Mužíková, B., Středa, T.: Analysis of Relationship between Wind Speed on Windward and Leeward Side of Shelterbelts. Šiška, B. – Hauptvogl, M. – Eliašová, M. (eds.). Bioclimate: Source and Limit of Social Development International Scientific Conference, 6th – 9th September 2011, Topoľčianky, Slovakia

ANALYSIS OF RELATIONSHIP BETWEEN WIND SPEED ON WINDWARD AND LEEWARD SIDE OF SHELTERBELTS

Bronislava Mužíková[1], Tomáš Středa[2]
[1]*Institute Of Applied And Landscape Ecology, Faculty of Agronomy, Mendel University in Brno, Zemědělská 1, Brno 61300, The Czech Republic*
[2]*Czech hydrometeorological Institute, Kroftova 43, Brno 61667, The Czech Republic*
E-mail: *bronislava.muzikova@mendelu.cz, tomas.streda@chmi.cz*

Abstract
The paper presents partial findings of shelterbelt effect on wind speed by chosen windbreaks in erosion endangered localities on heavy soils in south Moravia. The ability of shelterbelts to reduce wind speed is indisputable, although there is a considerable seasonal changeability in connection with foliage changes of deciduous trees that form the shelterbelts. The air velocity is also characterized by considerable temporal and spatial variability, including the occurrence of extreme values, even within a relatively short episodes and local scale. Detailed measurements of wind field demonstrate this heterogeneity. The paper presents results of the relationship between wind speed on the windward and leeward side of windbreaks in a few episodes with distinct heterogeneity of air velocity. The time shift of measurements on the leeward side was not considered. Tightness of the relationship, expressed by index of determination, influenced by volatility of data file, and amplified by the influence of windbreaks seems to be insignificant.
Keywords: windbreak, shelterbelt, air velocity

Introduction

Wind erosion remains a global problem, causing both economic damages, as well as less quantifiable damage to human health or to plants such as eutrophication of water. Extensive soil units, lack of landscape vegetation and cultivation of crops inadequately covering the soil contribute to the development of wind erosion. It occurs mainly in drier and warmer climate areas with light soils.
In Moravia, wind erosion threatens up to 40 % of arable land (Pasák, 1984).
There is a number of more or less effective measures against wind erosion. Shelterbelts, protective forest belts, are traditional structures, which protect adjacent lands from the effects of wind. They operate as individual components or entire system of windbreaks. The ability of windbreaks to reduce wind speed, therefore the effectiveness of windbreaks, is determined by many factors. The most important are the porosity, height, orientation, width and arrangement of vegetation (Skidmore, 1977).
Measuring efficiency of windbreaks (wind speed reduction on the leeward side) is not so often carried out in the field in the world. Much research is done using models (Vigiak et al, 2003), often with the help of wind tunnels (Huang et al., 2005).

Materials and methods

Both localities are situated in South Moravia. Blatnice is located in the surrounding of the town Veselí nad Moravou (5 km east) and Suchá Loz is located about 6 km southeast from Uherský Brod.

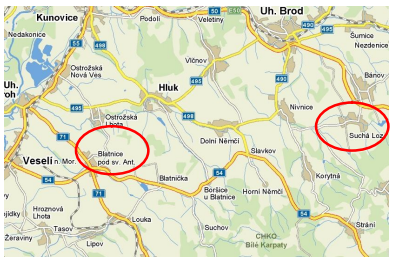

Figure 1. Chosen localities (www.mapy.cz)

Wind speed measurements were held using sets of mobile outpatient anemometers type W1 and W2 (Fig. 1) from Tlusťák. W1 and W2 sensors use rotary blade cross for measuring wind speed. Scanning speed of the cross is made optoelectronically and transmitted in digital form for processing. W2 sensors are also equipped with a rotary vane for measuring scapular wind direction. Data is stored in a data logger Hobo.

Figure 2. Anemometer W2

Measuring the specific impact of windbreaks on the wind field was always on the windward and leeward side. It monitors the influence of windbreaks on the horizontal wind profile. Each measurement takes at least 40 minutes. The data are registered in the five-second step.

When measuring horizontal wind profile anemometers are placed at a height of 2 m above the surface at the following distances from the windbreaks: 50, 100, 150 and 200 m.

Figure 3. Shelterbelt in Suchá Loz

Research on the impact of windbreaks on the wind speed was carried out at different wide windbreaks in areas at risk of wind erosion. Measurements were located in the period when the arable land was threatened by wind erosion the most, ie out of the main growing season of field crops and also to the period when the changing foliage of trees (spring and autumn).

Observed windbreaks consist of deciduous trees, phenological observations of tree species in windbreaks were therefore also performed and changes in optical porosity were evaluated.

For this paper only single measurements from windbreaks Suchá Loz and Blatnice pod Svatým Antonínkem have been evaluated. It was the April 27, 2009 (Sucha Loz) and December 10, 2010 (Blatnice). The aim was to assess the tightness of the relationship of wind speed on the windward and leeward side.

Shelterbelts description

Windbreak in Sucha Loz is formed by four rows (linden-poplar) and sparse shrubs floor. It is moderately high (20 m), occupies a strip of about 12 m in fields. The trees were planted in four rows and the element has parameters of permeable windbreaks.

Upper level consists of two rows of mature individuals of Canadian poplar (*Populus* x *canadensis*). In the lower storey there are younger oaks (*Quercus robur*) and linden (*Tilia cordata*), with interspersed individuals of ash (*Fraxinus excelsior*). The shrub layer is represented by European spindle (*Euonymus europaeus*), Dogwood (*Swida sanguinea*), rose hip (*Rosa canina*) and hawthorn (*Crataegus monogyna*). Occasionally there are groups of involved blackthorn (*Prunus spinosa*).

Windbreak in Blatnice has ten-rows, (linden-oak), where oaks (*Quercus robur*) dominate, with sparse shrubs floor. It is about 10 m high, 18 meters wide. In the shrub layer elderberry (*Sambucus nigra*) dominates and in the trees layer there are mainly oak (*Quercus robur*) and linden (*Tilia cordata*) trees, interspersed with spruce ash (Fraxinus excelsior) individuals.

Climatic conditions of the area

The nearest climatological station from both localities is Strání. The station is located in South Moravia, in the southeast corner of the Zlín Region. It is situated in the valley, which is surrounded by mountains and hills - near the highest mountain of the White Carpathian Mountains, Velká Javořina - 971 m.

According to agroclimatic conditions of Czechoslovakia (Kurpelová et al, 1975) the area belongs to slightly warm macroregion, the relatively warm region, moderately dry subregion and subdistrict of moderately cold winter.

Figure 4. Measuring of horizontal profile of wind speed on leeward side of shelterbelt

The area geologically belongs to the Western Carpathians, mainly to flysh zone of the Tertiary period. Furthermore, the area consists of Neogene sediments and also Quaternary Pleistocene and Holocene sediments. The most common substrate is loess. Heavy clay and loamy-clay soils dominate. Most of these soils are calcareous and deep.

Results

Figure 5 shows the course of measured wind speeds at the locality Blatnice.

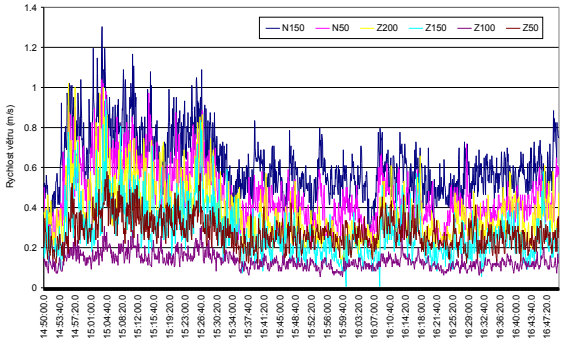

Figure 5. Wind speed on locality Blatnice, 10.12.2010.

Although at first glance appears to be some correlation between wind speed on the windward (N 150) and leeward (Z50) side, the graph in Figure 6 did not show significant relationship between wind speed on both sides of shelterbelt. Standard deviation is 0.98 on the windward side for average wind speed 7.69 m/s and 0.49 on the leeward side (wind speed 3.61 m/s). Index of determination is equal to 0.18 (see Figure 6).

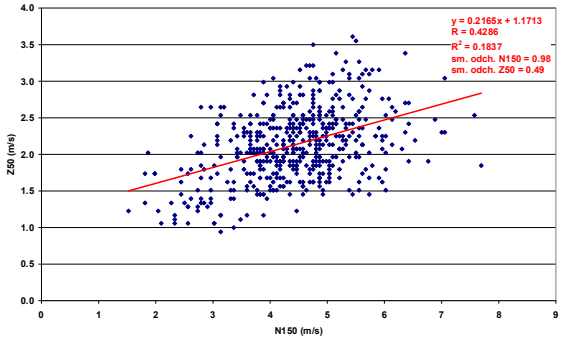

Figure 6. Regression analysis of the relationship between wind speed N150 and Z50, Blatnice 10.12.2010, interspersed with linear trend

The graph in Figure 7 is an example of the relationship between wind speed on the windward (N150) and leeward (Z50) side of the windbreak during the episode with significant heterogeneity of air velocity (standard deviation 1.99, the average wind speed of 6.78 ms-1, 1.23 respectively at 4.12 ms-1) during a two-hour episode of measuring in Suchá Loz 27.4.2009. Tightness of the relationship, expressed as an index of determination (0.0075), influenced by volatility of data file, and amplified by the influence of windbreaks is so negligible.

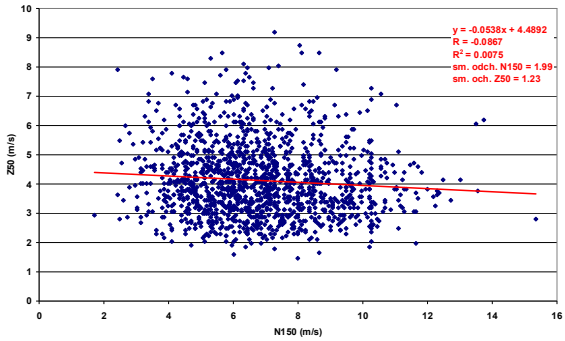

Figure 7. Regression analysis of the relationship between wind speed N150 a Z50, Suchá Loz 27.4.2009, interspersed with linear trend

Conclusions

For selected windbreaks the ability to reduce wind speed has been shown. The effect of reduction is noticeable especially on the leeward side, on the windward side of windbreaks is less pronounced. Reduction of wind speed by shelterbelts is undisputed, although there is significant seasonal variability in connection with changes in the foliage of trees in windbreaks. Effect of shelterbelts on air flow is manifested even when the main tree species are not yet in leaf, but with reduced efficiency.

The air velocity is also characterized by considerable temporal and spatial variability, including the occurrence of extreme values, even within a relatively short episodes and local scale. Detailed measurements of wind fields show this heterogeneity. The paper presents results of evaluation of the relationship between wind speed on the windward and leeward side of windbreaks in a few episodes with distinct heterogeneity of air velocity.

Time shift of measurements on the leeward side was not considered. Tightness of the relationship, expressed as an index of determination, influenced by volatility data file and amplified by the influence of windbreaks appears to be negligible.

Future work will take into account the time difference of measurements and more episodes of measurements at several other locations will be evaluated.

Acknowledgements

Results of this thesis are part of the project NAZV No. QH82099 "Criteria of wind erosion development on heavy soils and the possibility of its limitation with biotechnological measures".

References

HUANG LONG, MING ZHANG SHUHAO, 2005: Study on the effect of wind reduction by the successive windbreak fence. Journal of Agriculture and Forestry. 54: 2, 113-127. 20 ref.

KURPELOVA, M., COUFAL, L., ČULIK, J., 1975: Agroklimaticke podmienky ČSSR. Priroda, HMU, Bratislava, 270 p.

PASÁK, V. A KOL., 1984: Ochrana půdy před erozí. SZN Praha. 164 p.

SKIDMORE, E. L. AND HAGEN, L. J., 1977: Reducing Wind Erosion With Barriers. Trans. ASAE, v. 20, p. 911-915.

VIGIAK, O. STERK, G. WARREN, A. HAGEN, L. J., 2003: Spatial modeling of wind speed around windbreaks. Catena. 52: 3/4, 273-288. 22 ref.