ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 63 15 Number 1, 2015

http://dx.doi.org/10.11118/actaun201563010113

THE METHODS OF LOCATING AREAS EXPOSED TO WIND EROSION IN THE SOUTH MORAVIA REGION

Jana Podhrázská[1], Josef Kučera[1], Hana Středová[2]

[1] Research Institute for Soil and Water Conservation, Lidická 25/27, 602 00 Brno, Czech Republic

[2] Department of Applied and Landscape Ecology, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

Abstract

PODHRÁZSKÁ JANA, KUČERA JOSEF, STŘEDOVÁ HANA. 2015. The Methods of Locating Areas Exposed to Wind Erosion in the South Moravia Region. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 63(1): 113–121.

The conditions for the development of wind erosion are determined by the soil and climatic conditions as well as by the presence or absence of wind barriers. It is because of its climatic and soil conditions that the territory of the South Moravia Region has been affected by erosion for centuries. Combined with the atmospheric conditions, the dry and warm climate enables the development of aeolian processes both in light, drying soils and – under certain climatic conditions – in heavy, clay-loam soils. Soil erosion exposure maps have been prepared in order to identify the territories which are potentially exposed to wind erosion in terms of the soil and climatic conditions. Six exposure categories have been applied to the soils. However, the impact of permanent vegetation barriers – line elements – must be considered in order to identify the most exposed areas. Protective forest belts were planted in the 1950s to counter the effects of wind erosion and they are included in the database of the Institute for Economic Forest Management. The network of these wind barriers and the heath condition of the individual elements are often unsatisfactory because of poor maintenance. The purpose of the study was to evaluate the spatial function of the network of protective forest belts using the map of the potential exposure of soil in the Region of South Moravia. The method used to evaluate the spatial function of the windbreaks presented in the study using GIS instruments.

Keywords: Wind erosion, protective forest belts, spatial function of windbreaks, soil characteristics, climatic conditions, geographic information system, wind erosion exposure maps

INTRODUCTION

Within Europe, the region of South Moravia, in particular its southern and south-eastern part, has been affected by wind erosion for ages.

This phenomenon is caused by a number of factors. The main cause is the wind and other preconditioning climatic factors. Until humans interfered with the environmentally balanced landscape, the disruptive effects of the wind did not exceed the limits of natural erosion. It was human economic activity that created conditions in the landscape that enabled the destructive effects of the wind.

The deforestation of a number of mountain ridges, hills, mountain saddles and valleys can be seen as one of the key causes as such places became the gateway for winds, allowing the emergence of the typical wind flow lines (Švehlík, 1996). The subsequent cultivation of the original clear-cut areas exposed the soil surface and opened it to the effects of wind and water erosion. The danger of wind erosion was underestimated in the transition to the large-area, one-crop land management in the mid-1900s. The resulting damage to the crops, property and human health and microclimate changes led to the need for creating permanent barriers in the form of vegetation – protective forest belts. As early as 1950 an expert conference was held to deal with the issue of protective forest belts, including the building and maintenance thereof (ČSAZ, 1950). Windbreaks were planted at the time mainly on consolidated blocks of land in south-east Moravia in the Znojmo, Břeclav and Hodonín area and, to a lesser degree, in central Bohemia. The windbreaks were usually created following the Soviet template, forming integral networks in the farming landscape. A total of 1,754 hectares of windbreak forest belts were planted in the Czech Republic, with 67% of this area located in the Region of South Moravia. The original area decreased in time (Volný, 1995) and the interest in the maintenance and renewal of the growths dropped in general. In connection with the loss of biodiversity and the continued processes of soil degradation in territories with intensive farming, issues aimed at promoting the function of windbreaks and evaluating their efficiency have recently re-emerged.

Linear elements may perform multiple functions in the landscape (Brandle *et al.,* 2004). They help improve the quality of the environment and increase the production rates while, at the same time, working as protection against wind and water erosion, providing shelter to many animal species and assisting in facing the consequences of sever climate changes. Hodges and Brandle (1996) also see windbreaks as an important stabilising element in the growing of special crops using special agrotechnologies. A number of international and domestic authors have evaluated the efficiency of the individual linear elements, their structure in terms of species, the health condition, and determining the suitable parameters in terms of efficiency with a view to preserving the fertility of the soil. The wind speed reduction by certain windbreaks surveyed Středa *et al.* (2008) and found, that average wind speed in leeward side 50 m behind windbreak in compare with control sensor in windward side decreased usually from 17% up to 64%.

It is of equal importance to evaluate windbreaks in terms of their spatial layout and their effect as a system integrated with other landscape structures. An extensive study was performed in Romania by Danescu *et al.*(2007), who used the available climatic, geomorphological, pedological and other data to analyse 52 sites in terms of the location and layout of the network of protective forest belts. Windbreaks were also evaluated from both of these perspectives – the local zone of the windbreak and the regional effect of a network of windbreaks – by Guyot (1987) as well as other authors.

This paper presents the findings of a study dealing with the risks of the occurrence of wind erosion in the area of south Moravia, which is among the most fertile regions of the Czech Republic while facing the highest exposure to erosion phenomena. The contributing factors include the soil and climatic conditions as well as the high share of arable land in the region. Artificial linear elements built as protection against the destructive erosive effects of the wind – protective forest belts – therefore play a more important part there than in other regions. The objective of the study was to use maps defining soil that is potentially susceptible to wind erosion and the data layer of protective forest belts including their spatial layout and structure to identify territories with a higher priority of protection against wind erosion by means of targeted plantations of permanent linear vegetation.

MATERIAL AND METHODS

Material

The territory of the South Moravia Region was selected as the object of the study. Within Europe, this region, in particular its southern and south-eastern part, has been affected by wind erosion for ages. It is the warmest region of the Czech Republic, with the average yearly temperature of 8.6 °C and the average yearly rainfall of 574 mm. The high share of arable land contributes to the development of wind erosion – arable land accounts for more than a half of the area of the region in terms of the structure of the land (50.8%, compared to the national total of 39.2%). The recent weather extremes, in particular the dry and hot spells and the associated wind flows, increase the risk of wind erosion even in locations with lower previous exposure. The specific soil and climatic conditions, in particular those present in the south-east of the Region of South Moravia, enable the development of wind erosion even in heavy, clay-loam soils, in which the soil aggregates disintegrate during winter and the drying winds of spring carry great amounts of fine particles across significant distances.

The following materials have been used to determine the areas with the highest potential exposure to wind erosion:

- The potential wind erosion exposure map drawn up on the basis of the evaluation of the grain-size structure of the soils and the climatic conditions (Janeček *et al.* 2000, Podhrázská *et al.,* 2008), as presented on the SOWAC GIS portal of the Research Institute for Land Reclamation and Protection ("RISWC"). The soils are divided into 6 exposure categories by their susceptibility to wind erosion.
- The map of the potential exposure of heavy soils, prepared on the basis of the evaluation of the disintegration of non-erodible particles and the analysis of the weather conditions in winter (Dufková, Podhrázská, 2011; Podhrázská *et al.,* 2013), as presented on the RISWC website. The soils are again divided into 6 exposure categories according to their susceptibility to wind erosion.
- Analogue and digital data on protective forest belts for the territory of the South Moravia Region from the database of the Institute for Economic Forest Management.
- Regionalised soil units from the database of the Research Institute for Land Reclamation and Protection (RISWC).
- Orthophotomaps.
- Digital terrain model (DTM).

Methodology

For the purposes of the study, the outcomes were divided by district, for which summary analyses were prepared.

The two underlying maps expressing the potential exposure of the area to erosion from the soil and climate perspective were aggregated into a single synthetic map in which the cadastral district is the main display unit. For each cadastral district, the two maps were used to determine the exposure categories by applying the weighted of the individual categories of exposure, which were expressed in surface terms by means of polygons of the relevant soil units.

The underlying aggregated map of potential exposure of the cadastral districts to wind erosion was used to identify the networks of protective forest belts from the database of the Institute for Economic Forest Management in the individual cadastral districts with the exposure category of 4–6, i.e. areas with a high to the highest exposure exposure to wind erosion. Evaluation of the functional status of the protective forest belts was based on the concept of the methodology for the categorisation of the protective forest belt system. This methodology (Podhrázská, 2007, 2008) was applied in order to categorise the system of protective forest belts in the landscape. The categorisation is derived from the following assessment of the functional parameters of the forest belts:

1 Parameters Defining the Spacing of the Elements of the Protective Forest Belt Network

The spacing criteria mainly following a rectangular pattern of 350–600 m, with side belts at the ideal ratio of 1:4 to reach the maximum ecotone effect (Forman, Godron, 1993) (Tab. I).

2 Parameters Defining the Integration of the Elements in the Terrain – Geomorphological and Climatic Links

The assessment is performed on the basis of a digital terrain model and reference information on the direction of winds with erosive effects, as obtained by a field survey (Tab. II).

3 Landscape and Ecological Parameters Related to the Infrastructure of the Landscape and the Territorial System of Ecological Stability

The parameters of a local forest-type of a wildlife corridor were selected as the optimum value: minimum width of 15 m, maximum length of 2 km (Löw *et al.*, 1990; Míchal, 1992) (Tab. III).

Evaluation of the Reference Scoring System for the Categorisation of the System of Protective Forest Belts

The design of the scoring system is based on the characteristics of the reference criteria. The value scale of the criteria has the following algorithm (Tab. IV)

I: *Parameters defining the spacing of the elements of the protective forest belt network*

Criterion indicator	Value
B-1.1. The elements are not laid out in a system	1
B-1.2. Over 50% of the elements is laid out in a system not corresponding to the optimum	2
B-1.3. Under 30% of the elements is laid out in a system not corresponding to the optimum	3

II: *Parameters defining the integration of the elements in the terrain – geomorphological and climatic links*

Criterion indicator	Value
B-2.1. The position of over 50% of the elements do not comply with terrain morphology and wind direction	1
B-2.2. The position of 31–50% of the elements are suitably integrated in the terrain with regard to wind direction	2
B-2.3. Over 50% of the elements are in an optimum position.	3

III: *Landscape and ecological parameters related to the infrastructure of the landscape and the territorial system of ecological stability*

Criterion indicator	Value
B-3.1. Under 30% of the elements have the parameters of a wildlife corridor	1
B-3.2. 31–50% of the elements have the parameters of a wildlife corridor	2
B-3.3. Over 51% of the elements have the parameters of a wildlife corridor	3

IV: *Scoring system for the categorisation of the system of protective forest belts*

Forest belt system evaluation	Category	Total
Functional	3	8–9
Contingent functional	2	5–7
Predominantly non-functional	1	3–4

The cadastral districts with no protective forest belts cannot be evaluated and received a score of 0 – non-functional.

The sites with the highest priority of addressing wind erosion by targeted measures have been identified on the basis of the functional parameters of the protective forest belts under evaluation in the individual cadastral districts involving risks in terms of the climate and soil related criteria.

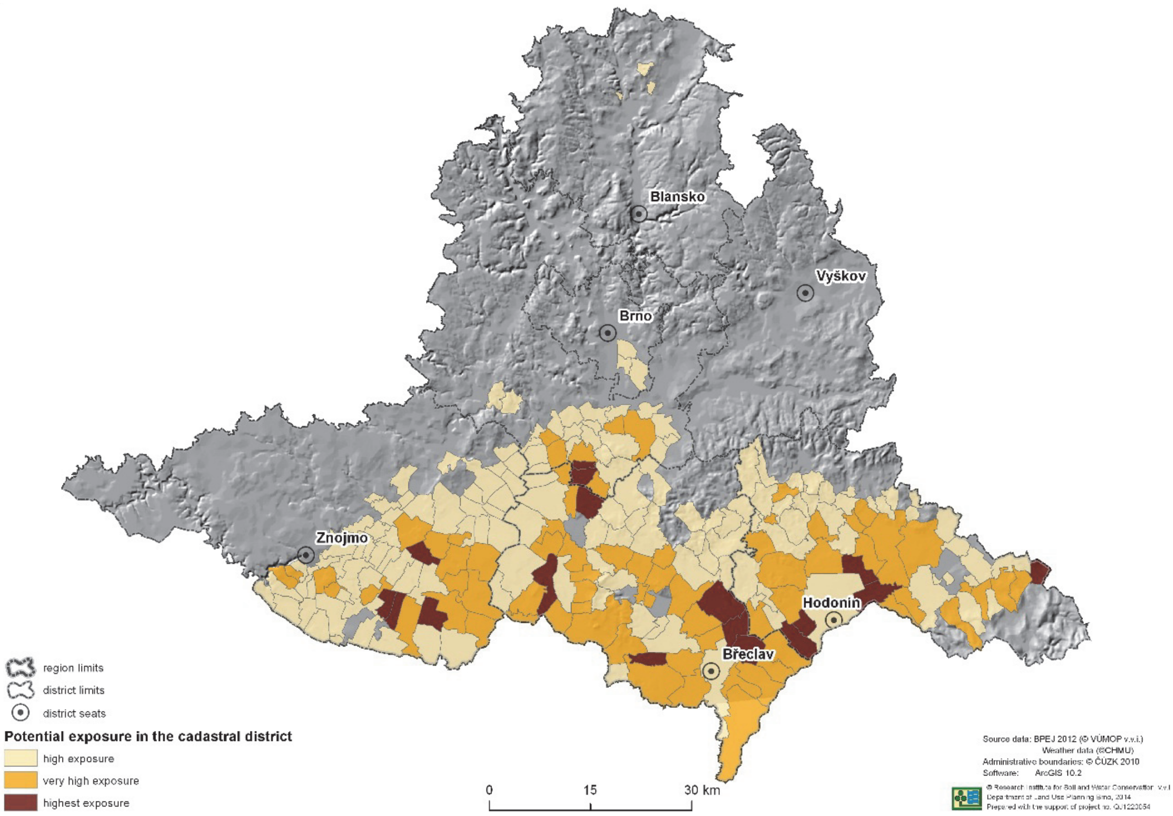
RESULTS, DISCUSSION

Using the underlying synthetic map of the level of exposure of arable soil to wind erosion in the 892 cadastral districts of the Region of South Moravia, the cadastral districts with a high to the highest exposure, i.e. those in categories 4, 5 and 6, were selected (Fig. 1).

A total of 231 cadastral districts fall into these categories; 143 of them are in category 4; a total of 70 are in category 5; and 18 cadastral districts are in category 6. The highest share of the category 4–6 cadastral districts is in the administrative district of Znojmo (Tab. V).

Tab. V indicates that the highest potential exposure is found in the administrative districts of Břeclav, Hodonín and Znojmo. Those are the districts with the highest percentage of land exposed to wind erosion. In terms of the share of arable land in the Region of South Moravia, this concerns 17.5% of arable land in the administrative district of Břeclav, 12.9% in the district of Hodonín, and 17.9% in the district of Znojmo (Tab. VI, Fig. 2).

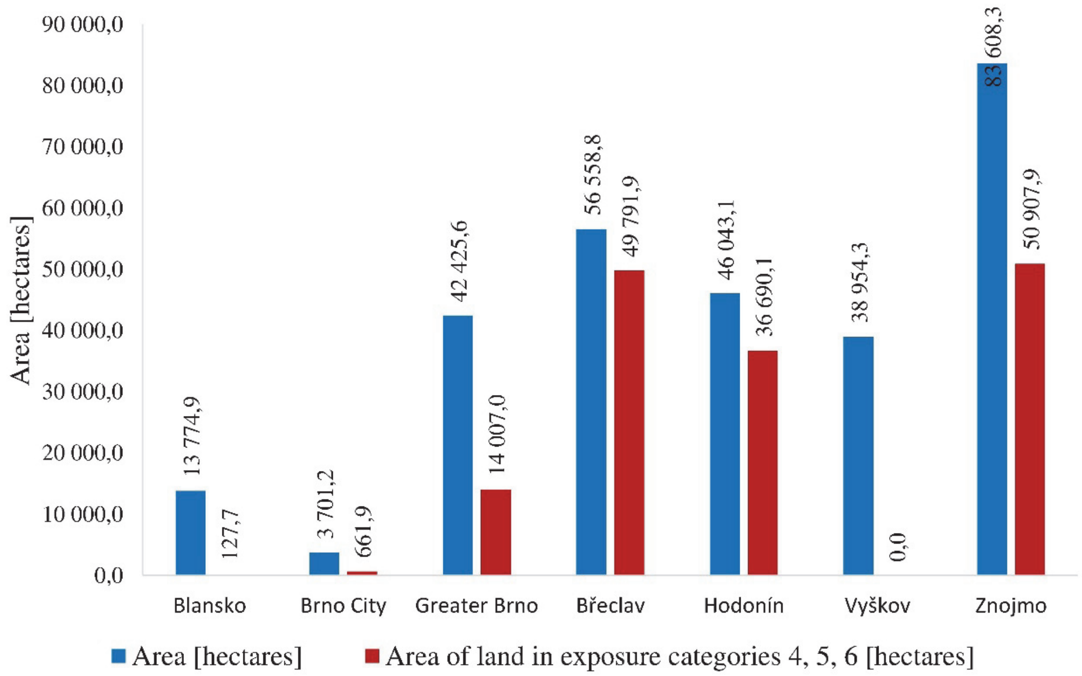
The selected cadastral districts (231) were further analysed in terms of the spatial layout of the windbreaks and their functional condition.



1: *Potential wind erosion exposure map of the territory of South Moravia*

V: *Number of cadastral districts in exposure categories 4, 5 and 6 in the individual administrative districts*

District/exposure category	4	5	6	Total
Blansko	3	0	0	3
Brno City	3	0	0	3
Greater Brno	21	6	2	29
Břeclav	30	29	7	66
Hodonín	35	20	5	60
Znojmo	51	15	4	70
Total	143	70	18	231



2: *Area of arable land and land exposed to wind erosion in the individual administrative districts of South Moravia*

VI: *Percentage of arable land exposed to wind erosion, by administrative districts in the South Moravia Region*

Administrative district	Arable land [hectares]	Area of land in exposure categories 4, 5, 6 [hectares]	Percentage [%]
Blansko	13,774.9	127.7	0.0
Brno City	3,701.2	661.9	0.2
Greater Brno	42,425.6	14,007.0	4.9
Břeclav	56,558.8	49,791.9	17.5
Hodonín	46,043.1	36,690.1	12.9
Vyškov	38,954.3	0.0	0.0
Znojmo	83,608.3	50,907.9	17.9
Total	285,066.3	152,186.5	53.4

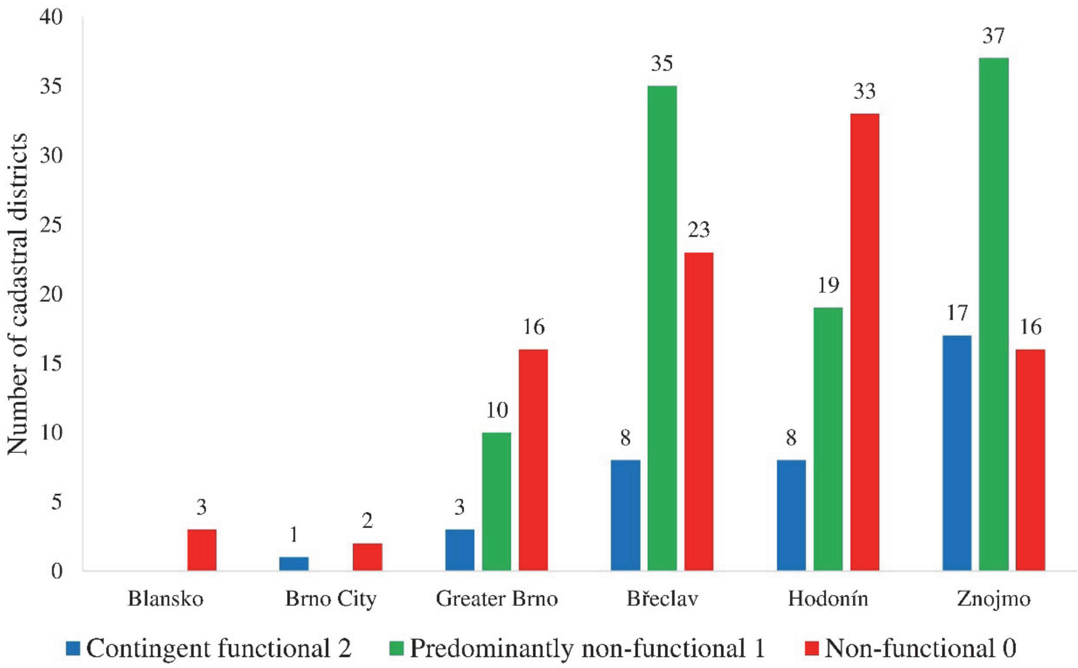
VII: *Evaluation of the spatial parameters of the protective forest belts in the individual cadastral districts*

Administrative district	Functional 3	Contingent functional 2	Predominantly non-functional 1	Non-functional 0	Total
Blansko	0	0	0	3	3
Brno City	0	1	0	2	3
Greater Brno	0	3	10	16	29
Břeclav	0	8	35	23	66
Hodonín	0	8	19	33	60
Znojmo	0	17	37	16	70
Total	0	37	101	93	231

The data processing technology relied on the intersection of the layer of protective forest belts with the digital terrain model and the orthophoto image. The category in which the network of protective forest belts found in that territory falls was determined for each cadastral district under review. The results were also aggregated to the level of administrative districts. (Tab. VII, Fig. 3).

The evaluation shows that no administrative district has a functional network of protective forest belts. In terms of the overall representation of the network of linear elements of various categories, the best coverage is in the administrative districts of Znojmo, Břeclav and Hodonín.

An overview was then prepared to show the representation of the individual categories of



3: *Evaluation of the spatial parameters of the protective forest belts in the individual cadastral districts*

VIII: *Representation of the individual categories of protective forest belts, by the degree of exposure of arable land*

Exposure/Forest belt category	Contingent functional 2	Predominantly non-functional 1	Non-functional 0	Total
4	16	61	66	143
5	13	35	22	70
6	8	5	5	18
Total	37	101	93	231

IX: *Urgency matrix*

Forest belt category/Exposure	4	5	6
0	3	2	1
1	4	3	2
2	5	4	3

protective forest belts by the degree of arable land exposure in the territory of the South Moravia Region (Tab. VIII).

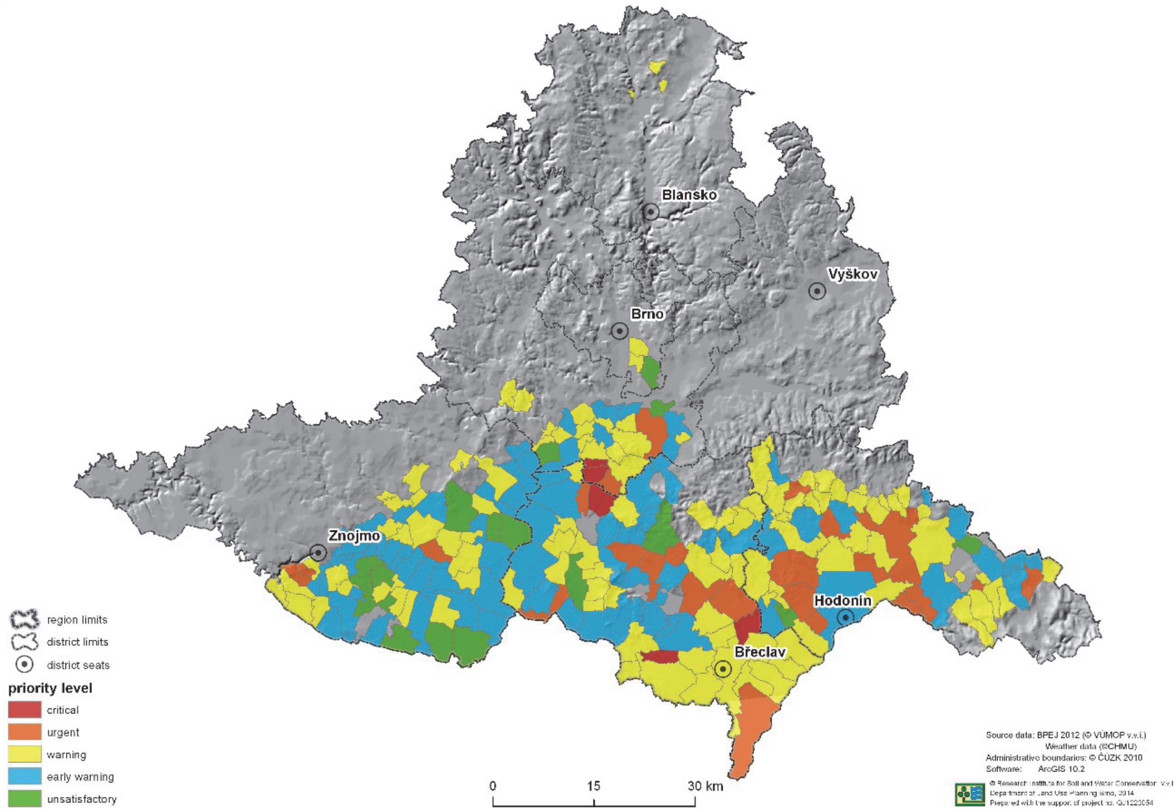
In the area under review, a total of 93 non-functional, 37 contingent functional and 101 predominantly non-functional protective forest belt systems were found. There were a total of 18 protective forest belt networks in the cadastral districts in the highest exposure category (category 6), which accounted for 7% of the total area of the cadastral districts under evaluation. A total of 70 protective forest belt systems were identified in category 5 cadastral districts (37% of the total area) and 143 protective forest belt networks in category 4 (accounting for 55%).

A matrix was prepared to express the degree of urgency of the implementation of measures aimed at the completion and/or creation of a network of linear elements as protection against wind erosion, according to which the level of priority can be set for each units (cadastral district) under review (Tab. IX).

The priorities are expressed on a 1–5 scale:

- Priority 1 critical.
- Priority 2 urgent.
- Priority 3 warning.
- Priority 4 early warning.
- Priority 5 unsatisfactory.

When compare the maps 1. and 4., it can be resulted, that the function net of shelterbelts can fulfil the requirements of protection the soils against wind erosion. The critical status was assigned to 5 cadastral districts, the measures are urgent in 27 cadastral districts, the warning status was associated with 109 cadastral districts, the early warning status to 74 cadastral districts, and the 16 cadastral districts were unsatisfactory. No cadastral district was found to be in satisfactory condition



4: *Map of priorities*

in terms of the representation of the network of protective forest belts. A map showing the areas where the priority of adopting wind erosion control measures is the highest was prepared on the basis of the findings. The unit of display is the cadastral district (Fig. 4).

The map (Fig. 4) of the priority areas in terms of the implementation of soil erosion control measures.

The findings of the research concerning the territory of the South Moravia Region confirm a fact that has long been pointed to: the wind barriers planted in the mid-1900s have faced long-terms neglect, received little care and no attention was paid to their maintenance and renewal. Similar results were obtained in the territory of Wisconsin, USA, by David and Rhyner (1999), who had recorded 2,600 windbreaks in central Wisconsin. It was found that only a small part of them provided effective protection and that it was necessary to support the renewal and reconstruction of the existing barriers as well as the plantation of new ones. Siddoway (1970) discussed the causes of the low utilisation of windbreaks for erosion protection. The reasons included costly plantation, a long time until full effectiveness, competition to field crops for moisture and nutrients, the absence of hard evidence of increased yields of crops, etc.

However, Kort (1988) clearly proved the benefits of windbreaks in reducing wind erosion, improving the microclimate and reducing damage to field crops. He emphasised the importance of the proper spatial distribution and correct parameters of windbreaks to achieve the maximum effect. Exact formula of wind speed reduction in dependence on distance from the windbreak and its optical porosity (construction) states Středová *et al.* (2012).

When addressing the issue whether or not it would be more advisable to apply other wind erosion control measures (organisational, agrotechnological) instead of the appropriation of arable land for additional plantations of linear vegetation, it is also necessary to consider other important properties of permanent linear vegetation, in particular in the area of ecostabilisation.

CONCLUSION

The agricultural landscape in the south and south-east of the Region of South Moravia shows signs of reduced ecostability caused by large-scale aration, the consolidation of land, intensive farming associated with limited crop rotation, a high rate of utilisation of farming mechanisation, and pursuit of maximum production rates. The cultivation methods of the past decades are reflected in the reduced quality of farming land, low diversity of plant and animal species, and poor water regime of the territory. The condition of the landscape allows for the development of ever-increasing water and wind erosion. The increasing frequency of extreme climatic phenomena (flooding, drought, wind storms) contribute to the expansion of the territories affected by erosion processes. The objective of the common agricultural policy of the European Union is to ensure the economical management of the natural resources and permanently sustainable rural development in the long-term. The maintenance, establishment, and reconstruction of permanent vegetation in the agricultural landscape form an integral part of this policy. Investments in these activities should be targeted in order to achieve the maximum effect in eliminating the defined risks. The study performed in the Region of South Moravia defined the most crucial areas in terms of the occurrence and potential development of wind erosion. The findings may be used to target investments in the proposal for and implementation of measures with conservation and ecostabilising effect.

Acknowledgement

This paper has been produced with support from project QJ1220054 "The influence of changes in climatic factors on the development of wind erosion processes and a policy proposal for land adjustment measures".

REFERENCES

BRANDLE, J. R., HODGES, L., ZHOU, X. H. 2004. Windbreaks in North American Agricultural Systems. *Agroforestry Systems*, 61: 65–78.

ČESKOSLOVENSKÁ AKADEMIE ZEMĚDĚLSKÁ. 1950. *Otázka ochranných lesních pásů v ČSR*. Soubor přednášek a referátů z vědecké ankety konané II. a III. Odborem ČAZ. 7.–8. 10. 1949. 1. vyd. Praha: Brázda.

DANESCU, F., COSTACHESCU, C., PETRILA, M. 2007. *Necessity study for installation of network shelterbelts for field protection in Constanta County*. Analele Institutul de Cercetari si Amenajari Silvice, 50: 299–316.

DAVID, C. A., RHYNER, V. 1999. An assessment of windbreaks in central Wisconsin. *Agroforestry Systems*, 44(2/3): 313–331.

FORMAN, R. T. T., GODRON, M. 1993. *Krajinná ekologie*. Praha: Academia.

GUYOT, G. 1989. Aerodynamic and microclimatic effects of windbreaks and of regional windbreak networks. In: *Meteorology and agroforestry. Proceedings of an international workshop on the application of meteorology to agroforestry systems planning and management*. Nairobi 9–13 February 1987, International Council for Research in Agroforestry, 485–520.

JANEČEK, M., TIPPL, M., PIVCOVÁ, J. et al. 2000. *Methods for restricting the degradation of soils by erosion and erosion control systems. Maps of the potential water and wind erosion threat to agricultural soils in the Czech Republic* [in Czech]. [online]. VÚMOP Praha-Zbraslav. Available at: http://www.sowac-gis.cz.

KORT, J. 1988. Benefits of windbreaks to field and forage crops. *Agriculture, Ecosystems and Environment*, 22(23): 165–190.

KOZLOVSKY DUFKOVÁ, J., PODHRÁZSKÁ, J. 2011. Wind erosion on heavy-textured soils: calculation and mapping. *Acta univ. agric. et silvic. Mendel. Brun.*, 59(6): 199–208.

HODGES, L., BRANDLE, J. R. 1996. Windbreaks: An Important Component in a Plasticulture System HortTechnology. *Agronomy & Horticulture – Faculty Publication*, 6(3): 177–181.

LÖW, J. et al. 1990. *Návod na navrhování územních systémů ekologické stability krajiny*. Podniková metodika Agroprojektu, Praha.

MÍCHAL, I. 1992. Územní systémy ekologické stability. *Ochrana přírody*, 47(8): 227–234.

PODHRÁZSKÁ, J. a kol. 2013. *Vliv změny klimatických faktorů na rozvoj procesů větrné eroze, koncepční řešení opatřeními pozemkových úprav*. An edited report on project QJ1220054. Brno: RISWC.

PODHRÁZSKÁ, J. a kol. 2008. *Optimization of functions of shelterbelts on agricultural land. Methodics*. Brno: RISWC.

PODHRÁZSKÁ, J. 2007. Metoda hodnocení větrolamů jako podklad pro stanovení jejich účinnosti. *Acta Universitatis Mendelianae Brunensis*, 55(5): 123–131.

SIDDOWAY, F. 1970. Barriers for wind erosion control and water conservation. *Journal of Soil and Water Conservation*, 25(5): 180–4. 21.

STŘEDA, T., MALENOVÁ, P., POKLADNÍKOVÁ, H., ROŽNOVSKÝ, J. 2008. The efficiency of windbreaks on the basis of wind field and optical porosity measurement. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 56(4): 281–288.

STŘEDOVÁ, H., PODHRÁZSKÁ, J., LITSCHMANN, T., STŘEDA, T., ROŽNOVSKÝ, J. 2012. Aerodynamic parameters of windbreak based on its optical porosity. *Contributions to Geophysics and Geodesy*, 42(3): 213–226.

ŠVEHLÍK, R. 1996. *Wind erosion of soils in southern Moravia* [in Czech]. Uh. Brod: CICERO plus.

VOLNÝ, S. 1995. Problematika větrolamových lesních pásů ve vztahu k činnosti lesotechnických meliorací – hrazení bystřin. In: *Význam a předpoklady rozvoje činnosti LTM-HB*, Teze příspěvků odborného semináře 14. 9., ČZLU Brno, 42–44.

Contact information
Jana Podhrázská: podhrazska.jana@vumop.cz
Josef Kučera: kucera.josef.jr@vumop.cz
Hana Středová: hana.stredova@mendelu.cz