WORKING PAPER

GENERAL PROBLEMS OF FOREST ENVIRONMENT PROTECTION IN POLAND

Andrzej Szujecki

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WP-89-73

Publication Number 98 of the Biosphere Dynamics Project

IIASA
International Institute for Applied Systems Analysis

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A-2361 Laxenburg, Austria

ABOUT THE AUTHOR

Professor Dr. Andrzej Szujecki was born in 1929, and is now Head of the Department of Forest Protection and Ecology, Warsaw Agricultural University. His main area of scientific work is taxonomy and ecology of insects. In 1962 he embarked on a series of experiments over many years to identify the effects of human activities on insects communities and functioning pine-forest ecosystems. He worked out the concept of forest ecological engineering as a set of counteracting methods against degradation of ecosystems. He is the author of *Ecology of Forest Insects*, 1987 (Dr. W. Junk Publishers). He has performed several functions in Polish science: Dean of the Faculty of Forestry WAU; President of the Polish Forestry Society; Chairman of the Scientific Council of the Forest Research Institute in Warsaw; Chairman of the Scientific Council of the Institute of Ecology, Polish Academy of Sciences; Chairman of the Section of Forestry and Wood Technology in the Technical-Scientific Council at the State Ministry of Agriculture, Forestry and Food Economy; Deputy Chairman of the Committee "Man and Environment" at the Presidium of the Polish Academy of Sciences; and Member of the State Council of Environment Protection. His address is:

Department of Forest Protection and Ecology
Warsaw Agricultural University
ul. Rakowiecka 26/30
PL–02-528 Warszawa
Poland

FOREWORD

Within IIASA's Environment Program, the Biosphere Dynamics Project seeks to clarify the policy implications of long-term, large-scale interactions between the world's economy and its environment. The project conducts its work through a variety of basic research efforts and applied case studies. One such case study, the Forest Study, has been underway since March 1986, and focuses on the forest-decline problem in Europe. Objectives of the Forest Study are:

a) to gain an objective view of the future development of forest decline attributed to air pollution and of the effects of this decline on the forest sector, international trade and society in general;

b) to build a number of alternative and consistent scenarios about the future decline and its effects; and

c) to identify meaningful policy options, including institutional, technological and research/monitoring responses, that should be pursued to deal with these effects.

In the framework of the Forest Study a whole series of working papers on the conditions of the Polish forest sector have been published. This paper is one in the Polish series under the auspices of the Forest Study. The objective of this study is to analyze new management systems for environmental protection of the forest resources in Poland.

B.R. Döös
Leader
Environment Program

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The author would also like to thank the Department of Forest Organization and Geodesy at the Warsaw Agricultural University for the construction of maps representing the dangers threatening Polish forests.

Special thanks are also dedicated to Peter Duinker (formerly a research scholar with the Biosphere Dynamics Project's Forest Study) for adjustments to this paper.

ABSTRACT

From the very beginning of mankind, forests affected the shape of human civilization by supplying environmental values and food, wood and its derivatives harvested in the course of merciless exploitation. Changes in the environment caused by human activity included whole forest biocenoses, which acquired an ever increasing degree of anthropogenic character over considerable expanses of Europe. Destruction of the earth's surface, forest fires, extreme weather factors, disease, outbreaks of noxious insects, and a mass appearance of game animals affected forests in Poland during the last 200 years, but especially in recent decades. Soil degradation is also observed, mainly in oligotrophic habitats of coniferous forests, as a direct consequence of overly intense forest utilization. Century-long changes in the turnover of elements in forest ecosystems overlapped with deposition of air pollutants over the last 40 years.

Poland belongs to the majority of European countries which receive from local sources and from abroad more atmosphere pollutants, e.g., sulphur, than they export. Complex influences of air pollutants under certain weather conditions lead to forest decline. However, trees die sometimes also under low concentrations of pollutants, without signs of insect or fungal activity, even under favorable climatic conditions. In this paper, the inventory of Polish forests, as well as the program for monitoring decline, is discussed and the regionalization of forest decline is shown. Then, counteracting methods against degradation of forest ecosystems used in Polish forestry are presented. I suggest new forest policies and propose a new model of forest management as well as restriction of technical pressures on the forest environment.

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GENERAL PROBLEMS OF FOREST ENVIRONMENT PROTECTION IN POLAND

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INTRODUCTION

The forests of Poland have been intensively exploited since the fifth century by an increasing population. As a consequence, there have been substantial changes in forest-area distribution, species composition, age-class structure, and growing stock. The properties of soil and groundwater in Poland's forested areas also were modified. These transformations involved the entire forest biocenosis which gradually assumed a more and more anthropomorphic character. Finally, the development of mining, fossil fuel energy, and industry resulted in air pollution that unfavorably affected the sanitary state of the forests and accelerated the transformation of forest biocenoses and degradation of forest habitats. Prevention of these threats was and is extremely difficult not only because of the development of a technical civilization that has taken little account of the environment, but also because of increased demand for wood which finds more and more applications.

Coordination of the productive and infrastructural (protective and social) functions of the forest is beyond the scope of traditional forestry and requires agreements among various sectors of a national economy. Thus the development of a general strategy of forest-environment protection is necessary as a component of the Home and World Protection Strategy of the International Union for the Conservation of Nature and Natural Resources (IUCN). The aim of this paper is to present general changes which took place in the forest resources of Poland during its history, the dangers to forests in recent times, and discussion of the problems of forest-environment protection.

PRESENT STATE OF THE FOREST ENVIRONMENT IN POLAND

Forest Area and Wood Reserves

When the Polish State arose some 1,000 years ago, forests covered 80% of the country's area (Wolak 1985). A noticeable shrinking of the area of forests in Poland started in the late Middle Ages (i.e., 13th–16th centuries) when iron smelting and glass, paper and potash production began, tar distilleries arose, building timber was exploited, and a wood industry began to develop. Enormous quantities of biomass were burned or moved to other ecosystems (Szujecki 1985). The first reliable data on the forest area in Poland were given at the beginning of the 19th century (Staszic 1807). The forests amounted at that time (within the boundaries of the State) to 32.7 million ha, which is 43% of the total area of the country. In 1923, forested terrain occupied 24.6%, in 1931 22.2%, and in 1945 22.7% (the latter being 6,465,000 ha of forest) (Czuraj 1982).

Between 1945 and 1985, owing to afforestation of wasteland and farmland of low productivity, the forest area increased to 8.67 million ha and the proportion of forests to 27.7% of the total area (that is, 0.23 ha of forest per inhabitant) (GUS 1987). Forests on old farmland now comprise 15% of the forest area, but their productivity is low and they are sensitive to diseases and pests (Szujecki 1983). The Polish proportion of forested land is lower than the European (31.8%) and world (29.8%) averages and cannot be considered satisfactory. In this connection, official plans call for the increase in forestage of Poland to some 30% by the beginning of the 21st century (Żurek 1988). Nevertheless, in the latest decades, destruction of forests simultaneously occurred in industrial regions owing to mining activity that resulted in the formation of depression craters, submersion, dying, and pollution of forest territory. Destruction also occurs owing to filling-sand exploitation and occupation of forest areas for non-forest purposes. In 1986 alone, damage from mining involved 34,000 ha of forest, and for other uses 1,313 ha were occupied (GUS 1987). The scale of fire as a forest-destroying agent is small in Poland. In 1978, 1,711 forest fires were recorded in Poland (4.7% of all forest fires in Europe). They destroyed 2,054 ha of forest (0.3% of Europe's losses) and brought about losses estimated on 1.5 million US$ (in Europe - 500 million US$) (Karlikowski 1981). Fires are not a cause of a reduction of forest area in Poland and most other countries, because burned areas are being promptly afforested or naturally regenerated. This is the case even with the biggest fires, as the one from 3 to 5 August 1982 which destroyed 1,161 ha of forest in the Lubsko district in western Poland.

The spatial distribution of forests across Poland varies widely - from 11.8% in the Płock district to 48.3% in Zielona Góra district (Bosiak 1986) (Figure 1). In many regions it is particularly unfavorable, mainly because of a disregard for the role of forests in natural-environment and landscape protection, in addition to inappropriate forest utilization and lack of precisely defined borders between forest and cultivated land. The situation is aggravated by severe disaggregation of forest complexes: for instance, the State Forest consists of more than 23,000 forest complexes, 6,000 of which do not exceed 5 ha (Bosiak 1984; Kassenberg and Rolewicz 1985). Nearly 1.2% of Poland's forest area consists of national parks and reserves, and 25% are protection forests (GUS 1987; Kassenberg and Rolewicz 1985). I consider both these values too low to fulfill properly the requirements of forest protection and development of the infrastructural functions of the forest.

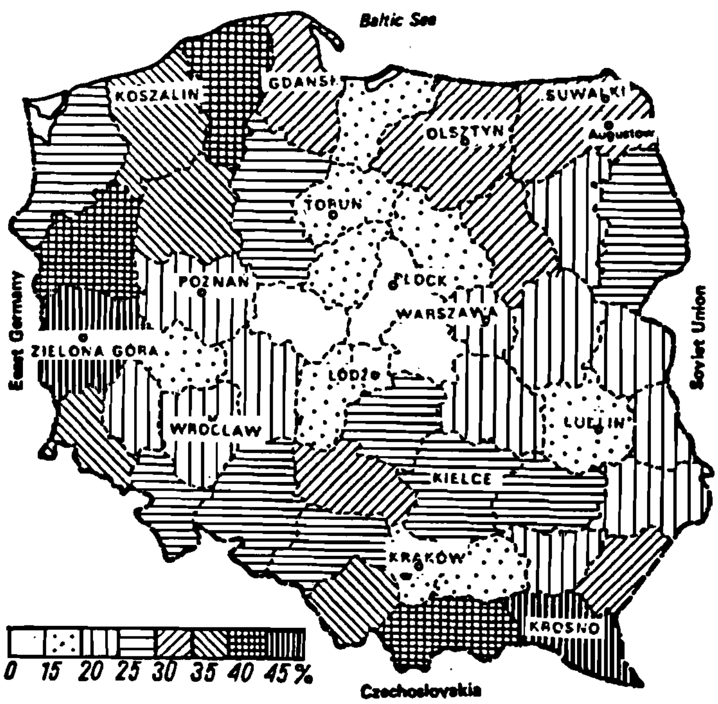

Figure 1. Ratio of forest area by districts in percent.

The basic forest type in Poland is coniferous forest, comprising ca. 82.3% of the forest area, with pine-dominated stands occupying 72.6% of the total forest area (Table 1) (GUS 1987). Spruce (*Picea excelsa*) is the main species in forest stands in the mountains and the northeastern part of the country.

Table 1. Proportions of Poland's forest area covered by different tree species. Data from Marszałek (1982).

Species	Proportion of total forest area occupied (%)
Pine (*Pinus sylvestris*)	72.6
Spruce (*Picea excelsa*)	7.2
Fir (*Abies alba*)	2.7
Oaks (*Quercus robur* and *Quercus sessiliflora*)	5.0
Birches (*Betula verrucosa* and *Betula pubescens*)	4.3
Beech (*Fagus silvatica*)	4.2
Alders (*Alnus glutinosa* and *Alnus incana*)	3.7

Following considerable afforestation since 1945, the gross growing stock now comprises 1.348 milliard m^3 of compact wood in state and non-state forests (GUS 1987) and the mean growing stock in State Forests is 181 m^3/ha. This is, among other things, the result of sustained transgression of the permissible annual fellings in the period 1950–1980 by about 115 million m^3 of the timber reserves, and it has led to utilization of immature stands (IBL 1981). The current volume increment, according to the young age of the stands (53 years in average) is relatively high in the State Forest at over 5.0 m^3/ha, and in all Polish forests about 4.5 m^3/ha. However, in spite of an annual gross increment in the State Forest of about 34 million m^3 and in all Polish forests of 38 million m^3 of wood, this increment cannot be fully utilized in view of a deformed area structure of the age of stands. The annual harvest reaches some 20 million m^3 (Marszałek 1982).

Danger to Forest Habitats

On about 15–30% of the area of Polish forests, a progressive deterioration of soil fertility is observed owing to the degradation of the important physical, chemical, and biological properties of the soil (IBL 1981; Siuta 1974; Szujecki 1981, 1983). This tendency is exacerbated by the inherent sensitivity of Poland's forest soils to degradation, especially in oligotrophic habitats of coniferous forests (Siuta 1974). The areas sensitive to degradation of forest soils coincide with outbreak areas of the majority of pine pests ("outbreak arc"), extending from Zielona Góra over Bory Tucholskie to Puszcza Augustowska forests (Nunberg 1951; Koehler 1971; Szujecki 1983) (Figures 2 and 3). Soil degradation is a consequence of:

(a) harvesting of biomass (i.e., litter, mushrooms, plant cover, brushwood, shrubs, trees, game) and its removal to non-forest ecosystems;

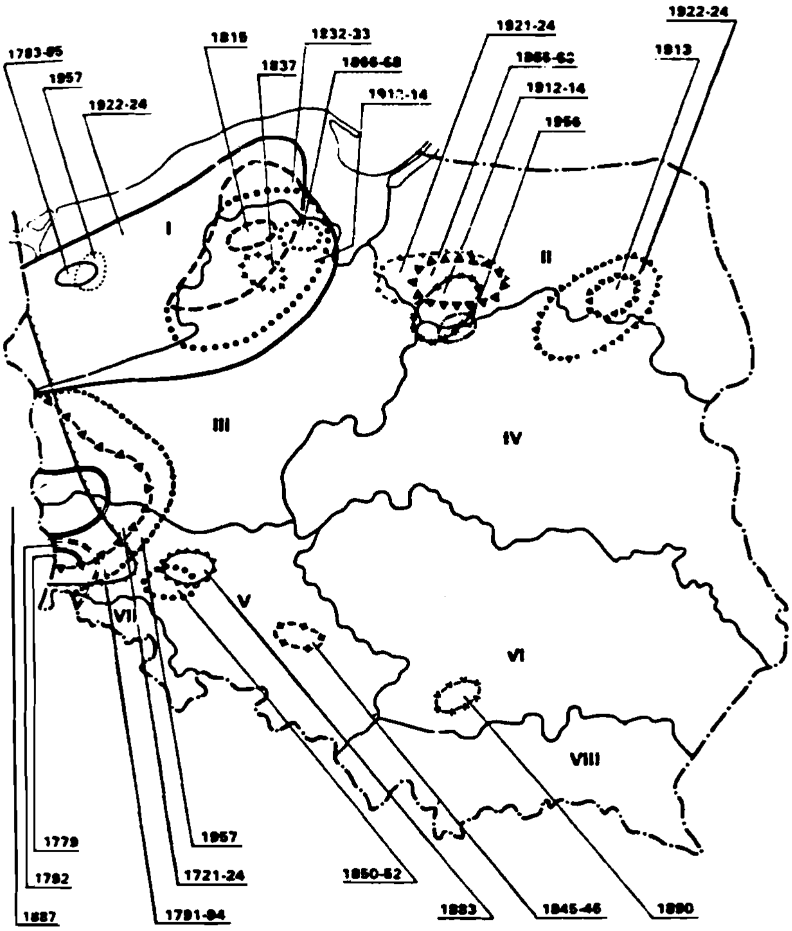

Figure 2. Historical outbreak areas of *Panolis flammea* (D. & S.) in Poland compared with the division of the country into natural-forest regions (Śliwa, after Koehler 1971).

(b) inappropriate forest husbandry for the last 200 years (e.g., coniferous monocultures, clear fellings, intensive soil cultivation, insufficient or incompetent stand management, excessive timber harvesting); and

(c) other anthropogenic influences (e.g., trampling or ruining by means of transport over the forest floor, grazing of farm animals, fires, chemical soil pollution, drainage of neighboring terrain.

In all these situations, the turnover of matter in the forest ecosystems is disturbed. The biogeochemical cycles are usually accelerated and incomplete, and the eluvial process is more or less intensive, depending on the intensity of the above-described transformations and the moisture of the environment.

These processes result in podzolization, the strength of which depends on the degree of disturbance and mineralization of organic matter (Mąkosa et al. 1987). Soil degradation is particularly favored by clear felling applied in Poland from the turn of the 19th century, insufficient utilization of natural renewal, use of heavy equipment for soil cultivation, cutting and skidding of trees, and insufficient stand density. All these factors intensify water runoff and leaching of nutrients from the soil. Soil degradation is, therefore, a direct consequence of overly intense forest utilization. Losses of the six main nutrients, nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur, may reach 3–4.5 t/ha solely from timber harvest in a 100-year cycle. Moreover, during obligatory burning of slash, nitrogen, sulphur, and chlorine pass to the atmosphere, and the remaining nutrients at the burning site are subject to leaching (Kowalkowski 1983).

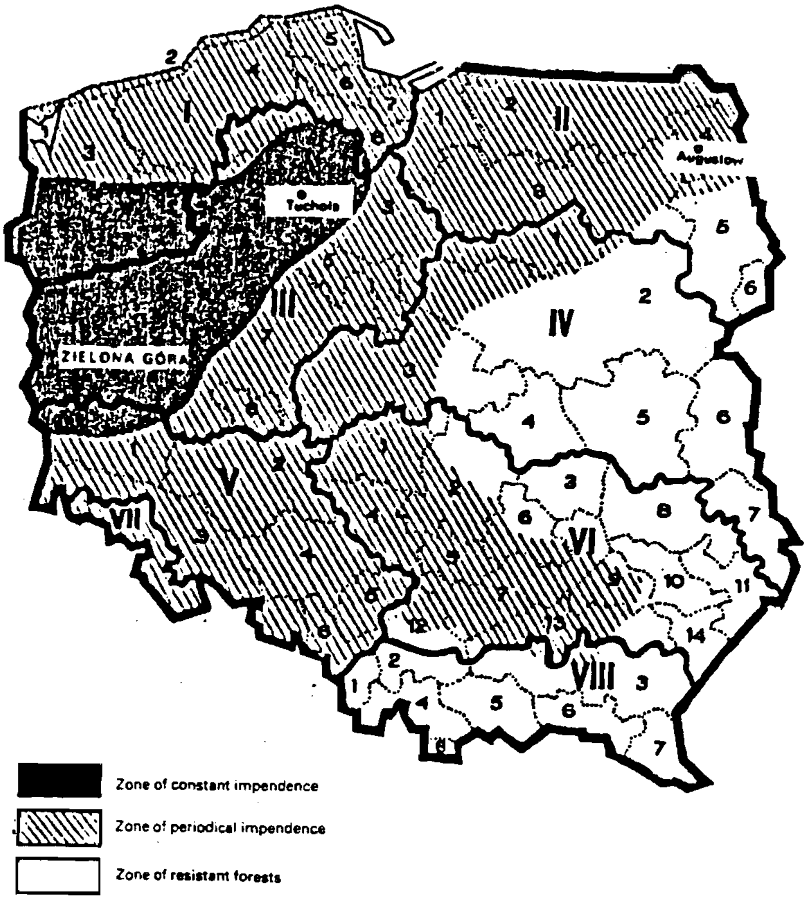

Figure 3. Sanitary zones of forests in Poland (after Nunberg 1951) compared with natural-forest regions.

Forest and ecological sciences have, on a world scale, accumulated sufficient evidence of the detrimental environment effects of clear fellings with associated intensive soil cultivation and use of heavy machinery and herbicides. These management practices severely deprive forest ecosystems of essential nutrients, and exert at higher trophic levels an influence stimulating mass appearance of noxious organisms. Another activity with similar consequences is the utilization of thinnings and roots. These practices, combined with monoculture of coniferous trees, lead to destabilization of forest ecosystems and a limitation of their productivity (Likens and Bormann 1974; Biały 1985; Huhtha 1976; Klimo 1984; van Migroet 1984; Szujecki 1971, 1973).

Since clear fellings are of great practical importance and the forest service has a traditional preference for this method, and so far science has not suggested an alternative satisfactory solution on poor habitats, a change of this system meets with considerable difficulties, if it is indeed possible at all. An example of great progress in this respect is the instruction of the Central State Forest Administration of Poland recommending utilization of natural pine renewal in the eastern regions of Poland (Lasy Państwowe 1983).

If we want to preserve forests for future generations, those who prepare research programs should evaluate the situation concerning this problem and suggest methods which would attenuate the negative consequences of clear-felling management. This means finding ways to manage pine stands from natural or artificial renewal without intensive soil cultivation.

Forest soils exposed in zones of dry and wet sulphur deposition (20–100 kg/ha/yr) become acidified and polluted with heavy metals (PIOS 1986). This enhances the degrading action of the factors discussed previously and is the cause of spontaneous soil degradation, especially in the poorest habitats.

There is little hope that in the near future, sulphur dioxide from Polish sources (amounting at present to 4.74–6.12 million tons per year) (GUS 1987) will be reduced. Moreover, since over 50% of the total sulphur deposition in Poland (1.74 million t/yr) comes from beyond this country (Monitor 1984; Żurek 1988), it may be expected that the degree of pollution in Polish forests will progress, further influencing soil degradation and pollution of groundwater.

Danger to Biocenoses

The age-old process of forest utilization for human needs has led to a considerable synanthropization of forest biocenoses consisting of substituting endemic and stenotopic components by cosmopolitan, allochtonic and eurytopic ones, or in other words, by substituting secondary systems of limited stability for primary ones (Faliński 1972; Szujecki 1979).

As a consequence of clear felling, substitutive biocenoses appear on one third of the forest area of Poland (Szujecki 1971, 1981, 1983). The strategy of rapid reproduction of numerous small short-living organisms with a broad ecological specialization dominates. The rates of biological production and organic-matter turnover increase and further modifications of biocenotic organization take place, from complicated to simpler ones with unknown mechanisms of internal regulation. The unity of the biocenosis with the biotope is lost, and the biocenoses are unable to inhibit the progressing degradation of the ecosystem. The sanitary state of the greater part of Poland's forest biocenoses has deteriorated on account of (a) degradation of forest soils, (b) destabilization of biocenoses, (c) prevalence of young and middle-aged stands, (d) atmospheric pollution by sulphur and nitrogen oxides, ozone, heavy metals, fluorine, and dust, (e) increasing penetration of forest by humans and vehicles, (f) natural calamities (e.g., hurricanes, snow, drought), and (g) outbreaks of noxious insects. Evidence of this may be found in the removal lately of about 70 million m^3 (i.e., about 6% of Poland's total growing stock) of dry or broken trees (Smykała 1986).

The greatest insect outbreak in Poland was that of *Lymantria monacha* moth, which in 1981, despite three years of chemical control, covered 2.3 million ha of forests in northern Poland (Śliwa 1986, 1988). The moth was controlled during the period 1979–1985 on a total area of more than 6 million ha. Historical data show that outbreaks of foliophages occur in Poland almost annually and every 8–10 years are quite vast, covering tens of thousands of hectares of forests. The situation is similar in many other countries of Europe, except Scandinavia and Great Britain. Simultaneously, partial defoliation of trees caused by phytophagous insects without outbreak trends is permanently observed. The occurrence of this damage, along with that of insects and fungi causing premature shedding of foliage, is reflected by results of the large-scale forest inventory which shows a high percentage of damaged trees throughout Europe (Bundesamt für Forstwesen und Landschaftsschutz 1984, 1985, 1986, 1987; Domont 1988; Forest Damage and Air Pollution 1986; FAO 1984; Latocha 1985; IBL 1987).

So-called secondary pests invading impaired trees constitute at present a permanent factor of forest decline in the whole of Europe. It is by no means a new phenomenon, nor is it dependent exclusively on chemical pollution of the atmosphere. In the decline of the 1870s and 1880s as a consequence of the occurrence of secondary pests, dead spruces with the volume of 2.7 million m^3 were cut in Czech forests and 3 million trap trees against bark beetles were set, while in the Harz Mountains 2.5 million m^3 of dead spruces were removed. The calamity was connected with the drought prevailing then in Europe (Szujecki 1983).

Mortality of 8.3 million trees invaded by insects during 1984–1985 (Smykała 1986) characterizes the extent of the most recent intensity of occurrence of secondary pests in Poland. While in the 1970s the volume of trees invaded by secondary pests amounted on average to 1.0–2.5 million m^3/yr, in the years following 1980 it was on average no less than 10 million m^3/yr. This is the consequence of hurricanes, snow-inflicted damage, outbreaks of *Lymantria monacha*, diseases of tree root systems, impact of industrial air pollution, drought, and soil degradation. The damage deranged the continuous structure of forest stands, impaired numerous trees and caused their mortality.

The number of microorganism species playing an important role in tree diseases is low, but their role in forest decline is serious. The greatest spread in Poland, particularly during recent years, indicated diseases of pine and spruce needles causing their premature shedding (*Cenangium* pine needle cats) and dangerous diseases of pine shoots (*Gremmeniella*). The latter appeared at the beginning of the 1980s as severe epiphytosis over vast areas of Europe, Asia, and North America. In Poland alone, the pine epiphytosis covered 200,000 ha. Other important species of infectious fungi – *Armillaria* and *Heterobasidium* – that attack tree roots for years have been present over ca. 230,000 ha (IBL 1981, 1987; Bosiak 1986).

While considering the impact of various organisms on forests, one cannot overlook the increase of numbers of cervids - redroe deer and moose – in whole Europe. These animals seriously damage about 90% of saplings in many regions of Poland, covering about 200,000 ha of forests. Besides, game animals prevent regeneration and introduction of indispensable deciduous undergrowth to coniferous stands (IBL 1981). Excessive numbers of cervids in the Tirol Alps result in 3/4 of the outlays for forest management to be consumed in the protection of young plantations against game. This makes reconstruction of forests difficult where older stands are declining.

Among weather factors, three exert the greatest impact upon the status of forests in Europe. These are hurricanes, droughts, and low temperatures. More and more authors are inclined to consider the two latter as main causes of forest decline on vast areas (Rehfuess 1987; Watt 1987).

During the period 1950–1980, hurricanes in Poland knocked down trees with a volume of ca. 10 million m^3, but during this decade these losses increased, particularly so in 1981–1983 when 15.3 million m^3 of downed trees were extracted in northern Poland (Smykała 1986).

Last but not least, there are droughts. Trees are adapted to a permanent level of groundwater supplying them with most of the water indispensable for life. Prolonged deficiency of rainfall during vegetation seasons occurring in Europe and in Poland during years of 1963–1964 and again in 1981–1983, resulted in lowering of groundwater level (and levels of lakes for that matter) by several scores of centimeters and even by up to 3 m, leading to impairment of forest health status on vast areas. During 1963–1964, five times more dying trees attacked by pests in northeastern Poland were cut than during average years (Wolski 1966). This situation repeated in Poland 20 years later and significantly contributed to the removal of at least 70 million m^3 of dying trees during this decade (Bosiak 1986). A similar situation prevailed throughout central Europe. Perhaps the detrimental role of air pollutants would not be realized until now if it had not been for the droughts of 1981–1983, which stimulated these losses or were in fact their real cause.

Severe frosts from among climatic factors are, under our conditions, of lesser significance. On the other hand fir, a tree particularly sensitive to low winter temperatures, has been repeatedly threatened by them or even died off locally. Beech showed similar response. Reports from the Alps also indicate a stressing role of low temperatures increasing the susceptibility of trees to air pollutants (Rehfuess 1987). The increasing frequency and intensity of hurricanes and weather anomalies of late might be considered as one of the symptoms of global climate alterations derived partly from deforestation in equatorial regions and giving a bleak forecast for the future (Boryczka 1984; Nilsson 1986; Pfister 1988; Trepińska 1973).

While considering the impact of weather and climatic factors upon the status of forests, one cannot neglect the danger, as stressed by numerous authors, resulting from the progressing content of carbon dioxide in the atmosphere and gradual warming of climate (Nilsson 1986). Alterations of this kind are indicated by an increase of the proportion of stenothermal deciduous tree species and the retreat of spruce during the past 70 years from natural forests of the Białowieża Primeval Forest (Kowalski 1982). The phenomenon coincided also with the lowering of average summer temperatures recorded in the northern USA since 1941, and is considered a possible cause of the retreat of certain tree species, particularly so in mountain areas (Watt 1987).

PROTECTION OF THE FOREST ENVIRONMENT

Protection of the forest environment should result from integration of the aims of economic and general social development with the natural permanence of forests for the profit of contemporary and future generations. This implies conservation, maintenance in a good state, and continuous utilization and renewal of living and inanimate components of forest ecosystems.

The main task of forest-environment protection may be achieved by:

(a) maintenance of the basic ecological processes and systems favoring continued existence of forest biocenoses (e.g., protection and regeneration of forest soils, matter turnover, and homeostatic mechanisms);

(b) maintenance of the genetic diversity of forest organisms, especially trees, to permit the indispensable practice of selection and silviculture; and

(c) ensurance of permanent utilization of forest organisms and whole ecosystems.

To achieve the general strategy of forest-environment conservation, its partial, indispensable aims are:

(a) the existence and observation of appropriate legislative acts;

(b) progress in spatial planning and industrial technology;

(c) elaboration of a new model of forest management, based above all on ecological and genetic engineering; and

(d) economization and protection of timber and advances in substitution of other materials for wood, to reduce the pressure of the economy and the population on wood reserves.

There are several Polish legislative acts defining principles of forest-environment conservation (Table 2). These and other documents supply a good basis for formal forest-environment conservation, but it does not always find implementation. Let us consider this through the example of an industry-forest conflict.

According to the Forestry Research Institute, the losses in increment of wood in forestry caused by industrial air pollution throughout the country amounted in 1986 to 25 milliard Złoty annually, and in the near future probably will increase to 90 milliard (Bosiak 1986). If we assume that half of these losses are due to noxious emissions in this country, then since 1970 they would amount to about 160 milliard Złoty (according to 1986 prices).

Part of the losses in forestry caused by industrial air pollution are covered by industry on the basis of special contracts intended for forest management in industrial regions. The basic task in these regions is improvement of the productivity of the degraded habitats and adaptation, as far as possible, of the forests to existing conditions. Usually it consists of modification of coniferous stands into mixed or deciduous ones, with utilization of

Table 2. Legislative acts and regulations defining principles of forest environment conservation in Poland.

No.	Name	Date	Authority	Main Features
1.	The Law on Nature Conservation	1949.04.07	Parliament	
2.	The Law on State Forests Husbandry	1949.12.12	Parliament	
3.	The Law on Animal Protection and Game Laws	1959.06.17	Parliament	
4.	The Instruction No. 143	1970.11.19	Ministry of Forestry and Wood Industry	Introduction of danger zones for forests from industry in these zones and assessment of the damage and cost of reconstruction of stands in forests under the noxious influence of gases and dust emitted by industry.
5.	The Law on Planning in Privately-Owned Forests	1973.11.22	Parliament	
6.	The Law on Conservation and Modeling of the Environment	1980.01.31	Parliament	
7.	The Decree	1980.10.15	Council of Ministers	Particular principles of forest protection against pollution with gases and dusts.
8.	The Law on Protection of Arable and Forest Land	1982.03.16	Parliament	
9.	Complex Program of Forest-Management Improvement to the Year 1990 (attached to the Decree)	1984.03.05	Council of Ministers 36/86	
10.	The Law on Spatial Planning	1984.07.12	Parliament	
11.	The Law on Forests and Forests Husbandry	In preparation.		

species more tolerant to air pollution (e.g., black pine, Weymouth pine, European larch, eastern red oak, pedunculate oak, aspen, birch, beech, hornbeam, maples, ash, linden, alder, American birdcherry, buckthorn) (Greszta 1987).

At the same time, expensive agromelioration and phytomelioration practices are underway. In industrial regions, 31,000 ha were reconstructed up to 1975, 17,800 ha in 1975–1980, and 15,800 ha in 1981–1985 (unpublished data of the State Forests). The activity of forestry in industrial regions is, however, not to produce wood but to modify the stands for the preservation of greenery.

ADVANCES IN SPATIAL PLANNING AND INDUSTRIAL TECHNOLOGIES

According to the Committee on Spatial Planning of the Country of the Polish Academy of Sciences (Kassenberg and Rolewicz 1985), it is indispensable to introduce into the plan of spatial management of the country an ecological system of protected areas ("ecological grid") which would constitute a harmonious system with high biological potential. The purpose of this system would be protection of the basic natural construction of the country. The body of the ecological system of protected areas should consist of the existing and planned national and landscape parks and reserves. In consideration of this postulate, the Commission of Planning of the Council of Ministers distinguished 18 problem areas of forestry comprising the most valuable forest territories that are (a) ecologically threatened, (b) play important roles in formation of the natural environment of the whole country, and (c) are important as a base of raw-wood renewal (Komisja Planowania R.M. 1986).

The following types of forest areas were among those identified:

(a) those of basic ecological or productive importance, localized chiefly in the northern part of Poland and partly in mountainous regions;

(b) those threatened by external factors, mainly along the western frontier of Poland, in mountainous regions and along the middle course of the Vistula River; and

(c) those particularly threatened by external factors, comprising the Karkonosze Mountains and the Katowice–Kraków region.

This diagnosis serves to evoke a spatially diversified policy of management of the country for its socioeconomic development. It also gives grounds for different premises concerning models of forest management in different regions of Poland in connection with the state of the agricultural environment, in order to undertake a suitable afforestation policy leading to forest coverage of about 29% of the country's area by the beginning of the 21st century. Afforestation is planned for the poorest farm soils in the zones with lowest annual precipitation and smallest forest area (Partyka 1987).

Air quality in Poland is deteriorating from year to year. In 1975, the area on which pollution exceeded the permissible norms was 8,400 km^2, and by 1980 it increased by 27% (Kassenberg and Rolewicz 1985). The contaminations emitted into the environment are cumulative, and when ecological barriers (themselves difficult to determine) are exceeded, irreversible degradation occurs.

Most of Poland belongs to the region with medium sulphur pollution, but the southwestern part shows the highest atmospheric concentration of this element in all Europe. Generally, the proportion of sulphur falling in Poland and coming from abroad was in excess of 50% and grows continually (Monitor 1984). It varies throughout the country according to the direction of prevailing northwest and southwest winds.

Models of the distribution of sulphur (mainly in the form of SO_2) in Europe indicate that in the mentioned area of its highest concentration in Poland, particularly in western and central Sudety Mountains, 80% of the deposition of this element comes from foreign sources, mainly the German Democratic Republic and Czechoslovakia. Emissions of sulphur dioxide in Poland according to data provided by EMEP and the Warsaw Technical University based on the energetic balance of coal combustion amount at present to not less than 4.3 million t/yr (Monitor 1984; GUS 1987; Żurek 1988). This amount would fill 160,000 railway carriages or, when given to each inhabitant of our country, would amount to 60 kg of pure sulphur once a year. It is, beside the USSR, the greatest emission of sulphur in Europe. Countries which still in 1983 emitted more sulphur than Poland (Great Britain, Italy), restricted it recently (Żurek 1988). From the emitted 2,150,000 t/yr of sulphur, 862,000 tons, i.e., 40.1%, falls on Poland, while 1,288,000 tons (59.9%) – on other countries and on seas. Forty-six percent of the sulphur emitted abroad falls on the USSR, 7.5% in Czechoslovakia, 6% in Romania, 3.5% each in Sweden, Hungary, and Yugoslavia, 2–2.5% each in the German Democratic Republic, Federal Republic of Germany, Finland, Austria, and 1% each in Norway and Denmark.

Local thermal-electric power stations and poor quality coal-combustion stations in towns and cities are important sources of pollution originating in the country. The total deposition of sulphur in Poland amounted at the beginning of the 1980s to 1,740,000 t/yr, i.e., 56 kg/ha/yr per inhabitant (German Democratic Republic – 81, Czechoslovakia – 77, Federal Republic of Germany – 55).

Therefore, the greatest impact on the status of Polish forests comes from pollution from the German Democratic Republic (15.8%), Czechoslovakia (9%), and local sources (49.5%). Probable reduction of SO_2 emission in other countries, e.g., in the Federal Republic of Germany, will have insignificant influences on atmospheric purity and the status of forests in Poland. Deposition in Poland of sulphur from the Federal Republic of Germany, according to sources cited above, amounted to 6.5%, from Great Britain 2.3%, Hungary and USSR 2% each, Yugoslavia, France, Denmark, and Italy – ca. 1% each of the total deposited.

Reduction of SO_2 emissions in developed countries following the Geneva Convention and Helsinki Protocol, along with the simultaneous increase in emission in the German Democratic Republic, Czechoslovakia, and Poland as a result of an increase in brown coal combustion, may bring about a decrease in the proportion of deposition from Western countries, but will not lead to a decrease in absolute values.

Contrary to the identification of mechanisms of sulphur spread in the atmosphere, information about other pollutants is rather scarce in Poland. Pollution caused by the combustion of petroleum and its derivatives, as well as emission of nitrogen compounds from intensively fertilized farmland and animal farms, is consistently on the rise. Emission of nitrogen oxides (NO and NO_2) brought about by human activities in Europe amounted in 1985 to ca. 6 million tons, which constitutes 15–30% of the anthropogenic world emission and the latter is by 4.5–15 times less than the emission from natural sources. In Poland at that time, 610,000 tons of nitrogen oxides were emitted. This means a sevenfold increase when compared to 1975. The emission of SO_2 increased in Poland during the same period by 18%. Nitrogen evaporates in the form of ammonia from farmland in great quantities. For instance, in Sweden 25,000 tons of nitrogen evaporate to the atmosphere annually. In this country such measurements have not been taken, but the phenomenon should be of a wide nature. In Switzerland 20–30 kg of nitrogen (NO_x and NH_4) fall each year on 1 ha of forest. The 5-year amount equals the total annual dose of nitrogen fertilizers applied in agriculture.

Although the effect of nitrogen dioxide on vegetation is strong, of much more significance is ozone and the compound called PAN which is easily formed under appropriate conditions by the oxidation of nitrogen oxides. These oxidants are not measured in Poland, however.

In 1980, 87% out of 915 noxious industrial plants producing dusts were equipped with dust collectors. The degree of reduction in dust pollution amounted to 91.7%. Of 897 noxious plants producing gases, 115 had devices collecting harmful gases and the degree of this pollution abatement amounts to 11.4%. Polish technology has at its disposal eight methods for reducing the emission of gases, mainly SO_2 (coal pyrite reduction, fluid kettles, SO_2 neutralization with dry additives, wet calciferous desulfurization of emissions, dialkaline and semidry desulfurization in low-power boilers with Raszka's method) (Żurek 1988).

All the above technologies were verified under Polish conditions along a semitechnical scale, and for some of them technical documentation was completed to a full technical scale. There is a plan of introduction of these techniques in various industrial plants. Should these projects be executed and action taken to reduce SO_2 in technological processes, one could expect the reduction of SO_2 emissions from Polish industry by ca. 1 million tons in 1995 and some 2.5 million tons in 2000. The rationalization of energetic and thermal economy, involving the reduction in fuel combustion before 2000–2010, should also significantly reduce the SO_2 emissions. Similar plans call for the reduction of emissions of nitrogen oxides so that around 2000 it should be stabilized at the 1985 level of about 1.5 million tons. It is difficult to say today how realistic these forecasts are.

The attainment of a satisfactory status of atmospheric purity will be beyond 2000 (if the German Democratic Republic and Czechoslovakia will join the plan). Even then, the effects of pollution of the forest environment will be visible through the middle of the 21st century.

In the face of low usefulness of the monitoring of atmosphere status carried out by various institutions in Poland for the needs of forestry, the State Forests initiated their own monitoring network in 1985. It is a modified contact method involving the measurement of the dry deposition of SO_2 and NO_x. Measurement points totaling 1,800 cover the entire country within the Network of International World Maps at the spacing of 4 × 4 km in the threatened areas, and otherwise 8 × 8, 16 × 16, and 64 × 64 km. It is planned to extend the monitoring to include other elements, mainly biological ones, to be registered on some 1,500 permanent plots. In light of the complex nature of forest decline, the existence of multifactorial biological monitoring, which could provide data comparable at least at a European scale and for long time series, should be considered fully justified also from a financial viewpoint (Dunikowski 1988).

NEW MODEL OF FOREST MANAGEMENT

The contemporary model of forest management based on the premises advanced by Austrian and German foresters in the 18th and 19th centuries and applied in all countries of the temperate zones requires thorough revision. The main reasons for this are:

(a) a marked increase in the demand for infrastructural functions of the forest;

(b) general transformations in the forest environment through the effects of anthropogenic pressures that threaten the biological production of forest ecosystems; and

(c) the great advances in biological and technological knowledge, allowing revision of the basic technologies applied to date in forestry (Szujecki 1987, 1988).

The question that should be asked now is: along what lines should development of forest protection and silviculture advance to fulfill the requirements of the new model of forest management? It would seem that this development should be based on ecological principles of forest engineering, a discipline which has only lately appeared in the curriculum of the Faculty of Forestry at the Agricultural University in Warsaw. The main strategic purpose of ecological engineering in the protection of forest ecosystems is enhancement of the efficiency and development of the homeostatic mechanisms of managed forests, determined by the structure and function of the biocenosis. A secondary aim of ecological engineering is elimination of factors destabilizing ecosystems, the action of which, under conditions of forest management, is beyond the regulatory capacity of the biocenosis. These aims can be accomplished by:

(a) adaptation of natural biological systems to the conditions of managed forest;

(b) acting upon biocenotic systems and biocenosis components by ensuring habitat factors essential for them; and

(c) acting upon ecosystems by way of regulation of energy flow and matter turnover (Obmiński 1977; Szujecki 1984).

Adaptation of biological systems to the changed environmental conditions (that is, modification of homeostatic mechanisms) implies a number of partial plans, for instance, influencing forest-biocenosis component development of biotic structures by means of succession processes.

Ecological engineering is based on:

(a) a good knowledge of the taxonomy of ecosystems and principles of their functioning;

(b) complex proceedings concerning protection and development of forest ecosystems; and

(c) logical sequences of ecological engineering practices in the whole production cycle of forest stands (Szujecki 1984).

Effective functioning of ecosystems depends on correct management of their material resources. Progressing degradation of habitats results from the shrinking of these resources or their inaccessibility. Under such conditions, particular care should be taken to adapt forest techniques to local habitat conditions by:

(a) protection of organic matter and its enrichment from sources beyond the forest;

(b) application of mineral fertilizers, especially appropriate nitrogen forms; and

(c) utilization of nitrophilous plants (Górny 1986).

Fertilization should be considered not only as casual supplementation of nutrient components for plants, but as a practice reducing matter loss, stimulating soil development, and improving the absorption complex of soils; in short, fertilization is favorable to the condition of trees and growth increment.

Forest ecological engineering is very selectively applied in contemporary forest management. Examples are the often-quoted silviculture practices undertaken within the program of forest-management improvement up to 1990. They do not, however, constitute a program of forest ecological engineering since they do not fulfill the above-given features of complexity and do not have a sufficient theoretical basis. Therefore, in the Department of Forest Protection and Ecology of the Agricultural University in Warsaw, a new research program was initiated entitled "Ecological bases of forest management and development of forest capacity to fulfill various functions". The chief aim of the program is to attain an ability to ensure ecological equilibrium of forest areas and to designate environmentally safe technologies in forest management. This means that a model of the functioning of forest ecosystems under different conditions of anthropogenic pressure, particularly of forest management and designation of the consequent principles of forest ecological engineering, should be elaborated. The program, in which more than 300 scientists participate, should develop the knowledge of forest ecology that is indispensable in planning environmentally safe, multifunctional forest management.

The search for a new model of forest management did not appear suddenly and is not of revolutionary character. Neither is it uniform in the suggestions presented by foresters the world over (van Migroet 1984). In the first phase, it appeared as a sometimes emotional "return to nature" in silviculture. This trend, advocating a rejection of schematic solutions in silvicultural planning and forest cultivation, is at present very popular, but on account of its primitive form it is viewed skeptically in many countries.

A renewal of this trend has taken place in Poland in the last 15 years under the influence of the opinions of forester circles as a reaction to numerous disasters which befell the forests and the effect of scientific analyses concerning the state of forest ecosystems. The projects on improvement of the state of Polish forests, especially of their homeostatic capacity, have been formally worded in the *Complex Program of Forest-Management Improvement to the Year 1990* (Ministerstwo Leśnictwa P.D. 1983), elaborated by the Ministries of Forestry and Wood Industry with significant contributions from forest scientists and learned societies.

Here we examine several important provisions of this document (Ministerstwo Leśnictwa P.D. 1983) concerning protection of the forest environment and finding expression in practical application, especially in silviculture principles:

(a) in the field of protection and management of soil and improvement of biotic conditions:
   - limitation of clear felling by way of obligatory application of strip and group cutting in mixed coniferous habitats;
   - admission, mainly in eastern Poland, of seed-tree management in fresh coniferous forest;
   - consistent reduction of size of clear fellings;
   - introduction of leafy undergrowth into pine stands on an area of 30,000 ha annually;
   - reconstruction of 400,000 ha of coniferous stands in rich habitats to mixed stands, at a rate of 7,000–8,000 ha annually;
   - designation of standard soil areas of the character of forest soil reserves;
   - application of forest mineral fertilization, mainly in forest cultures, on 15,000–25,000 ha annually; and
   - change of silviculture policy in afforestation of waste- and old farmland, involving birch as the main species in the first forest generation and introduction of a herb layer and undergrowth into pure coniferous forests;

(b) regarding improvement of the genetic structure of forest stands:
   - increase up to 1990 of specially protected, seed-crop stands from 10,000 to 12,000 ha, managed seed-crop stands from 230,000 to 260,000 ha, of elite trees from 3,000 to 5,000 ha, of seed plantations from 360 to 700 ha, and an increase of seed production from selected trees;
   - commencement of a program of selection of forms resistant to industrial air pollution; and

(c) regarding forest protection, toxic agents have been restricted by:
   - use of about 300,000 pheromone traps for bark beetles, *Lymantria monacha* L. and *Rhyacionia buolinana*;
   - introduction of short-life pyrethroids for insect control and advances in application of biopreparations; and
   - continuation of use of the "complex focal" (integrated) method (Koehler 1968) as an important prophylactic means of inhibiting mass outbreak of foliophagous pine pests.

Research and field service for forest protection have been strengthened and immense effort has been devoted to regaining a good sanitary state of forests after natural calamities and outbreaks of pests. In addition, a fire-observation network is very well organized as a collaboration among the forest field service, fire brigades, and volunteer fireguards; this network has greatly reduced the total area of forest-fire damage.

To determine the current sanitary and health state of Poland's forests, an annual large-scale stocktaking has been introduced in 1983 in the State Forests. This allows managers to direct efforts in forest protection to the most threatened areas and to forecast trends in the health state of specific stands.

The concepts outlined above have been extended in decision No. 9 of the Council of State Forests of 22 June 1987 (Lasy Państwowe 1987), stating that, during the next 20–30 years, the basic trends of forest cultivation should ensure:

(a) preservation of existing forest ecosystems and development of multiple uses of forests in the spatial management of the country;

(b) introduction of new forest plantations onto land not suitable for agricultural production, to compensate the loss of forests in heavily polluted regions; and

(c) afforestation of soils undergoing erosion and the process of steppe development, and establishment of forests on aquifers and watershed areas around water bodies and urban-industrial agglomerations.

In Ministerstwo Leśnictwa P.D. (1983), particular emphasis is laid on implementing the genetic and tree-nursery program, and improving the effectiveness of work in the field on reproduction and forest tending, with special attention to afforestation of abandoned farmland and prophylactic activity. Therefore, because of the poor state of Poland's forests as a result of centuries of exploitation, forestry faces an immense, difficult, and expensive task of radical forest modification and introduction of technologies safe for the environment.

The affirmation that Polish forests require radical reconstruction is not merely a postulate; it is mainly a recapitulation of the earlier-mentioned activity of State Forests described by the document "Improvement of the state of forest management up to 1990". Forest remodeling should not be considered solely as the reconstruction of specific single stands, which after all are components of forest ecosystems. Thus:

(a) Reconstruction of stands should involve, over many years, 30% of the forest area, including mixed coniferous forest habitats and parts of mixed forest that until now were erroneously classified as a fresh forest (thus, not less than 2 million ha consisting at present mainly with pure coniferous forest, especially pine). Mixed and fresh coniferous forests usually grow together, frequently in mosaic form; hence, the possibility of differentiating timber production in them was not taken into account and in this way the production potential of mixed forest habitats was not utilized. Therefore, if we postulate a possibility of increasing the productivity of Polish forests, we should consider that in mixed forest habitats where pine grows well, quite good broad-leaved timber, mainly oak, can be produced. The faults committed in the past have for a long time forfeited the possibility of harvesting and exporting this raw material which is in high demand on European markets.

(b) Undergrowth should be introduced into pine stands in fresh and dry coniferous forest habitats (thus, an area of about 3 million ha). This would be important for increasing and prolonging the productivity of the habitats, protection of soils liable to degradation, protection from acid deposition, and maintaining general resistance of stands to mass outbreaks of primary pests.

(c) Stand reconstruction should be done in the near future on a further 1 million ha of stands subjected to or expected to be exposed to the direct influence of industrial and urban agglomerations, mainly in Silesia and mountain regions.

(d) Ecological reconstruction is required to restore forest ecosystems in forests arising on old farmland and wasteland (thus, in State Forests on an area of about 1 million ha).

(e) Remodeling and improvement of productivity is also required in stands on extensive stretches of northern Poland which suffered calamities such as outbreaks of *Lymantria monacha*, snowbreak and windbreak, the structure of which have been unequally depleted.

After calculating the areas already remodeled and reconstructed, and the reduction resulting from overlapping of the areas requiring remodeling for various reasons mentioned above, one may estimate that this kind of management should be practiced on about 60–70% of the forest area. Therefore, Polish forests require a radical, extensive remodeling (reconstruction and rehabilitation). Of course, activity in this respect is already under way, but its rate and extent and the means available are far below the needs. A sufficient theoretical basis also seems to be lacking for the rehabilitation and restitution of forest ecosystems.

The following questions arise: (a) is such forest restoration possible in view of the overall threat to forests by increasing air pollution?; (b) is there a possibility of attenuating the consequences of forest poisoning and soil acidification?; and (c) how high is the degree of true threat to the forests from industrial air pollution?

The area of forest damaged visibly by air pollutants in central Europe was in 1982 estimated at 2.6 million ha, i.e., 1.7% of the total forest area. When a serious soil-water deficit occurred in 1984, the damage covered 5.8 million ha, i.e., 3.1% of the forests. The proportion of healthy trees locally was reduced from 90% to 30–40%, as, for instance, in Baden-Württemberg and Bavaria (Federal Republic of Germany). In areal respect, the most severe damage during 1982–1984 was recorded in forests of the Federal Republic of Germany (2,250,000 ha, i.e., 37%), Poland (654,000 ha, i.e., 8%), Czechoslovakia (450,000 ha, i.e., 10%), German Democratic Republic (350,000 ha, i.e., 14%), Austria (330,000 ha, i.e., 10%) (FAO 1984).

Forest inventories in Europe (without the USSR) in 1985 estimated the area of forest seriously damaged by air pollutants to be 10 million ha, i.e., 8% of the total forest acreage (Table 3). Particularly difficult, and locally even catastrophic, situations arose in mountain areas, where practically the sole forest-forming species are fir, spruce, and beech and thus species most susceptible to air pollutants, particularly to sulphur dioxide and ozone.

In Poland until recently, the large-scale damage inventory (carried out in 1983 and 1985) was based on different principles than in other European countries. The classification of damaged trees was more complex and connected with the criterion of tree quality in a stand. Without going into details, one may state that only the loss of more than 30% of the assimilation apparatus in spruce and fir and 30–60% in pine, birch, and oak assigned a tree to the group of impaired or threatened trees. If this procedure were applied in western Europe, the percentage of damaged trees in the Federal Republic of Germany in 1985 would "decrease" from 52% to 19%, and in Switzerland from 34% to 5% (Bernadzki 1986).

Still another procedure is taken in the delineation of the emergency zone around industrial plants for the purpose of execution of compensation. There are study areas on which tree damage indices are determined. Indices are different for individual tree species. Seven emergency zones are identified on this basis, namely:

zone 0	–	no emergency
zone I	–	low emergency
zone II	–	medium emergency
zone III	–	high emergency
zone IV	–	post industrial shrubs
zone V	–	post industrial sod
zone VI	–	post industrial desert.

Table 3. Estimation of forest area damaged by air pollutants in Europe (except the USSR) in 1985 (after Latocha 1985).

Country	Forest area (in thousands of ha)		Percentage of area damaged
	total	damaged	
Austria	3754	910	24
Belgium	616	111	18
Czechoslovakia	4600	1250	27
GDR	2900	350	12
France	15075	-	-
Hungary	1600	176	11
Italy	6363	400	6
Luxemburg	82	42	51
Netherlands	309	138	45
Norway	8330	400	5
Poland*	8677	685	8
Sweden	26500	1000	4
Switzerland	1200	408	34
FRG	7371	3824	52
Yugoslavia	9500	1000	11
Others	39087	-	-
Total	135964	10694	9

*after GUS (Chief Central Statistical Office) 1987.

In 1983 some 418,109 ha were in zone I, 199,127 ha in zone II, and 36,292 ha in zone III, altogether 654,528 ha, i.e., 7.6% of forests in Poland (Table 4).

Losses in wood-volume increment are estimated to be 25% in zone I, 50% in zone II, and 75% in zone III of emergency.

Until 1987, the opinion was held that the emergency status of forests included in the damage zone mentioned does not cover the so-called latent damage which is not formally recorded. These are such physiological injuries of trees which reduce the increment of wood volume by ca. 10%. According to data from the early 1980s, the Forest Research Institute in Warsaw estimated that this kind of damage occurs on half of the area of our forests and brings about a loss of 3 million m^3/yr of wood. The inventory of damage carried out with the aid of the comparable ECE procedure in 1988 on some 10 thousands of sample plots covering 40–100-year-old forest stands distributed all over the country revealed that 43.1% of trees in stands are in the class of trees without foliar damage (class 0); 33.1% are in the class of slightly damaged trees; 19.9% are in the class of moderately damaged trees; and 3.9% – severely damaged ones (Trampler and Dmyterko 1988).

Table 4. Dynamics of forest emergency in I–III zones of damage in Poland during years 1967–1983 (in thousands of ha).

Year	Zones of damage			Total
	I	II	III	
1967				176
1971	114	79	46	239
1978	235	110	21	366
1980	247	109	26	382
1983	419	199	36	654

Air pollution is the main cause of foliar damage in trees (85.5% of damage), while 10% is caused by insects and fungi. Due to this foliar damage, there are losses of increment which greatly surpass estimates from the early 1980s (Trampler et al. 1987; Trampler 1988). At the same time, analysis of the damage structure in stands revealed that in Poland, 73.6% of forests are damaged, including 8.1% severely and extremely damaged (Trampler and Dmyterko 1988).

The region of greatest industrial damage in Poland coincides to some degree with isolines identifying SO_2 concentration above 60 g/m^3 of air and sulphur accumulation in pine needles at 1,950 ppm (0.15% of sulphur contents). It covers the area of southern and western Poland from the state border to Zielona Góra, Częstochowa, and Tarnów (Molski 1987) (Figure 4). Particularly serious damage occurs in forests situated in regions where SO_2 emissions exceed 100 g/m^3 of air. This includes Sudety Mountains, Upper Silesian Industrial District, Kraków Industrial District, Legnica – Głogów Copper District. Apart from the Isère Mountains, where forest decline acquires the form of an ecological catastrophe, forests are threatened in central and eastern Sudety Mountains and in Silesian Beskid, situated under a strong impact of air pollution coming from the south via the Moravian Gateway. Forests in the Opole province, representing good and even very good health, are exceptions in the southwestern region of forest emergency status in Poland. Isolated regions of emergency due to air pollution were formed in the Tarnobrzeg Sulphur Basin, in the vicinity of Puławy, Toruń, Włocławek, and Bełchatów. Serious damage was found in Karkonosze, Ojców, Świętokrzyskie, Pieniny, and even Wielkopolski National Parks. The highest proportion of forests threatened by industrial air pollution in 1983 was indicated by the following provinces: Katowice (78.7%), Jelenia Góra (30.4%), City of Kraków (54.3%), Tarnów (28.5%), Bielsko (28.9%). Simultaneously, the Wałbrzych province recorded only 6.1% of threatened forests. The same province four years later announced the status of ecological calamity in connection with widespread forest decline in the Kłodzko Valley. This evidences an enormous dynamic of forest decline processes and uncertainty of forecasts in this field.

The pollution of forests in the Karkonosze Mountains is an accomplished fact, and at present the Forest Service signals a shift of the danger zone to the east as far as the Western Beskid Mountains. The damage has particularly involved stands in the Świętokrzyskie Mountains, a most important range in the Polish landscape. This situation is not only a local ecological and economic disaster, but it may also have definite consequences for the adjacent lowland areas and the whole country due to cessation of water retention in the mountains which is dependent on the forest cover. The cause of mountain forest decline is no doubt connected with the direct strong action of pollutants

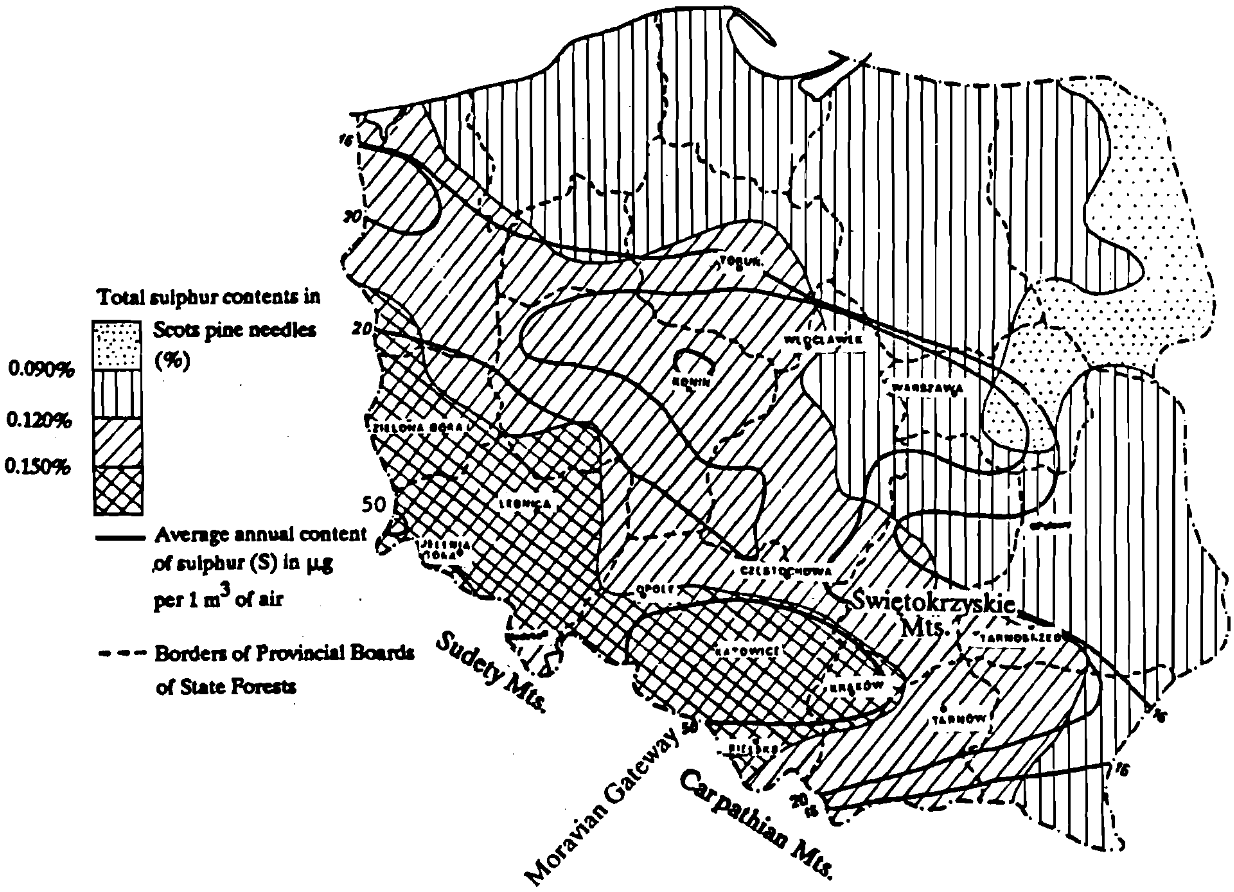

Figure 4. Zones of environment contamination by sulphur in Poland in 1986 (compiled after Molski 1987 and Trampler et al. 1987).

on tree foliage and root systems.

On the territory of the Beskid Śląski and Beskid Żywiecki, forests occupy about 100,000 ha. They consist of 80% spruce of high quality and some fir and beech stands (Smykała et al. 1987). In the last decade, debilitation and gradual tree death in the highest elevation stands have been observed, as well as the spread of *Armillaria mellea* foci on lower areas (Smykała et al. 1987). In the upper mountain region, trees are dying singly, in groups and clusters, belonging to all age groups, especially on the ridges in the peak areas and on wind-exposed slopes. Beginning at about 800 m a.s.l. and upwards, trees shed needles which previously had turned from light yellow-green to brown. Gradual dying of needles, mainly old ones, progresses from the inner to the outer part of the crowns which become less and less dense and finally die. A reduction of growth increment in spruce stands older than 60 years in the zone above 1,000 m a.s.l. by one half of the increment for the period 1951–1960 has been observed (Smykała et al. 1987). Thus, the ecological situation is similar to that known earlier from the Western Sudety Mountains and still earlier from the Erzgebirge. The damage in the Beskid Mountains is concentrated in a zone about 200 m higher than in the Sudety Mountains.

The causes of the presently deteriorating state of the Beskid Śląski stands are complex, historically and geographically conditioned. Nevertheless, data indicate that at present the most dangerous factor is industrial air pollution, even more important than predisposition of these stands to disease. As an immediate consequence of secondary pest control and removal of diseased trees, the amount of minor forest products has increased from about 75,000 m^3 in the years 1974–1982 to about 300,000 m^3 in the period 1984–1986 (Smykała et al. 1987).

The principles of management of these areas, as elaborated by the Central Administration of State Forests and the Institute of Forest Research (Smykała et al. 1987), suggest different procedures in the most threatened zone I (above 1,000 m a.s.l.), the highly threatened zone II (800–1,000 m a.s.l.), and the moderate-danger zone III (up to 800 m a.s.l.). Cessation of felling in zone I, intensification of management practices in zone II, and increased protection and tending in zone III are contemplated. For renewal and undergrowth, native species will be used exclusively and fir will be protected (its regression is not connected with pollution damage, but rather with earlier mismanagement).

The course of destruction of pine forests around industrial plants on lowland is similar. Notwithstanding the lack of comparability of the methods and the doubts as to their validity and accuracy in estimation of damage, the most important reservation with respect to current assessment methods is that they seldom reveal the cause of damage and distinctly indicate the role of industrial pollution in forest decline.

Similar disease symptoms, especially at a greater distance from emission sources, may be caused by many other factors, including those which make normal tree nutrition difficult. In this case, evaluation of the degree of danger by industrial air pollution on great stretches of pine forest in Poland, supplying 80% of the raw-wood supply and situated on soil particularly susceptible to degradation, presents certain difficulties. The pine is less sensitive to the direct action of pollutants, so the main threat to pine stands is connected with the accumulation of dry and wet deposition of sulphur and nitrogen oxides and the progressing soil acidification. This accelerates leaching of nutrients and activation of such noxious substances as Al, Cu, Zn, and Cd. Further consequences include malnutrition of the trees, destruction of mycorrhizal associations, gradual dying of shallow roots, and inhibition of increment, effects which, according to the Institute of Forest Research (Bosiak 1986; IBL 1987), have been recorded in as many as 25% of the trees in the majority of Polish forests.

Unfortunately, full data are not available on the progress and extent of the area of forest-soil acidification and loss of nutrients. Only such data could allow an objective evaluation and prognosis of the situation on the greater part of the territory of Poland.

The "outbreak arc" extending from Zielona Góra through the Noteć Forest, Bory Tucholskie, Pisz Forest to the Augustów Forest mentioned earlier has various causes of forest emergency. This area is predominantly covered with soils sensitive to degradation with at least a 200-year history of mass outbreaks of pine pests. Even-aged and pure stands favor damage caused by insects. This damage, in turn, leads to the thinning of stands and increased susceptibility to hurricanes, snowbreak and fire (Szujecki 1981, 1983, 1986). Large-scale inventory of these forests carried out in 1985 revealed the following proportions of damaged stands in the following Provincial Boards of State Forests: Toruń – 61.1%, Szczecinek – 55.6%, Poznań – 47.7%, Piła – 47.5%, Gdańsk – 31.7%, Białystok – 18.4%, and Olsztyn – 12.6%. The damage was not caused by industrial air pollution, since only in the Provincial Board of State Forests in Toruń was the proportion of this category of damage considerable, amounting to ca. 1/4 of the above area of damaged stands. The main causes of damage were leaf-grazing insects (*Lymantria monacha*, *Diprionidae*) and secondary pests.

The state of the herb layer and undergrowth as well as the abundance of soil fauna are not correlated with the damage observed in the status of needles in pine-tree crowns. Since the end of the 1970s, a rapid development of ground vegetation including broad-leaved trees, and changes in soil fauna communities, were registered all over the northern part of the country. These phenomena were not only followed by light admission to the forest floor as a result of the loss of needles, but probably also due to eutrophication of the ground layer in the pine forest ecosystems. This implies that pine forests in the north, less-polluted area are in the process of deep-stress changes influenced by various factors, among them the fertilizing effect of air pollutants and insect outbreaks.

Damage-causing factors influencing forest in the central provinces of Poland are undoubtedly of a complex nature and their occurrence is evidenced by losses of needles in pine- and fir-tree crowns. Disease symptoms in pines are indicated by the lack of three- and even two-year-old needles, and this makes tree crowns thin with brushy shoots. The proportion of dying trees is high. Mortality of fir in the Świętokrzyskie Mountains and morbid appearance of pines seem to be connected with a consistent impact of sulphur dioxide on local stands. As indicated by measurements of air pollution, the proportion of SO_2, although lower than in the most threatened regions of Poland, is here on the increase. The lowered level of groundwater recorded in various parts of Poland may also seriously affect the health status of forest stands. So-called harassing pests, feeding on buds and needles and those sucking phloem and needles, as well as pine-needle diseases, which have been for a long time attacking stands growing under extreme edaphic conditions on degraded forest sites, present further threatening factors. The percentage of trees damaged in the Provincial Board of State Forests in Lublin amounted in 1985 to 48.7%, in Łódź to 46%, in Radom to 19.3%, and in Warsaw to 1.9%. Forests situated along the eastern border of Poland belong to those least threatened by biotic factors. This status has not changed since forest health status has been monitored. On the other hand, increases in soil acidity and relatively high depositions of sulphur were found in northeastern Poland. The main direction of the movement of air masses is from the southwest. Varying with the distance of transportation, the air loses alkaline compounds present in dusts from cement mills and the ceramic industry. These compounds neutralize free acids, so acid rains are formed. Acidification is evident in podzolic soils, and particularly so in podzol-gley soils. In this connection also in eastern Poland, one can expect progressing soil degradation and forest decline.

The 1988 forest inventory revealed that the highest proportion of trees ($> 65\%$) with damaged foliage (from low to high) is situated in forests of the Provincial Boards of State Forests in Katowice, Wrocław, Łódź, Szczecinek, Piła, Toruń, and Lublin (Trampler and Dmyterko 1988). Most of these forests are situated beyond the zone of the highest SO_2 concentrations in air (Figures 5 and 6). In comparing the health status of Polish forests with that of other countries' forests in central Europe, one may state that in 1988 the proportion of undamaged trees was lower in Polish forests than in the forests of the Federal Republic of Germany, Czechoslovakia, and Austria, but the proportion of moderately and strongly damaged trees was higher (Trampler and Dmyterko 1988).

In western Europe, three views are advanced concerning the disastrous situation in forests (Bernadzki 1986):

(a) forest decline is a temporary phenomenon evoked by a combination of unfavorable conditions, among which two years of drought (1982, 1983) were of decisive significance; such damage has occurred before and yet forests continue to exist;

(b) forest decline is an irreversible phenomenon; forest-management efforts are of no avail here, and the objective should be simply to salvage the timber;

(c) forests are threatened to a degree unparalleled in the past; conditions should be created for the forest to survive through to the time when emissions will be greatly limited.

None of these views could be accepted without reservation, and both the pessimistic salvage of timber and the optimistic waiting for drastic pollution cuts are unacceptable. It is certain that various anthropogenic pressures on forests will increase in the future, and none of the damaging factors will disappear without leaving long-lasting consequences for the forest environment. It is not so much the gradual decline of forests that should be the object of interest to politicians, scientists and foresters, but its causes, especially the permanent degradation of forest soils, the structural, chemical, and biological rehabilitation

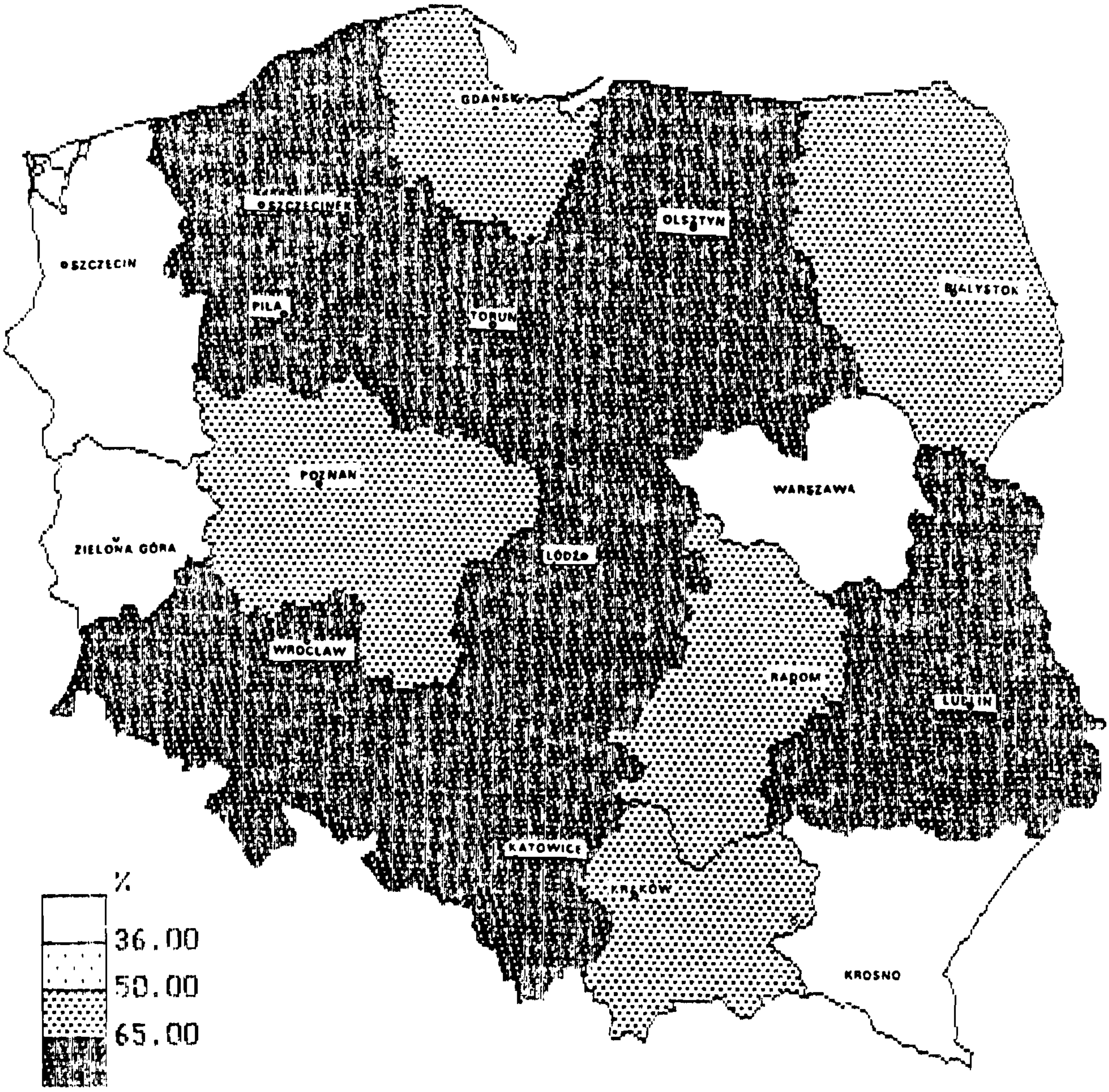

Figure 5. Results of forest damage inventory in Poland – percent of damaged trees in 1988 (from low to high) (after data from Trampler and Dmyterko 1988).

of which is, as we know, very difficult if not impossible.

The comparison of the extent of damage in the forests of central and western Europe for 1983–1984 and 1984–1985 as a proportional deviation from the mean, indicated a stabilization of damage in coniferous stands during 1984–1985, owing to the improvement of weather conditions on the one hand, and to rather rapid increases in damage in deciduous stands on the other. This suggests that both in Europe and in Poland the extent and rate of forest decline is strongly correlated with the course of weather. Lack of a stable climate in Poland where effects of Atlantic and continental climates are confronted, makes such a diagnosis particularly difficult. Nor is there any certainty as to the scale and composition of air pollution in the perspective of years to come. The adherence of most European states to the Geneva Convention on the reduction of sulphur emissions to the atmo-

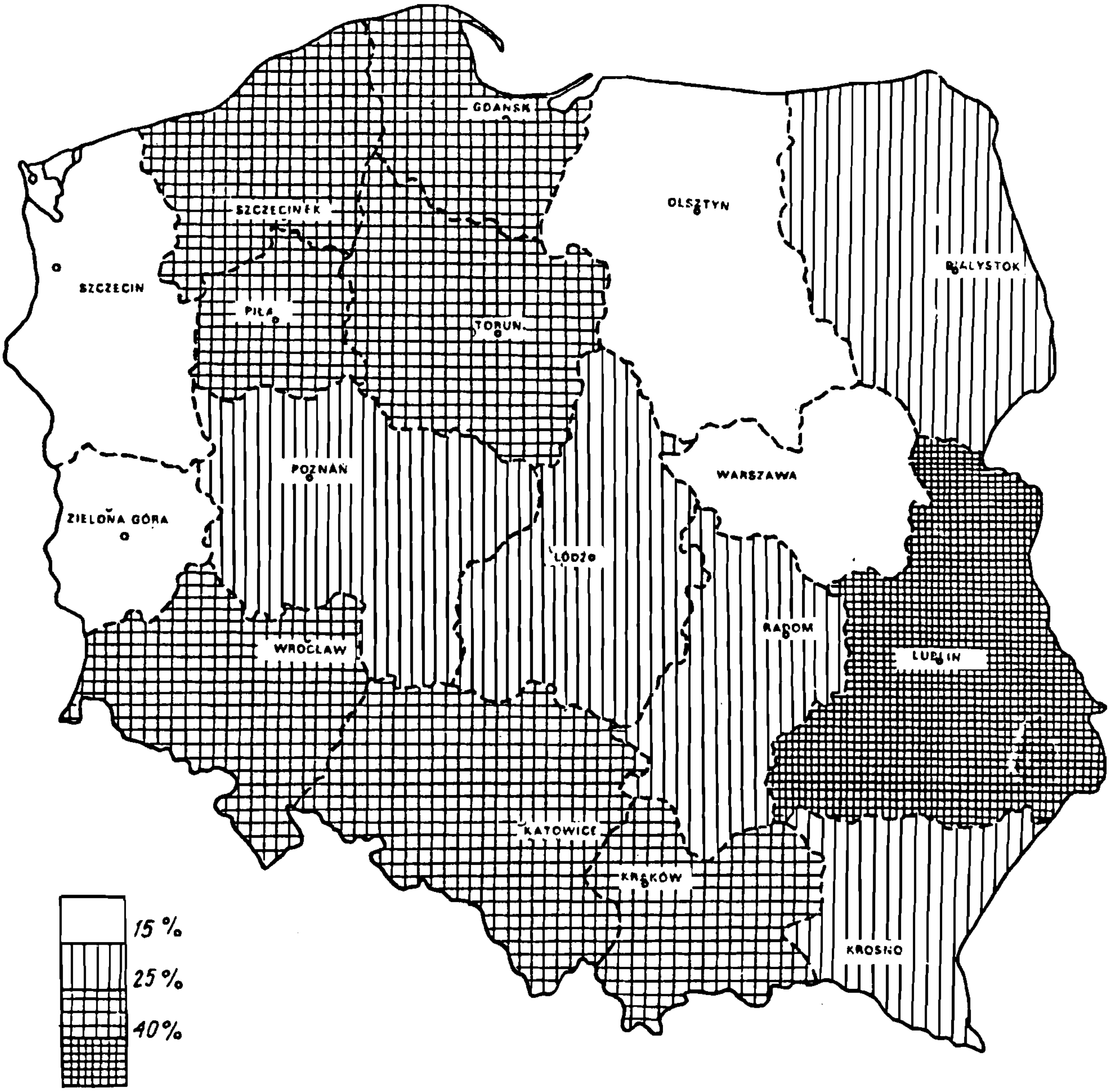

Figure 6. Results of forest damage inventory in Poland – percent of moderately and severely damaged trees in 1988 (after data from Trampler and Dmyterko 1988).

sphere by 30% before 1993 when compared to 1980, even if executed by all signatories (Poland does not belong to them), will not remove already existing pollution consequences in environment. Among other things, the proportion of acid soils will continue to increase until 2050 (Anonymous 1988) as indicated by simulation models developed at the International Institute for Applied Systems Analysis (IIASA). Still longer time will be required to reconstruct the destroyed forests and to improve the impaired structure of forest stands. Consequences of the present status of the forest environment will be projected on the health status of forests and wood resources throughout the entire 21st century, provided that forests will be saved now.

On the other hand, the bad status of forests forces an increase in the extraction of wood which ought to be salvaged before depreciated. There are forecasts that wood extraction in Europe will increase in 2000 by 18% when compared to years of 1979–1981 (Kuusela 1987). The increase in wood extraction will occur first of all in countries of the European Economic Community. Planning agencies in Poland anticipate a regular decrease in wood extraction until 2000 – from 23.7 million m^3 in 1985 down to 21.7 million m^3 in 1990 and to slightly below 21 million m^3 during years of 1995–2000. This will result in a reflexive reduction in the planned production of softwood timber by ca. 1 million m^3 when compared to 1985, i.e., down to 7.5 million m^3. Such a situation should not reduce forest resources in Poland, because wood-volume increment, despite losses caused by various factors, is positive. This is a result of the development of predominantly young forest stands and a remarkable increase in forest acreage achieved in years following 1945.

These forecasts are optimistic. They assume the survival of forest stands until the moment of a drastic reduction of emissions. As it, however, results from previous considerations, this is not the sole factor threatening forests. For Poland, these forecasts ought to consider the possibility of increment loss in currently young and medium-aged stands as a consequence of degradation and stress fatigue of soils.

What kind of forecast can be made in the case of mountain areas which, when deprived of forest, will cease to perform their soil protective and water flow regulating roles? In other words, how real is the ecological risk connected with abandonment of intensive and radical actions for the protection of the atmosphere and forests now? They will be far cheaper than the ecological catastrophes to come, as the one which occurs now in western and central Sudety Mountains.

The opinion is quite frequently advanced that the best guarantee of forest-environment protection is rational forest management. This argument might be acceptable if our views on what is rational management were unanimous. If we assume that rational forest management corresponds to the criteria of the current model of forest management, the formulation under discussion has to be rejected. This model has, at least theoretically, rationalized the principle of timber production in the forest, and this changed the exploitation character of this process to a process of timber harvesting in a continuous cycle. This model, one-sided although very progressive 200 years ago, is limited only to one element of the ecosystems – trees – but it does not take into account rational management of other components of these ecosystems, above all chemical elements and their turnover. Thus, the system of exploitation continues to be applied.

Contemporary forest management, together with rational silviculture and active forest protection, is unable to guarantee protection of the forest environment and the continuity of forests as viable ecosystems. It may solely solve problems in emergencies of maintenance of timber production. Such a limited function was assigned to forest ecosystems many years ago, thus arresting the development of forest associations at successional stages appropriate to this function and preventing the penetration or development of undesirable species. Hence, there are widespread tendencies in many research institutions and international organizations to introduce a model of forest management which includes not only rational treatment of tree stands, but of whole ecosystems in which timber is produced and from which it is dependent, a model which would take into account the ecological, social, and economic consequences of the infrastructural functions of forests. Only if such a model would be considered could one say that rational forest management is the best guarantee of forest-environment protection.

We must decide whether the ecological disaster in Polish forests is the result of the activity of European industry, and whether unexploited possibilities of increasing timber production still exist in the forest environment. Notwithstanding the answers and decisions in this respect, the noxious and threatening influence of air pollution in forests cannot be a screen dissimulating exploitation of the forest environment by way of the current forest-management model. This exploitation is real and should not be disguised. It is a natural consequence of satisfying human needs, with a lack of applicable concepts of coupling production with protection of resources. This exploitation should, however, be limited to the minimum to ensure the longest possible existence of forests.

For these reasons the need to search for a model of forest management that is safe for the environment, and the necessity of expressing this search in corresponding research programs, is stressed. This is not only a Polish problem, but concerns the whole world; people responsible for forest practices are not more responsible in this respect than scientific circles.

Forestry requires high financial support for undertaking all possible preventive measures against forest habitat degradation, and for silviculture and protective practices. For their motivation, no discussion of ecological and economic consequences of the disappearance of forests is necessary; they are sufficiently well known. These measures should be set in operation as soon as the financial means and investments for limiting pollution emissions from industrial plants are in place.

The inter-war period in the history of Polish forestry was characterized by the possibility to wrench from the private owners most of Poland's forested land and turn it over to the State by nationalization. This allowed the establishment of a Central State Agency directing forest management, which doubtlessly contributed after 1945 to the multiplication of forest resources in this country, in spite of heavy forest exploitation, and saved them from various disasters.

Forests as general national property of vital environment-forming importance must, in the socioeconomic system of the State, be governed under a uniform forest law which hopefully would be an impassable barrier to potential overexploitation of timber and environmental resources.

Forests are an essential part of Poland's natural environment. Their importance for the climatic and water equilibrium of the whole country, as long-lasting associations producing raw timber over long periods of time, is uncontested. They are currently not capable of adapting their functions to changing economic conditions, but remain dependent on the situation and laws of nature; moreover, they are expected to produce a wide spectrum of timber assortments. The reconstruction and protection of forests, since nature is indispensable for maintaining timber production under the increasing human pressure on the environment, requires high financial investments. Differentiation of these needs on a country-wide scale, and regional differentiation of the income from timber sales, are an argument for the existence of central guidance and central financing of the fight against degradation of the forest environment. Forests are the property of the whole nation and should remain under its control.

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