ASSESSMENT OF GULLY EROSION ACCORDING TO ADMINISTRATIVE UNITS OF SLOVAKIA

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Abstract: *Within the research of spatial organization of gully erosion in Slovakia, the most significant and unique (also from the international point of view) work of its kind is the "map of the density of gully erosion" by Bučko and Mazúrová from 1958. Since its publication there was not enough attention paid to this issue at all. This study proposes the assessment of the average density of gully network according to the regions and districts of Slovak republic on the basis of the results in the above-mentioned map. The whole presented method is based on integration of input data and final analysis by means of geographic information systems. Obtained results show, that Slovak territory is relatively evenly affected by gully erosion from the point of view of its territory classification to regions. The comparison of the districts shows greater differences which are caused mainly by smaller area of these administrative units and the district position within geomorphologic classification of Slovakia.*
Keywords: *gully erosion, geographic information systems (GIS), the region, the district*

INTRODUCTION

Erosion is one of the main processes influencing the degradation of soils and therefore it significantly participates on problems related to the nutrition of the world population. The most extended type of soil erosion is the water erosion because the water is everywhere all over the earth surface, it circulates on the land and causes the erosion in different ways. Within the water erosion the most widely spread is the rain erosion. Runoff of rain water flowing from the whole slope causes sheet erosion. By concentrating flowing water into the channels we can observe the linear erosion. One of the demonstrations of linear water erosion are the gullies, therefore the water erosion, which causes the gullies is called the gully erosion. Gully erosion is the erosion process whereby runoff water accumulates and often recurs in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths (Poesen et. al., 2003). Nowadays, the intensive gully research is carried out in the area of the Myjava Highland by Stankoviansky, who characterizes the formation of the gullies as a result of runoff process activity. The runoff processes are understood as a geomorphologic processes caused by the overland flow of the water during the extreme rainfalls and snow thaw (Stankoviansky, 1998a). Runoff processes are regarded to be the equivalents of pedogenetic term of water erosion. The gully erosion is bound to the network of deep linear forms of the relief concentrating the runoff. In these linear forms there are concentrated the time limited rivers, the display of which is the

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transport of the part or the whole cultivated layer in the horizontal axis of the natural and artificial linear elements and the creation of the shallow depression in their bottoms oblong in the direction of the temporary activity river. The main reason for forming the gullies is the enormous amount of the water. This condition can be caused either by the climatic change or by land use. In the conditions of the central Europe is the forming of the gullies determined mainly anthropologically, whereas the decisive factor controlling the location of the gullies is the original in, other words, pre-collectivization kind of the land use. Therefore the inevitable criterion for creating the gullies in our conditions is deforestation and agricultural exploitation of the original forest land having the attribute of a little resilience substratum and a deep mantle rock (Stankoviansky, 2003b). In general, the gullies are formed in a relatively short periods during several consecutive extreme events, but the process of forming the gullies is not finished and the gullies grow in the next period. It implies that the gullies are not formed in one single phase but in many stages (Zachar, 1970, Stankoviansky, 2003b). They often grow in a regressive way and at the end they have different height level, and in this extent they tend to be the most active. The gullies as a geomorphological forms cause the fragmentation of the slopes whereby they limit the agricultural soil by reducing its expanse, they degrade the unpaved field paths and forest roads, they form the communication barriers. The need for the stabilization of the gullies by the forest crops is the must for this.

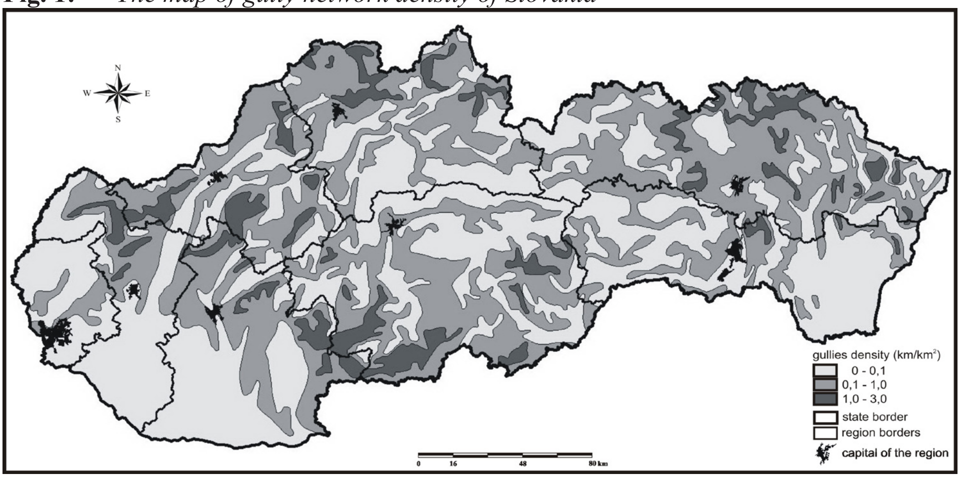
Within the research of gully erosion in Slovakia the researchers aimed predominantly on the space organization and density of gullies (e.g. Bučko and Mazúrová, 1958), (Barabas, 1996, 1997). Harčár (1995) evaluated the relation of gullies to topography and geological underlay in Low Beskyds region. Nowadays, the research of gully erosion in the Myjava Highland is worked out by Stankoviansky (2003a, 2003b, 2003c), who deals mainly with causes and dating of the inception of gullies.

However, the spatial assessment of gully erosion according to administrative division of Slovakia was quite forgotten, up to now. The aim of this contribution is the gully erosion assessment according to regions and districts of Slovak republic. This assessment from this point of view can help the government in agricultural and environmental planning on lower administrative level. Furthermore, this generalization of the problem can help in the initial phases of the research of gully erosion processes in larger scales.

ASSESSMENT OF GULLY EROSION IN THE SLOVAKIA

Knowing the erosion as a surface forming process is important information for the practical purpose. Therefore, a lot of attention was given to this field in the early times of erosion research development. A favorable increase of erosion and soil eroded mapping began in the mid fifties of the 20th century when GÚ SAV started to deal with the gully erosion mapping intensively. After mapping some experimental regions (Mazúrová, 1955; Bučko, 1956) it was possible to propose complex assessment of gully erosion in Slovak standards developed in the "Map of gully erosion of Slovakia" (Fig. 1) by Bučko and Mazúrová from 1958 made in the map scale of 1:400 000 by planimetric evaluation of the area with different gully density (km.km^{-2}). Gully density was derived from topographic maps in the map scale 1: 25 000. On the basis of this map results, the most densest network of the gullies is bound to the upland and highland relief in which the favorable interplay of all the factors enormously affected the erosion activity of the runoff, because they represent the transitional zone between the lowlands and the lower basin parts on one side and the mountains on the other side. This transitional zone is built mostly by the complex of rocks less resilient to the runoff processes. It is possible to assign some areas with the densest gully network. The large but discontinuous area is located in the west part of the upland relief and it covers the most parts of the Myjava Highland, the Javorníky, the Kysuce Upland and the Podbeskydská Upland; also the west part of the Strážov Mountains is joined to it. In the Easternbeskyd bend of the flysch belt there are located two important areas which cover the western and eastern part of the Ondava Upland and the Šariš Upland. Another typical area with the dense gully network is represented by the territory situated in the north part of the Nitra Highland, the Krupina Plain and the Ipeľ Basin. The smaller enclaves are in the parts of the Trnavská Highland, the Žitavská Highland, the Hornonitrianská Highland, the Košická Basin and the Revúcka Upland. Insignificant gully erosion is located in the area of the massive mountain chains with continual forest complexes, on the bottoms of hollow basin and on the alluvial floodplains due to the large amount of vegetation in the first case and relief declension in the other. However, the relevance of this map is limited by reliability of gully network described on this topographic map and of course the age of the map. Since its publication the gully network has overcome the 60 year evolution (Fulajtár and Jánský, 2001). Despite of this, the map is the most distinguishing and the only work addicted to complex assessment of the gully erosion in Slovakia up till now.

Fig. 1: *The map of gully network density of Slovakia*



Source: Zachar, 1960

METHODS AND INPUT DATA

The above mentioned map of gully erosion becomes the basis of our work in order to compare the gully erosion occurrence according to the particular regions of Slovakia. Due to time consuming digitalization of the original map we used its generalized version published in the work of Zachar (1960). The map shows the gully erosion expansion divided into three erosion areas that are furthermore divided into six levels of gully erosion (Tab. 1). In comparison to the original map the areas with the eolic erosion are excluded.

Tab. 1: *The classification of gully erosion according to map of gully network density*

Gully erosion area	Gully erosion level	Gullies density (km / km^2)
None and insignificant gully erosion area	1. insignificant	under 0,1
Low and moderate gully erosion area	2. low	0,1 - 0.5
	3. moderate	0,5 - 1,0
	4. high	1,0 - 2,0
	5. very high	2,0 - 3,0
Intensive gully erosion area	6. very high	above 3,0

Source: Bučko and Mazúrová, 1958; Zachar, 1960

The scanned map was georeferenced out of the coordinate system S-JTSK in GIS ArcView 3.2. In the above GIS we vectored the gully erosion areas according to the analogue base. Each area was given the number for the density of the gullies in km/km$^{2.}$ Because these values are for individual areas and level stated in a range, we set the average value statistically representing each area so that we could use the particular value for the calculation of the gully erosion state for defined spatial units.

Digital map prepared in this way, was the ground for the input data basis for further calculations performed in GIS GRASS. We imported the gully erosion map by the order *v.in.shape* together with the mentioned attribute of the average number of the gully density on km/km^2. In the same way we imported vector data layers of regions and districts areas of Slovak republic to GIS GRASS. Then we calculated the average values of gully density in chosen territory unit by *r.average* command (Neteler and Mitasova, 2002). For the use of our contribution we transformed these calculations to particular regions area of Slovakia and then to the districts areas within particular regions. Originally we wanted to distribute the result values to the ranges according to particular gully erosion levels by Bučko and Mazúrová, (1958), so that we would keep the unified methodic of gully erosion assessment in the whole work. However, the obtained average values for regions and districts are just in three original ranges (2nd – 4th gully erosion level), and 70% of the districts and 75% of the regions belong to 2nd low gully erosion level. Therefore we decided to edit and refine the range width, which would be more practical for our results especially because of the final visualization (Tab. 2). The transformation of results into the chosen ranges was performed by *r.recode* command in GIS GRASS (Neteler and Mitasova, 2002). Command *r.report* (Neteler and Mitasova, 2002) helped us for statistics calculation of the area expanse and of the proportion of particular gully erosion areas to whole region expanse from the map gully erosion (Zachar, 1960).

Tab. 2: *Adjusted classification of gully erosion for the needs of final visualization*

Gully erosion area	Gullies density (km / km^2)
None and insignificant gully erosion area	under 0,2
Low and moderate gully erosion area	0,2 - 0,4
	0,4 - 0,6
	0,6 - 0,8
	0,8 - 1,0
Intensive gully erosion area	above 1,0

Source: Author

RESULTS

By the application of the above mentioned method we obtained the results, which enable us to compare gully erosion situation in the regions of Slovak republic and in the deeper analysis in particular districts within the regions themselves. The integration of the objective territories into our ranges and gully erosion levels according to Bučko and Mazúrová, (1958) does not propose complete information in comparison the territories of the same level of gully erosion. Therefore we propose the exact data of gully erosion density for all the regions and districts of the Slovak republic (Tab. 6).

If we compare the particular regions in their full scale area, then on the basis of gully erosion density we can include the regions into three intervals of gully erosion ranges from the total number of 7 ranges, specified by our own classification. The most of the regions (4) belong to range of 0,4 – 0,6 km/km^2 according to the gully erosion density network. Three regions belong to the range of 0,2 – 0,4 km/km^2 and just one region (the Bratislava region) belongs to range of gully network density under 0,2 km/km^2. All the regions are classified as the low and moderate gully erosion area (Tab. 3). In general, it allows us to claim that the area of Slovakia is affected by the negative consequences of the gully erosion quite equally. It is supported by the gully erosion map too.

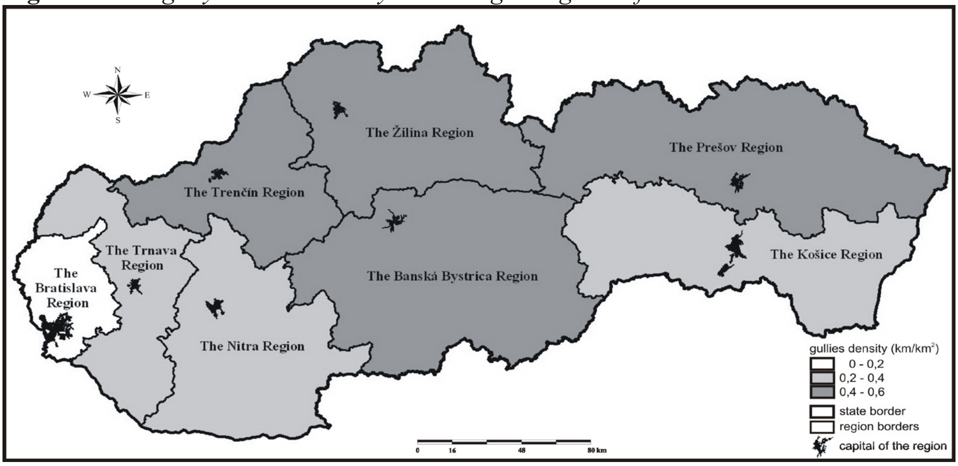
Tab. 3: *The gully network density according to regions of Slovakia*

The region	BA	TT	TN	NI	BB	ZA	KE	PO
Gullies density (km/km^2)	0,187	0,330	0,584	0,406	0,485	0,461	0,259	0,505

Source: Author

The gully erosion density expressed in absolute values proves, that the most affected by the gully erosion is the Trenčín region followed by the Prešov region. On the contrary, the least gully density is in the Bratislava region. The highest values of the Trenčín and the Prešov regions are related to the location of these regions in the western part of upland-highland relief of flysch-klippen belt (the Trenčín region) and in the Easternbeskyd bend of flysch belt (the Prešov region). These territories are the largest, although discontinuous areas with the highest occurrence of gullies in Slovakia (Bučko and Mazúrová, 1958). The lowest value of the Bratislava region is related to the fact that the largest part of region territory lies on the Záhorská Lowland and on the Danubian Lowland; lowlands are the areas with the least occurrence of gullies especially due to the low slope angle. The map of gully erosion according to the regions of Slovakia (Fig. 2) shows the dependence of the gully erosion on the geomorphologic classification of a territory. Regions with the densest gully network (the Trenčín region, the Prešov region, the Banská Bystrica region and Žilina region) are situated in the mountainous part of Slovakia. The Nitra region, the Trnava region and the Košice region are located in the transitional zone between mountainous and lowlands parts of Slovakia, whereupon the gully network density in these regions reaches lower values, depending on the proportions of mountainous and lowlands parts.

Fig. 2: *The gully network density according to regions of Slovakia*



Source: Author

Also, the expanse (Tab. 4) and the percentage (Tab. 5) of the gully erosion area from the total region area according to the map of gully erosion shows, that the regions, which are situated on the lowlands areas (the Bratislava region, the Trnava region, the Nitra region, the Košice region) are typical for their none or insignificant gully erosion, while the other regions (the Trenčín region, the Žilina region, the Banská Bystrica region and the Prešov region) show low and moderate gully erosion. Intensive gully erosion area covers the smallest area, with the highest value in the Banská Bystrica region. On the other hand the Bratislava region has not got this area at all. The comparison of the percentage ratio of particular gully erosion areas to total regions areas and the average value of gully network density within regions show, that especially the change of the mutual proportion of none and insignificant gully erosion areas and low and moderate gully erosion areas influences the final average value of gully network density for particular regions. The assessment of regions according to percentage ratio of gully erosion area shows again that the least effected region by the gully erosion is the Bratislava region, where 79% of the land area proves none or insignificant gully erosion. The most effected region is the Trenčín region. Although it has the lowest ratio in the range of none or insignificant gully erosion together with the Prešov region (34 %), it shows the highest ratio in the range of the intensive gully erosion (14 %), what is the highest value of all the regions in Slovakia.

We show the spatial character of this phenomenon within the internal regional division by the detailed analysis of the gully density in the particular regions. In this work we used the classification according to districts of the region.

Tab. 4: *The territory expanse of gully erosion areas in the regions of Slovakia (km^2)*

Gully erosion level/ The region	BA	TT	TN	NI	BB	ZA	KE	PO
1. level	1618	2786	1516	3431	3947	2766	4527	3019
2. - 3. level	435	1149	2325	2395	4548	3526	2108	5133
4. - 6. level	0	290	660	517	960	582	118	839

Source: Author

Tab. 5 *The territory percentage of gully erosion areas in the regions of Slovakia (%)*

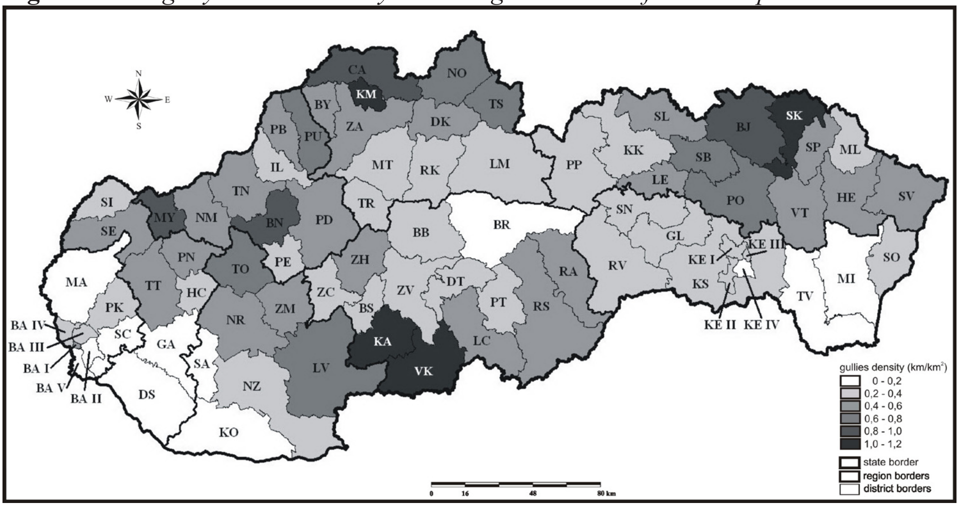
Gully erosion level/ The region	BA	TT	TN	NI	BB	ZA	KE	PO
1. level	79	66	34	54	42	40	67	34
2. - 3. level	21	27	52	38	48	51	31	57
4. - 6. level	0	7	14	8	10	9	2	9

Source: Author

The *Bratislava region* as the least effected region by gully erosion, has no intensive gully erosion areas and does not reach high values of gully erosion density in most of its districts. However there is a paradox that the highest value of gully density is found in the built up area of district Bratislava 1. It is necessary to point out that the methods used have the character of mathematical calculation of the data input and they do not take into consideration the other phenomena occurring on the earth surface. We need to regard also the small expanse of the district which causes that by the average value calculation logically the smaller areas have a tendency to reach the higher final value. These facts suppose that in similar future analyses we will have to exclude the built up areas to a minimum. The results of particular districts in the Bratislava region demonstrate the geomorphological influence on the gully erosion. The districts with higher values of gully network density are situated in the Malé Karpaty Mountains, whereas the districts in the area of Záhorská Lowland and Danubian Highland have lower values (Fig. 3). The district of Senica reaches the highest value of gully density within the *Trnava region*. It is caused mainly by the district location on the Chvojnická Highland and Myjavská Highand. The average values of gully network are decreasing towards the Danubian Plain. The *Trenčín region* belongs to the most effected regions by the gully erosion, so more then half of the districts of this region reach the third level of gully erosion. The Bánovce nad Bebravou district has the highest value of gully density. Districts of the *Nitra region* are situated on the northeast part of this region, so it is a transitional zone between Slovenské Stredohorie Mountains and Danubian Lowland. Districts on the Danube Lowland have just insignificant gully erosion. In the *Banská Bystrica region* there are two (Veľký Krtíš, Krupina) out of four districts, which belong to 4th level of gully erosion according to classification by Bučko and Mazúrová (1958). Generally, as in the previous cases, the results of the districts are related to the geomorphological division of the area. The mentioned districts with the highest values are located in the mid zone between the lowland and highland similarly to the districts of Rimavská Sobota and Revúca on the east of the region. The districts with the highest values within the *Žilina region* are situated in the northern part of the region.

Here is also the district of Kysucké Nové Mesto which is the one of the four districts in Slovakia in the fourth level of the gully erosion. It is not surprising, because there are situated the highest mountains of the flysch belt.

Fig. 3: *The gully network density according to districts of Slovak republic*



Source: Author

Districts on the western and more mountainous part of the *Košice region* have higher values of the average gully network density then the districts situated on the Východoslovenská (Eastern Slovak) Lowland. The exception is the Sobrance district, which is situated mostly on the Výchdodoslovenská (Eastern Slovak) Highland. The *Prešov region* is the second most effected region by gully erosion. It is supported by the fact, that more than half of its districts belong to third level of gully erosion (Bučko and Mazúrová, 1958) and the highest value has the Svidník district, because major part of the territory is covered by the flysch mountains.

CONCLUSION

Comparing the results of the average density of gully network in the regions and districts of Slovak republic we can claim, that on the basis of the methods used, the final values for administrative units depend on two main factors: the area of an administrative unit and its location within Slovak geomorphologic classification. When examining the regions, the region area has dominant role and therefore it reduces the influence of the region location within Slovak geomorphologic classification. From this point of view are the regions of Slovakia according to gully erosion relatively the same. Most of the regions belong to second level of gully erosion according to Bučko and Mazúrová classification (1958) with the gullies length from 0,1 to 0,5 km/km^2. Even the two regions (the Trenčín region, the Prešov region) belonging to the third level, are located just above the limit of 0,5 km/km^2. The final values of particular districts are influenced especially by the district location within the geomorphologic classification. Differences between the districts are therefore greater than between the regions, however the most of the districts belong to second level gully erosion according to Bučko and Mazúrová classification (1958). The exceptions are only the districts of The Trenčín region and The Prešov region where the dominating districts are those in the third level of the gully erosion but only in minimal majority (55 % - the Trenčín region, 54 % - the Prešov region).

Tab. 6: *The gully network density according to districts of Slovak republic*

District	Average gully density (km / km^2)	District	Average gully density (km / km^2)
THE BRATISLAVA REGION		THE PREŠOV REGION	
Bratislava 1	0,412	Bardejov	0,778
Bratislava 2	0,105	Humenné	0,523
Bratislava 3	0,308	Kežmarok	0,331
Bratislava 4	0,306	Levoča	0,380
Bratislava 5	0,105	Medzilaborce	0,309
Malacky	0,147	Poprad	0,230
Pezinok	0,312	Prešov	0,573
Senec	0,138	Sabinov	0,608
THE BANSKÁ BYSTRICA REGION		Snina	0,510
Banská Bystrica	0,240	Stará Ľubovňa	0,530
Banská Štiavnica	0,389	Stropkov	0,401
Brezno	0,213	Svidník	0,974
Detva	0,373	Vranov n. Topľou	0,459
Krupina	1,056	THE TRENČÍN REGION	
Lučenec	0,483	Bánovce n. Bebravou	0,953
Poltár	0,350	Ilava	0,297
Revúca	0,512	Myjava	0,908
Rimavská Sobota	0,544	Nové mesto n. Váhom	0,581
Veľký Krtíš	1,057	Partizánske	0,359
Zvolen	0,347	Považská Bystrica	0,772
Žarnovica	0,250	Prievidza	0,522
Žiar n. Hronom	0,422	Púchov	0,463
THE KOŠICE REGION		Trenčín	0,457
Gelnica	0,269	THE TRNAVA REGION	
Košice 1	0,346	Dunajská Streda	0,103
Košice 2	0,226	Galanta	0,132
Košice 3	0,259	Hlohovec	0,348
Košice 4	0,216	Piešťany	0,462
Košice okolie	0,364	Senica	0,608
Michalovce	0,180	Skalica	0,336
Rožňava	0,260	Trnava	0,498
Sobrance	0,263	THE ŽILINA REGION	
Spišská Nová Ves	0,271	Bytča	0,423
Trebišov	0,167	Čadca	0,874
THE NITRA REGION		Dolný Kubín	0,395
Komárno	0,103	Kysucké Nové Mesto	1,001

Levice	0,627	Liptovský Mikuláš	0,269
Nitra	0,432	Martin	0,235
Nové Zámky	0,256	Námestovo	0,633
Šaľa	0,129	Ružomberok	0,248
Topoľčany	0,732	Turčianske Teplice	0,283
Zlaté Moravce	0,548	Tvrdošín	0,724
		Žilina	0,486

Source: Author

The accuracy of obtained results depends mainly on the accuracy and the quality of input data. Thus the precising of the results requires the updating of the map of gully erosion density (Bučko and Mazúrová, 1958), it means we need to take into consideration the sixty years development of gully network since the map publication. From the point of view of the calculation process it is necessary to sectionalize the map at least according to gully erosion levels and not just according to areas.

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HODNOTENIE VÝMOĽOVEJ ERÓZIE PODĽA ADMINISTRATÍVNYCH CELKOV SLOVENSKA

Zhrnutie

Erózia je jedným z činiteľov vplývajúcich na znehodnocovanie pôd, a preto sa významne podieľa na problémoch spojených s výživou obyvateľstva sveta. Jedným z prejavov líniovej vodnej erózie sú výmole, preto vodnú eróziu, spôsobujúcu vznik výmoľov, nazývame **výmoľová erózia**. Inicializácia výmoľovej erózie je spôsobená pôsobením ronových procesov, pod ktorými chápeme geomorfologické procesy iniciované povrchovým odtokom vody po svahoch počas extrémnych zrážok a topenia snehu (Stankoviansky, 1998a). Hlavnou príčinou vzniku výmoľov je nadmerné množstvo vody, pričom táto podmienka môže byť spôsobená buď klimatickou zmenou, alebo využitím zeme. Doteraz však bolo opomenuté priestorové hodnotenie procesu výmoľovej erózie vo vzťahu k administratívnemu členeniu Slovenskej republiky. Cieľom tohto príspevku je hodnotenie výmoľovej erózie podľa krajov a okresov Slovenskej republiky. Hodnotenie z tohto aspektu môže napomôcť štátnej správe pri poľnohospodárskom a environmentálnom plánovaní na nižšej administratívnej úrovni. V neposlednom rade takáto generalizácia tejto problematiky môže poslúžiť nástupnej fáze detailnejšieho výskumu výmoľovej erózie vo väčších mierkach.

Základným podkladom našej práce sa stala generalizovaná mapa výmoľovej erózie autorov Bučka a Mazúrovej (1958), uverejnená v práci Zachar (1960). Po zdigitalizovaní bola mapa spracovaná v GIS-e GRASS prostredníctvom príkazu *r.average,* na základe ktorého sme prepočítali priemerné hodnoty hustoty výmoľovej siete pre jednotlivé kraje a okresy Slovenska.

Ak navzájom porovnáme jednotlivé kraje v plnom rozsahu ich území, tak na základe hustoty výmoľov môžeme kraje zaradiť do troch nami zvolených intervalov výmoľovej erózie, z celkového počtu siedmych intervalov. Najviac krajov (4) patrí, podľa hustoty výmoľovej siete, do intervalu v rozsahu 0.4 až 0,6 km/km^2. Tri kraje sa nachádzajú v rozmedzí 0,2 až 0,4 km/km^2 a iba jeden kraj (Bratislavský) sa nachádza v intervale s hustotou

výmoľovej siete pod 0,2 km/km^2. Čo sa týka okresov, tak najviac (42 %) ich spadá do intervalu s hustotou výmoľovej siete 0,2 až 0,4 km/km^2, nasledovaný intervalom 0,4 - 0,6 km/km^2 (27 %). Aj preto až 84 % okresov patrí z hľadiska hustoty výmoľovej siete do oblasti miernej až stredne silnej výmoľovej erózie, zatiaľ čo do oblasti žiadnej až nepatrnej erózie patrí 13 % okresov a do oblasti intenzívnej výmoľovej erózie iba 4 % okresov (okresy Kysucké Nové Mesto, Krupina a Veľký Krtíš).

Porovnaním výsledkov priemernej hustoty výmoľovej siete v krajoch a okresoch Slovenskej republiky môžeme konštatovať, že na základe použitej metodiky konečné výsledné hodnoty pre jednotlivé administratívne celky závisia od dvoch hlavných faktorov, a to od rozlohy daného administratívneho celku a jeho polohy v rámci geomorfologického členenia Slovenska. Pri krajoch zohráva dominantnú úlohu rozloha krajov, ktorá je dostatočne veľká na to, že zatláča do úzadia vplyv polohy kraja v rámci geomorfologického členenia Slovenska. Z tohto dôvodu sú kraje Slovenskej republiky z hľadiska výmoľovej erózie na tom pomerne rovnako. Výsledne hodnoty pre jednotlivé okresy sú, naopak, ovplyvnené najmä polohou okresu v rámci geomorfologického členenia Slovenska vzhľadom na pomerne malú rozlohu týchto administratívnych celkov.

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