The effect of deforestation on spring water chemistry on Skrzyczne (Silesian Beskid Mountains, Poland)

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ABSTRACT: The Norway spruce dieback which occurred in the Western Carpathians is of interest to scientists in many fields. The goal of this research was to determine its effect on spring water chemistry. Due to environmental factors such as: high precipitation – up to 1,400 mm·year^{-1} while the average for Poland is 600 mm·year^{-1}; kind of bedrock (the area is built of Godula Sandstone) which causes shallow water circulation so that springs are considered as shallow supplied, it was expected that the plant cover changes might affect spring water chemistry. Such observations were partially confirmed by Astel et al. (2008), when differences between types of forest stands were found. Those results showed that the presence of mixed stands caused an increase in pH values and an increase in calcium and magnesium concentrations compared to the spring waters of Norway spruce monocultures growing on the same geological bedrock. Currently another point of view was a possibility to analyse what was before and after deforestation. The research was carried out in 2004 and 2009 in two catchments on Skrzyczne in the Silesian Beskid Mountains. The research did not show any statistically significant differences in water chemistry with one exception: pH in June 2009 was higher (average of 0.61) in springs without plant cover change than in the second group. This might be an effect of more water flowing through the more acid soil horizons with higher concentration of humic acids on the deforested area, where large amounts of organic matter were left. It is possible that changes will be observed in the years to come so that further monitoring should take place.

Keywords: pH; mountain springs; snowmelt; rainfall; forest and water interaction

Skrzyczne (Fig. 1) is the highest peak in the Silesian Beskid Mountains – 1,257 m a.s.l., it is built of Godula Sandstone which has siliceous or calciferous binding cement and is relatively resistant to weathering. Precipitation in this area is up to 1,400 mm·year^{-1} (average for Poland – 600 mm·year^{-1}) (Nowak 2002). These circumstances suggested that vegetation cover could affect the spring chemistry. Water supplying springs come mostly from precipitation, which has to pass through the plant cover on its way to the soil and bedrock. The landscape of the Silesian Beskid Mountains has changed dramatically in the last few years. Slopes of the mountains previously covered by spruce (*Picea abies*) stands are now almost entirely deforested. The effect of deforestation on surface water was described by Li-kens et al. (1994) and Sienkiewicz J. et al. (1995). Dieback of spruce stands in the Beskid mountains was predicted many years ago (Orzeł 1993; Barszcz et al. 1996; Kozak 1996) and preventative measures were taken in 2003 in the framework of the "Programme for the Beskid Mountains". Its goal was to convert Norway spruce stands of allochthonous origin, which were often located on unsuitable sites, into forests suitable for the Beskid Mountains. The conversion was not finished when the very dry summer of 2006 came, which allowed the spread of *Ips typhographus* and growth of *Armillaria* sp. Large-scale forest dieback began.

MATERIAL AND METHODS

The research was carried out in two catchments lying on opposite slopes of Skrzyczne – in Czyrna catchment and Malinowski Potok catchment. Sam-

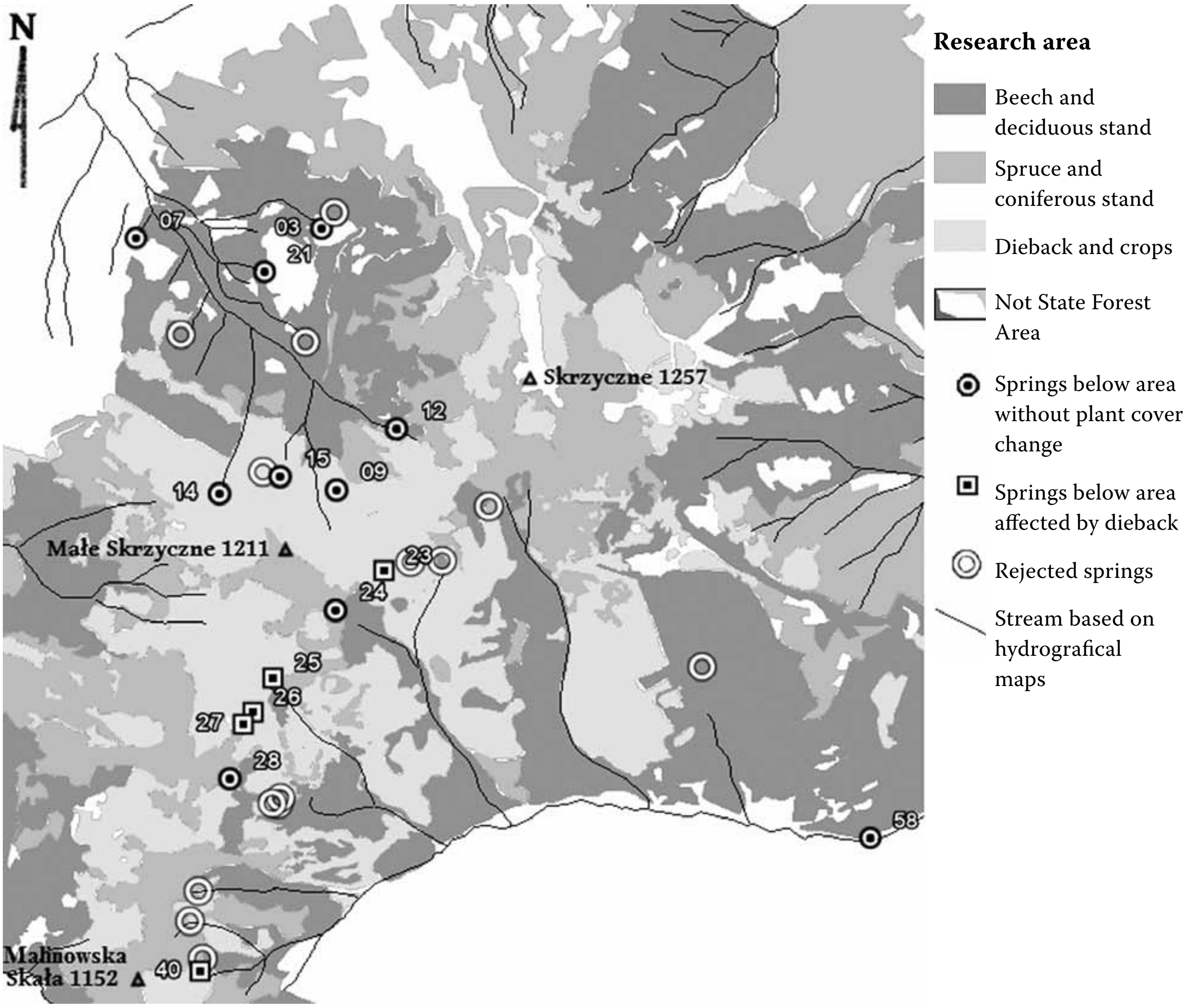

Fig. 1. Research area and vegetation cover in May 2009

ples were taken from 29 springs at the beginning, in the middle and at the end of vegetation period in 2004 (2–4, 9 of May, 18–20 of June, 15–17 of October) when the process of spruce dieback was noticeable, however it turned out to be only the beginning (Barszcz et al. 2009) and in 2009 (1–3 of May, 16–17 of July, 10–11 of October) when probably all unstable spruce stands on Skrzyczne were killed.

Chemical analyses were conducted in a laboratory of the Department of Forest Ecology. Ion concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, Cl^-, NO_3^-, SO_4^{2-}) were determined on a Dionex-320 chromatograph, pH – with Eijkelkamp 18.37, conductivity – with Eijkelkamp EC 18.34.

Data analysis provided a comparison of springs divided into two groups:

- springs whose water supply area is located in a deforested region,
- springs whose water supply area remained without the change of plant cover.

For statistical significance of differences the Kolmogorov-Smirnov test was used.

RESULTS

After rejection of springs with low data value due to periodical drying or errors in the analysis 15 springs were left. The plant cover above 10 of them (the first group) did not change. These are numbers:

3, 7, 21 – below meadows,
14 – on a ski trail,
9, 15 – spruce-larch – mountain pine crops,
12, 24, 28 – spruce stands,
58 – leafy stand.

The changes in plant cover above the remaining 5 springs (the second group) located in 2004 in spruce stands are as follows:

23, 25, 27, 40 – deforested area,
26 – spruce crops after previous clearcut.

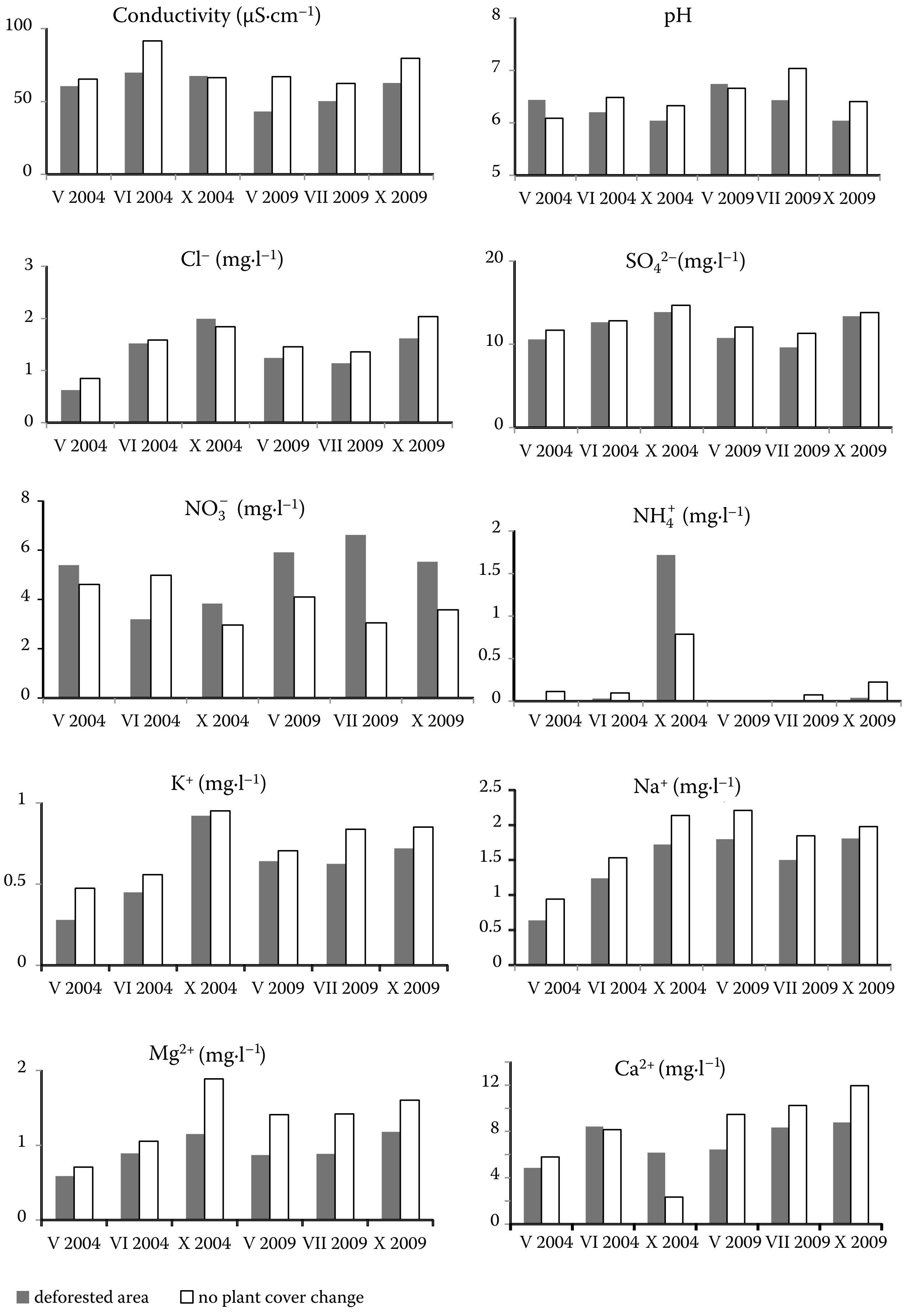

Fig. 2. Comparison of average ion concentrations, conductivity and reaction in groups of springs

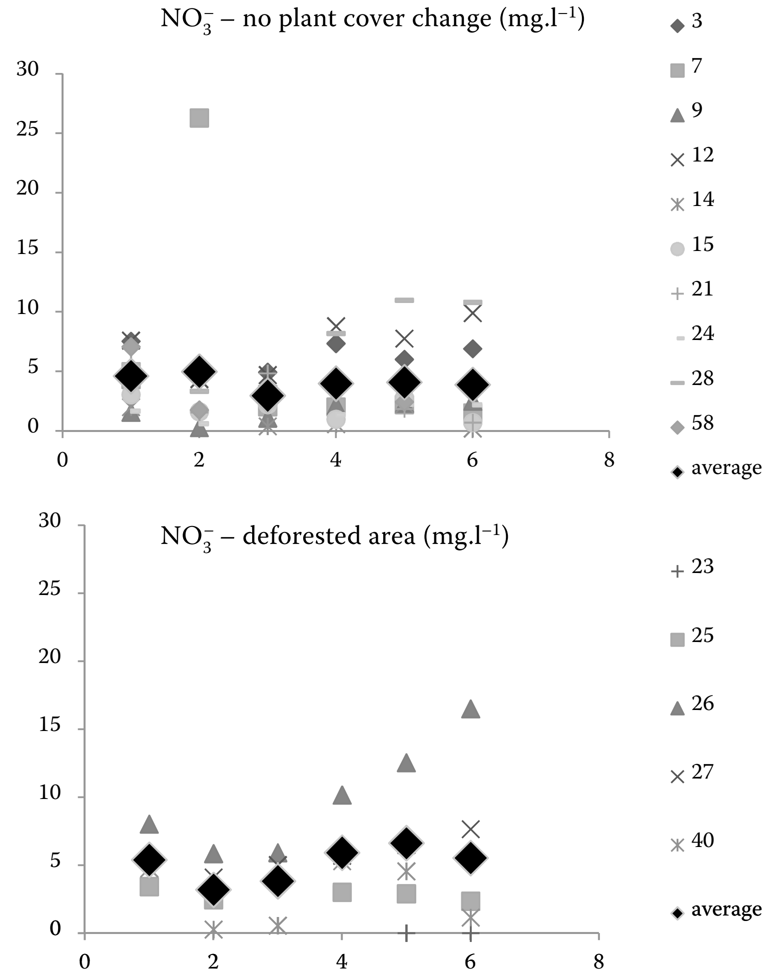

Fig. 3. Detailed comparison of NO_3^- concentrations in groups of springs

The Kolmogorov-Smirnov test did not show any significant differences in most cases (except pH in July 2009 – Fig. 4), also shown in diagrams (Fig. 2). The course of changes in NO_3^- , Ca^{2+} and conductivity differed between the groups. More detailed charts with all springs showed possible reasons. The peak of NO_3^- in July 2004 was inflated by spring number 7 (26.3 mg·l^{-1}) – Fig. 3. Such a high concentration of NO_3^- may be caused by fertilizing the meadow above the spring. The increase in average NO_3^- concentration in the deforested group was also caused by one spring only (26 up to 16.5 mg·l^{-1}) while in the second group we can see three such springs (3, 12, 28 – the highest value is 10.8 mg·l^{-1}). The presence of NO_3^- is considered, among other factors, as connected with air pollution (Humnicki 2007; Šrámek et al. 2010).

In the case of Ca^{2+} ions we can see a decrease in October 2004, which was much deeper (Fig. 2) in the second group. Average conductivity in springs whose water supply area was deforested was lower by 12–23 μS·cm^{-1}, however this difference was not statistically significant. Average Mg^{2+} concentrations seemed to be much higher in the second group since October 2004 but this difference was not statistically significant either.

Changes of reaction in time in 2009 were not similar between groups. In the first group the highest average reaction was in July – 7.04 while in the second group the highest average reaction was in May – 6.74. The difference in reaction between groups in July 2009 was statistically significant at $P < 0.05$ (first group – 7.04, second group – 6.43).

DISCUSSION AND CONCLUSIONS

Changes in spring water after deforestation on Skrzyczne are similar to changes in surface waters described by Sienkiewicz et al. 1995. These are as follows:

– The most visible change in spring waters in the deforested area is the absence of the rising peak of pH in the middle of the growing season. How-

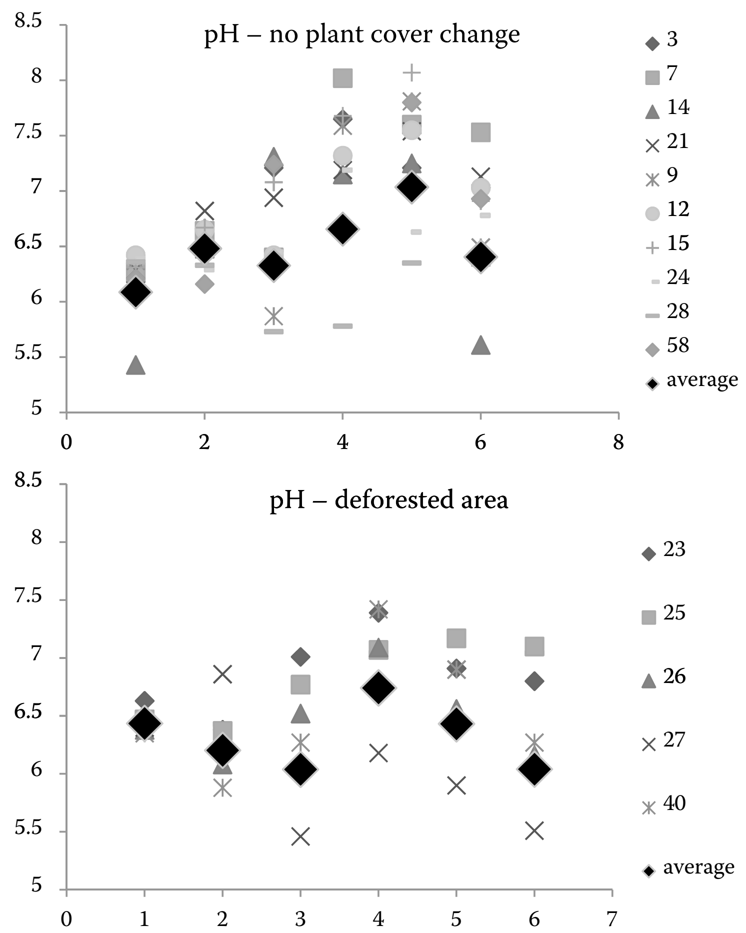

Fig. 4. Detailed comparison of reaction in groups of springs

ever, the decrease of pH was not correlated with nitrate concentrations. As Sienkiewicz et al. (cite the year please) wrote, after deforestation the outflow through upper-the most acid soil horizons increases.

– Despite the absence of statistical significance the difference in conductivity between groups was noticeable. In 2009 average conductivity for the particular seasons was lower by 12–23 μS·cm^{-1} on the deforested area than on the area without deforestation.
– Increased Ca^{2+} and K^{+} concentrations observed in the Hubbard Brook (USA) in surface waters described by Likens et al. (1995) were not recorded here.

In conclusion, the observed changes were smaller than expected, but it is possible that they will be observed in the years to come so that further monitoring should take place. The research coped with several difficulties which should be taken into consideration in future attempts of evaluating the effect of deforestation on spring water chemistry. The most important was drying of springs during periods without precipitation, which resulted in reduced samples. An alternative to the small amount of data in research of the presented profile is to increase the frequency of sampling. Another problem is a failure to predict where exactly the dieback would take place, however current literature describing the chemistry of springs in Poland gets richer (Ciszewski et al. 2004; Humnicki 2007; Jasik 2010) and will allow a comparison of the effects of large-scale deforestation in future.

References

Astel A., Małek S., Krakowian K. (2008): Sustainable afforestation as a tool of spring water sources protection in the mountain ecosystem. Polish Journal of Environmental Studies ***17***, 3A: 22–27.

Barszcz J., Małek S., Majsterkiewicz K. (2009): Dynamika zmian zagrożenia rozpadem świerczyn Beskidu Śląskiego i Żywieckiego. [Changes in dynamics of decay threat of spruce stands in Silesian and Zywiec Beskid Mountains.] Prace Komisji Nauk Rolniczych, Leśnych i Weterynaryjnych PAU, ***11***: 93–113.

Barszcz J., Kozak J., Widacki W. (1994): The forest degradation in the Silesian Beskid Mountains (Karpaty Mountains), Poland. In: Proceedings GIS'94 The Worlds Premier Symposium on GIS for Natural Resources, Environmental and Land Information Management, Vol. 2. Vencouver, 21.–24. February 1994. Vancouver, Polaris Conference, Inc.: 895–900.

Ciszewski D., Siwek J., Żelazny M. (2004): Naturalne i antropogeniczne uwarunkowania chemizmu wód wybranych źródeł na Wyżynie Śląskiej i Małopolskiej. [Natural and Antropogenic Factors of Water Chemistry in Selected Springs in Silesian Upland and Malopolska.] In: Partyka J. (ed.): Zróżnicowanie i przemiany środowiska przyrodniczo-kulturowego Wyżyny Krakowsko-Częstochowskiej. [Differentiation and Transformation of Natural and Cultural Environment Cracow-Częstochowa Upland.] Ojców, OPN, ***1***: 109–116.

Humnicki W. (2007): Hydrogeologia Pienin. [Pieniny Hydrogeology.] 1st Ed. Warszawa, Wydawnictwa Uniwersytetu Warszawskiego: 239.

Jasik M. (2010): Quality Assessment of Spring Water from the Area of the Łysogóry Mts. In Świętokrzyski National Park. In: Conference Proceedings of the 1st Forum Carpaticum, Integrating Nature and Society Towards Sustainbility. Kraków, 15.–18. September 2010. Kraków, Institute of Geography and Spatial Management, Jagiellonian University: 27.

Kozak J. (1996): Przestrzenny model degradacji lasów Beskidu Śląskiego. [The Spacial Model of the Silesian Beskid Forest Degradation.] In: Domański R. (ed.): Nowa generacja w badaniach gospodarki przestrzennej. [The New Generation of Spatial Studies.] Biuletyn KPZK, ***174***: 511–538.

Likens G. E., Bormann F.H., Pierce R. S., Eaton J. S., Johnson N.M. (1995): Biogeochemistry of a Forested Ecosystem. 2nd Ed. New York, Springer-Verlag New York, Inc.: 159.

Nowak A. (2002): Opis Mapy Hydrograficznej M-34-57-A. [Hydrographical Map.] Węgierska Górka, GUGiK Częstochowa.

Orzeł S. (1993): Ocena dynamiki przyrostu grubości drzewostanów świerkowych na przykładzie wybranych obiektów w lasach Beskidu Śląskiego i Żywieckiego. [Assessment of the dynamics of the thickness growth in Spruce Stands Based on Selected Objects in the Forests of Silesian and Zywiec Beskid Mountains.] Acta Agraria et Silvestria, Series Silvestris, ***31***: 3–15.

Sienkiewicz J. Kucharska K.,Wawrzoniak T. (1995): Zmiany ilościowe i jakościowe zasobów wodnych na wylesionych terenach górskich. [Quantitative and Qualitative Changes of Water Resources in Deforested Mountainous Areas.] Sylwan, ***12***: 51–60.

Šrámek V., Sitková Z., Małek S., Pavlenda P., Hlásny T. (2010): Znečistenie ovzdušia a výživa – príčiny hynutia smrekových porastov? [Air pollution and forest nutrition – what are their roles in spruce forest decline?] In: Hlásny T., Sitková Z. (eds): Hynutie smrekových porastov v Beskydoch. [Spruce Forest Decline in the Beskids.] Zvolen, National Forest Centre – Forest Research Institute Zvolen, Czech University of Life Sciences Prague, Forestry and Game Management Research Institute Jíloviště-Strandy: 49–67.

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