SOIL EROSION MODELING IN CADASTRAL AREA TRENČIANSKA TURNÁ

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Abstract: Paper deals with calculation and modelling of soil erosion in chosen area. The case study area is in municipality of Trenčianska Turná, area is selected because this location is monitored and data of soil and climatic characteristics are available, as well as information about cultivated crops and crop management. Paper deals with both wind and water erosion. Potential and actual erosion soil transport is calculated by means of soil loss equation USLE and by means of WEQ equation for wind erosion. Results show how erosion soil transport can be decreased.

Key Words: water erosion, wind erosion, soil loss, WEQ, USLE

INTRODUCTION

Processes of erosion in natural unspoiled conditions run through without harmful effect. In agriculturally intensively used land are those effects multiple accelerated (Antal 2013). The most significant consequence of erosion processes is destruction or completely damage of soil as a fundamental production tool in agriculture (Streďanský 2012). Water erosion causes in addition to decrease of arable soil layer also physical and chemical properties degradation and also water regime degradation (Antal 2014).

Wind erosion represents one of physical occurrence, which does negatively influence soils in arid and semi-arid areas worldwide. Approx. 550 mil. hectares of soils world widely may be affected by wind erosion process (Skidmore 1968). The process of wind erosion (aeolian) is caused (performed) via the loss of the soil surface by mechanical wind forces (abrasion), moving and transporting the soil particles by wind (deflation) and depositing them elsewhere (accumulation), (Grešová 2011). In our conditions wind erosion affects about 6.2% of agricultural soils, mostly in area of Záhorská, Danubian and East-Slovakian lowland, what represents more than 150 000 hectares. Water erosion affects more than 44% of agricultural soils (1 066 000 ha) and in comparison with wind erosion is dependent on slope of area.

We tried to demonstrate the possibility of soil erosion calculation by the soil loss equation USLE (see Equation 2) and by the wind erosion equation WEQ (see Equation 3) using ArcGIS 10.1 software and define soil transport amounts as the basic information to apply more effective agricultural land use in chosen area or for erosion prevention measures application which can reduce this degradation process.

MATERIAL AND METHODS

Territory characteristics

Municipality Trenčianska Turná is situated in the middle of Trenčianska basin, on the left waterside of river Váh. According to territorial and administrative division, cadastral area belongs to Trenčín self- governing region, district Trenčín. Acreage of reviewed area is 629.54 ha. Cadastral area has character of agriculturally used land. Character of area in northern part is flat, south part has broken terrain (see Figure 1). Predominates used areas, which are bordered with areal or line vegetation, forest or with roads. From north and east is area protected with southern part of Strážovské highlands and from south-east is bordered with mountain range Považský Inovec. Area is characterised with brown soils which are suitable mostly for thermophilic plants. Soil has potential to be agriculturally used. Quality is based on adequate geological sub-soil, morphological and climatic conditions of actual area. Climate is continental, mild with more than 50 summer days during the year. Average annual temperature is 9°C. Total rainfall is in range of 700–750 mm for year.

Figure 1 Territory ortophoto map (Google Earth 2015)

Erosion soil transport calculation

Potential erosion represents possible (theoretical) soil erosion by means of water erosion processes with no vegetation factor included (see Equation 1).

$$\mathbf{P_E = R.K.LS} \quad (1)$$

(Wischmeier, Smith 1978)

Actual soil erosion represents real vulnerability of water erosion processes if in calculation is included actual vegetation cover and way of cultivation (see Equation 2).

$$\mathbf{A_E = R.K.LS.C.P} \quad (2)$$

(Wischmeier, Smith 1978)

R - rainfall erosivity factor, which is defined as conjunction of rain energy and its maximal 30 minutes intensity. For area Trenčianska Turná it is value 14.21.
K - soil erodibility factor is influenced by basic soil parameters as grain size, soil structure, organic matte content, permeability. Value of K factor for actual area is within the limits 0.2–0.72.
LS - topographic factors representing length and slope, The effect of topography on amount of transformed soil mass express relief impact. Length (L) presents proportion of soil loss from surface with standard length 22.13m. Slope (S) presents proportion of soil loss from surface with certain slope to soil loss from surface with standard slope 9%. Maximal counted value for actual area was 40.006.
C - cover factor represents protection impact of vegetation cover and impact of used agrotechnics on erosion intensity. Based on planted vegetation were values within the limits 0.02–0.6.
P - support particles factor which is defined as relation of soil loss which is farmed alongside of contour and standard tillage (not included in our calculation).

$$\mathbf{E = I.K.C.L.V} \quad (3)$$

(Woodruff, Siddoway 1965)

I – soil erodibility factor
Represents factor of erodibility and is possible to express it as potential average annual soil loss. Value

of I factor was derivated on the base of BPEJ (bonited soil-ecological unit) and potential endanger of wind erosion. In our area is I factor represented by values 138 and 213 for proper BPEJ areas.

K - soil roughness factor

This factor is a measure of the effect of ridges made by tillage and planting, or other means of creating systematically spaced ridges. In most cases we do not consider this factor in calculations and we bind set value 1 for whole analysed area. In our case we do not consider this factor.

C - climatic factor

Determines the index of wind erosion due to the impact of moisture at the surface of soil particles and the average wind velocity. The calculation input values are annual average temperature 9°C, wind velocity 8 $m.s^{-1}$ and annual average total rainfall for actual cadastral area 700 mm. Values are took over from SHMÚ. C factor value for our whole area is 27.74.

L - unsheltered factor

Represents the length of the unprotected erosion surface between two stable barriers (artificial, natural) in the direction of prevailing wind. On the base of created barriers map was determined its mutual distance in the direction of prevailing wind by means of proper algorithmic relations. Prevailing wind direction is according to Slovak hydrometeorological institute (2014) north-west.

V - vegetation cover factor

On the base of tests in wind tunnel (Lyles, Allison 1980) and (Armbrust, Lyles 1985) was defined as equivalent of chosen grass kinds and vegetation remains protection for soil particles on soil transport caused by wind, decrease by means of equation (see Equation 4).

$$\mathbf{SG_e = a \,.\, X^b} \tag{4}$$

Legend: SGe - flat small-grain equivalent ($kg.ha^{-2}$)
X - amount of biomass ($kg.ha^{-1}$ of dry mass),
a,b - constants specific for single plants

RESULTS AND DISCUSSION

Factors calculations which are included in final calculation were based on climatic, soil and vegetation properties of modelled area for year 2015. Based on calculated values of V and C factor we assumed that the higher the value of factor is' this higher protective action it takes which influence smaller erosion soil loss. Maps outputs, which represent soil erosion in selected area caused by water and wind erosion, were created based on USLE and WEQ equation in ArcGIS 10.2 software.

Absolute altitude on soil units is within the limits 201.575 a.s.l. and 326.084 a.s.l., this is caused by multiple surface. Digital relief model (see Figure 2) do provide basic information about altitude on soil units. It is a basis for next counts and deductions of relief morphometric parameters as slope, exposition and other. It is also basis for LS factor calculation.

Figure 2 Digital relief model (Michal 2015)

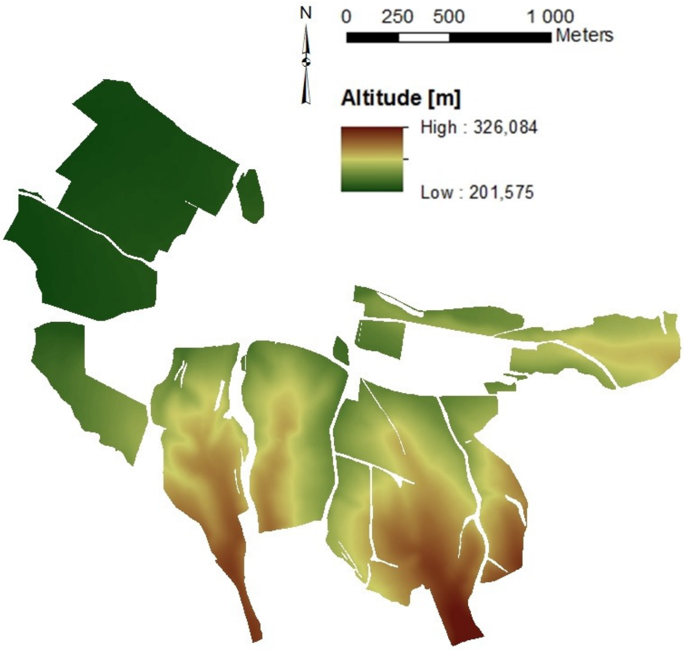
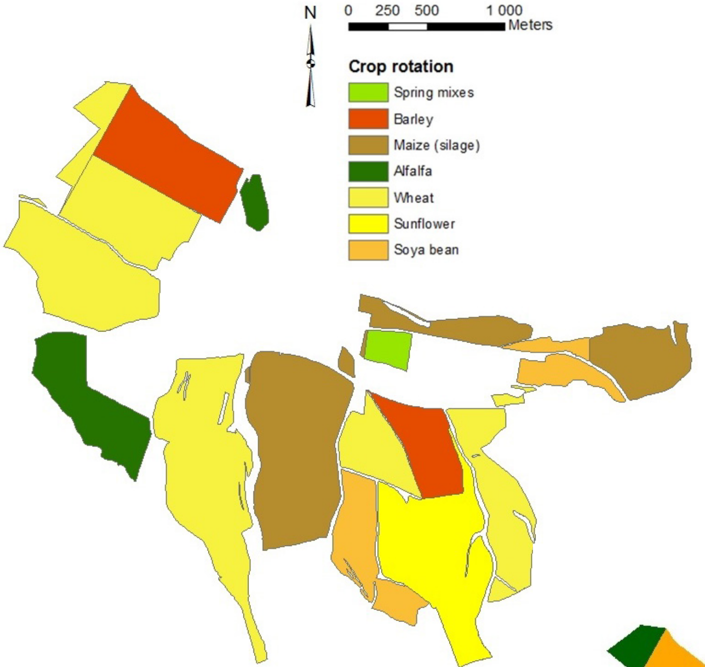


Figure 3 Vegetation cover of the area for the year 2015 (Michal 2015)



For single soil units was identified vegetation cover as reported agricultural farms in selected area for year 2015 (see Figure 3).

After taking into consideration vegetation factor, wind velocity and barriers total erosion soil loss will raise with increasing unprotected field length in area of interest. Maximal erosion soil loss in 2015 (see Figure 4) was calculated to 42.26 t. ha^{-1}.$year^{-1}$.

Figure 4 Map of actual wind erosion (Michal 2015)

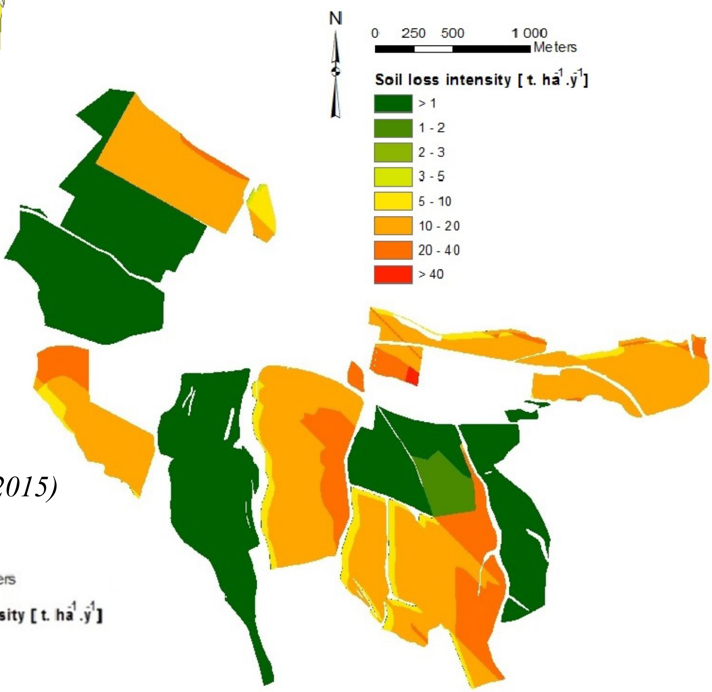
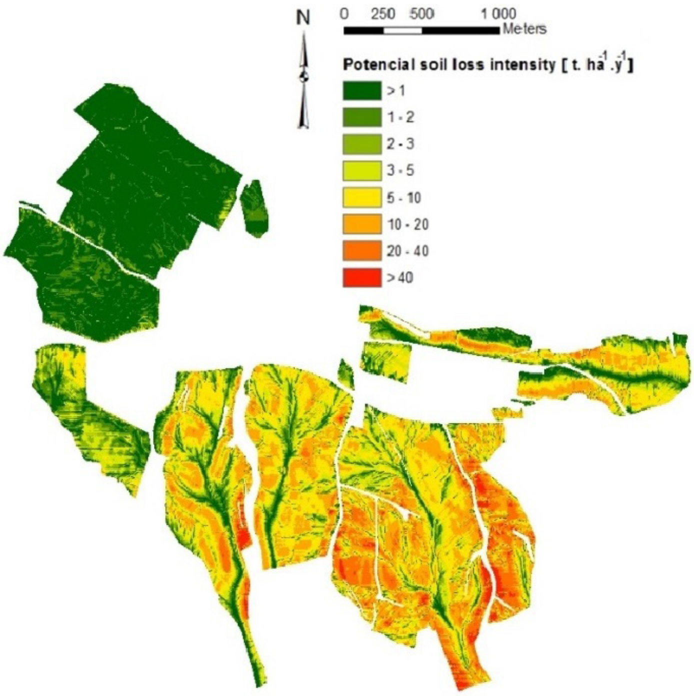


Figure 5 Water erosion - potential (Michal 2015)



Impacts of water erosion intensity are visibly represented on down-slope areas with higher slope. In those areas water erosion intensity is higher than 40 t. ha^{-1}.$year^{-1}$. In flat areas was value of soil erosion was calculated lower than 2 t. ha^{-1}.$year^{-1}$, even on areas with no vegetation cover (see Figure 5).

Actual water erosion (see Figure 6) represents erosion, which can be observed directly in field. Results are strongly influenced by soil vegetation cover. In location where potential erosion calculation reached soil transport values over 40 t. $ha^{-1}.year^{-1}$, was erosion effect eliminated by protective agricultural vegetation or by presence of permanent grass cover and on whole area water erosion soil loss was not higher than 1 t. $ha^{-1}.year^{-1}$.

Figure 6 Water erosion - actual (Michal 2015)

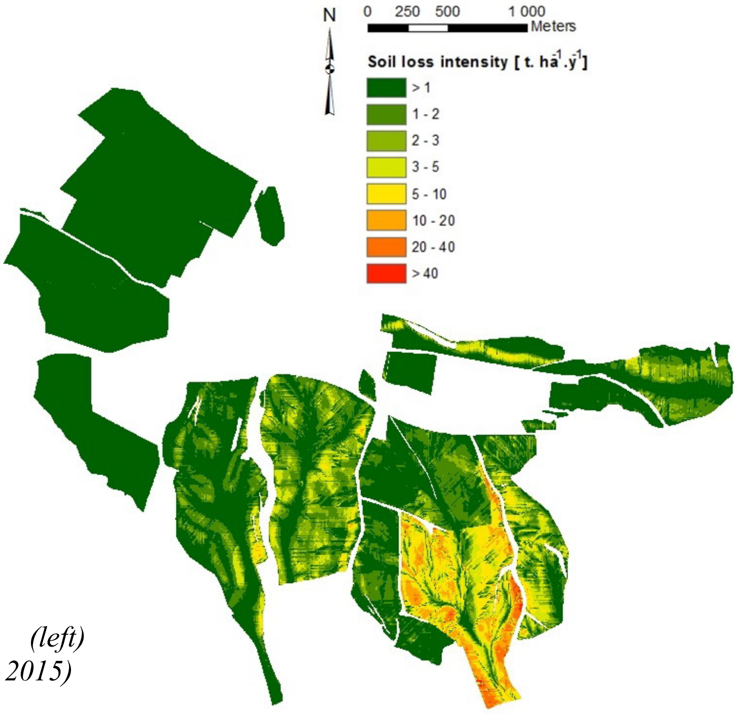
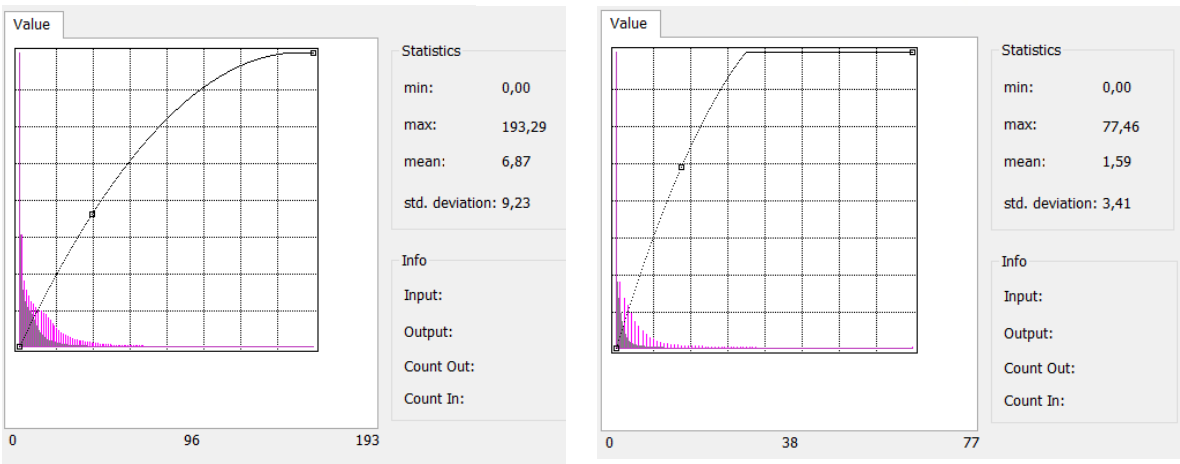


Figure 7 Histograms of potential (left) and actual (right) water erosion (Michal 2015)



Based on potential and actual erosion histograms comparison (see Figure 7) it is clear that with the effect of vegetation protection the influence of water erosion was decreased. Potential erosion calculation reached maximum erosion soil loss value of 193.29 t. $ha^{-1}.year^{-1}$. The actual erosion reached maximal value 77.46 t. $ha^{-1}.year^{-1}$. The average values of soil erosion did not reach in both cases value over 10 t. $ha^{-1}.year^{-1}$.

CONCLUSION

By equation USLE and WEQ we are able to determine erosion susceptible areas for any territory using mathematical modelling in ArcGIS 10.1 software. In the area of Trenčianska Turná maximum soil transport by wind erosion was calculated as 42.24 tons per hectare per year. Calculation of potential maximum for water erosion was calculated as 193.29 and average as 6.87 tons per hectare per year for soil loss by water erosion in the same area. Real erosion for water erosion reached the maximum value of 77.46 and average 1.59 tons per hectare per year. It may be concluded that the vegetation cover, which is selected for selected field units, helps eliminate both wind erosion as well as water erosion processes.

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