GEOGRAFICKÝ ČASOPIS

48 1996 2

*Martina Cebecauerová, Tomáš Cebecauer**

INTENSITY OF EROSION PROCESSES IN RELATION TO NATURAL AND CONTEMPORARY LANDSCAPE (CASE STUDY: PART OF ZÁHORSKÁ LOWLAND, WEST SLOVAKIA)

Martina Cebecauerová, Tomáš Cebecauer: Intensity of erosion processes in relation to natural and contemporary landscape (case study: part of Záhorská Lowland, West Slovakia). Geogr. čas., *48*, 1996, 2, 5 figs., 10 refs.

In the case of Slovakia erosion affects above all intensively exploited areas and the danger of the process increased in the last decades proportionally to the introductions of the methods of cooperative and state management of the agricultural soil. The purpose of our work was to analyse water and wind erosion, to project the territories threatened by erosion processes in the maps and to observe the spatial distribution of the units with the limit values and units, which exceeds the limit values of the soil, in relation to natural conditions and land use.In the study area located in western part of Slovakia were constructed maps of natural landscape types, potential wind and water erosion and land use. Comparison of maps of erosion with map of natural landscape types shows the most affected natural landscape types by erosion. Based on the map of land use were delimited areas where man activites make suitable condition for erosion. Combination of maps of wind and water erosion show areas threatened by high wind and/or water erosion.It should be noted that it is a comparison of potential erosions and therefore the limit and inadmissible category of soil erosion using the optimum anti-erosion protection may by changed into admissible values of soil erosion.

Key words: natural threats (hazards), erosion processes, natural landscape, land use

INTRODUCTION

Morphodynamic processes represent a broad spectrum of the processes proceeding in landscape. Important position is that of *soil erosion* - one of the processes

* Geografický ústav SAV, Štefánikova 49, 814 73 Bratislava

triggering off the movement of large amounts of material, directly participating in the destruction of original surface, creation of new forms and an overall picture of the landscape. Even if the erosion processes do not always procced rapidly from the point of view of long-term action their consequences at extensive areas are sometimes disastrous for the man and the society. That is why this process must be considered one of the most dangerous agents limiting the fertility and cultivation of the soils and consequently agricultural production.

Soil erosion affects in our country above all intensively exploited areas and the danger of the process increased in Slovakia in the last decades proportionally to the introductions of the methods of cooperative and state management of the agricultural soil, increasing the agricultural production regardless the protection of the soil fund. Agents conditioning and affecting the process of erosion are divided into *natural* (soil substrate, soil, hydrological conditions of the area, relief, climate, vegetation) interpreted as prerequisites necessary for the origin and action of erosion, and *anthropogenic* (distribution of cultures, used mechanisms, ploughing of grassy growth, severity of microrelief caused by agro-technical interventions, canopy of vegetation cover, way of cultivating the crops, way of fertilizing, degree of agro- and constructional-technical measures, position of the road and water network, etc.) initiated by the man's activities.

Nature and human society are in relation that can represent in certain conditions mutually stimulating links and in other cases the limiting ones. Jeopardizing of the interests of human society by natural processes that limit its quantitative, extensive development and functioning, deserve more attention of the geo-scientific disciplines. These negative impacts on society are studied and evaluated as *natural threats*, understood in the sense of the work Minár and Tremboš (1994). Water and wind erosion can be viewed at from the position of impact of natural environment also as threats while besides the direct action on man and his interests we neither should forget the feed-back to the natural systems and their remodelling to new shape.

The purpose of our work is the evaluation of initial natural processes which together with the sensitivity of natural environment represent natural threats. Predictions of threat of intense water and wind erosion is the first and simultaneously the basic relation to other relations, final aim of which is the project of landscape-ecological regulations. The aim of this contribution is to analyze water and wind erosion, to project the territories threatened by erosion processes in the maps and to observe the spatial distribution of the units with the limit level and inadmissible removal of the soil in relation to natural conditions and land use. Basic assumptions is that if we compare severely threatened areas by wind and water erosion with contemporary landscape use, we can more precisely analyze the causal relations and comparing with natural conditions we can identify the geo-complexes under the heaviest pressure of the erosion processes.

STUDY AREA

Study area (3,5x3,5 km^2) is located in northern part of the Záhorská Lowland, prevailing part of which consists of geomorphological sub-unit Unínska Hilly Land (Mazúr and Lukniš 1980). In the area there is a commune Smolinské on the floodplain of Smolinský Brook cutting the hilly land along the thick Neogene-Quaternary fault.

Natural landscape has passed through a long development at the end of which man began to form a new - cultural (human) landscape masking the original - the natural one. These two phenomena do not appear separately, they are in an intense bilateral interaction, connected by the flow of substances, energy and information, and continuous development.

West from the commune Smolinské heavy erosion processes condition the prevailing sand soil textures on softly modelled relief, while in the east the occurrence of sand-loamy and loamy soils is more frequent with erosion processes accelerated by more sharply cut relief with higher relative altitudes.

Territory is being influenced by man since the Neolithic Age. The principal intervention in the landscape was the change of forest landscape to agricultural one. Contemporary character and physiognomy of landscape is heavily affected by the cooperative management of soil. Study area represents agricultural land with rural settlement structure, where the dominant functional land use is an intense use of arable land. Large agricultural enterprises in an effort to set out good conditions for large-scale production caused the damage of majority of tree and shrub vegetation along the fields and the origin of "cultural steppe". Small forests and line greenery constitute only little remnant areas with a pronounced protective function. A continuous forest growth consisting of pine monoculture and accacia forest can be found in NW of the territory. Its important function besides stabilization of covers of blown sands is also the forestry and the recreation. Grassy lands are situated along the water streams.

Forms of land use were identified by means of aerial photographs of 1990 and field research. The most extensive class of land use is arable land. Its areas on aerial photographs indicate intense use of agro-technique. The small plots of arable land (small fields near the villages) are an important anti-erosion measure, use of which brings a considerable decrease of the intensity of erosion processes.

WORKING METHODS

Evaluation of soil water erosion

Evaluation of water erosion was based on USLE (Universal Soil Loss Equation) model:

$$A = R.K.L.S.C.P$$

where A - removal of soil, R - factor of erosion efficiency of the rain, K - factor of soil erodibility, L.S - factors of length and inclination of slope, C - factor of soil cover (vegetation), and P - factor of anti-erosion measures.

Empiric-statistical USLE model is the most frequently used one in landscape-ecological methodics for the simplicity of the calculation and easy handling even without using the computer technique. But this model has some inherent and important drawbacks, namely the failure to reflect the differentiation of the removal of material of complex slopes, action of melt-snow water and other factors, as suggested in work Minár and Hofierka (1992). Possibility to assess water, as well as wind erosion is seen in introduction of new mathematical-physical erosion models and also in the methodigs and models dealing with evaluation and optimization of landscape structures.

Used values of the parameters R,K,L,S were taken from the methodical handbook of the State Melioration Administration (1991). As for the remaining factors (C,P) we do not consider them while calculating potential removal of soil by water erosion. Mean slope inclinations are 3-7°, the highest values reach more than 12° in the SE of the area. Stating the factor K.L.S and assuming that there is no anthropogenic effect, at constant climatic conditions and relief free of vegetation cover, we determined the potential soil removal. Thus calculated values were divided into nine categories and subsequently multiplied by the R factor for this climatic area so that the resulting values render at least the approximate picture of the material removed by water (Fig. 1).

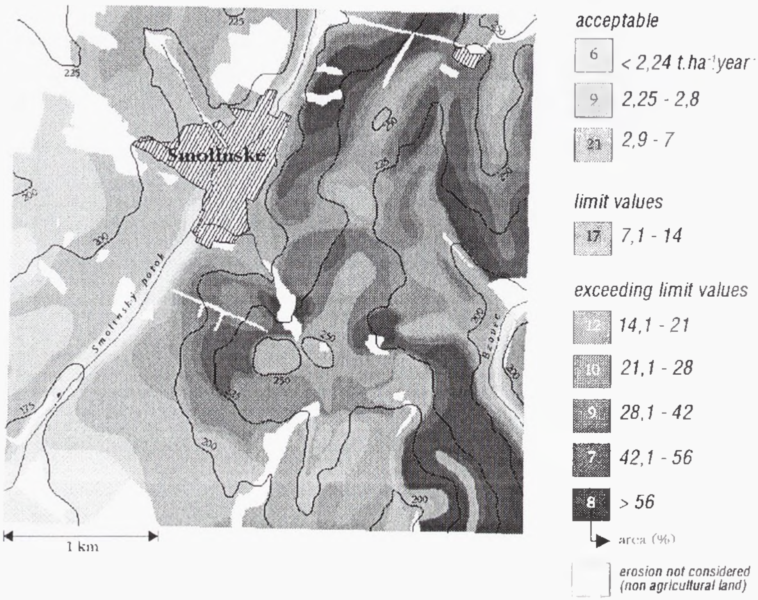


Fig. 1. Map of potential soil water erosion.

Evaluation of soil wind erosion

Assessing the wind erosion we used the model applied at the research of danger of accelerated wind erosion presented in the work of Minár and Tremboš (1994):

E = (T.R.S.O.B).P.V.U

where E - relative values of the hazard of accelerated wind erosion, T - factor of position, R - factor of relative elevation, S - factor of inclination of the slopes, O - factor of relief position in relation to prevailing erosion winds, B - factor of the barrier effect of the obstacles oriented upright to the direction of prevailing erosion wind, P - factor of soil erodibility, V - factor of soil moisture, and U - land use factor.

Based on the work of Minár and Tremboš (1994) the erosion velocity of wind 5-10 $m.s^{-1}$ was derived. While using some chosen factors (R, O, B) it is necessary to know the prevailing and secondary directions of these erosion winds. On our territory the main direction of their flowing is NW and the secondary is N. This main direction together with flowing of western wind is known in the area of Záhorská Lowland since the end of the Pleistocene, when fine material of the terrace accumulation of the Morava river was blown out and deposited further at the east.

A relatively independent part is the determination of waterlogging hazard, that can be further evaluated in the method for the calculation of wind erosion as a factor of soil moisture (V):

$$Rz = (A+B+C+D).E$$

where Rz - relative value of waterlogging hazard, A - morpho-geographic form, B - position, C - additional intake of surface water, D- infiltration ability of the soil, and E - meliorating measures (drainage).

Used methods of danger assessment of wind erosion facilitate differentiation of the territory according to the degree of material removal by wind, but they are not capable to categorize in more detail the areas of accumulation of the removed material. That is why we delimit one category of material accumulation, six categories of removal and one with negligible removal and accumulation - category of zero erosion (Fig. 2).

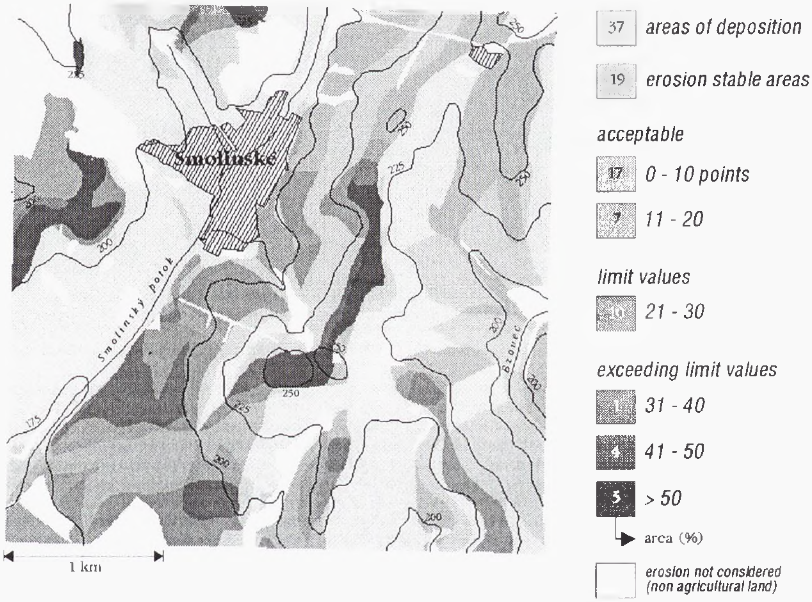


Fig. 2. Map of potential soil wind erosion.

Methods of GIS

In spite of wide possibilities of these methods in our work we limited the use of the GIS TopoL, GIS Spans in three aspects:

1. Generation of the digital map of erosion on the basis of maps of water and wind erosion,

2. Comparison of maps of erosion with the natural landscape types and contemporary land use,

3. Creation of map and tabular outputs.

Further possibilities of improvement can offer a more comprehensive use of the GIS environment, especially while calculating and constructing the maps of water and wind erosion.

COMPARISON OF WATER AND WIND EROSION WITH NATURAL AND CONTEMPORARY LANDSCAPE

Differentiation of potential water erosion is be conditioned above all by the inclination and length of the slope, soil types and textures (Fig. 1). Admissible annual soil loss for the deep soils covering the study area is 10 $t.ha^{-1}year^{-1}$ (Hrnčiarová et al. 1985). The limit category with removal of soil 7-14 $t.ha^{-1}. year^{-1}$ along with the classes with higher values of soil removal needs an independent proposal of their use with regard to the soil protection. The limit category can be found in hilly land on the slopes with inclination 3 - 5^0 , categories of inadmissible soil removal occupy the slopes of inclination more than 5^0. We can state that the most threatened are the Chernozems and Luvisols with higher agricultural potential covering the slope of hills and Regosols poor in mineral substances and humus mostly sandy with high susceptibility to erosion. The most fertile Fluvisols occupying a small area on loamy-sandy fluvial sediments of the Smolinský Brook are not threatened by erosion processes.

Map of wind erosion represents a comparably complex dividing of the area but there is a distinct difference in intensity of wind erosion on windward and leeward sides of the slopes (Fig. 2). Areas of accumulation can be found on leeward side of the slopes namely on slopes oriented to Smolinský Brook and Bzovec Brook. Belt of zero erosion is formed in the half of the windward NW slopes and longitudinal slopes with regard to the prevailing orientation of the winds as we can see on slopes oriented to Bzovec Brook and protected by high barriers. On windward slopes (SE from commune Smolinské) there are formed 3 belts in a strike from the piedmont towards the top, course of which is determined by the relief forms of lower hierarchic order:

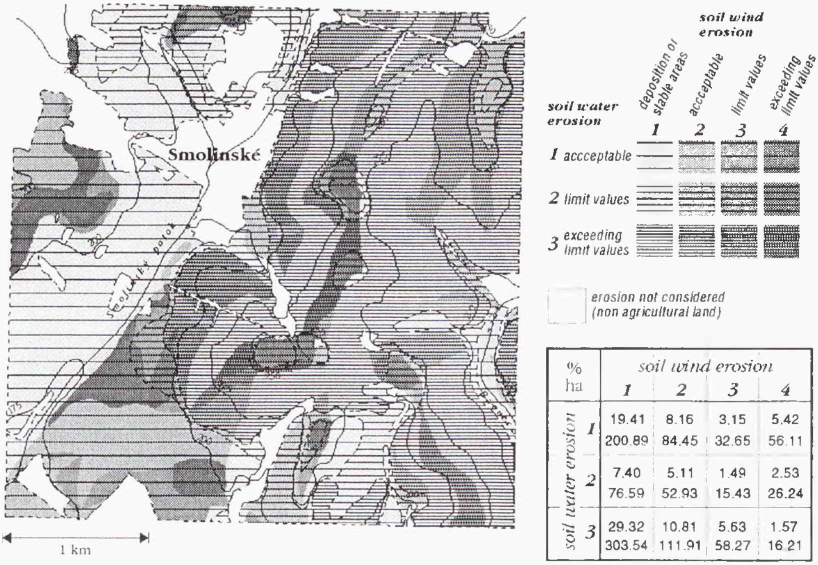
1. Erosion grows up to the limit category and slightly surpasses it.
2. Erosion and accumulation are compensated - belt of zero erosion.
3. Erosion surpasses the limit category and grows in direction to the top plains.

We can say that the most important factor influencing wind erosion are the barrier effect of the obstacles oriented upright to the direction of the prevailing erosion wind, relative altitude and inclination of the slopes. Also the action of the factor of soil erodibility directly related to the soil textures is strong. On the east and west side of the Smolinské on top plains extensive areas of intensive action of wind erosion are formed in spite of the different relative altitudes and slope inclinations. West from the commune Smolinské, in direction to Morava river, are lower ralative altitudes and inclinations of slopes, but the amount of soil with sand textures is increasing. On the other side of the Smolinské Brook are erosion processes conditioned largely by higher relative altitudes and inclinations of slopes and less by soil textures which are mostly sand-loamy.

Spatial comparison of water and wind erosion suggests the following (Fig. 3):

- categories of admissible soil removal of both types of erosion occupy only 27,6 % of the territory and they are located on the fluvial sediments of larger brooks and leeward slopes with inclination 3^0 and less,

- category of the limit values of admissible soil removal by water and/or wind



% / ha		soil wind erosion 1	2	3	4
soil water erosion	1	19.41 / 200.89	8.16 / 84.45	3.15 / 32.65	5.42 / 56.11
	2	7.40 / 76.59	5.11 / 52.93	1.49 / 15.43	2.53 / 26.24
	3	29.32 / 303.54	10.81 / 111.91	5.63 / 58.27	1.57 / 16.21

Fig. 3. Map of potential soil erosion.

erosion (17,2 %) can be found on slopes little exposed to the prevailing direction of the winds and inclination of 5^{0} and less,

- category of inadmissible soil erosion by wind and/or water erosion occupies almost 1/2 of the area of agricultural land (55,2 %) , this is the case of windward slopes with blown sands of all inclinations and slopes of hills covered by other substrates with inclination from 5^{0}.

Study area represents agricultural landscape with rural settlement structure (Fig. 5), where the dominant functional landscape use is an intense use of arable land by agricultural cooperatives. The places of the most fertile soils linked to the flood plain of the Myjava and fertile soils of hilly land have a high agricultural potential signaling a positive landscape use in agricultural production but no always are the limit values of soil erosion accepted (Fig. 4). Large reserves of anti-erosion protection on study area is the division of large plots into smaller ones, insufficiently applied deep ploughing along the contour lines, alternation of the monotone agricultural landscape by greenery, thus shortening the slope length, alternation of crops using their various anti-erosion effects. Agricultural use of Regosols is limited by anthropogenic conservation of soil properties of this soil type. If the fertility and agricultural potential of these soil under the effect of erosion or other factors drops, cultivation of the soil becomes unsuitable and forestation or grassing will be the optimum way of use.

CONCLUSION

These statements lead to a conclusion that in the study area almost half of arable land 55,2% is strongly degrated and 17,2% is on the boundary of degradation of soil by erosion. It should be noted though, that it is a comparison of potential erosions, and therefore the limit and inadmissible category of soil removal using the optimum

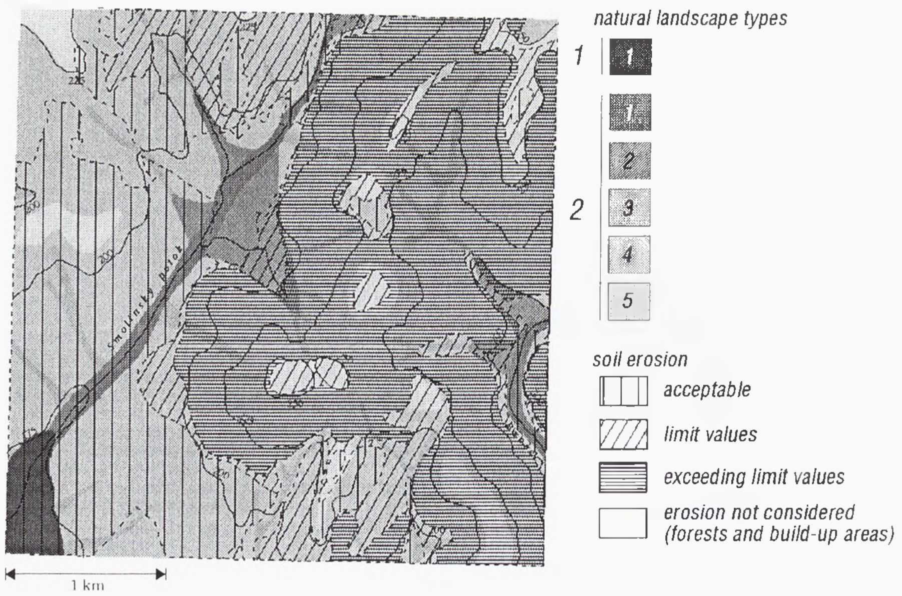


Fig. 4. Comparison of potential erosion map with map of natural landscape types.

Natural landscape types

1. Flood-plain with porous ground waters.

1.1 Fluvial and solifluction-fluvial cones formed by proluvial sandy loams and loams with high bearing of ground waters with Fluvi-gleyic Phaeozem to Fluvi-mollic Gleysol and Eutric Fluvisol and with Elm floodplain woods.

2. *Proluvial-eolian hilly land* with capillary-porous to capillary ground waters.

2.1 Narrow flood plains on loamy-sandy fluvial sediments with high bearing of ground waters with Elm floodplain woods moustly on Fluvi-gleyic Phaeozem and less on Fluvi-eutric Gleysol.

2.2 Solifluction-fluvial and fluvial cones with loamy and sand-loamy proluvial sediments with high bearing of ground waters with Pannonian oak-hornbeam woods on Orthic Luvisol and lokal on Dystric Planosol.

2.3 Dells and dell-like valleys (bottoms) with medium bearing of ground waters on Neogene sand lays and claystones, on eolian sands and loesses with Pannonian oak-hornbeam woods and Oak woods with Pontilla alba on Eutric Regosol, Luvic Arenosol and even Stagno-gleyic Luvisol.

2.4 Polygenetic hill slopes (also denudational saddle backs) with little bearing of ground waters with covers of eolian sands and loesses and with Neogene sandy clays and claystones with Pannonian oak-hornbeam woods and Oak woods with Pontilla alba on Eutric Regosol and Luvic Arenosol, Luvi-haplic Chernozem, Orthic Luvisol and less on Stagno-gleyic Luvisol.

2.5 Plains of hilly land with little bearing of ground waters with covers of eolian sands and loesses and on Neogene sandy clays and claystones with Oak woods with Potentilla alba, Oak woods with Quercus cerris and local Acidophilous pine woods and sand dune grassland dominant on Eutric Regosol and Orthic Luvisol to Luvic Arenosol, less on Distric Planosol.

anti-erosion protection can by changed into admissible values of soil erosion. This fact should orient the territorial planning policy of the administration and agricultural firms to an elevated attention to the soil protection and particular interventions in the landscape.

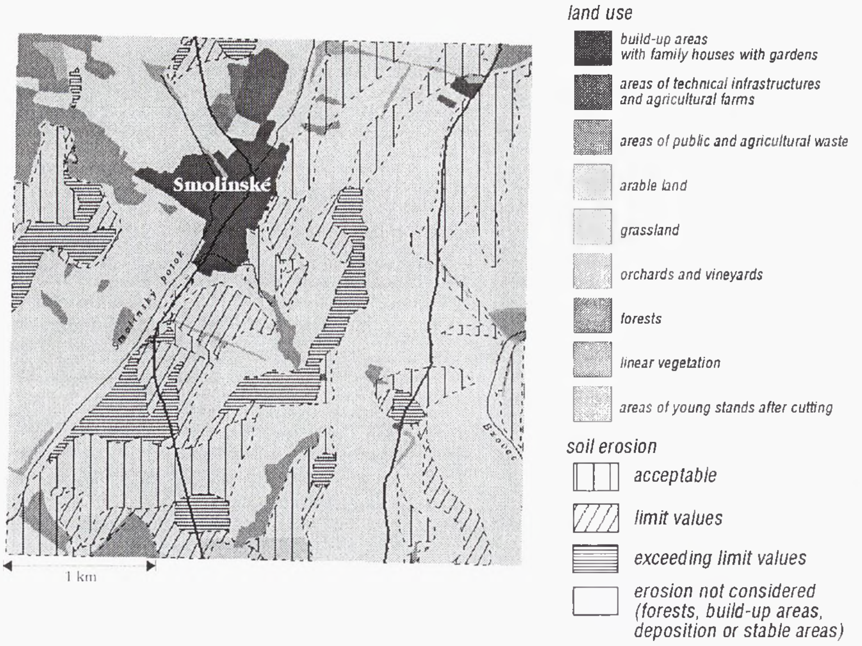


Fig. 5. Comparison of potential erosion map with map of land use.

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Martina Cebecauerová, Tomáš Cebecauer

INTENZITA ERÓZNYCH PROCESOV VO VZŤAHU K PRÍRODNEJ A SÚČASNEJ KRAJINE (ČASŤ ZÁHORSKEJ NÍŽINY, ZÁPADNÉ SLOVENSKO)

Príroda a ľudská spoločnosť sú vo vzťahu, ktorý môže za určitých podmienok predstavovať navzájom sa stimulujúce a v iných prípadoch zase limitujúce väzby. Ohrozenie záujmov ľudskej spoločnosti prírodnými procesmi, ktoré obmedzujú jej rozvoj a fungovanie, si zasluhujú v súčasnosti zvýšenú pozornosť v geovedných disciplínach. Tieto negatívne vplyvy na spoločnosť sa študujú a vyhodnocujú ako prírodné hrozby - hazardy, ktoré chápeme v zmysle práce Minár a Tremboš (1994). Na vodnú a veternú eróziu sa môžeme z pohľadu vplyvov prírodného prostredia pozerať tiež ako na hrozbu. Na Slovensku je väčšina intenzívne využívaných území ohrozená eróziou pôdy. Toto ohrozenie vzrástlo práve v posledných desaťročiach so zavedením metód družstevného a štátneho obhospodarovania pôdy.

Cieľom príspevku je analyzovať vodnú a veternú eróziu, kartograficky znázorniť územia ohrozené eróznymi procesmi a identifikovať priestorové rozloženie jednotiek s limitným a neprípustným odnosom pôdy vo vzťahu k prírodným podmienkam a využitiu zeme. V našej práci vychádzame z predpokladu, že ak porovnáme územia silného ohrozenia vodnou a veternou eróziou so súčasným využitím krajiny, môžeme bližšie analyzovať príčinné vzťahy a identifikovať oblasti , kde človek vytvára vhodné podmienky pre eróziu a pri porovnaní s prírodnými podmienkami dokážeme vyšpecifikovať geokomplexy pod najsilnejším vplyvom eróznych procesov.

Študované územie (3,5x3,5 km^2) sa nachádza v severnej časti Záhorskej nížiny a jeho prevažnú časť tvorí geomorfologický podcelok Unínska pahorkatina.

Pri hodnotení vodnej erózie sa stal východiskom model USLE:

A = R . K . L . S . C . P, kde A - odnos pôdy, R - faktor eróznej účinnosti dažďa, K - faktor pôdnej erodovateľnosti, L,S - faktory dĺžky a sklonu svahu, C - faktor pokryvu pôdy (vegetácie) a P - faktor protieróznych opatrení.

Pri stanovení veternej erózie sme metodicky vychádzali z modelu aplikovaného pri výskume nebezpečenstva urýchlenej veternej erózie v práci Minár a Tremboš (1994):

E = (T . R . S . O . B) . P . V . U, kde E - relatívna hodnota nebezpečenstva urýchlenej veternej erózie, T - faktor polohy, R - faktor relatívnej výšky a hĺbky, S - faktor sklonu, O - faktor orientácie georeliéfu voči prevládajúcim eróznym vetrom, B - faktor bariérneho efektu prekážok orientovaných kolmo na smer prevažujúceho erózneho vetra, P - faktor erodovateľnosti pôdy, V - faktor nadmernej vlhkosti pre stupne nebezpečenstva zamokrenia a U - faktor využitia zeme.

Relatívne samostatnou časťou je určenie rizika zamokrenia, ktoré sa ďalej hodnotí v metodike na výpočet veternej erózie ako faktor nadmernej vlhkosti (V):

Rz = (A + B + C + D) . E, kde Rz - relatívna hodnota rizika zamokrenia, A - morfogeografická forma, B - poloha, C - dodatočný príjem povrchovej vody, D - infiltračná schopnosť pôdy a E - melioračné opatrenia (odvodňovanie).

V našej práci sme využili GIS Topol a Spans na vytvorenie mapy erózie územia zo vstupných zdigitalizovaných máp vodnej a veternej erózie, ďalej na porovnanie mapy erózie územia s typmi prírodnej krajiny a súčasným využitím zeme a napokon pri tvorbe kartografických a tabuľkových výstupov.

Na záver môžeme konštatovať, že v skúmanom území je procesom silnej degradácie pôd eróziou postihnutá viac ako polovica ornej pôdy (55,3 %) a 17,2 % je na hranici únosnosti degradácie pôd eróziou. Treba však poznamenať, že ide o porovnanie potenciálnych erózií, z čoho vyplýva, že limitná a neprípustná kategória odnosu pôdy pri použití optimálnej protieróznej chrany môžu dosiahnuť prípustné hodnoty erózie pôdy. Krajinné typy s najúrodnejšími pôdami viažucimi sa na nivu Myjavy a úrodné pôdy pahorkatiny majú vysoký poľnohospodársky potenciál, čo signalizuje pozitívne využitie krajiny pre poľnohospodársku výrobu. Ako sme mali možnosť vidieť v teréne, nie vždy sú však dodržané limitné hodnoty erózie pôdy. Veľkými rezervami protieróznej ochrany na študovanom území je členenie veľkých parciel na menšie, nedostatočne uplatňovaná orba po vrstevnici, spestrenie monotónnej poľnohospodárskej krajiny výsadbou zelene, a tým skrátenie dĺžky svahu, ako aj striedanie kultúr s rôznym protieróznym účinkom. Tento fakt by mal nasmerovať územnoplánovaciu politiku správnych orgánov a poľnohospodárskych podnikov na zvýšenú pozornosť ochrany pôd, čo by sa malo prejaviť v konkrétnych zásahoch do krajiny.

Obr. 1: Mapa potenciálnej vodnej erózie pôdy.

Obr. 2: Mapa potenciálnej veternej erózie pôdy.

Obr. 3: Mapa potenciálnej erózie pôdy.

Obr. 4: Porovnanie mapy potenciálnej erózie pôdy s mapou prírodných krajinných typov.

Prírodné krajinné typy:

1. Fluviálna rovina s pórovými podzemnými vodami.

1.1 Náplavové a soliflukčno-náplavové kužele tvorené proluviálnymi piesočnatými hlinami a hlinami s vysokým zvodnením podzemnými vodami s čiernicami typickými až glejovými a fluvizemami typickými a s lužným lesom nížinným.

2. Proluviálno-eolická pahorkatina s kapilárno-pórovými až kapilárnymi podzemnými vodami.

2.1 Úzke nivy na hlinito-piesočnatých fluviálnych sedimentoch s vysokým zvodnením podzemnými vodami s lužným lesom nížinným väčšinou na čiernici typickej a menej na fluvizemi glejovej.

2.2 Soliflukčno-náplavové a náplavové kužele s hlinitými a piesočnato-hlinitými proluviálnymi sedimentami s vysokým zvodnením podzemnými vodami s dubovo-hrabovým lesom panónskym na hnedozemi typickej a lokálne na pseudogleji.

2.3 Úvaliny a úvalinovité doliny (ich dná) so stredným zvodnením podzemnými vodami na neogénnych piesčitých íloch a ílovcoch, na eolických pieskoch a sprašiach s dubovo-hrabovým lesom panónskym a dubovým nátržníkovým lesom na regozemi typickej, hnedozemi arenickej a menej na hnedozemi pseudoglejovej.

2.4 Polygenetické svahy pahorkatiny (aj denudačné sedlá) s malým zvodnením podzemných vôd s pokrovmi eolických pieskov a spraší a s neogénnymi piesočnatými ílmi a ílovcami s dubovo hrabovým lesom panónskym a dubovým nátržníkovým lesom na regozemi typickej a hnedozemi arenickej, černozemi hnedozemnej, hnedozemi typickej a menej na hnedozemi pseudoglejovej.

2.5 Plošiny pahorkatiny s malým zvodnením podzemnými vodami s pokrovmi eolických pieskov a spraší a s neogénnymi piesočnatými ílmi a ílovcami s dubovým nátržníkovým lesom, dubovo-cerovým lesom a lokálne borovicovým kyslomilným lesom a trávnatými porastami viatych pieskov hlavne na regozemi typickej a hnedozemi typickej až arenickej, menej na pseudogleji.

Obr. 5: Porovnanie mapy potenciálnej erózie pôdy s mapou využitia krajiny.