The role of land use change on water erosion in the Gödöllő Hillside

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1. Abstract

The landscape of Hungary has changed radically in the past decades. As a result of an intensive need for land use (spreading of residential areas, greenfield investments etc.) the natural environment has been diminishing. On the other hand, the needs of society for intact areas have been increased more and more. The Gödöllő Hillside has a big environmental stress, because it is situated close to the Budapest agglomeration. In the recent years, the effects of suburbanisation manifest more significantly since the population has already started moving out from the capital city. Some settlements can meet the expanded requirements if they establish new residential areas. As a result of previous the area of cultivated lands has reduced whereas the amount of built up areas has increased. Due to a change in land use, such as the new roads, lots of houses and ever shrinking agriculture and sylviculture, the spatial structure becomes more and more fragmented. The fragmented spatial structure and hillside relief enhance the erosion processes. The observed hillside area is one of the mostly eroded lands in Hungary. The erosion processes can be stopped just in time applying the tendencies written in the survey. We show erosion maps using USLE model. In this way, the mostly endangered slopes can be determined. The surface run off and the potential rate of accumulation are calculated for slopes, which threatened by intensive erosion based on WEPP model, because for this purpose the USLE model cannot be applied. We are going to make suggestions based on the calculations, for altering the use of erosion areas which are mostly influenced by landscape change as a result of the created map database.

2. Introduction

The Gödöllő Hillside belongs to the Northern Mountain Ranges according to Marosi and Somogyi' s (1990) landscape classification. The area of Gödöllő Hillside is 550 km^2, and it consists of 16 settlements. The landscape's height above sea-level is between 130 and 344 m. It declines towards south-east (Marosi and Somogyi 1990). Thanks to the characteristics of the relief, this area accounts for a transitory region between plain terrain and mountain ranges of medium heights due to geological, climatic, botanical and soil features.

The deep structure of Gödöllő Hillside is determined by Mesozoic blocks. The formation of today's surface features can be reckoned from Upper – Pliocene. (Láng 1967). The north-western part of Gödöllő Hillside is covered with sandstone and gravel, later followed by sandy clay and alluvium in the south. During the Pleistocene loess and blown sand were deposited. It is thicker from south of the Pécel–Isaszeg line. The hillside is highly dissected and crushed (Marosi and Somogyi 1990).

The climate of the area is intermediate (Láng 1967). Duality can be seen between the northern and southern parts of the hillside. As a result of it, particular mesoclimate was formed in the region. The mean yearly temperature is 9,5-9,7°5C in the north and 9,7-10° in the south, the mean yearly rainfall is 600 mm (Marosi and Somogyi 1990). The area with heavy rainfall is boarded by Gödöllő-Bag-Kistarcsa-Budapest-Rákospalota-Isaszeg-Pécel, while the driest region is boarded by Monor-Zsámbok-Veresegyház according to the 50-year-old statistics. It rains the most at the beginning of the summer; it is the cause of the formation of significant erosion risk (Szabó and Tóthné Surányi 2003).

The Gödöllő Hillside has with a thick valley pattern, but the valleys are dry or they transport some water temporarily. The region of the water races are fluctuates, which is caused by permeable rocks (Láng 1967). Most of the water races are polluted so the conservation of the water and the water quality are serious problems (Marosi and Somogyi 1990). The significant water race of the area is Rákos stream. On the area of the Gödöllő Hillside there are plenty of reservoirs and artificial lakes, the largest of which is called lake Isaszeg (16 ha) (Marosi and Somogyi 1990).

At the most part of the hillside the bedrock consists of loess, sand and their mixture in the majority of the area. The micro region's dominant soils in the forests were and still are woodland soils. Besides the dominant woodland soils there are many intermediate sections in case of soils formed on loess and sandy loess and have been under crop for a long while. Meadow soils make up smaller, lower areas. Original soil profiles can be only found in small patches, due to the intense erosion. In most of the areas 'A' horizons are totally eroded and in some cases 'B' horizons have been worn down, too. This region is one of the most eroded landscapes in

Hungary (Stefanovits 1956). Soil erosion is especially intense in the northern part of the Gödöllő Hillside, on the Vácegres–Gödöllő–Pécel–Mende line. Channel erosion (e.g. around Isaszeg) and linear erosion (Láng 1967, Jakab 2006) is severe in this region. Erosion models were intensively used and developed in the last 50 years (Deer-Ascough et al. 1995, Evelpidou 2006).

3. Materials and methods

The well-known USLE (Wischmeier and Smith 1972) and WEPP models were used for the analyses.

The Water Erosion Prediction Project (WEPP) was started in 1985. Its purpose was to develop new-generation water erosion prediction technology, originally (as well as the USLE) for use in the USA. The WEPP model was developed by the USDA-ARS to replace empirically based erosion prediction technologies, such as USLE, RUSLE, MUSLE. The WEPP model simulates many of the formerly missing physical processes important in soil erosion (e.g. infiltration, runoff, raindrop and flow detachment, sediment transport, deposition, plant growth, and residue decomposition) as input parameters. The WEPP project is similar to USLE because it was constructed based on extensive field experimental program (on cropland, rangeland and disturbed forest sites). Sufficient amount of data was needed to parameterize and test the model. The model became functional with the cooperation of research locations, laboratories and universities. The WEPP model can be used on hill slopes and on smaller watersheds. The model can be used with Microsoft Windows operating system graphical interfaces, web-based interfaces, and integration with Geographic Information Systems since 1995. Watershed channel and impoundment components, CLIGEN weather generator, the daily water balance and evapotranspiration routines, and the prediction of subsurface lateral flow along low-permeability soil layers was developed and continuously improved (Chaves and Nearing 1991; Risse et al. 1994; Flanagan and Nearing 1995; Flanagan et al. 2007; Deer-Ascough et al. 1995; Flanagan et al. 2007; Grismer 2007; Romero et al. 2007a, b; Moffet et al. 2007; Kim et al. 2007; Bonilla et al. 2007; Moore et al. 2007).

Input parameters for the WEPP model: rainfall (amount 16.50 mm, duration 48 min), normalized peak intensity (2.73), normalized time to peak (0.15). Land use was tilled fallow. Slope length and slope angle was calculated based on the topography map of the area and on in situ check with GPS. Input parameters for the USLE model were: R = E = 0.3854, K = 0.009, LS = 4.75 (slope angle was 12%, length was 185m), C = 1, P=1.

4. Results

The results of the soil loss calculations with the WEPP model (Table 1.) show that 0-61 meter (appr. 33% of the total slope length) can be considered as a section with no erosion. Even after this section the calculated soil loss is very low, from 61.37 to 96.34 (another 19% of the total slope length) it is only 1 g m^{-2}.

Table 1 Results of the simulation with the WEPP model, Gödöllő, Hungary

PD (m) (m)	SOL (kg m^{-2})	PD (m) (m)	SOL (kg m^{-2})	PD (m) (m)	SOL (kg m^{-2})	PD (m) (m)	SOL (kg m^{-2})	PD (m) (m)	SOL (kg m^{-2})
61.37	0.001	83.85	0.001	106.33	0.033	135.05	0.027	163.77	0.079
62.62	0.001	85.10	0.001	107.58	0.037	136.30	0.029	165.02	0.091
63.87	0.001	86.35	0.001	108.83	0.041	137.55	0.031	166.27	0.102
65.12	0.001	87.60	0.001	110.08	0.044	138.80	0.033	167.52	0.113
66.37	0.001	88.85	0.001	111.32	0.048	140.05	0.035	168.77	0.115
67.62	0.001	90.09	0.001	112.57	0.051	141.29	0.036	170.01	0.116
68.87	0.001	91.34	0.001	113.82	0.054	142.54	0.038	171.26	0.116
70.11	0.001	92.59	0.001	115.07	0.058	143.79	0.040	172.51	0.116
71.36	0.001	93.84	0.001	116.32	0.061	145.04	0.041	173.76	0.116
72.61	0.001	95.09	0.001	117.57	0.064	146.29	0.043	175.01	0.116
73.86	0.001	96.34	0.001	118.82	0.066	147.54	0.044	176.26	0.116
75.11	0.001	97.59	0.003	120.06	0.069	148.79	0.046	177.51	0.116
76.36	0.001	98.84	0.008	121.31	0.067	150.03	0.047	178.76	0.116
77.61	0.001	100.09	0.012	122.56	0.060	151.28	0.048	180.00	0.116
78.86	0.001	101.33	0.016	130.06	0.020	152.53	0.050	181.25	0.116
80.11	0.001	102.58	0.021	131.30	0.022	153.78	0.051	182.50	0.116
81.35	0.001	103.83	0.025	132.55	0.023	161.27	0.058	183.75	0.103
82.60	0.001	105.08	0.029	133.80	0.025	162.52	0.067	185.00	0.038

PD = Profile distances are from top to bottom of hillslope, SOL = Soil loss

We have to visualize the results for better understanding in a diagram (Figure 1.). Figure one shows the results of the simulation with the WEPP model.

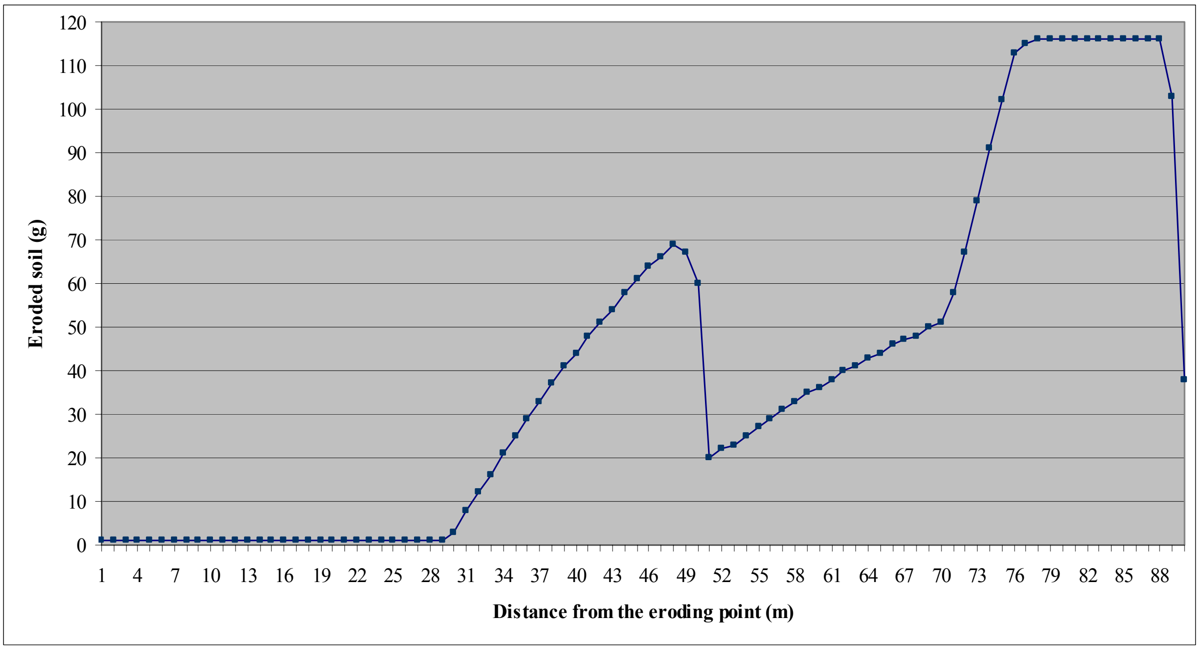

Figure 1 Results of the soil loss simulation with the WEPP model Gödöllő, Hungary

An important value of the simulation is the non-eroded slope length. Erosion starts at the distance of 78.86 meters from the top of the slope. The other important result is that after erosion starts it stays at very low value. For another 29 meters there is only 1 gram per square meter is calculated as soil loss. Overall outputs of the simulation with the WEPP model can be seen in Table 2.

Table 2 Basic overall results of the simulation with the WEPP model, Gödöllő, Hungary

Area of Net Loss	Soil Loss (mean)	Soil Loss (STDEV)	Max. loss	Max. loss point	Min. loss	Min. loss point
(m)	(kg m^{-2})	(kg m^{-2})	(kg m^{-2})	(m)	(kg m^{-2})	(m)
60.13-185.00	0.041	0.038	0.116	181.25	0.001	78.86

Runoff outputs were as follows: runoff volume 1.54 mm, peak runoff rate 5.80 mm/hr, effective runoff duration 15.89 min and effective length 124.88 meters (Figure 2.).

Figure 2 The results of WEPP simulation, Gödöllő, Hungary

Based on the calculations with the USLE model the amount of the soil loss with the given input parameters is 16.47 kg for this rainfall event. The total amount calculated with the WEPP model is 3.67 kg. USLE calculates 4.5 times more soil loss which is not measured in situ but can be reliable if we take into account the soil thickness of the area: there are shallow soils on the upper third of the slope (that is considered as non-eroded by WEPP) and at the lower third of the slope clay is dominant in the soil particle size distribution that assumes higher erosion rate above this section.

Calculated values can be considered high in both cases because this simulation was made for one rainfall event. There are much more erosive events, especially during the summer on these slopes, even rill erosion occurs. Much more attention should be paid by local farmers in order to protect these soils for future use. However the area provides excellent possibilities for students to study erosion!

5. References

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