Transect Studies on Pine Forests Along Parallel 52° North, 12-32° East and Along a Pollution Gradient in Poland: General Assumptions[1]

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Abstract

The responses of pine forest to changing climate and environmental chemistry were studied along two transects following the pollution and continentality gradients in Poland. One axis begins on the western border of Poland, crosses the country along the 52nd parallel, and ends on the eastern border of Poland in the area of Bialowieza National Park, Biosphere Reserve. The second axis begins in industrial Upper Silesia in southwestern Poland and ends at the same point in the Bialowieza area on the eastern border of Poland. The west-east latitudinal transect follows the gradient of cooling and continentality, whereas the Silesian transect follows the pollution gradient. The extension of the continental transect to the west (Germany) and the east (Belarus) was possible after 2 years of the program. This "large transect" covers 20° of latitude, with a difference in mean annual temperature of 3.5 °C. The general assumptions of this program, e.g., philosophy of gradient/transect studies, selected global change scenarios, current climatic conditions, and air pollution exposure in central Europe, are reviewed. The International Geosphere Biosphere Program on Global Change predicted temperature increases of 1.5-2 °C in our climatic zone, which are close to the difference in thermoclimate registered along the transects in this study. In the description of transects, Polish systems of forest monitoring and procedures used for stand selection are introduced. The phytosociological characteristics of the studied stands and their position in the classification of vegetation has been determined, as well as some of the present changes in pollutant distribution.

Introduction

Because pollution in Silesia is clearly elevated but has steadily decreased in recent years, it is important to understand changes in local sources of contamination and their impact on Polish forests. Our transect studies are an attempt to relate the field test of pine forest responses to global warming. Because central European pine forests are seriously affected by air contamination, we try to include in the same program the influence of pollutants on forest behavior. Sites distributed along two-axis transects were studied (*fig. 1*). One axis begins on the western border of Poland, crosses the country along the 52nd parallel, and ends on the eastern border of Poland in the area of Bialowieza National Parks, Biosphere Reserve. The second axis begins in industrial Upper Silesia in southwestern Poland and ends at the same point in the Bialowieza area on the eastern border of Poland. The west-east latitudinal transect follows the gradient of cooling and continentality, whereas the Silesian transect follows the pollution gradient. The extension of the continental transect to the west (Germany) and the east (Belarus) was possible after 2 years of the program. This "large transect" covers 20° of latitude, with a difference in mean annual temperature of 3.5 °C.

This paper studies the phytosociological characteristics of pine stands, their position in the classification of vegetation, and some of the present changes in pollutant distribution in order to analyze the process of pollution transect selection and assumptions about its use as a research tool.

General Assumptions

The change in global climate anticipated and most probably occurring now is expected to produce changes in the functioning of terrestrial ecosystems. The very rich ecological literature dealing with this subject has resulted in the development of a variety of proposed methods to evaluate changes in ecosystems. These include

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laboratory treatment of individual organisms with differing doses of CO_2 and different thermic regimes; experiments more closely approximating natural conditions (especially through the widespread "open chambers" in which various simulated climates are applied to plants or habitat fragments enclosed in plastic tubes open at both ends); studies of the reactions of whole ecosystems to artificially manipulated changing climatic conditions (e.g., through heating of tundra soil); or studies on natural gradients of rising mean monthly air temperatures. Studies on comparative analysis of the same type of ecosystem functioning over suitably long periods of time in different climates are probably the most accurate. Certainly the use of such methods avoids the problems linked with extrapolating results from laboratory or semi-laboratory conditions to the field, and reduces the risk that the ecosystem response to sharp experimental intervention may be unpredictable or chaotic.

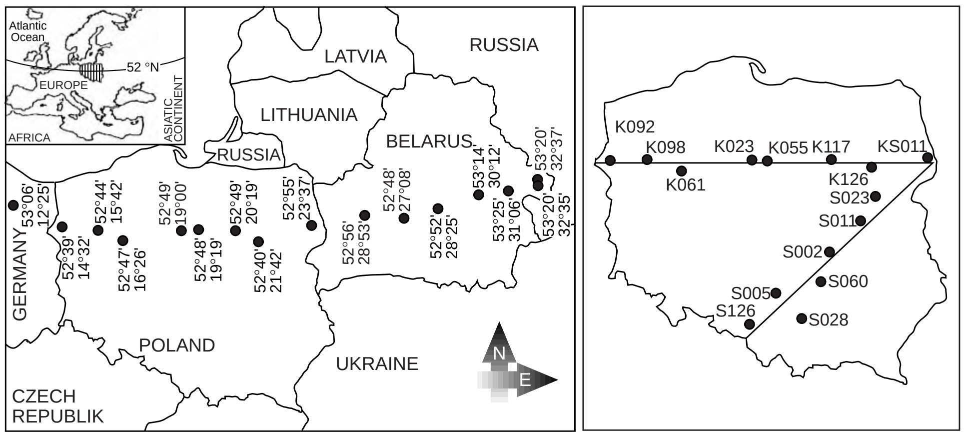


Figure 1 — (A) - "Large" climate transect along the parallel 52° N. Position of 16 stands measured by Geographic Positioning System (GPS) Geo Explorer, Trimble Navigation, Model 17 319. (B) - Two axes of climatic and pollution transects on the schematic map of Poland. Site names numbered according to Institute of Forest Research monitoring system; "K" = climatic transect, "S" = Silesian transect. Site "KS011" is common to both transects; it is the coolest site in the climatic transect and the "cleanest" site in the Silesian transect.

In gradient-related ecosystem research, stability is assumed in all environmental factors except the one studied, which varies gradually but sufficiently to modify the functioning of the ecosystem. The correlation between the changes in the factor being studied and observed departures in the functioning of the ecosystem are considered to express cause-effect relationships. Ideally, ecosystems that are selected carefully to be similar may also be treated like the same ecosystem subjected to gradually-changing intensities of a given factor. Gradients in space are thus considered, within limits, as substitutes of gradients in time, which would affect the ecosystem if it experienced the increasing action of the factor under consideration.

Published scenarios and considerations on global warming (*table 1*) have been quite consistent in their prognoses concerning "the geography of climate change." The most clear impact of warming is expected in the Northern Hemisphere in the zones of temperate and cool climate. Changes in atmospheric precipitation in these zones are difficult to predict, but the zones in question should experience a clear shift in the present ranges of the extensive deciduous and coniferous forest biomes.

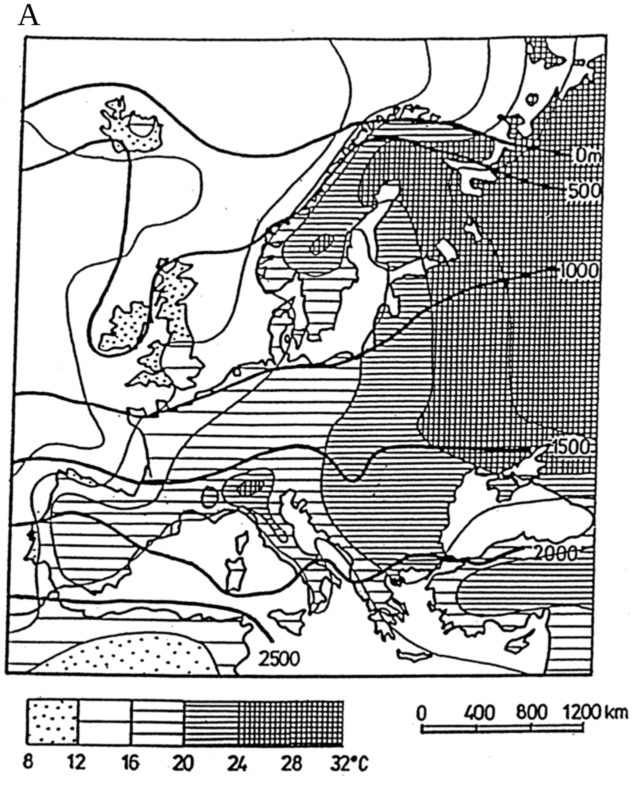
Table 1 — *Predictions of temperature response to change in $C0_2$ concentration (Bolin and others 1986).*

Model	Globally averaged surface temperature response to CO_2 doubling
WPC (1981)	1.5 - 3.5 ˚C
CDAC (1983)	1.5 - 4.5 ˚C
EPA (1983)	1.5 - 4.5 ˚C
Clark and others (1982)	2 - 3 ˚C
Julich (1983)	1 - 3 ˚C
Present assessment	1.5 - 5.5 ˚C

Attempts to predict global changes over time have been made by Boryczka and Stopa-Boryczka (1992), who expect annual air temperatures to decrease between 1990 and 2050, and then to rise between the years 2050 and 2100. The overall rise in temperature between 1990 and 2100 is an anticipated 0.5 °C, a figure significantly lower than that suggested in the various computer simulations and experiments linked with the International Geosphere Biosphere Program and usually involving a doubling of carbon dioxide concentrations by 2030 and a consequent warming of 2-3 °C (*table 1*).

Climatic conditions in central Europe are determined by Arctic influences along the north-south axis (cooling in the direction of the Pole), as well as by oceanic influences of the Atlantic along the west-east axis (greater extremes of temperature and cooling towards the interior of Asia) (*fig. 2*). Smialkowski (1995) described the climatic characteristics from meteorological stations near research sites along the transects (*fig. 3*). The mean annual air temperature declined from 8.3 °C in the west to 6.7 °C in the east, while the total annual precipitation amounted to just over 500 mm throughout. The Upper Silesian transect was characterized by a fall in temperature from 8.1 (Silesia) to 6.7 °C at the northeastern end. The mean annual amplitude of air temperature (based on monthly average temperatures), a measure of the continentality of climate, increased from 18.8 °C in western Poland to 22.3 °C near the border with Belarus.

A



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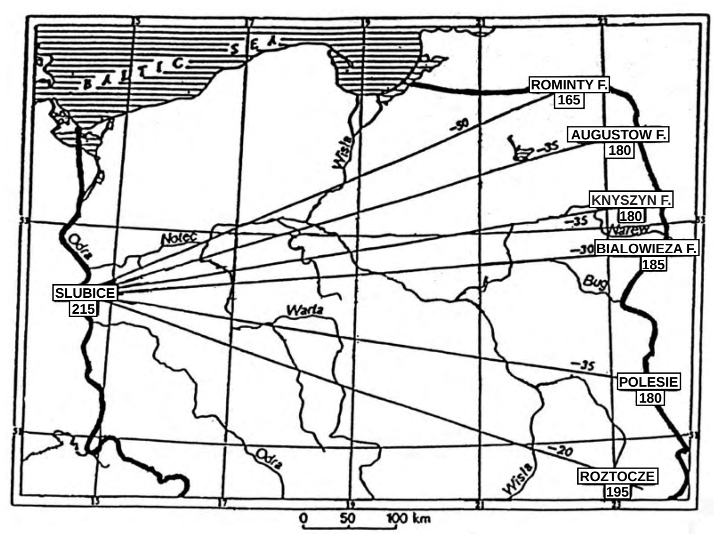

Figure 2 — (A)-Climatic differentiation of Europe: height of the timberline (in meters, isolines) in European mountains as an index of northward cooling; eastwards continentality expressed as increasing difference between temperatures of coldest and warmest month (in °C, shadowed surfaces) (Mayer 1984). (B)-Duration of the vegetation growing period (days) in various forests. Numbers placed on the lines show the difference between the warmest stand "Slubice" and individual stands (Falinski 1986).

Description of the Transects

Scots pine (*Pinus sylvestris* L.) dominates 70-80 percent of Poland's forests (in area covered or tree biomass) (Trampler and others 1987). The forests are very sensitive to pollution, and as a zonal community, must react in a distinct way to warming of the climate. It was accepted initially (Breymeyer 1994) that two complementary transects should be designated within Poland: a climatic (west-east) transect along parallel 52° N and a southwest-northeast transect running from polluted Upper Silesia to Bialowieza (*fig. 1*). Information on the state of Poland's forest across this large area has been collected by the forestry services. Monitoring of the state of Poland's forests is performed by various institutions. We used the network directed by the Forest Research Institute. Basic data are collected on permanent research plots (SPOs) covering the entire country and established in 1989 in stands of Scots pine, Norway spruce, fir, oak, beech and birch greater than 40 years old. The selection and siting of SPOs reflects the cover, age and species structure, as well as the condition of Poland's forests. Over 1,000 SPOs were established, each with 20 marked trees of the dominant species observed annually for the following characteristics:

- Morphological characteristics of the crown;
- Defoliation and the coloration/discoloration of foliage and assignment of trees to the appropriate damage classes;
- A phytopathological evaluation and an assessment relating to insect pests;
- Tree diameter measurements every 5 years.

The results of all measurements are recorded in a uniform manner in a databank.

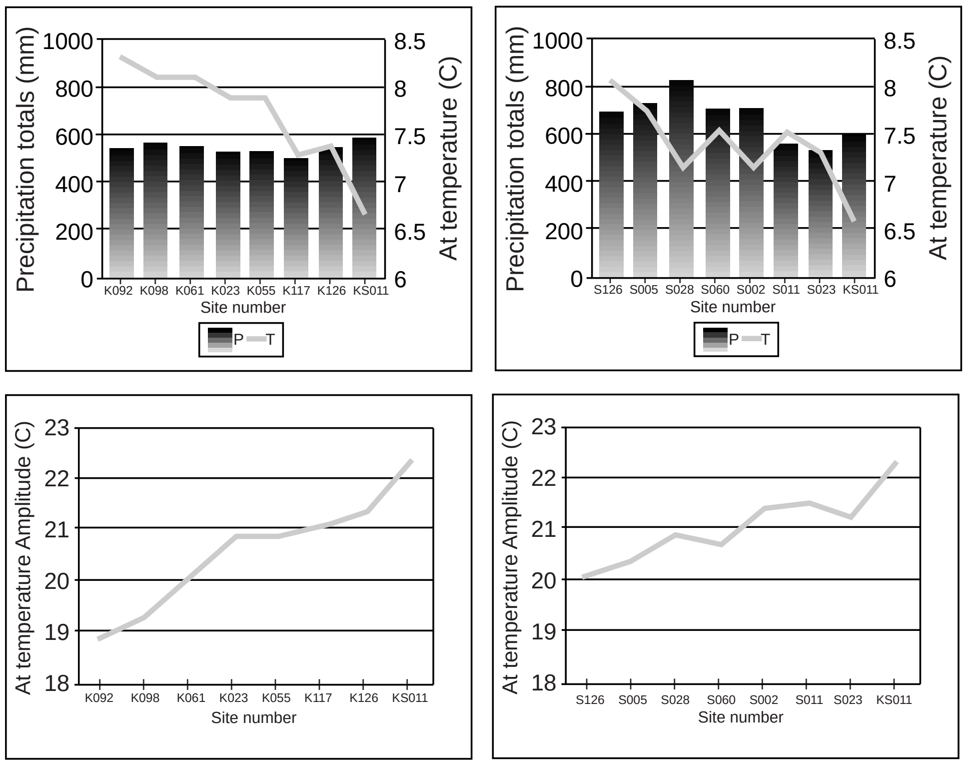

Figure 3 — Climatic characteristics of transects: mean annual air temperatures (lines), precipitation totals (bars) and annual amplitudes of temper-atures. Long-term data collected from meteorological stations in the vicinity of 15 studied sites (Smialkowski 1994).

Selection and Characterization of Sites

This research was based on a two-axis transect reflecting to some extent the influences of climate and pollution on the forests studied. The "Silesian" axis traced the gradient of air pollution from Silesia to the Bialowieza Forest, while the climatic axis traced the gradient of continentality along parallel 52° N from Poland's western to eastern borders, again terminating near Bialowieza on the same KS011 stand (*fig. 1*). Research sites were selected from a total of approximately 1100 SPOs based on the criteria of identical type of forest habitat, soil type, age of pine, indices of forest cover and stand quality, and similar aspect, slope, and elevations. The last stage of the selection process was implemented by site visits leading to the final choice of 15 permanent research plots.

Forests are complicated ecosystems; their functioning is conditioned by a long history (usually several generations of trees), by current and past management, and by a whole mosaic of habitat factors that vary considerably across Poland. Thus, the choice of sites along the transect was difficult, and despite considerable care and effort, we could not completely avoid the influence of confounding factors.

Ecosystems were mainly treated as functional units. According to Breymeyer (1981, 1984) and Breymeyer and Uba (1987), we assumed that the responses of ecosystems to environmental stresses can be measured via responses in the main processes occurring within them, including the cycling of matter (i.e., its production and decomposition). Responses to change by these processes may be intensified or reduced in strength under different conditions, and their proportions may change. However, the processes must continue and maintain the cycling of matter in the ecosystem. If these processes were to discontinue, the ecosystem would similarly cease to exist. Because changes in the intensity of ecosystem processes are measurable, the responses of ecosystems to stress are also measurable. Along the transects studied, the functioning of ecosystems was evaluated by measuring litter fall and the rate of decomposition of organic matter in the litter layer and in underlying soil layers.

The structural features of forest ecosystems are composed of soil, vegetation and different groups of organisms. The composition and structure of vegetation were used to group plant communities according to phytosociological classification. The forests of Poland and central Europe have been described and classified by using the Braun-Blanquet system, and maps of the potential vegetation of Poland and Europe have been established. The forests studied in our program have been described in accordance with this classification. All of the sites studied belong the *Dicrano-Pinion* alliance and include two associations of pine forest: *Peucedano-Pinetum* (sub-continental pine forest) and *Leucobryo-Pinetum* (sub-oceanic pine forest), as well as mixed forest of *Querco-Pinetum* type. Pine forests occupy the same place along the scale of humidity, but differ in the degree of continentality (Matuszkiewicz and Matuszkiewicz 1973) (*fig. 4*). The communities of the *Leucobryo-Pinetum* association cover a large area and are the most common types of forest in Poland, showing little regional differentiation. Further east, the sub-oceanic type is replaced by the sub-continental *Peucedano-Pinetum*, which occurs to the east of the line formed by the Bug and Lower Vistula Rivers. Sub-continental forest is much richer floristically and characterized by the presence of continental species, mainly perennials of a somewhat xerothermic nature, as well as by limited regional variation. Some of the sites had a deciduous component, so they were classified ultimately as mixed pine forest of the *Querco- Pinetum* type (*fig. 4*).

In the series of stands described above, the changes in behavior of pine ecosystems were measured by groups of specialists. The following indexes of ecosystem

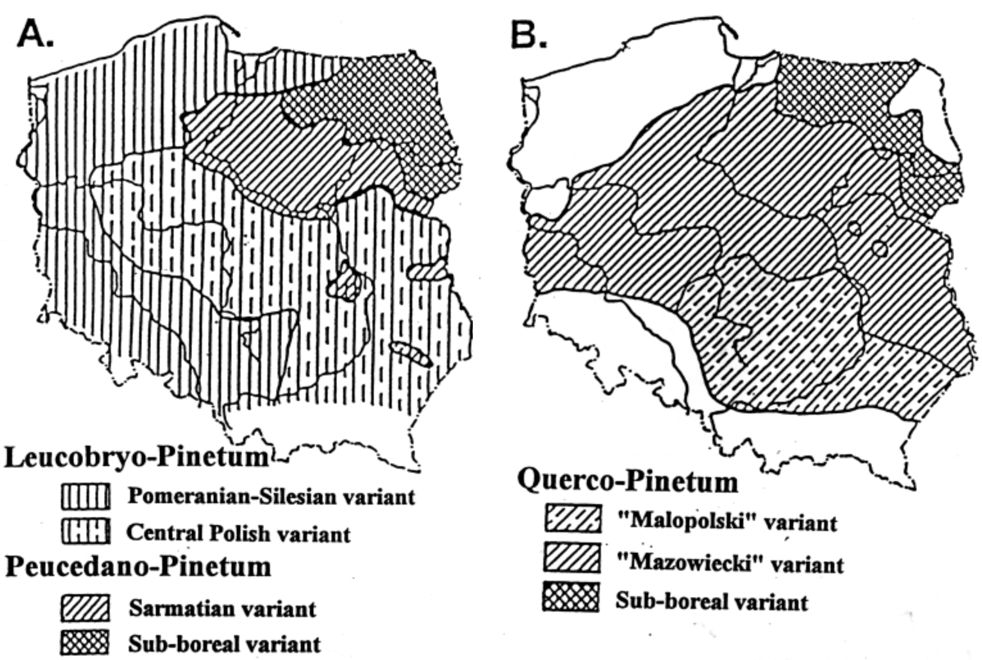

Figure 4 — Regional diversity of pure coniferous (A) and mixed (B) pine forests in Poland (Matuszkiewicz 1987).

function and structure were selected for study:

- Soil characteristics such as vertical structure and physio-chemical properties;
- Cotton decay in various soil layers as an index of the stratification of biological activity;
- Litter fall and decomposition as an index of cycling rate of organic matter (OM budget);
- Tree rings increment as an index of stand history influencing its present condition;
- Potential vegetation (sensu Tuxen 1956) of the stand as an index of stands similarity and position in the vegetation classification system;
- Selected characteristics of present plant cover: diversity of species and forms, biomass, and chemistry (nutrients and pollution) of dominant species of herbs and shrubs.

All these indexes are related to simultaneously evaluated climatic factors and inputs of pollutants.

The fundamental idea of the double transect, with gradients focused mainly on two groups of factors (climate, pollution), has since been affected by certain changes. At the time the research began it was obvious that the pollution transect must run from the south-west (Upper Silesia region) to the north-east (Bialowieza forests). In the literature from the previous 20 years, very high levels of pollution were reported for the industrial Silesia region. Furthermore, mathematical modeling of the origin and distribution of pollution throughout the country demonstrated that Silesia was the dominant pollution source region (Juda-Rezler and Abert 1994; *fig. 5*). However, recent years show a clear improvement in air quality, with a progressive decline in air pollution in the province of Katowice, Silesia's largest city (*table 2*). Recent years have also seen a distinct decrease in air pollution at "background" monitoring sites in regions far from emission sources (Przbylska 1995; *fig. 6*). Some time will doubtless pass before the first signs of improvement in the condition of forests are noted, but such changes will certainly occur. Thus, the research reported here is expected to document changes in forest condition which will certainly occur; and this research will coincide with a certain blurring in the gradient of pollution gradient along the axis between Silesia and northeastern Poland. In such a situation, local pollution is inevitably of greater significance than had been anticipated.

We decided to run the climatic gradient latitudinally along the 52nd parallel for several reasons. This avoided the inclusion of sites conditioned by higher altitude characteristics for the southern half of Poland. In addition, the selected transect is the longest one possible for the country's coniferous forests, and it allows for extension to the east or the west without changing the above conditions.

This extension was of value in the second year of the research, when a first expedition to Belarus led to the designation of six new sites between the Poland-Belarus and Belarus-Russia borders (*fig. 6*). The third year of the study, two more

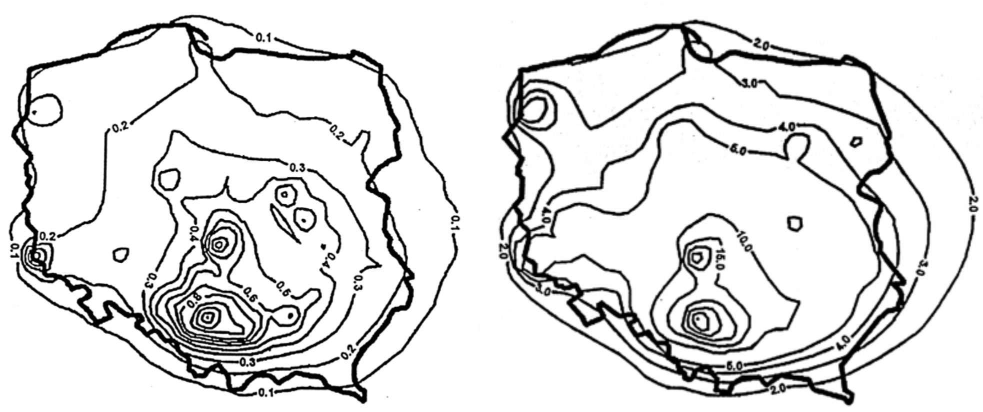

Figure 5 — Mean annual concentrations of S and N compounds over Poland in 1990 (Jura-Rezler and Abert 1994). (A)-Concentration of NO, isolines: 0.1-1.5 µg N per m³. (B)-Concentration of SO_2 (µg S per m³), isolines: 2, 3, 4, 5, 10, 15, 20, 25, 30, 35.

sites were added in Germany (at the western end of the transect). The extended transect currently runs across 20° of longitude (from 12°25' E to 32°60' E), has a range of annual temperatures of 3.5 °C (from 5 to 8.5°), and has annual amplitudes of temperature ranging from 18.2 (west) to 26 °C (east). However, this study has focused on results from the original Polish portion of the transect.

***Table 2** — Emission of air pollutants in the Katowice District (1985-1992) (Katowice Voivodship Statistical Manual 1993).*

	Emission of Pollutants (thousand tons / year)	
Year	**Dust**	**Gases**
1985	453.9	1540.9
1986	418.7	1509.9
1987	389.3	1505.2
1988	327.9	1306.3
1989	305.3	1309.2
1990	227.1	1003.3
1991	186.7	850.2
1992	127.1	738.1

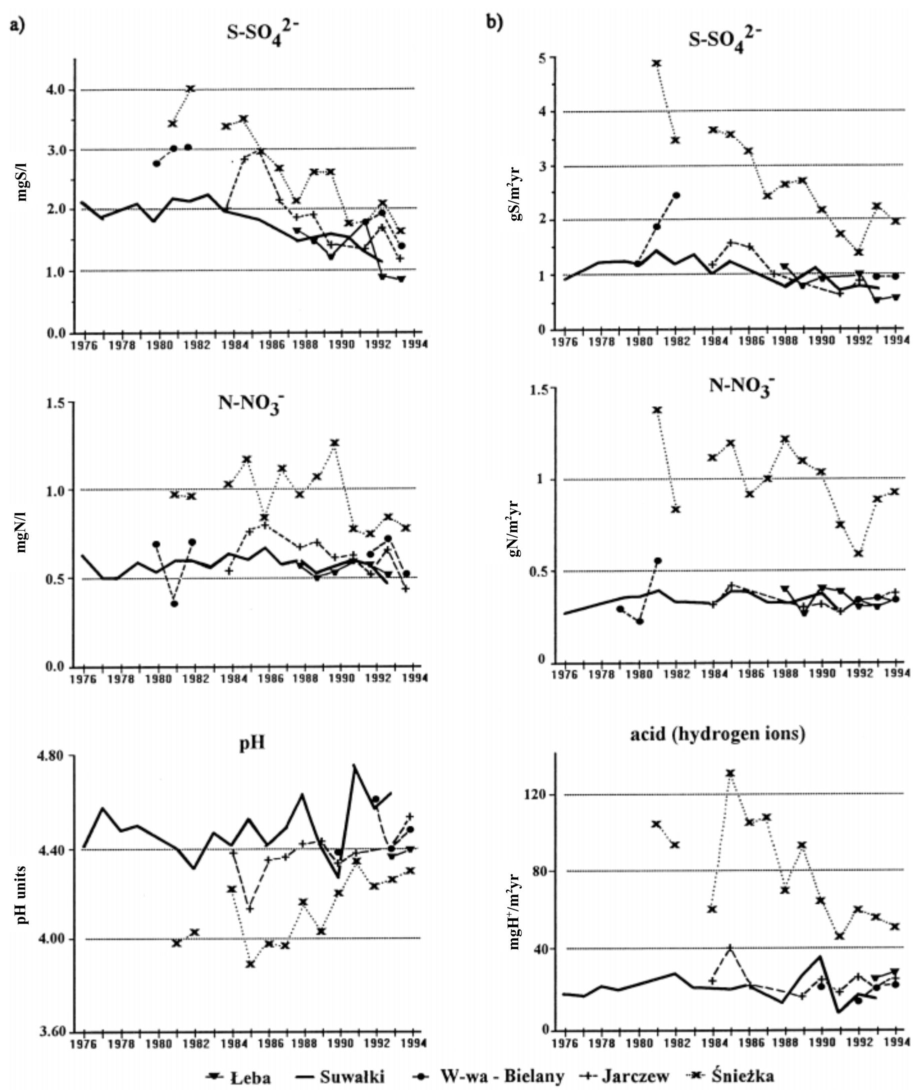

Figure 6 — Concentration in atmospheric precipitation (A) wet depositions (B) of some elements, hydrogen ions and pH as measured in five meteorological stations located across Poland. The program of observations is comparable to the international systems WMO, EMEP, BMP, as well as to the Polish national monitoring system (Przybylska 1995).

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