

Response of Scots Pine Stand Vitality to Changes in Environmental Factors in Poland, 1991 - 1995¹

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Abstract

Vitality inventories of Scots pine stands, the most common species in Poland, have been done since 1991 by using the ICP-Forest methodology. In Scots pine stands older than 40 years, 1,040 observation plots were established. Defoliation was used as the primary indicator of stand vitality. During 1991 to 1995, SO₂ and NO_x were measured at 1,417 forest locations using passive samplers. The interrelation between changes of precipitation amounts during the growing season and vitality of Scots zones with different air pollution levels was studied. The analysis was done in three zones of Poland: north Poland is considered a relatively clean area; the central part of Poland is characterized as having an average level of pollution; and south Poland has the highest pollution. In each of these zones, decreasing concentrations of SO₂ and NO_x were observed during the past 5 years. Changes of vitality in Scots pine stands caused by the amount of precipitation and air pollution level in the growing season were studied for each of the three zones.

Introduction

Forest health status in Poland has been strongly influenced for many years by high levels of air pollution. Emissions of SO₂ (5,000,000 tons) and NO_x (2,500,000 tons) in the 1980's were among the highest in Europe (Ochrona Srodowiska i Gospodarka Wodna 1987). Vegetation condition of forest trees in Poland have been unfavorable. The forests in Poland grow on mainly sandy soil with poor nutrient availability and shortage of water because of low precipitation during the growing season. In these circumstances impacts of air pollution on forest health are particularly profound and cause increases of damage reflected in high defoliation levels (Malachowska and Wawrzoniak 1995). In the beginning of the 1990's, rapidly declining air pollution levels were observed. Emission of SO₂ and NO_x was reduced by 30 to 50 percent (Ochrona Srodowiska 1993). In spite of this, forest health condition did not indicate signs of improvement. A second essential factor that impacted forest health condition was the amount of precipitation during the growing season. The combination of air pollution and water deficiency determined the health status of foliage and its photosynthetic ability. Generally, the long-term health condition of Scots pine stands on a regional scale has been determined by the level of air pollution, but yearly changes of health condition has depended on the amount of precipitation during the growing season (Malachowska and Wawrzoniak 1995). If water deficiency occurs during the growing season, response of stand vitality differs between relatively healthy stands situated in low polluted areas and more damaged stands in highly polluted areas.

The purpose of this study was to identify the reaction of Scots pine stand vitality in various levels of air pollution in three zones of Poland impacted by a shortage of water during the growing season in 1991-1995.

Methods

Mean defoliation of Scots pine stands in specific zones was used as an indicator of forest vitality. This parameter was calculated on the basis of defoliation assessments on 5,000 trees in each zone (*fig. 1*). According to the ICP-Forest Manual (United Nation Economic Commission for Europe 1994), assessments were done by trained staff every year between July 1 and August 30, 1991-1995.

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Figure 1 — The three district air pollution zones and locations of observation plots in Poland. I – north Poland (low level of air pollution), II – central Poland (medium level of air pollution), III – south Poland (high level of air pollution).



SO₂ and NO_x deposition were determined by passive method with 1-month exposure of samplers (Krochmal and Kalina 1997). Measurements were made at 600 points in each zone. Mean values of SO₂ and NO_x were calculated separately for winter and summer periods in each zone. Yearly precipitation during 1991-1995 was calculated as the mean of values from about 60 meteorological stations.

Results and Discussion

Comparison of air pollution levels during the summer period expressed in SO₂ and NO_x indicator values shows differences between the three zones (fig. 2). The highest values were above 8 mg/m²/24h in southern Poland and below 4.5 mg/m²/24h in north Poland (fig. 2).

Considering mean defoliation of Scots pine stands in specific zones, a distinct difference was found between south Poland and north Poland or central Poland, but no difference between north and central Poland (fig. 3). The low level of air pollution in north Poland seems to be an important factor influencing the condition of pine stands that appear more healthy than in south Poland where air pollution is much higher. The lack of differences between central and north Poland is difficult to explain, despite differences in air pollution level.

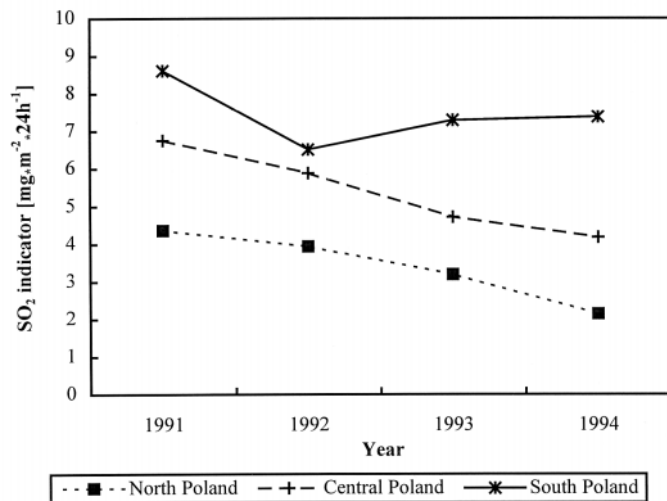


Figure 2 — Changes in the SO₂ indicator during the summer period for 1991 to 1995.

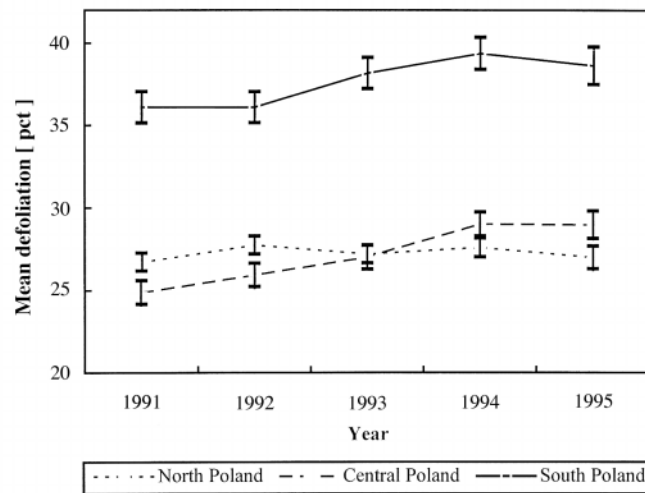


Figure 3 — Changes in Scots pine defoliation (two-tailed Tukey's Test) from 1991 to 1995.

The most interesting question that should be considered is the response of Scots pine stands of various health status to changes of precipitation during the growing season. By comparing changes between mean defoliation in a specific year and changes of precipitation in the same year, a pattern was found in the healthy stands of the north Poland zone. In 1992 and again in 1994, decreased precipitation (Miesięczny Przeglad Agrometeorologiczny 1991-1995) was followed by increased mean defoliation in the same year. In 1993 and in 1995, increased precipitation was followed by decreased mean defoliation levels in the same year (fig. 4).

The response of Scots pine stand vitality, indicated by mean defoliation to changing amounts of precipitation, was different in the more polluted and more damaged stands in the south Poland zone. Decreasing precipitation in 1992 was not followed by increasing mean defoliation in the same year, as happened in north Poland. However, mean defoliation increased in 1993 despite increased precipitation. Improvement in stand health condition, indicated by decreased mean defoliation, was found in 1995 after 2 years of increased precipitation (fig. 5).

Similar reactions of Scots pine stands to precipitation amount was also found in central Poland (fig. 6) where the air pollution level is lower than in south Poland (fig. 2), and the health condition of Scots pine stands is better (fig. 3).

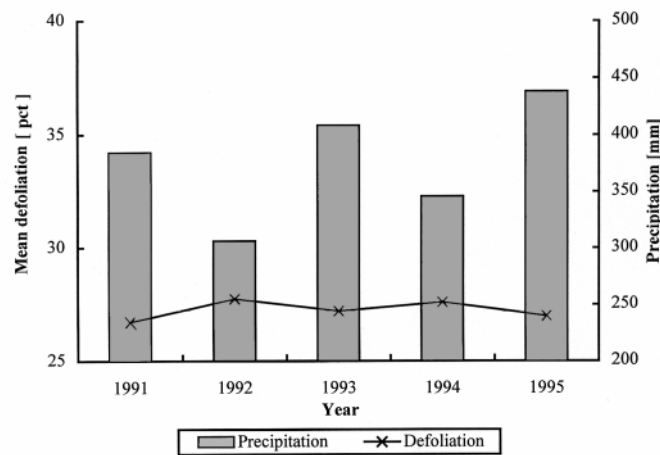


Figure 4 — Changes in Scots pine defoliation compared to the sum of growing season precipitation in north Poland from 1991 to 1995 .

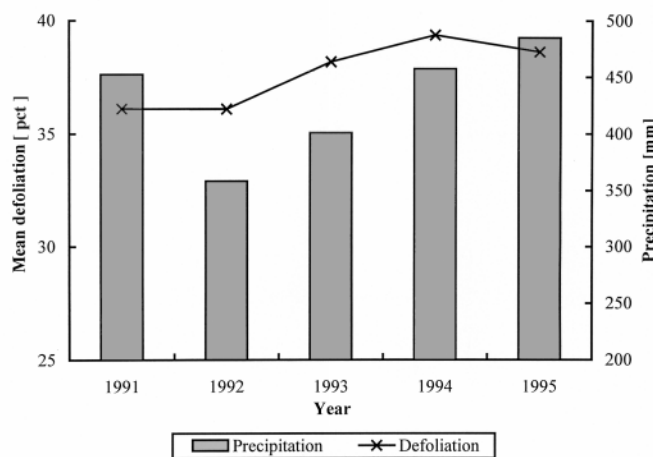


Figure 5 — Changes in Scots pine defoliation compared to the sum of growing season precipitation in south Poland from 1991 to 1995.

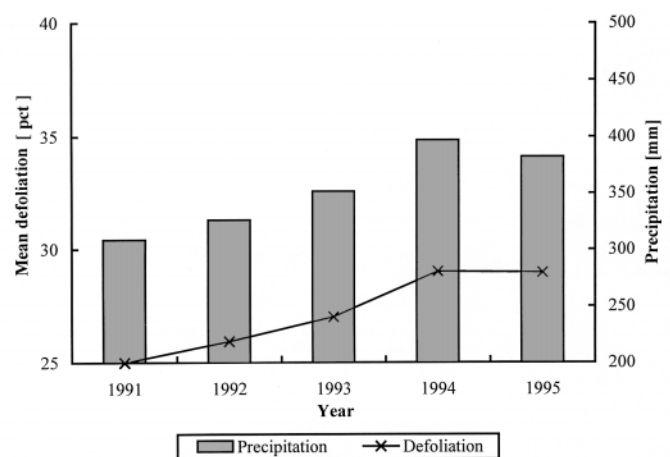


Figure 6—Changes in Scots pine defoliation compared to the sum of growing season precipitation in central Poland from 1991 to 1995.

The different responses of the vitality indicator (mean defoliation) to changes in precipitation amount during the growing season seems to be connected to the level of health condition at the beginning of the period studied.

In healthy pine stands in north Poland, the majority of trees had three or four years of needles. A small amount of precipitation during the growing season resulted in a shortage of water and trees immediately dropped one or two of the oldest years of needles, regardless of the consequences to buds for the next year. Trees in this region easily regenerate foliage the following year, when precipitation in the growing season is increased.

Scots pine stands in south Poland are in poor health condition and usually trees have 2 years of needles. If precipitation is low during the growing season, trees cannot drop needles without weakening the assimilation processes and endangering their survival for the next year. The only possible response in this condition is limiting bud formation in the same year and maintaining needle retention at the same level in the following year. If precipitation is adequate during the growing season, Scots pine trees show more effective bud formation in the current year and the improved vitality of stands is reflected by increased needle retention in the next year.

Conclusions

The response of Scots pine stand vitality to a shortage of water during the growing season is different in high polluted areas and low polluted areas. The health condition of Scots pine stands at the beginning of drought periods is crucial to the response of the stands. Scots pine stands in good health condition respond to drought during the growing season in the same year by dropping needles. Scots pine stands in poor health condition respond to drought in the growing season by changes in the bud formation process and increased defoliation in the following years.

Acknowledgments

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