Possibility to distinguish tree-ring reductions caused by landsliding and by air pollution (example from Western Carpathians)

I. Malik[1], M. Polowy[1], K. Krzemień[2], M. Wistuba[1], E. Gorczyca[2], T. Papciak[1], D. Wrońska-Wałach[2], A. Abramowicz[1], M. Sobucki[2] & T. Zielonka[3]

[1]*Faculty of Earth Sciences, University of Silesia, Katowice, Poland*
[2]*Institute of Geography of Spatial Management, Jagiellonian University, Cracow, Poland*
[3]*Institute of Biology, Pedagogical University, Cracow, Poland*
E-mail: irekgeo@wp.pl

Introduction

Tree-ring reductions occur in trees due to the impact of diverse environmental factors e.g. air pollution, insect outbreaks, stem wounding etc. (Thompson 1981, Camarero et al. 2003, Danek 2007, Malik & Owczarek 2009). Multiple factors causing reductions can act at the same time in the same area (Ashby & Fritts 1972), so environmental reconstructions can be affected by errors. Therefore there is a need to conduct studies on recognizing specific environmental factors responsible for tree-ring reductions. In the Polish Carpathians we have studied European silver fir (*Abies alba* Mill.) specimens growing on landslide slopes and at the same time within the zone affected by air pollution. Preliminary studies have shown that these trees develop strongly reduced annual rings. The aim of the research was to develop a basis for distinguishing tree-ring reductions caused by landsliding from reductions caused by air pollution.

Study area

The study was carried out on a slope of the Kamień Mt (857 m a.s.l.), in Beskid Niski (Western Carpathians, Poland, Fig. 1). We have selected two sampling sites: the first located on a landslide slope, the second one a stable reference site, 1 km from the landslide slope. Bedrock of the Beskid Niski Mts. is composed of flysch sandstones and shales which create favourable conditions for landslide development. Earlier studies have shown a high frequency of small-scale landslide movements occurring almost every year in the Carpathians (Wistuba et al. 2013). Climate conditions in the study area are typical for lower mountain ranges of the Carpathians with precipitation of ca. 800 mm per year. The study area is located in Magura National Park with natural beech and fir forests. There are no large urban and industrial areas in less than 20 km from Kamień Mt, but the study area is located within an old Central Industrial District (CID) which flourished in Poland from 1920 to 1940. Steel mills, chemical and power plants, automobile and aircraft factories were developed in the CID. After the 2nd World War CID began to decline but other industrial districts developed and emitted harmful air pollution to the atmosphere from 1960 to 1990 (Malik et al., 2012). After 1990 environmentally friendly technologies were introduced and air pollution decreasedand the suppression of tree growth stopped.

Methods

In Kamień massif we have sampled 20 silver fir specimens. Using Pressler borer we took two cores from each tree, first from the upslope side of each stem and the second from the downslope side. Half of the sampled trees were growing on the landslide slope, the other half on the stable reference slope (without any growth disturbances caused by landsliding). For all trees ring-width measurements were done and chronologies for the landslide slope and the reference site were developed separately.

We also calculated ring reductions and divided them into three classes (Schweingruber et al. 1985):

1) moderate reductions: 30-50%,
2) strong reductions: 50-70%,
3) very strong reductions: >70%.

Furthermore, the percentage of sampled trees showing ring reductions in each year was calculated. These ring reductions were also devided into three groups:

1) reductions formed only on one side of a stem,
2) reductions formed on both sides of a stem with the same depth,
3) reductions formed on both sides of a stem with different depth.

We presumed that reductions formed only on one side of a stem are caused by landsliding, because trees growing on an active landslide are tilted and produce eccentric rings (Braam 1987), reduced on one side of the stem only (up- or downslope). On the other hand trees affected by air pollution produce reduced rings within the whole stem perimeter. Trees affected simultaneously by landsliding and air pollution produce reduced rings within the whole stem perimeter, but with different depth of reduction on up- and downslope side of a stem.
We have also calculated the number of missing rings within all samples taken and used them as a record of environmental stress affecting trees.

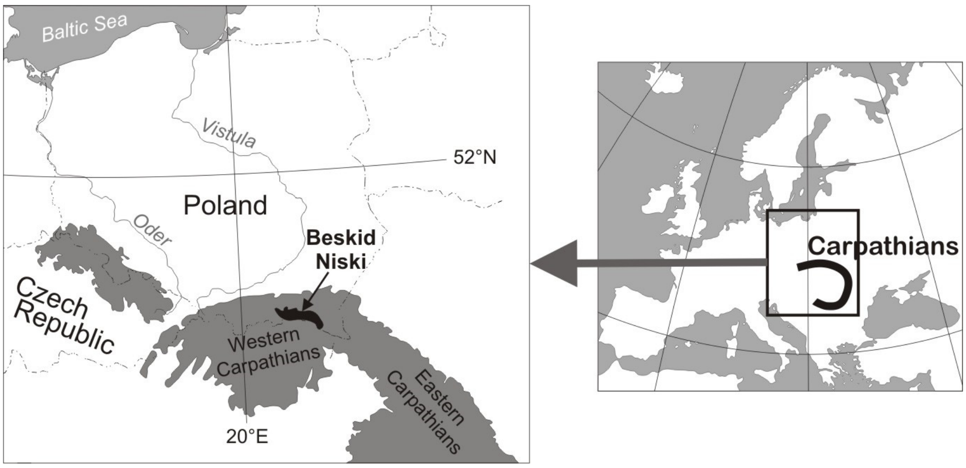

Figure 1: Study area.

Results and Discussion

Based on the chronologies developed for both sites, we have found periods with tree-growth suppressions (Fig. 2). In the chronology developed from trees growing on the landslide slope, strong reductions occur in 1920-1950 (Fig. 2A). The period is synchronous with the development and prosperity of the Central Industrial District, which means that tree-ring reductions probably were caused by the appearance of industrial air pollution, but we can't also exclude landslading as a factor that determined reductions.
In the chronology developed from annual rings of trees growing on a reference slope reductions occur in 1960-1995, chronology is relatively short, and it id not possible to This period is characterized by the dynamic development of industry not only in Poland but also in whole Europe. Numerous examples of ring suppressions due to air pollution are known from this period, even from areas located relatively far from sources of pollution (Juknys et al. 2003, Elling et al. 2009). We suppose that reductions in the studied firs in 1960-1990 also result from air pollution. By comparing both chronologies we have found that in the period 1960-1995 trees growing on the reference site have developed clearly stronger reductions than trees growing on the landslide slope (Fig. 2A). It is probably an effect of eccentric growth of trees on active landslide slopes.

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Reductions on one side of a stem are accompanied by more intensive growth and wider rings on the opposite side of the stem. The situation is typical for trees growing in tilted position due to different environmental factors, among them landsliding (Wistuba et al. 2013).

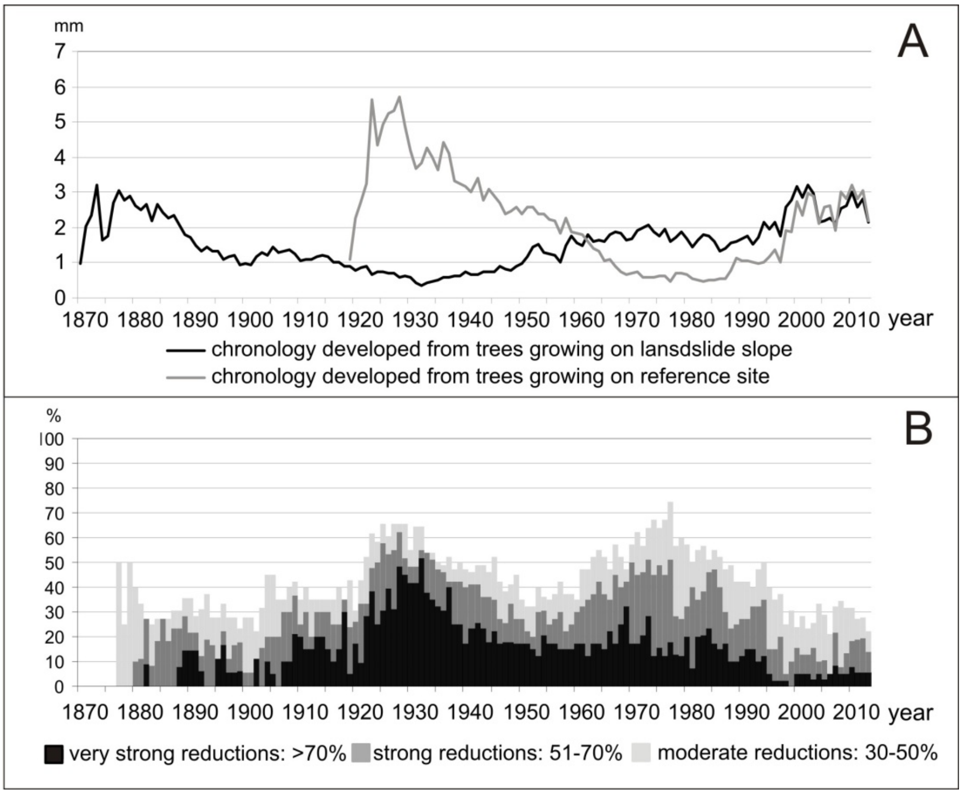

Figure 2: Chronologies and ring reductions calculated for sampled tress: A – chronologies developed from trees growing on landslide slope and on reference site, B – tree-ring reductions in all trees sampled.

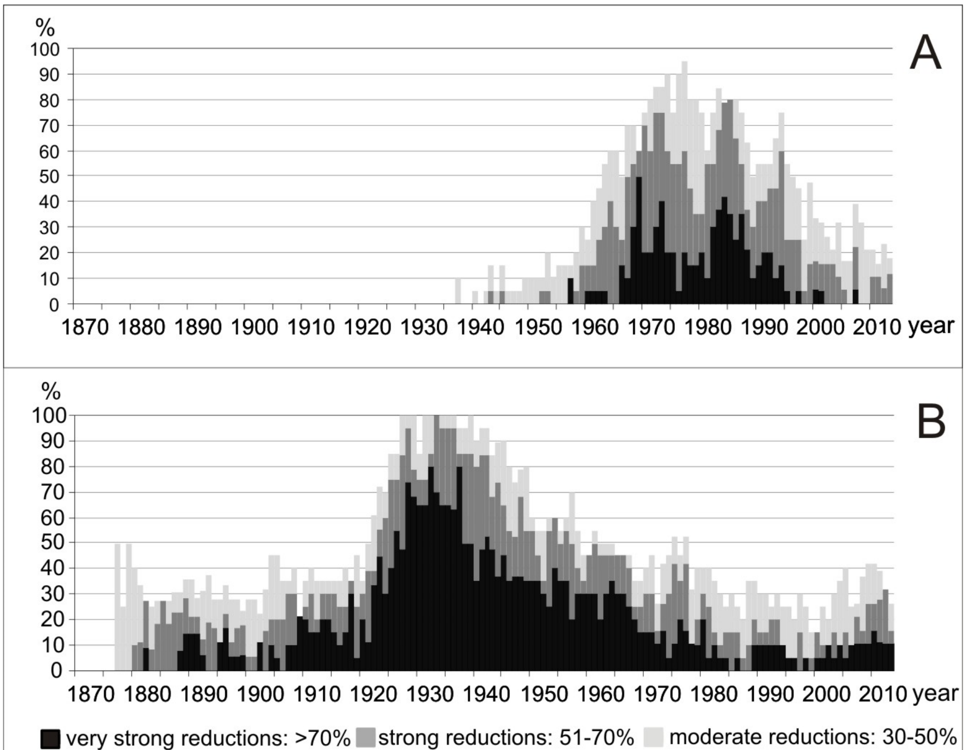

Figure 3: Tree-ring reductions calculated for trees growing on reference site (A) and on landslide slope (B).

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Both periods with ring reductions (1920-1950 and 1960-1995) present in sampled trees are clearly visible on a graph showing percentage of trees with reduced rings in relation to a total of specimens sampled on landslide slope and reference site (Fig. 2B). Reductions which occurred in 1920-1950 are stronger than reductions from 1960-1990 (Fig. 3).

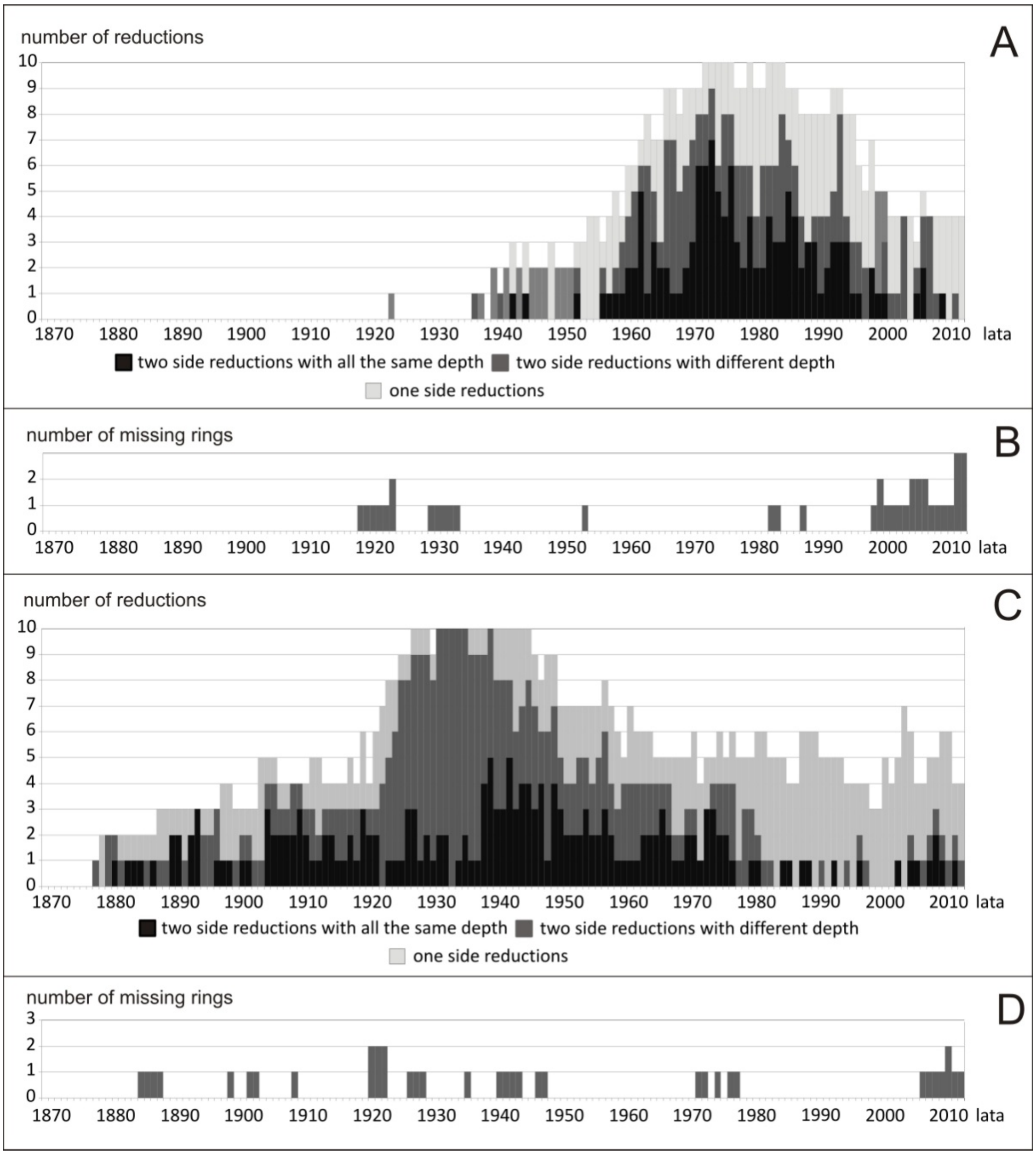

Figure 4: Tree ring reductions and missing rings, A – reductions calculated for trees growing on reference site, B – missing rings in trees growing on reference site, C – reductions calculated for trees growing on landslide slope, D – missing rings in trees growing on landslide slope.

In case of trees growing on the reference slope ring reductions on both sides of the stems with the same depth are clearly dominant (Fig. 4A). It is typical for firs developing reductions of annual rings due to air pollution. Trees growing on the landslide slope have developed much more one-sided reductions. This results from the eccentric growth related to landslide activity (Fig. 4C). In periods of heavy air pollution (1920-1980) firs growing on landslide slope have developed large number of two-sided ring reductions with a depth that differs between up- and downslope side of a stem (Fig. 4C). The effect described comes from overlapping stresses caused by air pollution (the same reduction on whole stem perimeter) with stresses caused by landsliding (reductions occur on one side of a stem). Since the 1980s, when air pollution decreased significantly one-sided reductions related to landslides dominate (Fig. 4C).

Missing rings occur in periods when two factors causing reductions (pollution and landsliding) overlap, mostly in: 1920-1950 and 1970-1980 (Fig. 4B, D). Missing rings occur also during the last 10 years, but the reason of their occurrence is unknown.

Conclusions

In case of trees growing on the landslide area and at the same time affected by air pollution there is a chance to recognize tree-ring reductions caused by pollution and landsliding. If the reductions occur on two opposite sides of a stem, according to slope inclination (up- and downslope), they were caused by air pollution emission. If the reductions are one-sided than they were caused by landsliding. In case when reductions are two-sided, but they occur with different depth then both landsliding and pollution are responsible for growth suppression (Fig. 5). Additionally in periods of simultaneous impact of air pollution and landsliding in studied trees we have identified missing rings, which record high environmental stress.

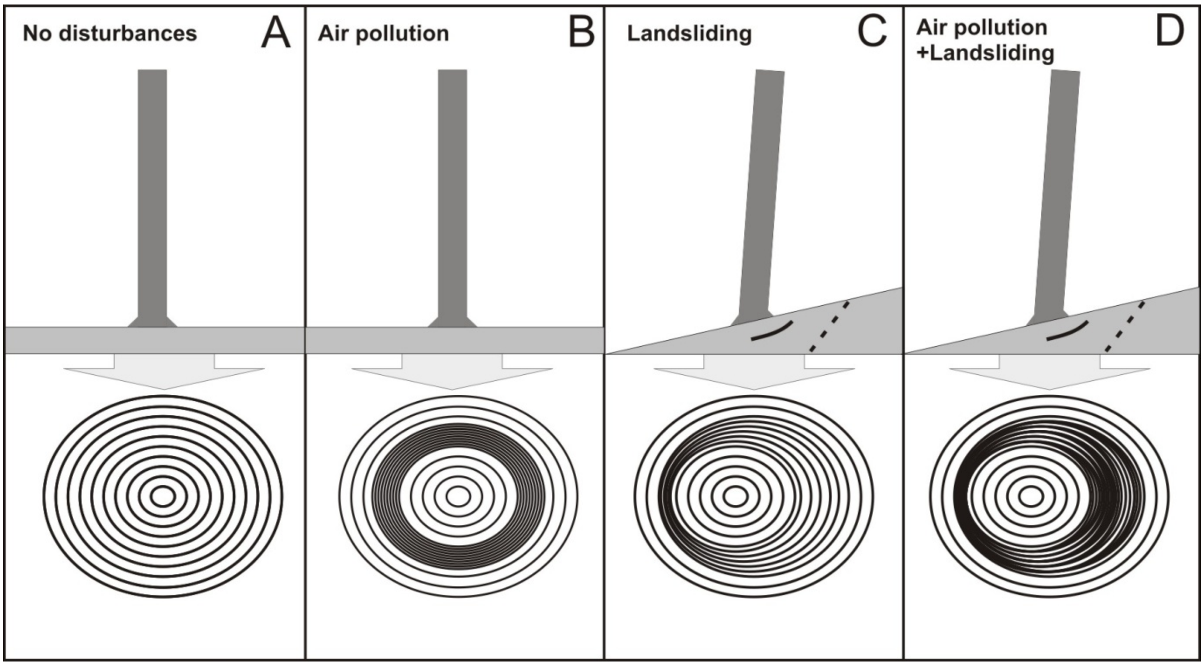

Figure 5: Comparison of tree-ring patterns formed as effects of landsliding and air pollution: A – tree ring pattern in trees growing without any influence of landsliding and air pollution, B – tree ring pattern in trees growing with influence of air pollution, C – tree-ring pattern in trees growing with influence of landsliding, D – tree-ring pattern in trees growing with influence of both landsliding and air pollution at the same time.

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