THE POTENTIAL RISK OF WATER AND WIND EROSION ON THE SOILS OF THE CZECH REPUBLIC

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The first maps of soil erodibility by water and wind for the territory of the Czech Republic were constructed in the 1960's. Since that time, the methodology of erosion evaluation has developed considerably, mainly in association with the advances in computing technology. It was particularly the creation of the geographic information systems (GIS) which boosted the progress. In the context of delimitation of areas suitable for conversion of arable lands into permanent grasslands or forests, which is a part of the program of reduction of agricultural production in the Czech Republic, the need has appeared for a sound scientific basis allowing to optimize this process. As the dense grass cover itself is a perfect protection of soil from erosion, the attention is logically focused on the arable lands which are much more susceptible to erosion. Therefore, maps of the potential soil erosion risk by water and wind were constructed using an ARC/INFO geographic information system. The potential soil loss estimate was averaged over individual cadaster territories. A modified Universal Soil Loss Equation was used to assess the risk of water erosion such in a way that the variable factors (*L*, *C*, *P*) were replaced by constants while the remaining relatively stable factors (*K*, *S*) were estimated using the pedologic database of the Research Institute for Soil and Water Conservation (RISWC). To determine the soil erodibility by wind, a methodical procedure previously used by the author was applied, exploiting the same soil data base. The data have been stored on a disk of the work station at RISWC and can be used for further interpretations.

reduction of agricultural production; water and wind erosion; geographic information system; maps of soil erodibility; erosion risk

INTRODUCTION

The first synoptic map of soil erodibility by water and wind in Czechoslovakia was constructed by B u č k o et al. (1964). The map identified the zones on the territory of the former CSSR endangered by sheet and gully erosion, the density of the gully network and the areas susceptible to wind erosion.

To produce this map, the territory of the whole country was divided into squares of 81 km^2 in area by placing a grid over the map. The area of the agricultural land endangered by water erosion was determined by the methodology developed at the Department of Irrigation and Drainage of the Faculty of Civil Engineering at the Czech Technical University in Prague (H o l ý , 1970) and assigned to particular squares of the grid. The ratio of the endangered area to the overall area of the square was adopted as a „degree of erodibility“ of the territory by water erosion. The territory of Czechoslovakia was divided into four categories according to the degree of erodibility: I – less than 25% agricultural land endangered, II – 25–50% a.l.e., III – 50–75% a.l.e. and IV – more than 75% a.l.e.

Continuous contours were then drawn through the grid squares to separate different categories of the agricultural land erodibility by water erosion of both the sheet and the gully types.

To determine the density of the gully network, the territory of the country was divided into squares of 4 km^2 in area. The total length of gullies was determined in each of these squares. Three categories of the gully network density were then distinguished: I – less than 0,1 km/km^2, II – 0,1–1 km/km^2 and III – more than 1 km/km^2.

Even before that, the Regional Institute of Studies in Brno and, later, the Czechoslovak Academy of Agricultural Sciences, at the Brno symposium in 1949 (C a b l í k , J ů v a , 1963), attempted to determine the areas subjected to wind erosion in Czechoslovakia. The corresponding maps summarizing this effort were then constructed at the Hydrometeorological Institute. In these maps, the areas susceptible to wind erosion were divided into three categories, depending upon the type of wind prevailing in the area: dry, cold, or the one causing direct soil deflation. Later, P r e t l (1963) used the data of the National Water Management Plan of the Czechoslovak Republic (accomplished in 1955) as well as his own research and survey data to construct another map of wind erosion.

P a s á k and J a n e č e k (1971) delimited the areas susceptible to wind erosion in Czechoslovakia using a climatic erosion factor C (expressing the effect of wind speed and soil moisture content) and a map of the soil texture classes.

However, since the time when the above-mentioned cartographic works had been compiled, the methodical procedures of erosion evaluation as well as the computing technology have progressed considerably. Although the idea of geographers to create a computerized system for storage and arrangement of spatial information arose more than thirty years ago, it is only during the last fifteen years that this expanding technology known as „geographic information system“ (GIS) has become widespread. In parallel with the advances

in technology, the spectrum of applications of GIS has also been widening and is now capable of providing a high quality cartography as well as of evaluating various environmental components of the landscape, such as the soil erodibility.

MATERIAL AND METHODS

WATER EROSION

In the context of the ongoing delimitation of areas suitable for conversion of arable lands into permanent grasslands or forests, which is a part of the program of reduction of agricultural production in the Czech Republic, a requirement has been formulated that other than economic factors should be also taken into account. As a dense grass cover with closed canopy or a herb layer in the forest provide themselves a good protection of the soil against erosion, it is logical that the above measures should be applied mainly on shallow, easily erodible soils on slopes.

The most accurate and practically most applicable tool to determine the degree to which the soil is endangered by water erosion can be expressed by the following so-called Universal Soil Loss Equation (W i s c h m e i e r , S m i t h , 1965, 1978):

$$G = R \,.\, K \,.\, L \,.\, S \,.\, C \,.\, P$$

where: G – long-term average amount of soil loss by water erosion (t/ha/year)
R – factor of rainfall erosivity depending upon the frequency of occurrence, amount, intensity and kinetic energy of the rainfall
K – factor of soil erodibility
L – factor of slope length
S – factor of slope steepness
C – factor of protective effect of vegetation cover
P – factor of effectiveness of erosion-control measures

The Universal Equation is suitable for evaluation of the erosion risk on an arbitrary plot by comparing the USLE – estimated soil loss with the maximum admissible one (1 t/ha/year for shallow soil < 30 cm, 4 t/ha/year for medium deep soil 30–60 cm and 10 t/ha/year for deep soils > 60 cm). In case that these limits are exceeded, protective measures are proposed to be taken while their effectiveness can be immediately checked by the same method. However, before applying this procedure, it is necessary to establish the particular values of the input factors applicable to a concrete territory and field.

The factors L and S represent together a so-called topographic factor (LS), which is the ratio of the soil loss per unit area on an arbitrary slope to the soil loss on a standard plot of 22.13 m in length and 9% in slope. During the ongoing process of privatization of land in the Czech Republic, the changes in shape and area of the plots (*L*-factor) and the ways of their exploitation (*C*-factor, perhaps also *P*-factor) are taking place while the remaining factors (*R*, *K* and *S*) are relatively stable.

Regionalization of the *R*-factor for the territory of the Czech Republic (Janeček et al., 1992) was attempted, based on the existing ombrographic records of storm rains obtained at the stations of the Czech Hydrometeorological Institute. However, as the lengths of the records are variable and often too short (less than 50 years), an assumption of spatially uniform probability of occurrence of storm rains over the territory of the Czech Republic currently seems to be more adequate, even though some local differences certainly exist.

The factor of soil erodibility (*K*) can be derived from soil texture, soil organic matter content, soil structure and permeability. Zuska and Němeček (1986) published an approximate procedure of the *K*-factor determination for 60 soil units (main soil forms). The procedure was based on the mean soil texture and humus content of the representative soil units. The latter values were obtained by processing data from about 2,500 soil profiles observed in selected pits during the Complex Soil Survey of the Czechoslovak Republic (Mašát, Němeček, 1983). The soil structure and permeability for water were also considered. In this way, the *K*-factor was related to the units of the basic map resulting from the Complex Soil Survey and to the main soil forms according to the system of the Valuated Soil Ecological Units (VSEU). The VSEU are coded in such a way that the first figure of the code denotes a climatic region, the second and the third ones denote the main soil unit and the fourth figure stands for the slope and its orientation.

These characteristics of VSEU have been stored in the numerical database of an integrated Soil Information System at the Research Institute for Soil and Water Conservation in Prague and can be easily used for any computerized processing. This information can also be used to determine the *S*-factor.

Assuming that the constant average value of the *R*-factor is 20 for the territory of the Czech Republic, that the *C*-factor is ranging from 0.2 to 0.3 (which corresponds to an average crop rotation on arable land), assuming no erosion-control measures, i.e. $P = 1$, and taking hypothetically the average length of the plots along the slope as 60–150 m, which corresponds to the value of *L*-factor 1.66–2.61, we arrive at an approximate factor of ten with which one has to multiply the product of the factors (K x S) to obtain the value of *G* to measure the potential risk of water erosion on an arable land.

Due to the local variability of the factors *L*, *C* and/or *P*, this rule of thumb cannot, of course, be applied to individual plots. Therefore, the cadaster territory (a historical municipality territory) was chosen as the smallest unit

for a cartographic representation. The areal percentage of different VSEU within a cadaster territory was found for each such territory and the average value of the product (K x S) was derived from it.

WIND EROSION

Previous results (Pasák, Janeček, 1971) were applied to delimit the susceptibility of areas to wind erosion. Firstly, a map of the climatic-erosion factor *C* was used which shows the effect of climatic conditions, i.e., the wind speed and the soil moisture content, on wind erosion.

The original relation for determination of the climatic-erosion factor, due to Chepil (1956), was modified into:

$$C = 100 \,.\, (3 \,.\, 6\, v)^3 \,.\, (J_z + 60)^{-2}$$

where: v – average annual wind speed at the standard height of 9 m (m/s)
J_z – index of moisture according to Konček (1956)

To calculate the climatic-erosion factor from the frequency of occurrence of winds > 5 ° Bf the formula was modified as follows:

$$C = 100 \,.\, (6 + 0{,}52\, \check{c})^3 \,.\, (J_z + 60)^{-2}$$

where: $\check{c}$ – frequency of occurrence of winds > 5 ° Bf in per cent per year

The values of $C = 20$ and 40 were taken as the boundaries between the zones of different wind erosion risk. Isolines of these values were plotted on the map of the Czech Republic. As the various textural classes of soils show different susceptibility to wind erosion, a relationship of the soil erodibility by wind to the percentage of soil particles < 0.01 mm was derived by Pasák (1966). By applying both criteria in parallel, the areas susceptible to wind erosion in the Czech Republic can be divided into six categories:

Category	Soil erodility by wind	Climatic-erosion factor *C*	% of particles < 0.01 mm
I	no erodibility	< 20	> 30
II	very weak	20–40	> 30
III	weak	20–40	20–30
IV	medium	20–40	0–20
		> 40	> 30
V	heavy	> 40	20–30
VI	very heavy	> 40	0–20

RESULTS

WATER EROSION

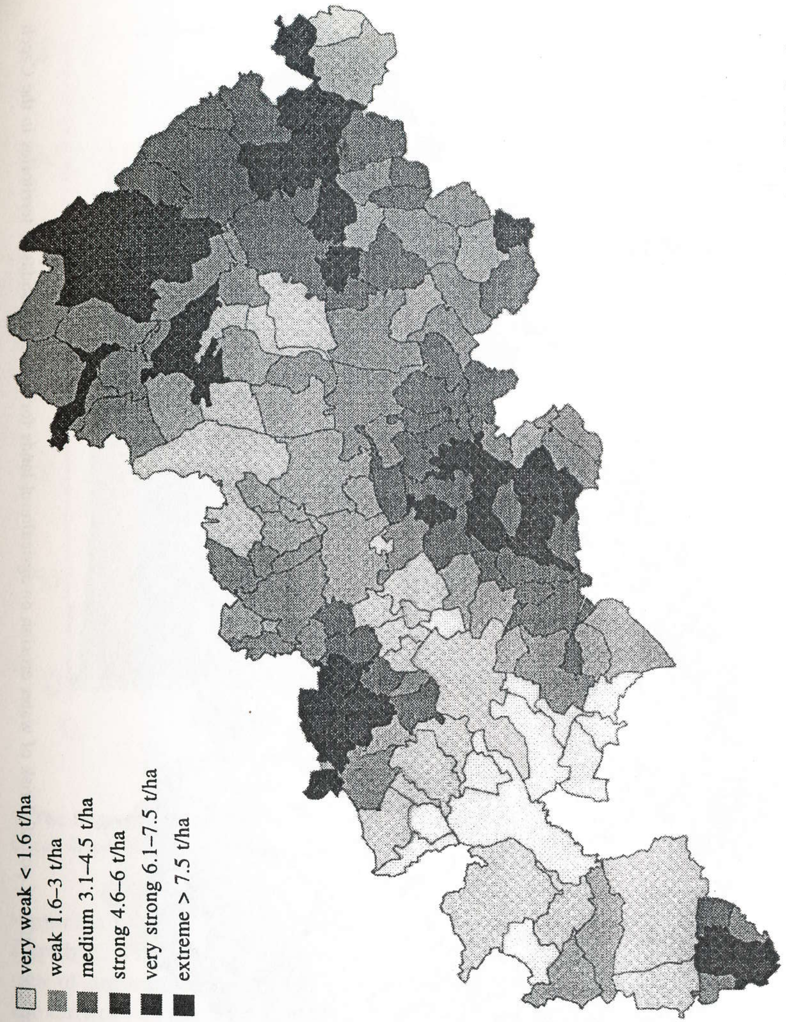
Using the VSEU characteristics and the information about the areal extent of VSEU's stored in the database of the integrated Soil Information System, each cadaster territory identifier was assigned an average value of the product (*K* x *S*). This was done in the form of a map layer in the ARC/INFO geographical information system. In this way, the average degree of potential of water erosion was determined for individual cadaster territories – see Fig. 1.

Such a generalization, particularly if two or more extremely different categories of VSEU are present within the same cadaster territory, cannot of course depict a real situation in detail. It only characterizes a cadaster territory as a whole. Despite of that, the resulting set of maps for individual districts as well as a general map for the whole of the Czech Republic provide a good overview. The potential for water erosion in particular cadaster territories, can be expressed qualitatively using a scale of six degrees - see Fig. 2. The soils were found as potentially extremely erodible in 2,951 cadaster territories, as very strongly erodible in 1,502 cadaster territories, as strongly erodible in 22,234 cadaster territories, moderately erodible in 1,626 cadaster territories, weakly erodible in 2,930 and very weakly erodible or not erodible in 349 cadaster territories, while for the remaining 229 cadaster territories (without agricultural land or belonging to military zones) the information is lacking – see Fig. 3.

The percentage of total area occupied by agricultural land obviously varies from one cadaster territory to another. Therefore, beside the map showing an average degree of the potential erosion risk on all soils in a cadaster territory, another map was prepared indicating the average potential soil loss per 1 hectare of agricultural land, again using a scale of six degrees – see Fig. 4. This map delimits very clearly the territories in which it is necessary to investigate in detail the susceptibility of individual plots to water erosion by applying all factors of the unabridged Universal Equation and to undertake the corresponding organizational, agronomic or technical erosion-control measures.

WIND EROSION

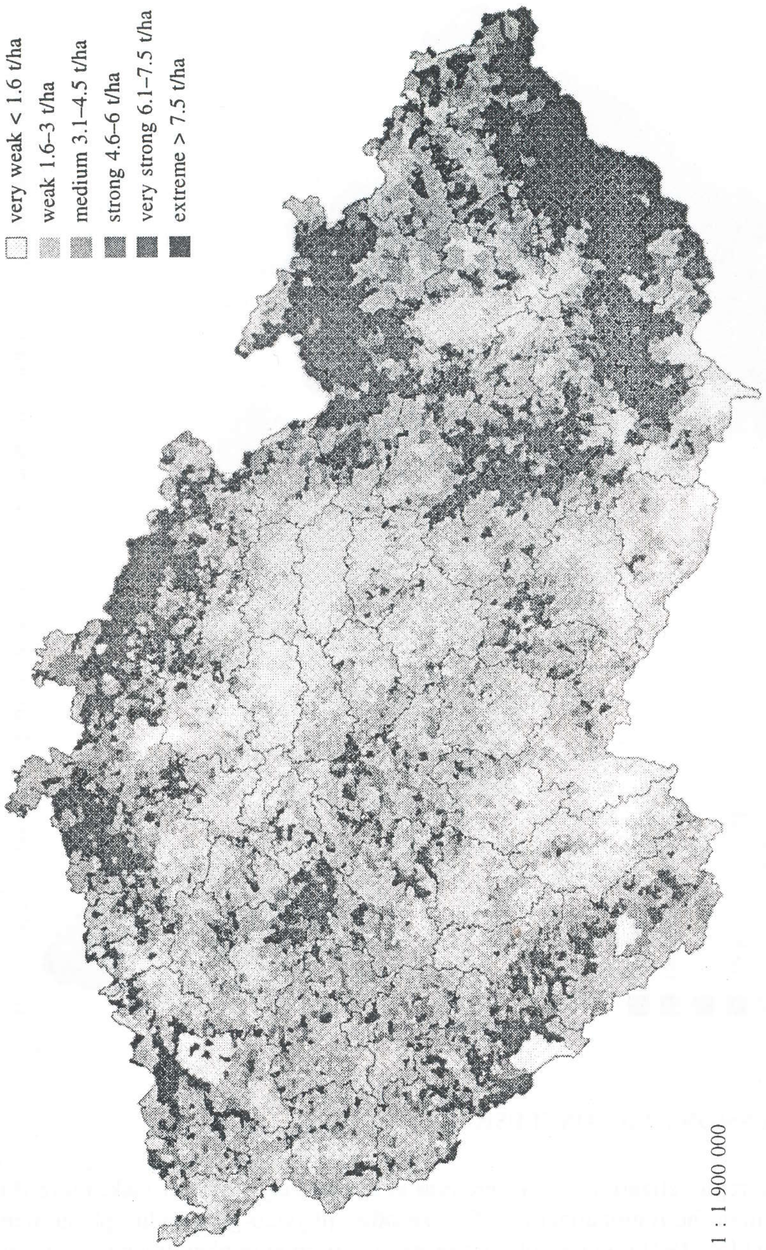
Using the pedological database of RISWC, the maps of soil erodibility by wind for individual districts were constructed, showing separately the forest areas (Fig. 5), as well as a synoptic map of the Czech Republic (Fig. 6).



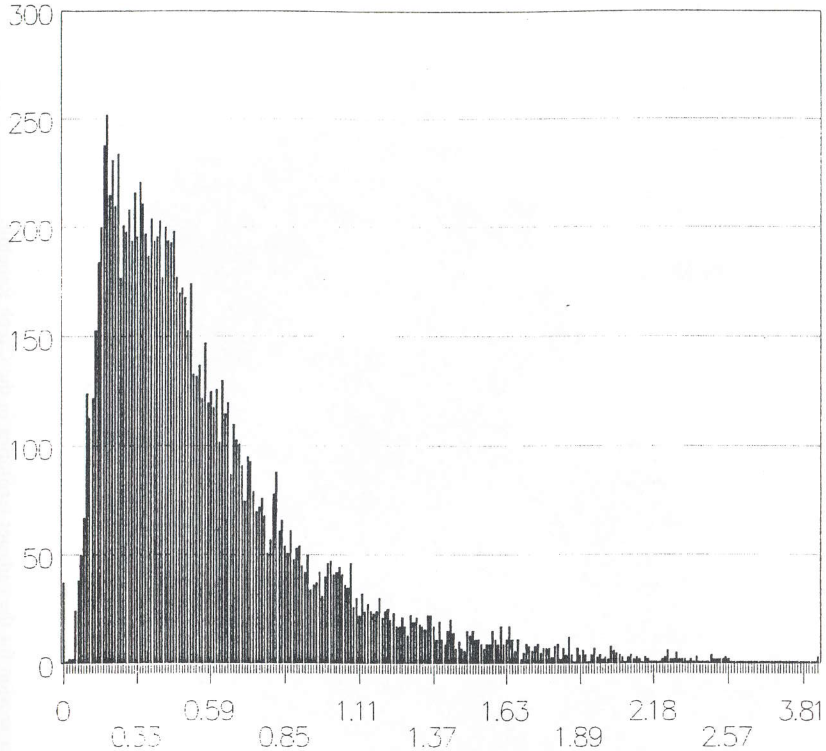
1. A map showing the average degree of potential risk of water erosion on agricultural lands for individual cadaster territories in the Přerov district

DISCUSSION AND CONCLUSION

The regionalization of soil erosion is a relatively difficult task, more difficult than the regionalization of some other physico-geographic phenomena (Stehlík, 1971). Direct observations of soil erosion phenomena and meas-

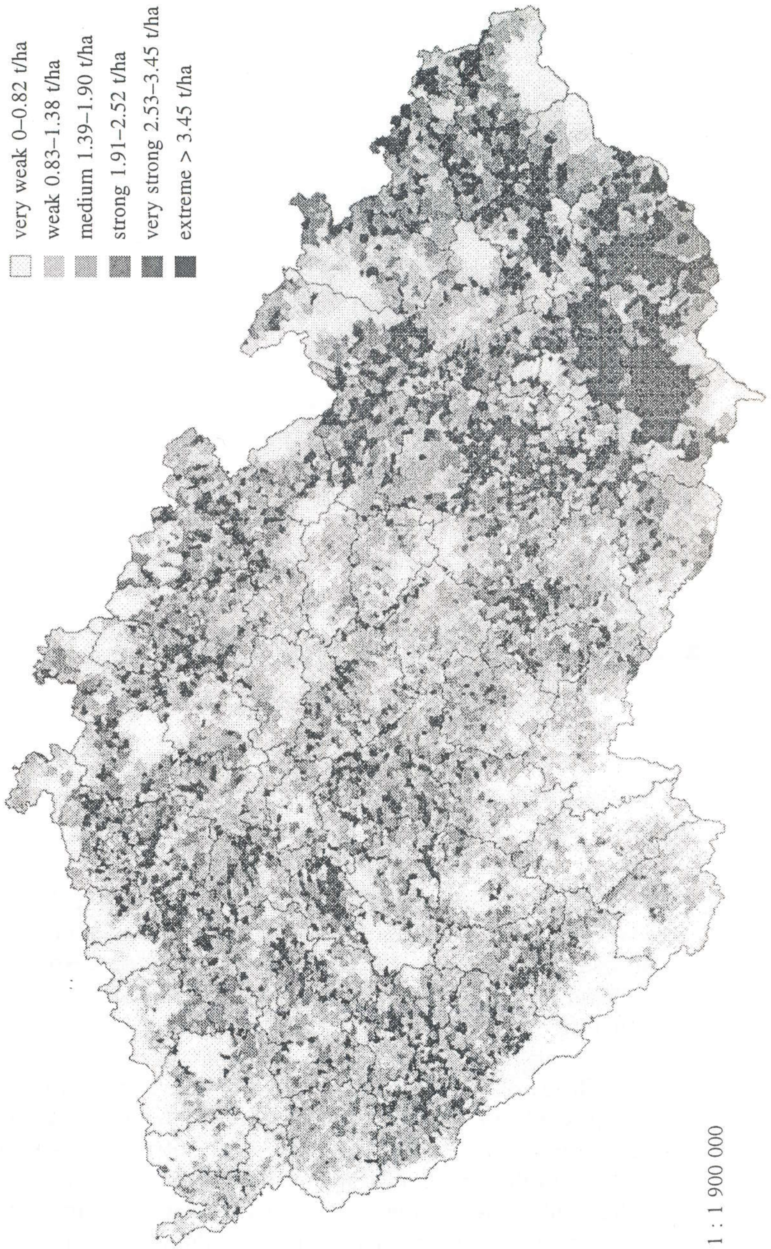


2. A map showing the average degree of potential risk of water erosion on agricultural lands for individual cadaster territories in the Czech Republic



3. The freguency distribution of the average product (*K* x *S*) for the cadaster territories in the Czech Republic

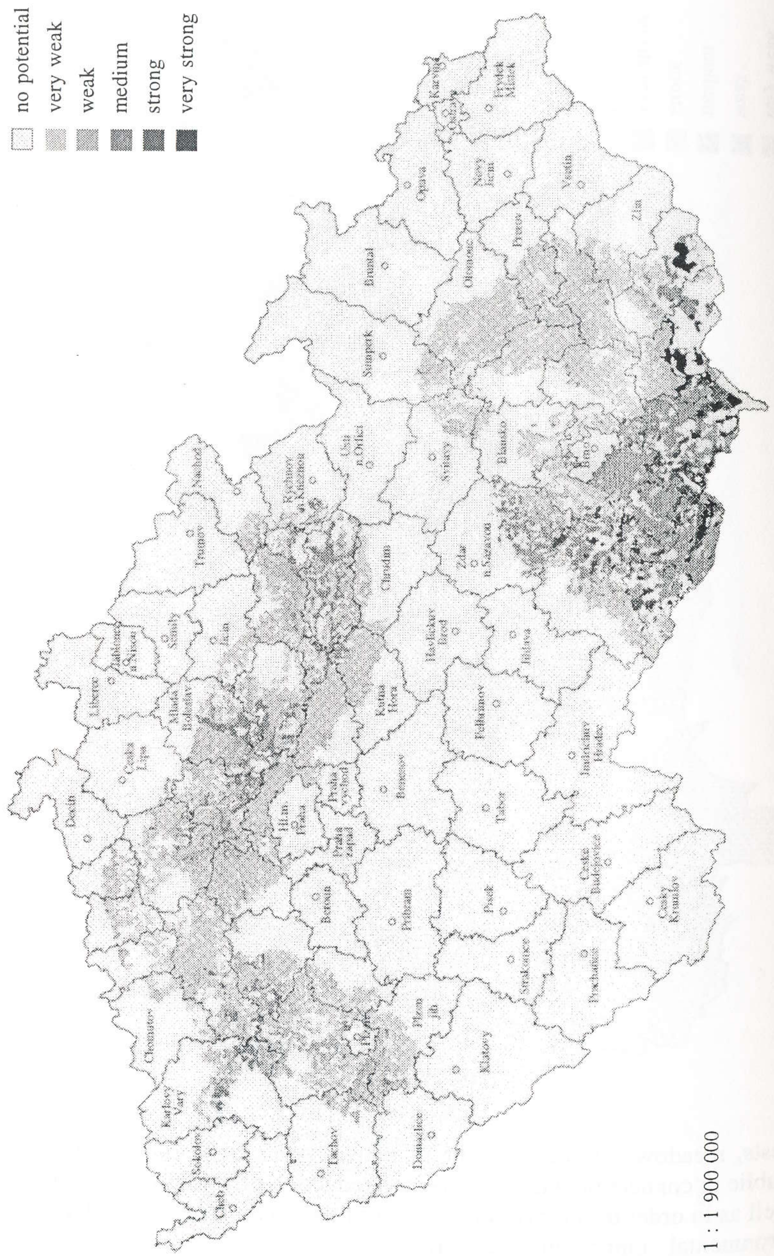
urements of their intensity are not yet regular and systematic in the Czech Republic. The above-mentioned maps are nothing but a further step in a series of attempts to characterize the danger of the soil erosion processes on the territory of the Republic. The described procedure of the map construction is most similar to that used by Stehlík (1970) and Očadlík, Urban (1980) or, if foreign authors are to be mentioned, to the method published by Vold et al. (1985). The availability of the necessary software and hardware in RISWC made it possible to use GIS for these purposes. The data for individual cadaster territories have been stored on a disk of a work station and can be subjected to further interpretations in future. They can easily be used to document the need of the erosion-control measures and, in particular, the need for an areal expansion of the permanent types of the vegetation cover



4. The map of the average potential soil loss due to water erosion for the cadaster territories in the *Czech Republic*

5. The map of the potential soil erodibility by wind for the Hodonín district

(forests, meadows, pastures) in individual cadaster territories of the Czech Republic in connection with the expected reduction of agricultural production as well as in order to improve the level of protection of one of the elementary environmental component – the soil.



6. The map of the potential soil erodibility by wind for the Czech Republic

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Potenciální ohroženost půd České republiky vodní a větrnou erozí.
Scientia Agric. Bohem., *26*, 1995 (2): 105–118.

Od doby zpracování prvních map ohroženosti půd vodní a větrnou erozí na území našeho státu v šedesátých letech se vyvíjely jak metodické postupy hodnocení eroze, tak možnosti výpočetní techniky, zejména pak geografické informační systémy (GIS). V souvislosti s vymezením ploch vhodných pro převod orné půdy do kategorie trvalých travních porostů, popř. lesa, v rámci programu útlumu zemědělské výroby v České republice vznikl požadavek na optimalizaci tohoto procesu. Vzhledem k tomu, že hustý, dobře zapojený travní porost skýtá nejdokonalejší ochranu půdy před erozí, nalézá se logické směrování tohoto programu především na půdy ohrožené erozí. Za tím účelem byly v systému ARC/INFO zpracovány mapy potenciální ohroženosti půd vodní a větrnou erozí, generalizované na úroveň katastrů. K vymezení ohroženosti půd vodní erozí bylo použito modifikované univerzální rovnice pro výpočet ztrát půdy vodní erozí podle Wischmeiera-Smithe tak, že proměnné faktory, jako je faktor erozní účinnosti deště (R), délky svahů (L), vegetačního pokryvu (C) a protierozních opatření (P), byly nahrazeny konstantními průměrnými hodnotami pro území České republiky. K určení relativně stabilních, ale místně proměnlivých faktorů, jako je faktor erodovatelnosti půdy (K) a sklonu svahů (S), bylo využito půdoznalecké numerické databáze integrovaného systému Výzkumného ústavu meliorací a ochrany půdy Praha. Faktor K byl vztažen k jednotkám základní mapy komplexního průzkumu půd a k hlavním půdním formám bonitovaných půdně-ekologických jednotek. K určení ohroženosti půd větrnou erozí bylo použito autorem dříve užitého metodického postupu a zmíněné databáze ústavu. Data jsou uložena na pracovní stanici a je možné je využívat pro další interpretaci a při určování ohroženosti půdy erozí a lokalizaci protierozních opatření.

útlum zemědělské výroby; vodní a větrná eroze; geografický informační systém; mapy ohroženosti půd; riziko eroze

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