixed forests with spruce as a predominant species can be also found. In the mixed forests with low GS red pine prevails." From the structural point of view it has to be stressed that majority of these forests are classified as a group graded forests.

4.2 The structure of the forests of the imission area

Growing stocks and increments of this region are normal and a little higher than the Slovenian average (see table 4), both dendrometric characteristics do also not show any decreasing trends in the period from 1980-1990. A completely different situation can be seen in table 7, where it is easy to find out, that the long-term sustained yield has been endangered. The percentage of pole stands is much higher than it should be, while the percentage of old growths is too low. A very inconvenient structure is found in the region of Slovenj Gradec lacking with forests in regeneration (old growth in regeneration) and young forests. Both regions are also lacking with broadleaves, and it seems this problem can not be solved in the very near future.

Development of the forest stands is shown in tables, while growth trends can be found in table 4.

Table 7: Areal distribution of stand developmental phases (age classes) and corresponding growing stocks (estimate)

	Nazarje			Slovenj Gradec		
phase/age class	area/ha	area %	GS m^3/ha	area/ha	area %	GS m^3/ha
young growth (incl. trees with dbh<10cm)	4494	9.9	30	7275	12.3	11
pole wood	12523	27.6	202	24103	40.8	167
old growth	15370	33.8	306	23059	39.0	291
old growth in regeneration	8158	18.0	308	3983	6.7	268
selection forests	255	0.5	220	-		
other (coppice, degraded forests)	152	0.3	24	-		
undefined	4476	9.9	-	681	1.2	-

legend: GS = growing stock

4.3 Growth trends and the influence of imissions on reducing increment

It has to be stressed in the beginning that is very hard to offer any reliable estimates (due to a lack of data) about growth trends of the wider imission area, especially if SO_2 as a basic air pollutant is in question. FIS, the largest data base in use seems to be less effective for making any precise conclusions and the same can be referred to both forest decline inventories from 1987 and 1991. Due to this reason a summary of two studies (KOLAR 1989, FERLIN 1990) dealing with problematic is given in the continuation. Conclusions of both authors (*they are the result of studying the phenomenon on some (28) sampling plots*) certainly do have the scientific weight, though it has to be pointed out, that any extrapolation of these results onto a wider area may be - from statistical point of view - a speculation. Yet more, many authors who have researched causal relations between air pollution and forest growth are reporting about slightly different results.

4.3.1 Relations between tree decline and social structure of the stands

A tree decline is commonly dependant on a social status (e.g. dominant, codominant, understoried etc.) of the tree in a stand. In the forests of the wider imission area has been proved, that trees of lower social classes are more exposed to damages (competition for a better position) than the ones, belonging to the first class. This is an unambiguous sign that trees, chosen as a function carriers are less sensitive (*because of their higher vitality*) against harmful impacts from the environment. Right an opposite statement is reported for trees, being far from indirect imission area. In these forests, dominant trees (the highest, usually the largest in diameter) are the most damaged and therefore most sensitive to far distance pollution transports (FERLIN 1990).

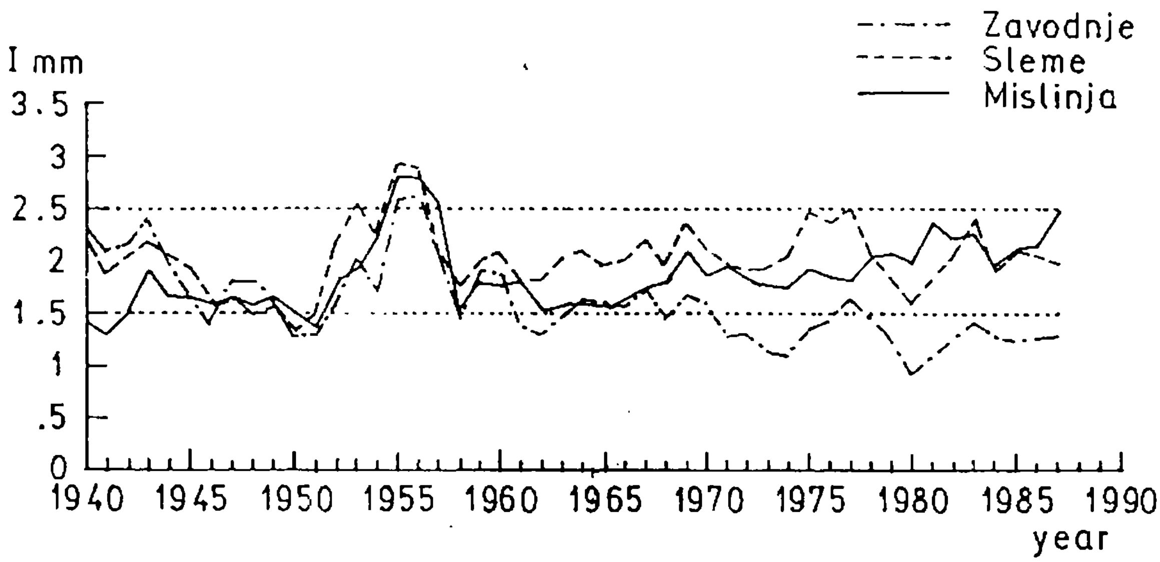
Slightly different opinions are reported by HOČEVAR (1990), who claims (*investigation was carried out in spruce forests of Pokljuka and Jelovica plateau, about 20 km from Bled, west Slovenia*) that trees of the first social class (dominant) are less damaged and high defoliation rates are almost not seen. On the other side an intensive competition is taking place in the crown story where all rates of defoliation are observed. The similar lawfulness as reported by FERLIN for spruce is reported by HLADNIK (1990) for fir. The most vital and healthy are old and dominant firs, on the contrary, the most dominant spruce trees are severely damaged. Both mentioned researches were carried out in the forests far from the ŠTPP, where SO_2 has not been considered as a pollutant.

Worth mentioning are also too low visual assessments of forest decline and are the consequence of mortality, which is usually not included in the final score. FERLIN (1990) claims, actual damages are 3-23% higher in the moderately damaged stands and 20-57% higher in the severely damaged stands. The similar conclusion is reported by HLADNIK (1990).

4.3.2 Relations between growth and crown defoliation

The influence of imissions on the growth of trees and stands has been studied by two methods. With the classical biometrics analysis (KOLAR 1989) and by combined methods of biometrics and dendrochronology (FERLIN 1990). More thankful, though much more intricated is the latter one, giving more reliable results. All stands, studied by FERLIN (1990) had similar growth directions until 1960 and were influenced only by climatic factors. The growth behaviour of all stands named Zavodnje, Sleme, and Mislinja was in a high accordance (especially Sleme and Zavodnje). We can see this from the growth depression in the period from 1946-1951 and from the highly increased growth during 1952-1957. After 1961, and even more after 1968, we can see the large differences in growth directions. Nowadays slightly endangered stand in Mislinja (about 25 km from emission source) changed its growth direction towards increasing an increment, while both stands of the Saleska valley retained similar growth directions, but positioned on different levels (50% difference in annual increment).

Figure 1: Tree rings widths of the most dominant trees (largest in diameter) in various pollution conditions (according to FERLIN 1990)



Unexpected, 3-5 years long increment decrements, appeared quite soon (1961-1962, 1971-1975, 1978-1982) in the Saleska valley, and they prove, the physiological weakness had appeared long before external damages (FERLIN 1990, KOLAR 1989). The first two decrements coincide with inconvenient climatic conditions, while the third one is independent of them; yet more, the author claims, that nearly all growth-trend changes, appearing in the Saleska valley, were independent of climatic conditions.

In comparison with a slightly damaged stand in Mislinja, both stands of the Saleska valley have had the lower relative growth efficiency since 1967. The trend of decreased growth of both stands is almost identical (coefficient of the same direction =81.5***), and is again much lower in Zavodnje (the most damaged stand). The relative values compared to the values of the control stand in Mislinja are shown in table 8.

Table 8: Relative efficiency of the tree (for trees with the largest diameter) growth (according to FERLIN 1990)

stand location	time period			
	1967-71	1972-76	1977-81	1982-86
Zavodnje	80.4	57.2	61.2	62.8
Sleme	99.5	100.5	86.2	92.8
Mislinja	100.0	100.0	100.0	100.0

Relative growth efficiencies of stands of the Saleska valley have been also compared to emissions from the ŠTPP. The correlation is negative (increasing emissions, decreasing increment) and significant (Zavodnje - ŠTPP emissions; r=0.762***, Sleme-ŠTPP emissions; r=0.470**).

Consequences of increment losses are reflected in various ways. Mostly as a loss of biomass (growing stock), current volume increment as well as in long-term losses of growth potentials. According to data, growing stocks of the severely damaged forests were reduced from 32-39%, and from 15-26% in the moderately damaged forest stands. Considerably lower figures are given by KOLAR (1989), who estimated biomass losses to 7.5% (this is the average of the total area !!!); precisely, to 13.5% in stands growing on the tonality bedrock and 1% in stands on the andhesite tuff.

Quite large losses are examined for the average stand volume increment. FERLIN (1990) estimates losses in highly endangered forests to 4.8m^3/ha/year, and to 2.3 m^3/ha/year in the moderately damaged stands. Similar losses were examined by HOČEVAR (1990) in Pokljuka (10%) and Jelovica (8%) for pure spruce forests (about 1m^3/ha/year).

4.3.3 Irregular cuttings and their cause

In the beginning of 1980 the foresters of this region noticed more frequent cuttings in those forest parts that were more exposed to SO_2 imissions. Such a trend is still present, though the cuttings are less intensive. A complete report about cuttings in the past does not exist, because such a monitoring started as late as 1989. Since 1984 we have had only some data for the Slovenian level. The proportion between regular cuttings and cuttings of damaged trees has been continuously changing; 74% of the regular annual cutting (silviculture) was carried out in 1984 and only 68% in 1990. The decrease is shown in the table below. It is designated to intensive cutting during the years 1984-1988, when imission damages (burnings) were the most severe. By intensive tree cutting, foresters have done a double work; they removed nearly all severely damaged trees from the forests and they also made a selection among the less vital trees. It must be stressed, the strong selection was also a consequence of lacking knowledge about tree growth of handicapped trees, and very high precautions against insect calamities. A quite large possibility of recovery of less damaged trees was proved by carrying out further forest decline inventories (1987 and 1991).

Another circumstance we should explain is a rather small amount of sanitary cut in the region of Nazarje. Comparing to the region of Slovenj Gradec which has more imission centers (Mežica, Ravne) and is much more exposed to direct long distance transports, the region of Nazarje is more in the west and therefore in a shelter. Nevertheless, nearly a half of irregular cuttings, caused by imissions are exploited in the region of Bele Vode, the most exposed to the ŠTPP imissions (GGNA 1993). Very similar conditions are also observed in the most exposed regions of Slovenj Gradec (*cuttings are much higher in the cadastral communities of Spodnji and Zgornji Razbor and Velunja (GGSG 1993)*).

Table 9: Forest cuttings in m^3 with respect to a cause of damage in the region of Slovenj Gradec (AHAČIČ 1993)

	imissions			windfalls, snowfalls, icebreak			diseases, insects		
year	con	brdl	total	con	brdl	total	con	brdl	total
1989	56479	494	56973	10382	936	11318	8114	78	8192
1990	36541	222	36763	23211	740	23951	9696	110	9806
1991	26626	298	26924	14741	1173	15914	10023	103	10126
1992	14199	255	14454	7993	488	8481	15176	103	15279

Table 10: Forest cuttings in m^3 with respect to a cause of damage in the region of Nazarje (AHAČIČ 1993)

	imissions			windfalls, snowfalls, icebreak			diseases, insects		
year	con	brdl	total	con	brdl	total	con	brdl	total
1989	-	-	-	-	-	-	-	-	-
1990	4347	20	4367	11894	2037	13931	10883	398	11281
1991	2148	3	2151	20121	2680	22801	12915	516	13431
1992	2498	13	2511	5536	785	6321	20866	379	21245

5 A SUMMARY OF FINAL STANDPOINTS - EVALUATION OF THE MULTIPURPOSE FOREST

As seen from the text a forest decline is a very complex process, interacted by various factors. Commonly it is almost impossible to asses all interaction effects, especially not with the short-term researches; a complete assessment is possible only through the long-term observations on the permanent sampling plots (e.g. the Swiss method).

Up to now it is clearly accepted that a breast diameter increment is decreasing with increasing defoliation (KOLAR 1989, FERLIN 1990, HLADNIK 1990, HOČEVAR 1990, SCHMID-HAAS 1988, 1990). Unambiguous is also the fact, that the older stands are more affected by pollution than the younger ones, however it is still not possible to talk about a certain rate of damage causing a decrease of increment. Growth decrements are dependant on several factors such as tree species, site, location in the environment, age, many micro climatic conditions and nevertheless on intensity of forests management (compare to FERLIN 1990, KOLAR 1989, HLADNIK 1990, HOČEVAR 1990). It is also interesting that increment decrements do not seriously affect the total growing stock (widely speaking), exceptions can be found only in certain locations. In table 4 are shown positive trends for practically all dendrometric signs (growing stock, increment), similar are also the experiences of some other researches in Slovenia and abroad (HOČEVAR 1990, KENK 1989 cited by HOČEVAR 1990). Increasing stand growth - as reported by KENK - might be caused by big amount of CO_2 in the atmosphere, by fertilization with the atmospheric Nitrogen and by pleasant climatic conditions. The increased growth varies from 5-20% and would be probably even higher if the process of forest decline would not affect growth in such extent.

Due to the all mentioned facts it is almost impossible to asses influences, possibly caused by the ŠTPP emissions. On the other side the science has already proved harmful effects of SO_2 (compare STERN 1973 and others) on the living nature, and the ŠTPP is one of the biggest pollutants in the southern part of Central Europe. Reasons for improving actual ecological conditions must not be therefore supported only by the short-term economical parameters (such as a higher tree mortality and a decrease of increment) but by the long-term forest ecological potentials. More precisely, the decision of any kind of de-sulphurization must be supported by the multipurpose role of the forests of this region.

Evaluation of the forest functions seems to be of big help while planning the economy of a region. We dare to say (even we do not know the objective criteria for economic evaluation of the forest beneficial effects) that benefits, given by forests, are much greater than any profit given by the ecologically questionable industry. For this reason we expose some of the most important forest functions of the region:

1 Environmental function
- forest is the last "natural" ecosystem, it is a unique genetic reservoir and a habitat for living creatures
- forest is the most important preventer against erosion processes (balancing the water regime, balancing the climate, protection against landslides, avalanches etc.)
- forest is a source of air and enormous consumer of CO^2 and other substances

2 Economical functions
- wood supply
- source of non-wood products (littering, game, plants and fruits)
- forest is an element of the social security of the people, living on enclosures

3 Cultural functions
- forest is a recreational (tourist) object
- hygienic function

5.1 Environmental functions

Among all *ecological* functions, a forest as an ecosystem (and closest to nature) is put to the first place. In spite of all interventions in the past and present, forests have preserved the main characteristic of the natural systems - self preserving mechanisms - which make them possible to survive without any artificial energy inputs. Besides this, a forest is a unique genetic reservoir and a habitat for living creatures and can not be replaced regarding it from any point of view. From the referred follows, that forests can not be evaluated only through the economical parameters, but through much wider ethical aspects. The main assumption that helps to clarify this aspect is "how would the life run, if there was no forest". In the particular area this question is of big importance, because it has been proved, that genetic material of this region is the most damaged in Slovenia (DRUŠKOVIČ 1986).

Much easier than evaluating the forest as an ecological category seems to be evaluation of its *protection role*. Both parts (Nazarje and Slovenj Gradec) of the imission area are quite vulnerable due to the high relief variability and bedrock disintegration. For the region of Slovenj Gradec the following model of vulnerability was carried out (KOVAČ 1991): more than 33% of forest land needs protection against erosion, 38% demands moderate protection and 27% of forest land needs any protection.

Table 11: Forest area structure with an emphasis to protection function

demand after protection	A	% A	±S %	±A	forest capability of providing a protection function	A	%A	±S%	±A
large	202	33.4	5.2	10.5	large	91	45.0	9.2	8.4
					moderate	93	46.0	8.8	8.2
					low	18	9.0	22.6	4.1
moderate	235	38.9	5.6	13.2	large	96	40.9	9.6	9.2
					moderate	111	47.2	8.9	9.9
					low	28	11.9	18.6	5.2
low	167	27.7	6.5	10.9	large	81	48.5	10.4	8.4
					moderate	79	47.3	10.3	8.1
					low	7	4.2	39.1	2.7

A=area in km^2; S%=standard error

Similar models (with more ecological variables such as slope, bedrock disintegration, soil buffering, rate of changing of the potential vegetation, plant resistance against SO_2) were also made for the wider ŠTPP imission area. The final model gave the following results: 19% of the forest territory needs any protection, 48% of forest area is quite risky, on 33% of the forest area is possible to expect excessive situations.

On the basis of both models we propose the following percentages of the certain risk class:

- **33% of the imission forest area is very risky (very high probability of soil degradation)**
- **43% of the imission forest area needs moderate protection (50% probability of soil degradation)**
- **24% of the imission forest area is not risky.**

The next and very important forest function is a *hydrological* one. Forest as an enormous fungi refines water and regulates a water balance by retaining precipitation maximums and by reducing runoffs over the surface. Rough calculations show that coniferous forests (of Central Europe) consume about 43-46% of annual precipitation for transpiration (LARCHER 1991), while the rest of them are disappearing in the ground. Experiences from Tonto National Forest (Arizona) also show, that the water runoff is increased for 1500m^3/ha/year (ANKO 1982) if the vegetation is removed (cut, burnt). In the case forest conditions of this area will still worsen, we can only imagine what is going to happen (large relief variations, impermeable bedrock). As an example we can compare consequences of the large floods which were taking place in Slovenia in 1990. Natural disaster caused major damages right in this region (GAMS 1991, MEZE 1991). The affected area measured more than 500 km^2 and the largest landslide in the slope of Raduha mountain contained more than 1.300.000 m^3 of rocks and other material. The damage caused by floods was estimated (only for this region) to two-year gross national product of these communities. As a part of the former Yugoslavia Slovenia also asked the World Bank for a loan in amount of 30 million US$ (*** 1990).

By decreasing wind speeds and wind gusts, forest has an important *climatic* function; it decreases soil drying, regulates a micro climate and increases agriculture yields to 40% and more (dependant on the growing culture). A climatic function can be understood in the context of decreasing plant transpiration, when water - as the factor of plant growth - is in minimum. A plant can regulate a transpiration in unfavourable climatic conditions by closing leaf stomata, but it also stops the process of photosynthesis, and therefore a biomass production. LEIBUNDGUT (1975, cited by GOLOB 1988) refers that regulation of the wind speed is the most important forest function in lowlands, having mostly dry soils. The influence of the forest on the wind speed can be observed in the distance that equals 2-4 stand heights in ahead wind-side, and 10-15 stand heights on the back wind-side. Forest as an enormous ecosystem is also the largest consumer of CO_2 (compare LARCHER 1991) and is a natural filter as well as consumer of many other substances.

5.2 Economical functions

A *social economic* function is of particular importance in this region. Classic farming does not exist in this region but is mostly run on enclosures, dated centuries ago. Their number within our territory is yet unknown (at least to foresters). By taking into consideration the data received by the large scale landscape inventory (KOVAČ 1991) we can only assume, that the density (in the elevation zone above 600 masl) is at least 1 enclosure/ km^2. Enclosures are widely dependant on forest which is some kind of a bank reserve with very low interest rate on one side, and the source of current money flows on the other one. GOLOB and MRAKIČ (1987) are reporting that 60-88% of net income of the total primary production of the enclosure is received in the forest. A preservation of settlements (and cultural landscape) is therefore an imperative, not only for farmers but for the whole society. Similar conclusions are given by BRANDL and BURGBACHER (1985), who researched the same problematics in the region of Baden-Wuertenberg (Germany).

Besides already mentioned aspects, we still have to discuss shortly about non-wood products. Much similar research as reported by KARDELL (1986, cited by GOLOB 1988) from Sweden was launched in Mučka Dobrava in the Slovenj Gradec region. It was found out, that one hectare of pine forest can provide nearly 150 kg of blueberries/ha/year. An average production of the whole region is unknown, but seems to be much higher (better climatic conditions!) than in Sweden.

Besides picking fruits, it is worth to mention some other non-wood products (as a hint for economic evaluation if necessary) such as mushrooming (approx. 10 kg/ha/year), forest beekeeping (approx. 2-10 kg/hive/day), picking medicinal plants etc. (see Forest Wealth - Workshop Proceedings 1991).

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II.
BIOINDICATION OF SULPHUR E(I)MMISSION

Janko KALAN

The bioindication method of sulphur e(i)mission determination on the basis of total sulphur content analysis in assimilation parts of forest trees has been used in Slovenia for about ten years. Since 1985 we regularly follow forest contamination with sulphur compounds on plots of the 16 x 16km bio-indication grid. The main bio-indication tree species is Norway spruce *(Picea abies (L.) Karst)*, while in the areas where spruce does not grow and is not planted, black pine *(Pinus nigra Arnold)* and Scots pine *(Pinus sylvestris L.)* are chosen as bioindicators. Usually, the needles of above mentioned tree species are harvested and analysed for total sulphur content. A current year and one year old needles are used and the results of analysis are classified into four total sulphur content classes. In the first class are those bioindication plots with the lowest sulphur content, where concentrations of total sulphur in needles are corresponding to normal, nature values, and in fourth class are bio-indication plots with the highest sulphur contents.

Classification is made by help of marginal values from next two tables:

Table 1: Modified marginal values for classification of total sulphur content in current year and one-year old Norway spruce needles, analysed with SULMHOMAT 12-ADG instrument.

classes Sulphur content	contents (S) in % of needle dry weight	
	classes current year needles	one year old needles
1	up to 0.098	up to 0.115
2	0.098 - 0.123	0.115 - 0.149
3	0.124 - 0.158	0.150 - 0.192
4	over 0.158	over 0.192

Table 2: Marginal values for classes of total sulphur contents in current year and one year old needles

total sulphur content class	Sum of classes of total sulphur content in current year and one year old needles
1	2
2	3 and 4
3	5 and 6
4	7 and 8

Since 1985, when Slovenian 16 x 16 km bioindication grid was founded, total sulphur contents of Norway spruce needles has been analysed annually, sampled on 56 bioindication plots, using by the IUFRO (International Union of the Forest Research Organisations) prescribed method. Presented analysis of data is based on arrangement of bio-indication plots into total sulphur content classes according to measured total sulphur content in current year and one year old Norway spruce needles.

For each bioindication plot we calculated a frequency distribution of its total sulphur content classes in current year and one year old needles and plot's average sulphur content class for the period 1985-1991. Results are presented on the Fig. 1.

We found out that in the time period 1985-1991 there were six bio-indication plots in first average total sulphur content class, fifty-two plots in second class and the remaining twenty-eight plots were in third class. None of bio-indication plot was found to be all the time in fourth total sulphur content class.

From the frequency distribution of total sulphur content classes for the same period we found out:

- 26 bio-indication plots were all years arranged into first or second sulphur content class. Sulphur content was all the time lower than the marginal value at which we could expect damage on forest trees;
- 32 bio-indication plots were in first or second sulphur content class; by this sulphur content it is possible to expect some forest tree damage which can be ascribed to SO_2;
- 21 bio-indication plots were four to six times arranged into third sulphur content class, otherwise only in first or in second class;
- 7 bio-indication plots were at least once in fourth sulphur content class, that is under marginal value by which we could often see forest tree damage because of sulphur dioxide influence or in third content class.

Forests with the lowest influence of sulphur pollutants are in Alp region, Trnovski gozd, Snežnik, Javornik, Gorjanci and broader area of Kočevje and Ribnica. The most sulphur influenced forests are in the regions like Koroška, Celje, Ljubljana, Zasavje, Maribor and Prekmurje.

From the Fig. 1 is evident, that the nearest bio-indication plot to TPP Šoštanj, Andraž by Velenje (I, 4) is not very much influenced by SO_2. This plot is protected by mountain Oljka ahead of it, what does not allow to polluted air from Šaleška Valley and Celje basin to reach this area. Directly under the influence of TPP Šoštanj is bio-indication plot Podgorje by Slovenj Gradec (I, 3) and probably also the plot Gortina nearby Muta in Drava valley (I, 2). Podgorje is the most by SO_2 influenced plot from the whole 16 x 16 km bio-indication grid.In the time period 1985-1991 we detected only eight times a total sulphur contents of Norway spruce needles to be in forth class, and three times in samples of needles from the plot Podgorje. In other cases fourth class of total sulphur contents was always measured in needles collected from different bio-indication plots. On the plot Gortina till now we have not measured fourth content class, but sulphur contents in needles are among the highest on bio-indication grid. This plot has been for seven years in third content class.

Data about sulphur bio-indication in Slovenia have been systematically collected since 1985. The majority of samples were analysed in the laboratory of the Institute for Forest and Wood Economy in Ljubljana. This data were used also for the preparation of the map, where possible, by thermal power plant in Šoštanj influenced area is presented. Data were collected from area, which is limited by bio-indication plots of vertical bioindication grid lines G and K, and with horizontal line 5 of basic 16 x 16km bio-indication grid and on North with Austrian-Slovenian border (look at the Fig.1). For the certain so chosen localities within this area there were to many data, so it could happen that particular data would overposed another and would not be clearly seen from the map summary. This problem was sold with data reduction. Apart from sulphur content data from the samples collected on bioindication plots there are also data from two sampling profiles, which we can not be entirely presented on this map. So collected data are presented on Fig. 2.

From Fig. 2 the extent TPP Šoštanj influenced area can bee seen. It is also evident that Šaleška Valley is under high SO_2 imission influence. Some places with high level of SO_2 imission are also around towns like Žerjav and Ravne na Koroškem in Carinthia region due to these old SO_2 imission sources. High levels of SO_2 impact were measured also on sites like Graška gora (Plešivec) and Mislinja, where source of pollutants can be ascribed to TPP Šoštanj. It's surprising us that is the environment around the town Velenje relatively clean. That is because of temperature inversion which can be formed at the 100 m above the valley bottom protecting settlements from the polluted air from Šoštanj power plant.

For profile Smrekovec (1577m) - Vinska gora (806m), which crosses the Šaleška valley in windward direction under cyclonic weather circumstances we provided data on Fig. 3. On this profile, a sampling of Norway spruce needles was carried out in autumn 1990. Needles for total sulphur content analysis were sampled from the pair of two felled trees at every 50m of altitude in the profile. From the data shown a very high SO2 impact on Šaleška valley was estimated. Similar profile was made for Drava valley in Radelj area few years ago.

Data for both profiles are presented in two different ways. On Fig. there are data presented by total sulphur content classes (marks/signs) and on the Fig. the data are arranged in relative content classes (marks/signs). Relative classes were got from arrangement of data according to increased values of sulphur content. After that we devided data into five equally large classes so, that are in the first class sites with five lowest values of total sulphur content and in the fifth class are sites with five highest value of sulphur content. Relative classes were made for each class separately. With such presentation we got better overview about the imission situation on sites of sampling profile and it reflected well the influence of altitute, topography of sampling area and distance to thermal power plant.

In Šaleška valley is the most polluted air in western part of valley, in the altitude zone between 450 and 800m. Very high sulphur contents in spruce needles were detected also on some sites in valley, specially near TPP. A similar situation we can see also in Drava valley, on altitude profile between Črni vrh on Pohorje (1536m) over Radlje (cc 350m) to Kapucinarjev vrh on Kobansko (1092m). On this profile we coud see a higher sulphur contents in spruce needles in altutude zone between 500 and 900 m and in the valley bottom.

The data obtained by sulphur bioindication in great part confirmed correct decision about arrangement of TPP Šoštanj immission area, which was prepared by M. Šolar (Kalan et al., 1991, p. 82). He defined the following areas to be influenced by Thermal power plant in Šoštanj:

- Central imission area in the Šaleška valley and northwestern slopes.

In this area effects of polluted air are reflecting in uniform territory. It's very hard to find no damaged forests in this region.

External border of central imission area: Smrekovec (1577m) - Kramarica (1124) - Staknetov vrh (1257m) - Osekani vrh (1220m) - Tolsti vrh (1185m) - Sp. Sleme (1081m) - Bačovski vrh (1149m) - Kotnikov vrh (1220m) - Molakov vrh (1182m) - Farovški vrh (947m) - Kavnikov vrh (926m) - Rdečki vrh (867m) - Anžejev vrh (821m) - Hribarski vrh (760m) - Graška gora - Metulov vrh (815m) - Šmodivnik (923m) - Špik (1108m) - Slopnikov vrh (1063m) - Radojč (937m) - Vinska gora (806m) - Strmec (501m) - Gora (543m) - Andraž nad Polzelo - Gora Oljka (733m) - Šmartno ob Paki - Sedlo vas Gorenje - Soteska - Brezje - Radegunda - Mozirska koča na Golteh (1360m) - Konečka planina - Kal (1318) - Vranji vrh (1375m) - Črni vrh (1405m) - Smrekovec (1577m).

- Extrazonal imission areas

In ekstrazonal imission areas are damages on forests as a consequence of polluted air from TPP Šoštanj and they are lying out of the central imission area.

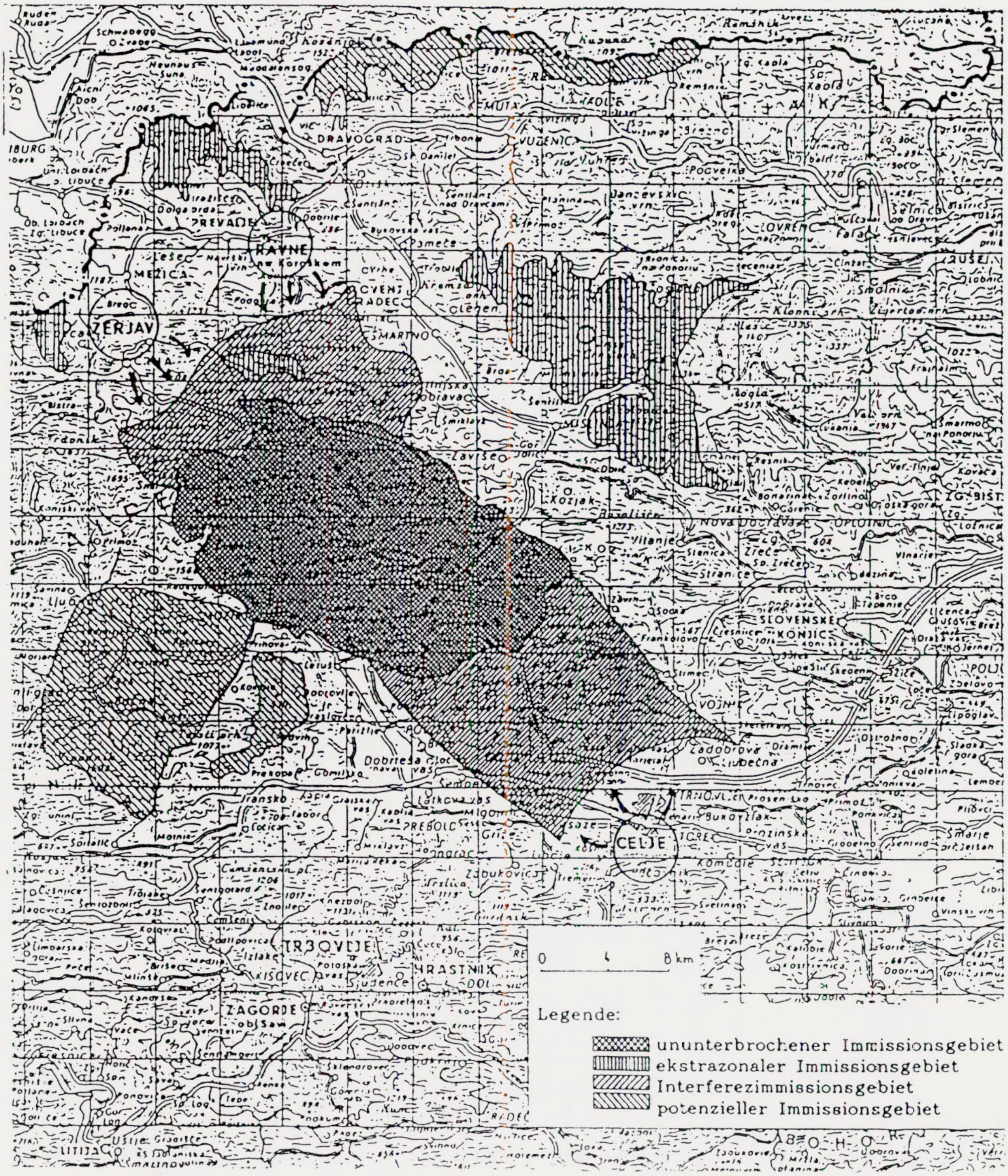

Abb.8: Einwirkungsgebietes von Kraftwerk Šoštanj

On the base of data obtained by sulphur bioindication methods the following extrazonal imission areas can be delimited:

1. Northern slopes of Mislinja Pohorje above altutude 800 m, and southern slopes above 1000 m;
2. On the top of highland/mountain chain between Dravograd and Holmec above 800m;
3. Southern slopes of Uršlja gora (1699m) above 1000m;
4. Eeastern slopes of Peca (Mala Peca 1731m) above 1000m.

- **Interferential imission area**

Interferential imission area is area, where are mixing influences of two or more emitters. In such cases it is very difficult to define a share of influence of decided emitter.

In our case we have to concern with two interferential imission areas, with Celje aglomeration and Mežiška dolina area. We consider that is TPP Šoštanj in treated area the decisive emitter (occasioner/originator of forest decline) also represented interferential imission areas:

1. All convergent territories of imission area Žerjav;
2. Podgorje near Slovenj Gradec, Razborje and Suhadol;
3. All convergent territories with Celje imission area, first of all in area between Gora Oljka and Vinska gora.

- **Potencial imission area**

In extended surroundings of pollution emitter(s) or in sites which are theoreticaly protected due to orography, wind and other climatic factors, periodicaly can happen to bring together such imission conditions which cause damages on forests. Decisive factors for damages on forests are contemporary action or coincidence of natural and anthropogenetic factors which act like triggers for forest decline in the sence of stresses of different origin.

Potencial imission area are:

1. A territory between Mozirje, Ljubno near Savinja, Gornji grad and Bočna;
2. Northern and eastern Menina slopes;
3. Dobrovlje;
4. Ridge territories of border highland/mountain chain between Košenjak and Remšnik.

Potencial imission area between Košenjak and Remšnikom is spreading over state border on Austrian areas (Koralpe, Lavanttal) on what we were warned by Austrian colleagues in visiting forests and investigations objects on both sides of state border. They noticed the increase of sulphur in air in Lavanttal and in Koralpe. They ascribed the increase of SO_2 imissions in this regions to TPP Šoštanj.

Influence of TPP Šoštanj on sulphur imission in Labotska dolina (Lavanttal) is explained also with wind map with air SO_2 concentrations data from air quality measuring station Herzogberg near St. Paul. From the Fig. 3 can be seen that concentration of SO2 in air increased when wind was blowing from Sout-West, the direction of Šoštanj termal power plant.

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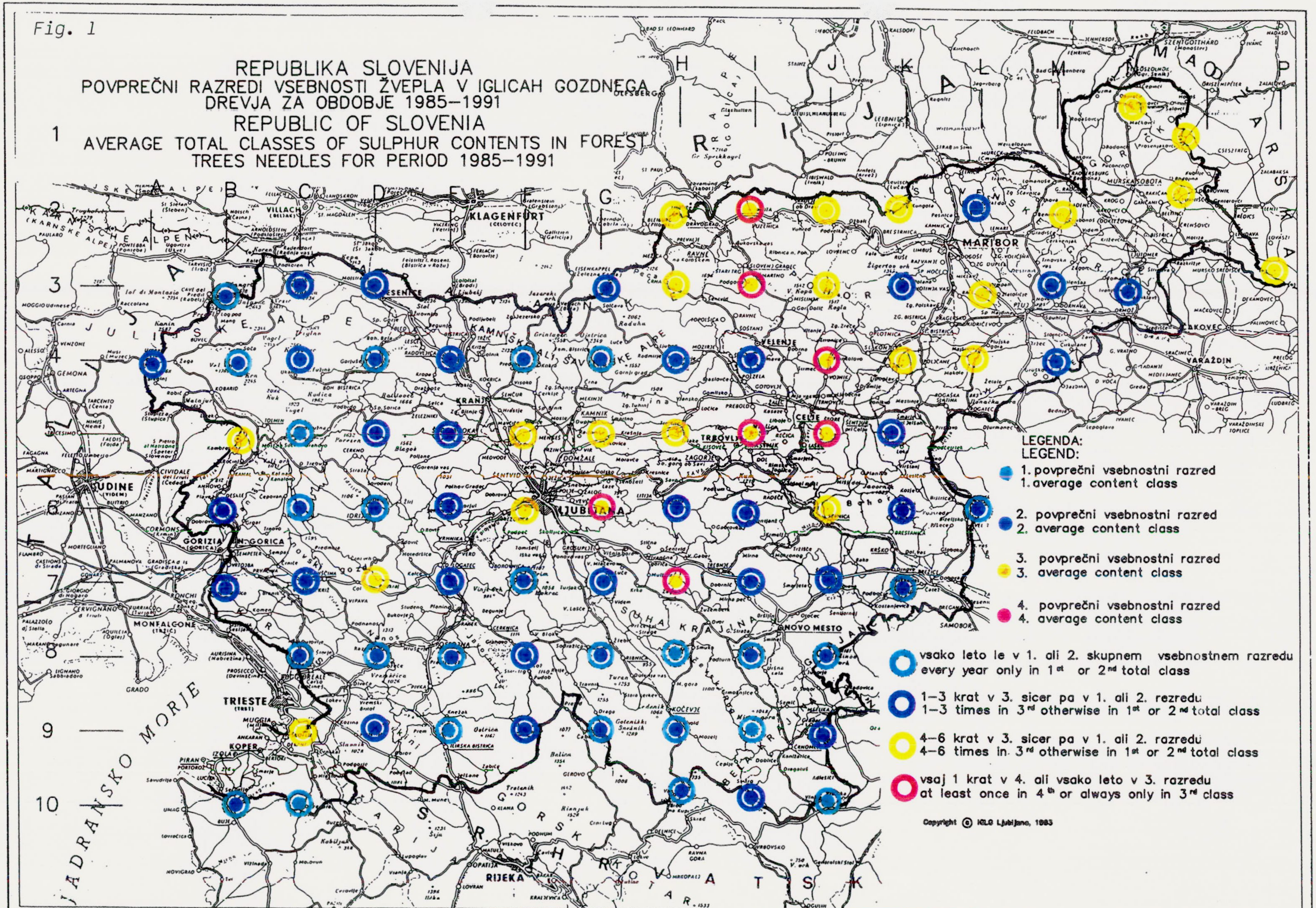
Fig. 1


REPUBLIKA SLOVENIJA
POVPREČNI RAZREDI VSEBNOSTI ŽVEPLA V IGLICAH GOZDNEGA DREVJA ZA OBDOBJE 1985–1991
REPUBLIC OF SLOVENIA
AVERAGE TOTAL CLASSES OF SULPHUR CONTENTS IN FOREST TREES NEEDLES FOR PERIOD 1985–1991
LEGENDA:
LEGEND:
1. povprečni vsebnostni razred
1. average content class
2. povprečni vsebnostni razred
2. average content class
3. povprečni vsebnostni razred
3. average content class
4. povprečni vsebnostni razred
4. average content class
vsako leto le v 1. ali 2. skupnem vsebnostnem razredu
every year only in 1st or 2nd total class
1–3 krat v 3. sicer pa v 1. ali 2. razredu
1–3 times in 3rd otherwise in 1st or 2nd total class
4–6 krat v 3. sicer pa v 1. ali 2. razredu
4–6 times in 3rd otherwise in 1st or 2nd total class
vsaj 1 krat v 4. ali vsako leto v 3. razredu
at least once in 4th or always only in 3rd class
Copyright © KLG Ljubljana, 1983
KLAGENFURT
MARIBOR
LJUBLJANA
TRIESTE
KOPER
RIJEKA
UDINE
GORIZIA
NOVO MESTO
CELJE
VARAŽDIN
JADRANSKO MORJE

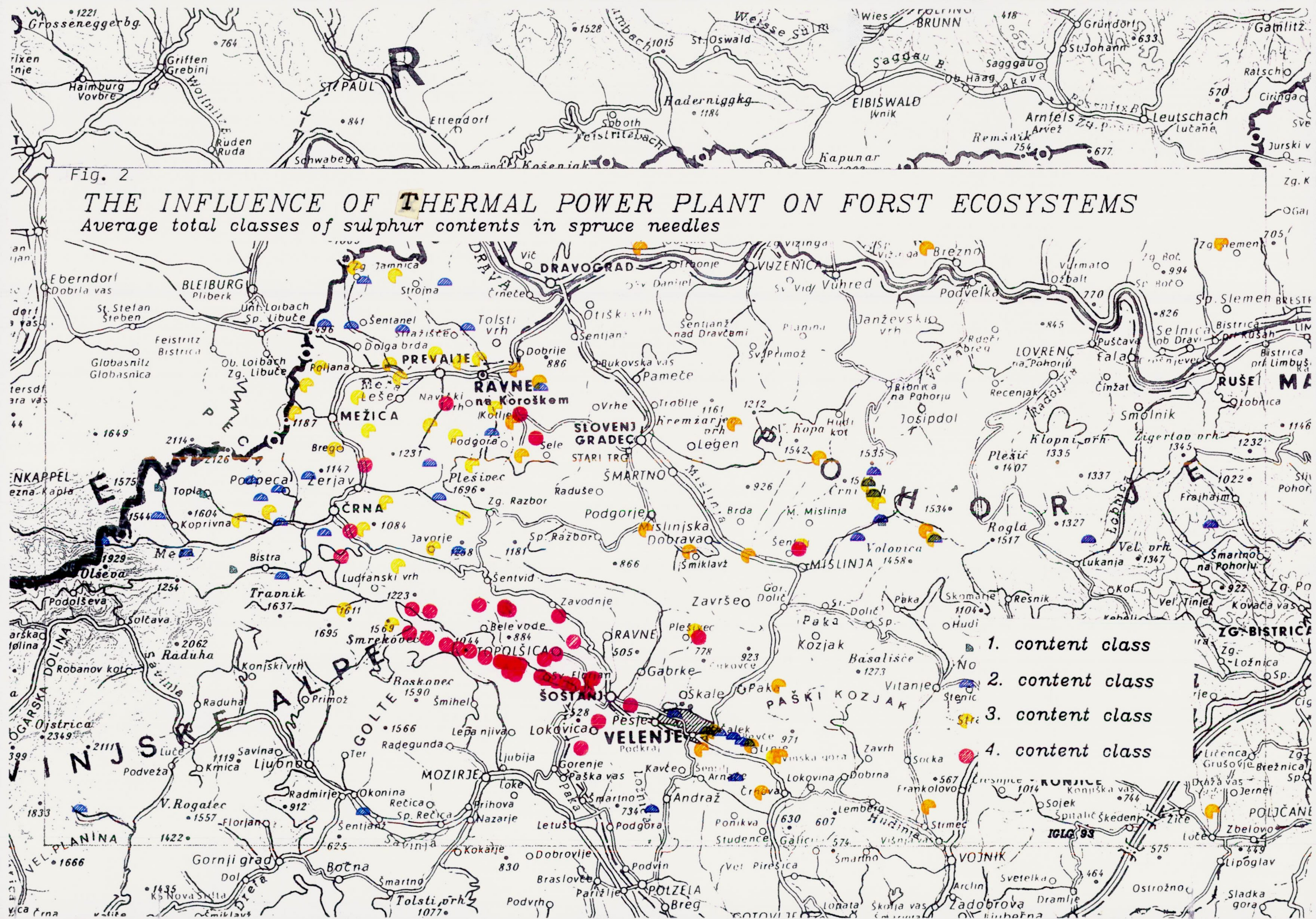
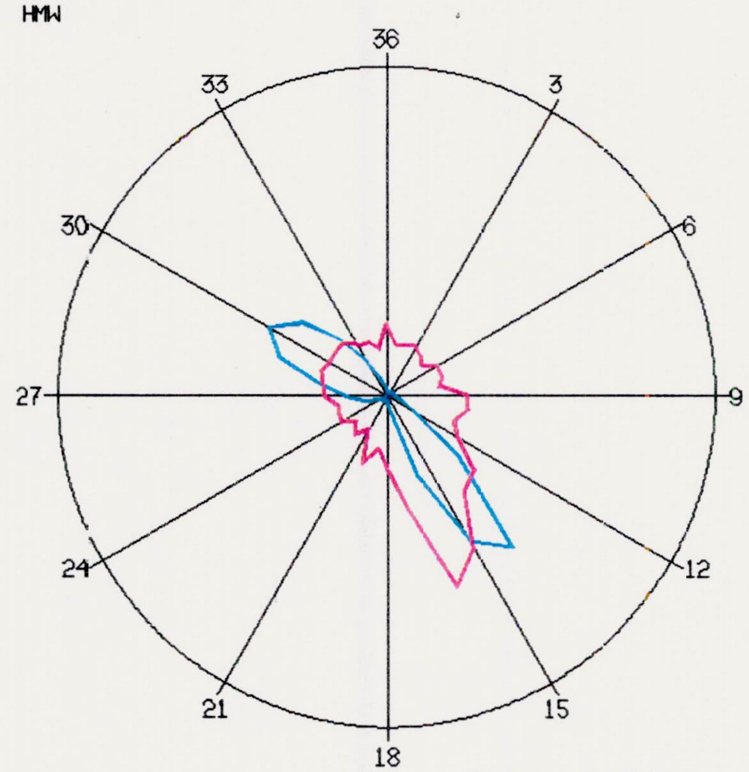


Fig. 2
THE INFLUENCE OF THERMAL POWER PLANT ON FORST ECOSYSTEMS
Average total classes of sulphur contents in spruce needles
1. content class
2. content class
3. content class
4. content class
IGLG 93

Fig. 3

St.Paul-Herzogberg Jaenner - Dezember 1992

Schwefeldioxid [mg/m3]
HMW



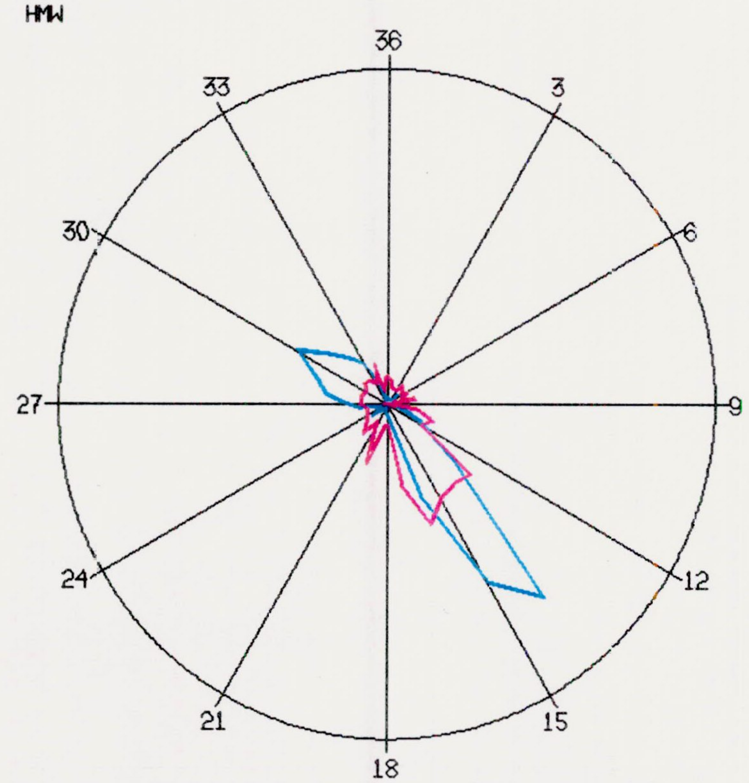
Klasse	Stunden	%	mittl.Konz.
0	1538.0	17.5	0.0102
1	19.5	0.2	0.0078
2	16.5	0.2	0.0084
3	11.5	0.1	0.0088
4	20.0	0.2	0.0079
5	18.5	0.2	0.0070
6	28.0	0.3	0.0069
7	27.5	0.3	0.0068
8	30.5	0.3	0.0079
9	38.0	0.4	0.0122
10	41.0	0.5	0.0126
11	73.5	0.8	0.0110
12	149.0	1.7	0.0128
13	506.5	5.8	0.0173
14	1044.0	11.9	0.0184
15	885.0	10.1	0.0263
16	451.0	5.1	0.0306
17	82.0	0.9	0.0175
18	38.5	0.4	0.0112
19	33.0	0.4	0.0082
20	28.5	0.3	0.0107
21	32.5	0.4	0.0058
22	25.0	0.3	0.0076
23	35.0	0.4	0.0061
24	48.5	0.6	0.0079
25	81.0	0.9	0.0079
26	144.0	1.6	0.0078
27	230.5	2.6	0.0098
28	365.0	4.2	0.0100
29	620.0	7.1	0.0109
30	734.5	8.4	0.0102
31	608.0	6.9	0.0102
32	384.5	4.4	0.0104
33	208.5	2.4	0.0090
34	96.0	1.1	0.0087
35	45.5	0.5	0.0072
36	38.5	0.4	0.0112

Radius entspricht:
Windrichtungshaeufigkeit 20 %
Schadstoffverteilung 0.05 [mg/m3]

Windstille (< 0.5 m/s): 1538.0 Stunden (17.5%)
Ausfall oder nicht gemessen: 183.5 Stunden

St.Paul-Herzogberg April 1993

Schwefeldioxid [mg/m3]
HMW



Klasse	Stunden	%	mittl.Konz.
0	140.5	19.5	0.015
1	1.5	0.2	0.007
2	1.0	0.1	0.005
3	2.0	0.3	0.005
4	2.0	0.3	0.007
5	3.5	0.5	0.005
6	0.5	0.1	0.007
7	1.0	0.1	0.005
8	1.5	0.2	0.060
9	0.0	0.0	0.000
10	2.5	0.3	0.009
11	7.5	1.0	0.015
12	18.5	2.6	0.012
13	38.5	5.5	0.033
14	107.5	14.9	0.031
15	88.0	12.2	0.032
16	43.0	6.0	0.038
17	9.5	1.3	0.025
18	5.0	0.7	0.008
19	3.5	0.5	0.007
20	2.5	0.3	0.017
21	1.5	0.2	0.006
22	3.0	0.4	0.011
23	6.5	0.9	0.008
24	3.5	0.5	0.007
25	3.0	0.4	0.007
26	11.0	1.5	0.006
27	17.0	2.4	0.008
28	27.5	3.8	0.008
29	33.0	4.6	0.008
30	45.5	6.3	0.007
31	33.0	4.6	0.009
32	25.0	3.5	0.009
33	19.5	2.7	0.007
34	9.0	1.3	0.012
35	1.0	0.1	0.004
36	0.5	0.1	0.009

Radius entspricht:
Windrichtungshaeufigkeit 20 %
Schadstoffverteilung 0.1 [mg/m3]

Windstille (< 0.5 m/s): 140.5 Stunden (19.5%)
Ausfall oder nicht gemessen: 13.0 Stunden

III

INVENTORY OF FOREST DECLINE 1987 AND THE EMISSION AREA OF ŠOŠTANJ POWER-PLANT

Dušan Jurc, Tone Kralj
Institute for forest and wood economy, Ljubljana, Večna pot 2

Systematic research on forest damages due to polluted air begun in 1969 in the vicinity of the largest emittors of pollution in Slovenia. In these areas specific damages of vegetation can be attributed to known pollutants. After 1980 new tipe of forest damages appeared, far from the emittors, where toxical levels of air pollution were not detected. This phenomenon was named "forst die-back", "forest decline" and it cause great concern not only to european forestry but worldwide. In the frame of UN/ECE Convention on Lang-Range Transboundary Air Pollution (Geneva, 1979), International Cooperative Program on monitoring forest damages was formed. Slovenia cooperates in this program from the beginning (1987), but as soon as in 1985 the first systematic monitoring of forest decline was performed.

Monitoring is being conducted on permanent research plots which consist of four subplots, every with 6 trees. (24 trees per plot). Plots cover whole forests in Slovenia in systematic 4 x 4 km grid (in most interesting forests it is condensed to 4 x 2 km grid). Due to the differences in critera of setting up a plot (allowing up to 200 m shift of the plot to come into the forest), the largest inventory was performed in 1987. It consisted of 1151 plots with 27.648 evaluated trees (in refined 4 x 4 km grid there is 560 plots). As 1987 inventory is the most extensive ever performed in Slovenia it is taken as the source of data for this contribution.

The mode of forest decline inventory is similiar in all european countries, but our includes more informations and is broader. On every of the 24 trees on the plot the following data are observed: tree species, social position, length of the crown, flowering or fruiting intensity, dbh and then qualitative and quantitative signs of damages: defoliation, yellowing and browning of tree crown, the types of these damages, the character of branching (whip-like, brush-like, claw-like branching). All important ecological parameters of every plot are registred.

From these data degree of damage to every tree is calculated (most of the result is derived from defoliation, yellowing and browning of the foliage) and arranged into 5 classes (0 - healthy, 4 - dead). The degree of damage of the whole plot is derived from all 24 tree degrees, every tree contributing to the result proportional to its degree of damage.

The results of 1987 inventory are showed in Fig.1. The intensity of forest decline is not proportional to known air pollution, but depends on many contributing and inciting ecological parameters. Forest decline is stronger on shallow soils, on windy areas, on warm, dry sites, in older forests, in forests with interrupted structure, on steep sites.

Higher degree of forest damage depends on the high share of conifers in the forest. In the analyses of 1987 inventory all these results were compared and the synthesis was done on regional basis (Šolar et al. 1989). The conclusion was: considering all inciting and contributing harmfull ecological factors in forest enterprises Slovenj Gradec and Nazarje (the borders of forest enterprises are showed on Fig.1), the reason for highest decline of forest in this area is local air pollution.

The influenced area is shown on the Fig. 1 in two categories: moderately damaged forests (the area contains forests with prevailing moderately and severely damaged plots) and severely damaged forests (included are only severly damaged plots which are groupped together around Šoštanj). This area is connected to Celje emission area in south-eastern part and to Maribor emission area in eastern part. The area of moderately damaged forests contains 100,691 ha of forests and the area of severely damaged forests contains 20,674 ha of forests.

One attempt to define the influenced area of Šoštanj power plant was already made, but the actual area was not determined (Kalan et al. 1989). In the mentioned study the influenced area was devided in four categories: central area,extrazonal influenced area, interferential influenced area and potentially influenced area. Comparison of the map from our study with the previons one (Kalan et al. 1989) shows that by our method we got approximately the same area of severely damaged forests and larger area of moderately damaged forests (for app.25%).

In this contribution only one kind of bioindication was used: the damages of trees. More profound view on the impact of Šoštanj power plant to the living sourrounding is achieved if bioindication with epiphytic lichens and bioindication with whole sulphur content of spruce needles are taken into consideration. Both methods detect only air pollutants, mostly sulphur and are presented in other contributions of this report.

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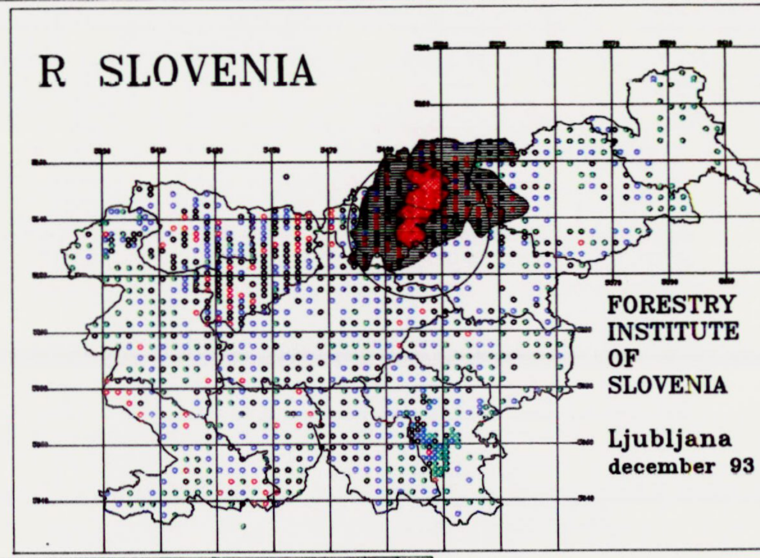
INVENTORY OF FOREST DECLINE

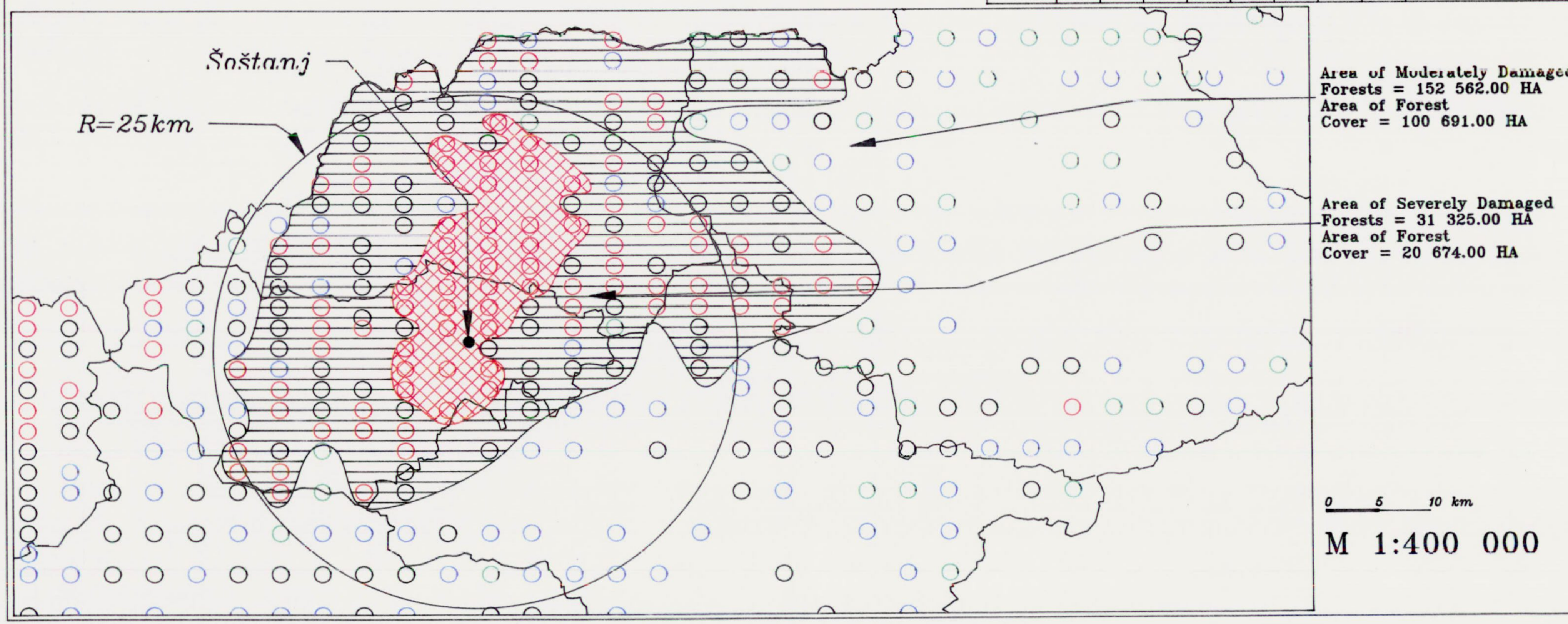
Fig. 1

LEGEND: **Forest Damage Classes**

- ○ – Healthy / 0–15%
- ○ – Slightly Damaged / 16–50%
- ○ – Moderately Damaged / 51–85%
- ○ – Severely Damaged / 86–100%

GRID: 4x4,4x2 km





IV.
BIOINDICATION OF AIR POLLUTION BY EPIPHYTIC LICHENS

Franc BATIČ

INTRODUCTION

Forest decline is very complex phenomena. Several theories and hypothesis have been evolved in order to explain the casuality of that process. Nowadays it is clear that there is no general explanation of that phenomena and that causes for new kinds of forest die-back depend upon time scale changed environment and land use practice. Nevertheless forest decline is still believed to be the consequence of air pollution which causes direct or indirect effects on forest ecosystem. Therefore in almost all investigations connected with forest decline research monitoring of air quality on research plots is necessary. Measurements of different air pollutants input in forest ecosystem are the fundamental approach. As these measurements are rather costly and difficult to carried out in remote and not easy accessible forest environments several bioindication methods have been developed in order to solve that problem. A bioindicator is every organism which responds with it's life function to changes in the environment, also to air pollution (ARNDT et. al. 1987, SCHUBERT 1985). According to the same authors bioindicators can be devided to reactive indicators and accumulators. In the first group are organisms which respond to environment/pollution with their activity, structure and distribution. Accumulators at first just accumulate certain pollutants without significant harmful effects within certain dose of exposition. Bioindicators help to monitor the environmental quality, and qualitatively complete chemical measurements of air pollutants. At Slovenian forest decline studies several bioindication methods have been implemented. Biochemical analysis of plant organs and tissues have been used to find out the disturbances caused by air pollutants. Total sulphur content analysis of Norway spruce needles is the typical example of bioindication method used in order to follow air pollution with sulphur compounds. For general air pollution assessments on forest die-back inventory plots another well known bioindicators we introduce, namely the epiphytic lichens.

METHODS

Epiphytic lichen vegetation has been used as air quality bioindicator in the forest die-back inventories since 1985 (BATIČ & KRALJ 1989, BATIČ1991). From the several observations and laboratory experiments it is known that lichens are one of the most air pollution sensitive plants (SKYE 1968, BADDLEY et all. 1973, HAWKSWORTH & ROSE 1976, GLIEMEROTH 1990, etc.) due to their structure and biology. The simplest lichen bioindication method was accepted, i.e. the mapping of crustose, foliose and fruticose epiphytic lichen thalli types in forest die-back inventory plots. For each thallus type the frequency and coverage were established separately at three heights of observed trees (three base: 0-0,5 m; three trunk at breast height: 0,5 - 2, 5 m; three crown : trunk above 2, 5 m and crown). From the data so obtained an index of atmospheric purity was calculated (IAP) representing air quality measure. The values of index were ranked into classes like forest damage or sulphur content in needles and entered into the map of Slovenia. A lichen map of Slovenia was constructed that way, representing well air pollution situation in comparison with measurements of air pollutants and distribution of the major air pollution sources. Air quality is monitored in Slovenia regularly on 42 measuring stations by Hydrometeorological Institute in

Ljubljana for at least twenty years. Unfortunately these measuring stations of air pollutants are situated mostly in more densely settled areas, i.e. major towns and other pollutants emitters what is connected with a care for public health. Some extra measuring stations are also around greater polluters like thermal power plants in Šoštanj, Trbovlje and Ljubljana. Measurements of air quality out of these areas are absent or limited to only few data obtained at certain activities dedicated to controlling energy productions, road building and urban planning but unfortunately not to forest decline studies. Another weakness of these measurements is that they are limited to sulphur dioxide and dust particles and on quite few measuring sites photooxydants (ozone, PAN, etc.), nitrogen oxides, fluorides and other air pollutants are being measured. That was another reason for use of bioindicators of air pollution at forest decline studies.

When staying at epiphytic lichens as air quality indicators there is another reason for their implication at forest decline studies. As has been already mentioned in this expertise by different writers forest decline is very compound process, where several partial processes are going on in atmosphere, plants and other organisms and in forest soils. Therefore all parts should be considered and when explanations are drawn in one system it should kept in mind its relevance for the whole system. In this respect , the epiphytic lichen vegetation reflects well air quality and is much less dependent on other variables which also influence the growth of trees. They depend on quality of forest soils only in regard of forest tree species distribution but not directly in supply of nutrients and water. Therefore we use epiphytic lichens as tools of differential diagnostic when explaining forest health status in certain forest stand. They reflect well air quality (presence or absence of air pollutants, moisture and light regime, wind influence, etc.) but not other factors which contribute to forest decline (degradation of forest soils through pollutants input or wrong land use, biotic factors like pests and diseases, etc.)

DELIMITATION OF EMISSION AREA OF THERMAL POWER PLANT IN ŠOSŠTANJ BY EPIPHYTIC LICHENS

The knowledge about emission area of thermal power plant in Šoštanj has grown during plant operation. At first nobody cared about the emission of pollutant gasses because only energy counted. That period was followed by period of so called "local emission areas" when it was believed that air pollution effected only close surroundings of emission sources. Big chimneys were constructed and air quality was measured in the neighbourhood of polluters. Much of this thinking is still presents in the area considered. Namely, all air pollution measuring stations are still in Šalek valley and measuring very well air quality in this area. None of stations (so called ANAS stations) has not been moved for longer period on more remote sites like ridges of Pohorje, or hill tops in eastward direction of the plant. Partly is such situation the consequence of public pressure in the valley but meteorologists who were in the past quite self-sufficient are also responsible. Therefore we must use bioindication methods for the evaluation the emission area of power plant in Šoštanj.

Several epiphytic lichen studies has been carried out and some are still going on in the area. We think that there is no need to prove that air in Šalek valley is severely polluted. Therefore we shall not present lichen data for the valley itself, especially as majority of lichens have disappeared from the valley and surrounding slopes. To show the influence of TPP in Šoštanj on epiphytic lichens and air quality in the Slovenian scale we took lichen data from the forest dieback inventory carried out in 1987 when grid of observation plots was the densest (4x4 km or even 4x2 km) and show well overall situation in Slovenia and also around Šoštanj. We took that inventory also therefore because in the middle of eighties there was a strong coincidence of air pollution effects and unfavourable climatic factors like strong winters, severe draughts and forest health status was worse than nowadays.

Data of epiphytic lichen observation in forest die-back inventory are presented in Fig. 1. State of epiphytic lichen vegetation on trees of forest-dieback inventory plot is expressed by values and classes of index of atmospheric purity (IAP). On the map presented in this report, the values of IAP are classified into four classes. Low values of IAP, red circles on the map, represent very poor epiphytic lichen vegetation and very polluted air, high values of IAP, green circles on the map represent very rich epiphytic lichen vegetation and clean air. Values of IAP which are between both extremes, violet and blue circles, represent polluted and slightly polluted air or poor and modest epiphytic lichen vegetations.

A review of so constructed lichen map (Fig. 1), based upon values of IAP reflects well overall air pollution situation in Slovenia. All major air pollution sources are clearly seen, the old ones like bigger towns and old industrious regions (Ljubljana, Celje, Maribor, Zasavje) are outstanding but the spread of pollutants from more recent source in Šosštanj (TPP) is also evident. It is also seen that all major emission centres meet together and that is difficult to delimit the influence areas of separate sources.

When focusing our attention on closer surroundings of TPP in Šoštanj we can delimit closer area of very polluted air (63,598.45HA, covered by forests 41,975.00 HA), with the lowest IAP values and striped red on the map. This area is much broader than Šalek valley area itself and it is seen that polluted air spills over hills and valley surrounding mountains in north-east direction, but also to Soothe-West. We did not match this area with also very polluted regions in the East around Celje where we face with an old pollution centre which is nowadays also influenced by TPP in Šoštanj. We have not indicated either very polluted higher elevation sites in east direction from the TPP which are influenced by Šoštanj source during cyclonic weather situation.

The broader emission influenced area is much bigger, representing polluted air and spreading more westward from TPP in Šoštanj due to prevailing wind direction. This area, striped grey, was constructed by matching plots with similar IAP values, mostly with polluted but some also with slightly polluted air due to position in protected sites. The whole area is very large (215,887.0024 HA) and forest cover is also high (142,485.00 HA). On the base of other, more specialist lichen studies (not presented in this report) we can state that the whole area influenced by emission from TPP in Šoštanj is much larger but of course there we must be aware of transboundary air pollutants transport and delimitation of pollution sources is even more difficult task. Therefore we have already planned to carry out more detailed study of the TPP Šoštanj influenced area, especially to define outer limits of influence. More detail description of that study and reasons for it will be described in final discussion of this expertise.

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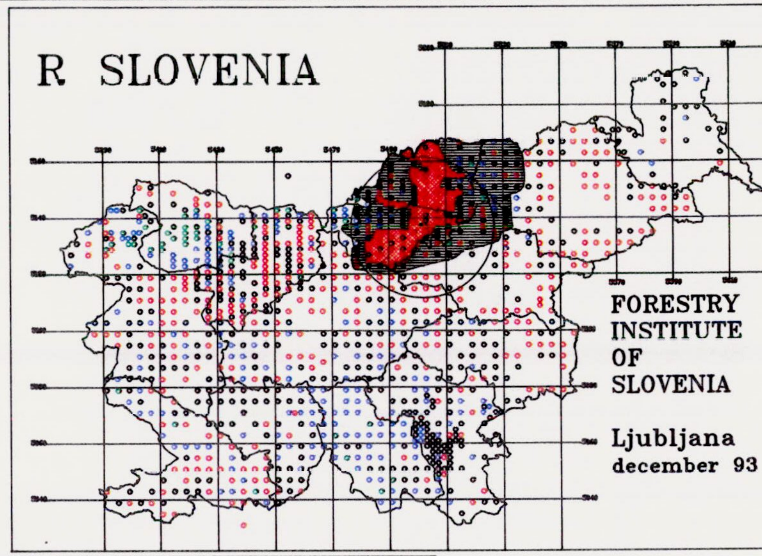
INVENTORY OF FOREST DECLINE

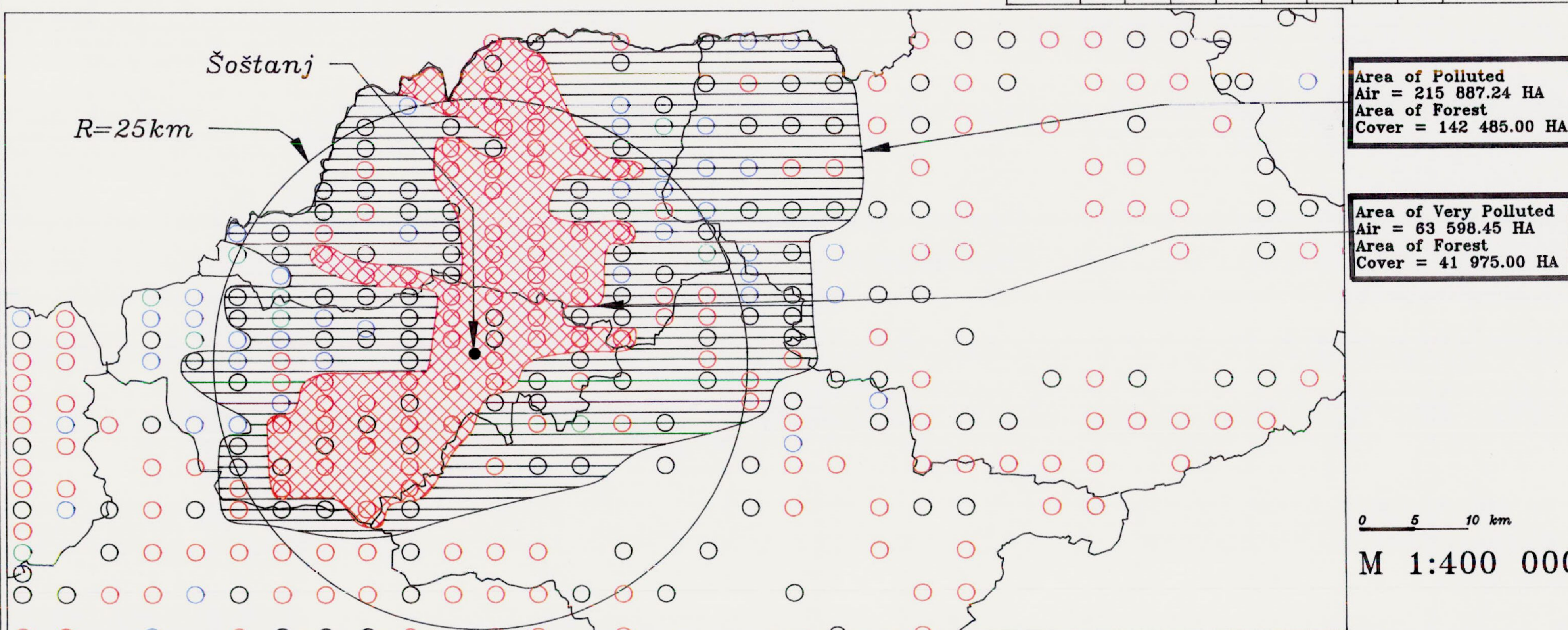
Fig. 1: Lichen map.

LEGEND: Atmospheric Purity Classes

- (red circle) – Very Polluted Air /0-7 IAP
- (black circle) – Polluted Air / 8-14 IAP
- (blue circle) – Slightly Polluted Air / 15 -20 IAP
- (green circle) – Clean Air / 21-28 IAP

GRID: 4x4,4x2 km





VI
PUBLIC OPINION AND FOREST DIE-BACK IN SLOVENIA

Dušan JURC
Institute for forest and wood economy, Ljubljana

This contribution is a summary of two research works which appeared as manuscripts (Štefe 1988, Štefe 1990). The first deals with Slovene public opinion about die-back in 1987 and the second compares the changes of the public opinion between the inquiry of 1987 and 1990.

Slovene public opinion is sistematically followed from the year 1968. The task is performed by the center for research of public opinion and mass media which belongs to the Faculty of sociology, political sciences and yournalism. The quistions about ecologocal problems first appeared in this research in 1973 and from that time to 1990 they were included in the questionnaire six times. The questions were the some all the time, but two additional ecological problems were added later : about nuclear energy and about forest die-back.
In the year 1987 there was 2033 persons inquired and 2051 in the year 1990.

The questions were asked in the following order (added are results for 1987 and 1990 in %) :
In your living and working sourrounding are you troubled, threatened ...etc., by the following phenomena:

	1987	1990
- a/ air pollution, smoke, bad smell	32,3	48,0
- b/ loud noise, rumble of traffic, factories	23,6	29,8
- c/ dirtiness of living sourrounding, rubbish, filth	49,8	55,9
- d/ industrial waste, chemicals, pollution of water	45,6	56,3
- e/ pollution of natural sourrounding, waste disposals	40,7	49,0
- f/ chemicals in food	52,8	62,2
- g/ traffic disorder, traffic accidents	50,5	51,8
- h/ threat of nuclear energy, radioactive materials and wastes	42,4	50,4
- i/ forest die-back	62,4	66,1

The ranges of threatening were groupped in following order (included are results for forest die-back for 1987 and 1990 in %) :

	1987	1990
- a/ it is not a problem in my sourrounding	15,4	5,0
- b/ it doesn't disturb me	5,4	5,6
- c/ it disturbes me, but not much	15,1	21,6
- d/ it disturbs me very much, it harms me	43,8	44,7
- e/ it threatens me, it threatens my life	18,6	21,4
- f/ I don't know, undecided	1,7	1,8

Forest die-back is estimated as the most important ecological problem by 66,1 % of the sample.

The same percent (66,1 %) of people think that this problem threatens their life or at least disturbs them very much (d, e), and if more neutral group is added (c - it disturbs me, but not much) we get an impresive percent of 87,7. This means, that only 12,3% of Slovene population doesn't look at forest die - back as serious existential question.

There is practically no diference between answers of men and women (0,5 %). Forest die-back is considered most important by most active categories of population. The youngest (up to 25 years) and the oldest (61 years and more) part of population have the lowest percent of positive answers about forest die-back problems. The respond depends very much of the education. If we consider only answers d and e (it disturbs me very much, it threatens my life), we get the following table:

	1987	1990
primary school	55,6	57,8
technical school	62,9	63,7
grammar school	67,3	73,8
high school	76,8	80,3

Besides the age education is the most important factor on which diferentation of opinion is determined. Again, the active part of the population considers forest die-back as most threatening ecological problem.

LITERATURE:

ŠTEFE, T., 1988: Slovensko javno mnenje in propadanje gozdov, Inštitut za gozdno in lesno gospodarstvo, Ljubljana, 33 p.
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CONCLUSIONS

On the basis of above commented topics and some other not yet cited literature data we would like to stress certain points which should be considered when decisions about sanation of unit five in TPP Šoštanj will accepted or omitted:

1 Extent of emission area of TPP in Šoštanj has not been delimited. Further ecological studies in this area are necessary even before the installation of cleaning devices on unit four. Therefore the investigation, entitled "Raziskava stanja gozdnega ekosistema na vplivnem območju Termoelektrarne Šoštanj pred obratovanjem odžveplevalne naprave v Termoelektrarni Šoštanj (Investigation of the state of forest ecosystem before installation of desulfurisation device in Thermal Power Plant Šoštanj") should be carried out to get enough data for delimitation of influenced area and more precise calculations of eventual timber and other losses.

2. Any kind of air pollution abatement is acceptable and economic reason should be respected but not with great risk of ecosystem damages or even disfunction.

3. It should be stressed that air pollution in TPP Šoštanj area is rather young phenomena and that all negative consequences have not expressed yet. In the nearest surroundings of the plant we can talk about classic emission zone with severe damages of aboveground plant organs, especially in years with unfavourable climatic conditions. This is demonstrated the best by high needle loss in Norway spruce, by high total sulphur content in needles and very poor epiphytic lichen vegetation (BELEC 1992). There are also first signs of soils damage in the sense of Ulrich's hypothesis of forest dieback (ULRICH 1983). Namely, there is already a noticeable elution of magnesium and calcium in forest floor on the most polluted sites like Zavodnje (SIMONČIČ 1992). This process can lead to acidification of forest soils and mobilisation of aluminium, which is toxic to plants. Such development of changes in forest soil can be expected in all areas with crystalline bedrock and in the case that pollution is not abated can lead to complete breakdown of forests resulting in steppe like grass vegetation. Such development can be expected especially on higher elevations on the Pohorje mountings where we have together two unfavourable elements namely crystalline bedrock and monocultures of Norway spruce. There are also signs of metabolic disturbances in Norway spruce needles which can be regarded as sequences of air pollution impact, i.e. changed chlorophyll age pattern content , changed activity of certain enzymes like peroxidase and diturbed levels of protected substances like ascorbic acid, thiols etc. (RIBARIČ-LASNIK 1991).

4. Evaluation of damages due to influence of air pollution only on the wood increment basis is completely unacceptable.

LITERATURE:

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