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Original article

# Long- and short-term incremental response of *Pinus sylvestris* L. from industrial area nearby steelworks in Silesian Upland, Poland

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ABSTRACT

In the current work, we present a complex analysis of the factors influencing the annual increment growth dynamics of Scots pine growing in the vicinity of the steelworks "Huta Katowice" in Dąbrowa Górnicza, Poland. The conifers investigated in this study originated from nine sampling sites and their growth covered the period from 1891 to 2012 AD. A morphologically diverse terrain of research area allowed for comprehensive and detailed analyses that considered a number of factors. We determined the climatic and anthropogenic effects of tree rings width, taking into account spatiotemporal distribution of growth reductions, depth of reduction with respect to distance from the emitter and local morphology, modifications of the relationship between tree growth and climate during the period of development of industry and during the application of a pro-ecological strategy. Common periods of strong growth declines are observed between 1960 and 1980s for most of the investigated sites. The reported results indicate that in terrain of a variable relief, the influence of local factors like morphology might be more important than the distance.



## 1. Introduction

Trees are very sensitive to anthropogenic pollution. They can accumulate environmental pollutants by deposition on the foliage or bark directly from the atmosphere, and indirectly via deposition on the soil. The pollutants disturb the metabolism and physiological processes of trees, and consequently they have an effect on morphology, anatomy, ultrastructure and isotopic composition (Schweingruber, 1996; De Vries et al., 2000; Pazdur et al., 2007; Sensuła et al., 2009, 2011a,b; Sensuła and Pazdur, 2012, 2013a,b; Pazdur et al., 2013). Abrupt changes of environmental conditions, such as an increase of air pollution, influence cambium activity and can be responsible for the occurrence of abrupt growth reductions or missing rings (Schweingruber, 1986). The specific geographic regions and climatic conditions have different effects on the pattern of ring widths of a given species (Lindholm et al., 2000; Wilczyński and Skrzyszewski, 2003; Frank and Esper, 2005; Wilczyński and Feliksik, 2007). Differential effects on tree growth can also result from conditions in microhabitats (Pretzsch and Köbel, 1988; Cedro and Lamentowicz, 2011; Wilczyński, 2013) and other events, such as cutting of trees (Wilczyński and Gołąb, 2001).

Therefore, the annual ring growth variability can be a source of information about industrial history and changes in the quality of natural environment (Cook and Innes, 1989). Industrial pollution is reflected in long-term growth depressions (Eckstein et al., 1983) that may be additionally strengthened by unfavorable climatic conditions (Laubhann et al., 2009). Over the last 20 years, dendrochronological monitoring was successfully used in studies of industrial development involving different types of industrial production, e.g., a power station (Levanič and Slapnik, 2006; Sensuła et al., 2015), chemical plants (Szychowska-Krąpiec and Wiśniowski, 1996), a metal smelter (Nöjd et al., 1996) and a zinc plant (Łukaszewski et al., 1988). The size reduction of tree ring width (TRW) can be affected by the chemical composition of pollution; this reduction also depends on the distance from the source of pollution (e.g., Vinš and Mrkva, 1973; Elling et al., 2009; Krąpiec and Szychowska-Krąpiec, 2001; Wilczyński, 2006; Wertz and Wilczyński, 2012). The highest reductions of TRW were found near the emitter (e.g., Malik et al., 2009), and the affected trees showed reduced response to climatic conditions (Nash et al., 1975; Levanič and Slapnik, 2006).

The southern part of Poland is one of the regions with the highest levels of air pollution in Europe (Kandler and Innes, 1995).

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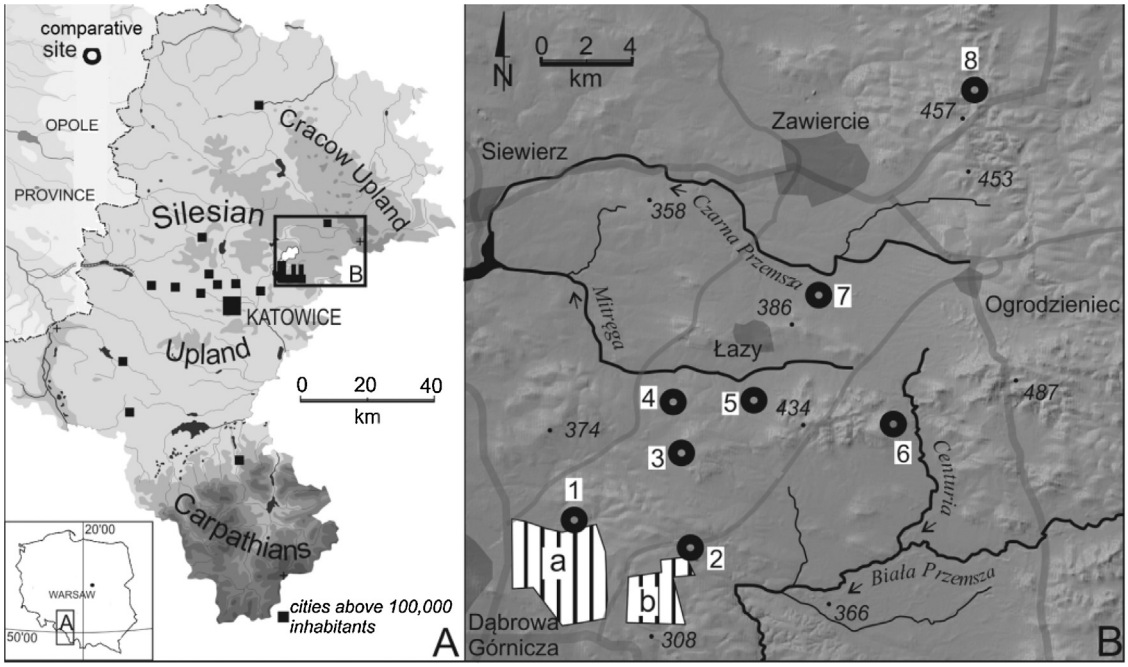


**Fig. 1.** Map of the study area: A—location of the study area in the Silesian Province showing the comparative site position, B—detailed location of the sampling sites (1–8) in the vicinity of the "Huta Katowice" (a) and Przyjaźń Coking Plant (b). Detailed characteristics of the research sites is given in Table 1.

The highest levels of dust and gaseous pollutants were recorded in the late 1970s (Marland et al., 2008). "Huta Katowice" (Katowice Steelworks, current name: ArcelorMittal Poland) in Dąbrowa Górnicza (50°20′31″N 19°16′1″E), whose first unit opened in 1975, is one of the largest steelworks in the southern part of Poland. The plant is located in the eastern part of Silesian Upland, in the vicinity of the Upper Jurassic edge of the Krakow Upland (Fig. 1). The main phytotoxic substances emitted by "Huta Katowice" are: sulphur dioxide, carbon monoxide, nitrogen oxides, fluorine compounds and dust. The highest levels of pollutant emissions from this plant were recorded in 1978–1980 (Fig. 2), while during the period 1981–1984 a significant decrease in dust and sulphur dioxide emissions was seen. These changes were the effect of correcting the design errors and implementing measures to improve the effectiveness of the protective devices. In the 1980s, the coking plant "Przyjazn" was constructed in close proximity of the "Huta Katowice". It has become a new source of emissions, and especially hydrocarbons, sulphur compounds and nitrogen oxides.

The area surrounding "Huta Katowice" has been used as a research testing ground for many years, especially when investigating the impact of high concentrations of toxic substances on air quality, forest ecosystems or physiological disorders in plants (e.g., Wyżgolik and Michalski, 1993; Pomierny and Ciepał, 2004).

The aim of the present study is a complex analysis of the factors influencing the radial growth dynamics of Scots pine (*Pinus sylvestris* L.) growing in the vicinity of the "Huta Katowice". The specific objective of this study was to determine the effects of the air pollution produced by the steel plant on: (1) spatiotemporal distribution of growth reductions, (2) depth of reduction with respect to distance from the emitter and local morphology, (3) changes of the relationship between tree growth and climate during the period of development of industry and during the development of pro-ecological strategy. The specificity of our study area being located within a morphologically diverse terrain, allowed for comprehensive and detailed analyses considering the above listed factors.

## 2. Materials and methods

### 2.1. Study area

The 8 sampling sites were exposed to anthropogenic stress of heavily urbanized areas in close to proximity of the large steel

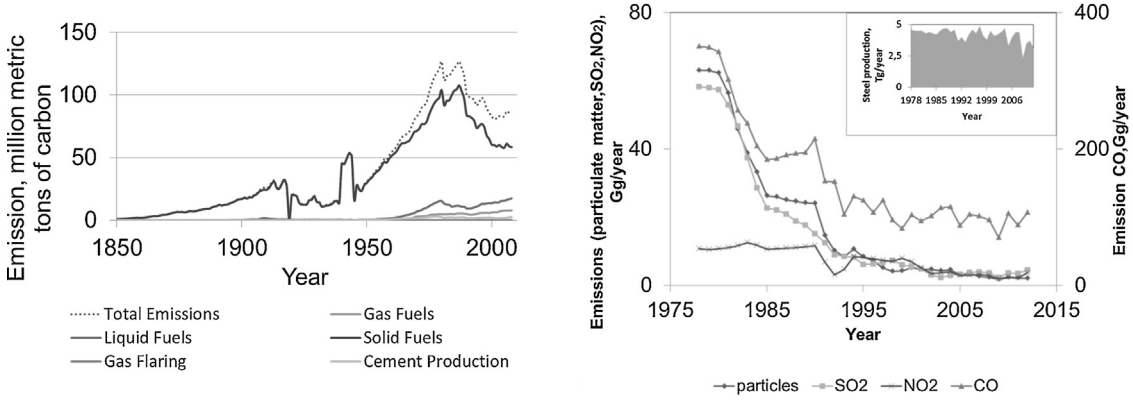


**Fig. 2.** Pollution in Poland. A—fossil fuel emission in Poland since 1850; B—particulate matter, $SO_2$, $NO_2$, CO emission from "Huta Katowice" since 1978.