SOIL LOSS THREATS UNDER DIFFERENT CLIMATIC CONDITIONS OF SIMILAR URBAN AREAS (ATHENS - BUDAPEST)

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EXTENDED ABSTRACT

Climatic changes affect both coastal and inland areas. Keeping ecosystems at a balance, reassuring clean water and air along with making rational use of arable land, are of great essence for the human population. Soil degradation processes, especially aeolian and water erosion, are seriously affected by the climatic conditions and the corresponding changes. Studies were undertaken on highly eroded slopes to show the effects of sedimentation in Greece and in Hungary. Quantitative and qualitative analyses were applied on the examined sediment to indicate its deepness and nutrient content.

The Hungarian study area is situated approx. 40 km the South-East of the capital (Budapest). The examined area is characterised by slopes of an average length of only 150-200 m, but the current farming practices and the climatic conditions already resulted in 2.6–3.2 m sediment at the bottom of the slopes. The nutrient content of the sediment is extremely high, reaching 2455 mg × kg^{-1} P_2O_5 content. Rainfall events of higher intensity are causing more runoff and much faster changes in the landscapes. Our aim is to present different scenarios for potential climatic changes that increase the possibility of more erosive rainfall events. Intense rainfalls highly increase the potential of soil loss and, thus, sedimentation.

The Greek study area is situated approximately 35 km North-East of the Capital (Athens), on Mountain Penteli, where intense erosion phenomena are met. The main reasons for the increase of erosion phenomena are the fires and the climatic changes that have taken place in the recent years. Due to slope steepness, contour log terracing has been applied to protect the burned areas from erosion. A representative location has been chosen in the southwestern slope of Mountain Penteli, in order to measure the erosion rate at the upper parts of the slope and the deposition rate at the lower parts.

KEYWORDS: soil erosion, climatic changes, nutrient loss, Penteli (Greece), Galgahévíz (Hungary)

1. INTRODUCTION

The present change of climatic, economic, demographic and political conditions calls greater attention on the importance of the protection of soil resources. One of the major soil forming factors is the parent material. Its research is important in order to understand the soil forming and soil degradation processes. During the research, two areas with very distinct geographical background were compared. On the Greek study site there was solid rock parent material while on the Hungarian site there was soft loessy material.

On the Greek study area (Mountain Penteli), the bedrock consists of metamorphic rocks, mainly marbles and schists (Lepsius 1893; Kober 1929; Avdis, 1990; Papadeas, 2001).The marbles are mainly composed by calcite (98%) and other minerals depending on the variety of the marble, such as muscovite, sericite and chlorite (Kleftakis *et.al.* 2000).

On the Hungarian study area geological (loess), pedological (soils formed on loessy material) and climatic conditions (high amount and intensive precipitation in June) result in a high amount of soil loss (Vona *et al.*, 2006; Centeri & Vona, 2006; Centeri *et al.*, 2006, 2008; Falusi *et al.*, 2007; Tóth and Centeri, 2008).

2. DESCRIPTION OF THE EXAMINED AREA

2.1. Description of the Greek study area

The mountain range of Penteli is situated at the NE part of the Athenian plain between Parnes and Hymettos. The elevation is 1,109 m and the mountain is mainly covered by forest (about 60 to 70%), although during the last twelve years the area has suffered three major fire events. The fires took place in July 1995, in August 1998 and in July 2007. These major fire events have reduced the forest coverage thus exposing the area to more intense water runoff and erosion.

Penteli area is characterised by shallow soils. The so called A-C soils (where A horizon is the humus rich layer and it is the only layer above the bedrock) are typical in Penteli. The soil forming factors do not allow the formation of thick soil layers and logging resulted in significant loss of the topsoil. Forest fires have degraded soil attributes and allowed further slimming of the soil layers. Thin soil layers appear mostly on less steeper slopes, as well as in shallow holes of the bedrock on slopes with higher inclination.

2.2. Description of the Hungarian study area

The Hungarian study area is near Galgahévíz village. It is situated approximately 40 km from the capital of Hungary (Budapest). Galga is a name of a river that formerly flooded the area in a strip of 800-1000 m wide. This flooding delivered coarse sandy material on the lower parts of the area, while on the upper slopes thick loess material exists.

13 different soil types may be found on the area, most of them were formed on loess or loessy sand material. Most of the soils belong to sandy soils and chernozem brown forest soils and only a small amount of other soil types are present (Fluvic Vertisols 2%, water effected Vertisols 13%, salt effected soils 10%, moving sand 4%).

The climate is continental. The average yearly temperature is 10-11°C, the coldest month is January with -2°C, the hottest month is July with 21°C. The yearly temperature range is 23°C. Measurements by meteorology stations started in 1900.

The yearly precipitation is 525-550 mm (<60% falls during the summer months, June has the highest amount of precipitation 65-67 mm). Only 10% of the precipitation arrives in solid form (mostly snow).

Thanks to the effects of the Mátra Mountain, the warming period takes longer in the springtime and the cooling period is faster in autumn. Abrupt temperature changes are frequent. In the first third of May, at the end of June and at the beginning of October sudden temperature falls are characteristic.

3. MATERIALS AND METHODS

3.1. Field measurements, data collection and analyses

Field work is carried out since December 2005. Based on contour log terracing that was applied in the area and with the aid of GPS technology, a set of metering devices have been installed. The location of the devices is accurately mapped and imported to the GIS (Figure 1).

Geological data was gathered from bibliographical references and fieldwork. Geomorphological data derived from interpretation of aerial photos and satellite images along with detailed field work. Satellite images were used as well, in order to determine

the land use on inaccessible areas. All this primary data was inserted into the GIS in order to be analysed and to create runoff models.
Empirical and bibliographical study led to the identification of the crucial parameters amongst the primary data, which are considered necessary for the outcome of the desired result. These parameters include lithology, vulnerability, slope, aspect and drainage density, which were calculated on a 100 x 100 m grid.
Lithology is estimated by grouping geological formations according to their resistance to weathering. Vulnerability expresses the complex value of resistance to erosion, taking into account chemical composition, tectonic strain and lithology parameters. Slope inclination parameters such as aspect and slope steepness define the direction and volume of soil movement. Drainage density determines the percentage of runoff.
Compiling all these parameters with an approach of a Boolean set of logical rules, within GIS environment, the final estimation of erosion risk took place. The results of the GIS modelling procedure were then compared to field work observations for verification.
Due to different environments, a different approach was used in order to address the soil loss issue. In the Greek study area research focused on soil volume loss. The thin soil layers on Mountain Penteli make the determination of soil volume transfer of great importance.
Measurements revealed a range of deposition justifying modelling data and estimations (see Figure 1). The five parameters: climate, topography, parent material and time that Jenny (1941) described, combined in different ways, sometimes give the same result through different paths.

3.2. Soil laboratory analyses

The distribution of P_2O_5, K_2O, $CaCO_3$ and soil organic matter content was examined in the upper and lower slope sections of the slope in Galgahévíz in 2004 and 2006. Average samples were taken from the upper 20 cm layer of the soil. Shallow drillings were made to examine sediment thickness in Galgahévíz (see Figure 2). Soil samples were taken every 20 cm from the drilling. Hungarian samples were examined at the Dept. of Soil Science and Agricultural Chemistry.

4. RESULTS

The aim of this research was to estimate the erosion risk and the soil deposition volume in the wider region of urban areas.

Table 1 shows that using a high amount of fertilizer can equalize the differences between the slope sections. The only data which proves that erosion occurs on these slopes is the $CaCO_3$ content. It is a well-known phenomenon that loess material is mixing with the upper soil layers during cultivation and erosion is taking place, because soil is getting shallower, while loess is getting closer to the surface. Loess has a high amount of $CaCO_3$ thus above 5 % $CaCO_3$-content of the soil is a sign of erosion when this value at the bottom of the slope is only 3.85%.

Table 1. Laboratory results of the upper soil layer (0-20cm), Galgahévíz, Hungary

Sample site (Galgahévíz)	**2004 pH**	**2006 pH**	**2004 pH**	**2006 pH**	**2004 $CaCO_3$**	**2006 $CaCO_3$**
	(KCl)	**(KCl)**	**(H_2O)**	**(H_2O)**	**(%)**	**(%)**
Arable land UTS	6.7	6.9	7.2	7.8	NA	7.57
Arable land LTS	6.9	6.9	7.2	8.1	NA	3.85
Sample site	**2004 SOM**	**2006 SOM**	**2004 AL-P_2O_5**	**2006 AL-P_2O_5**	**2004 AL-K_2O**	**2006 AL-K_2O**
	%	**%**	**mg*kg^{-1}**	**mg*kg^{-1}**	**mg*kg^{-1}**	**mg*kg^{-1}**
Arable land UTS	2	2,2	1524	819,9	218.4	185.9
Arable land LTS	1.5	2.4	1322	1653	218.4	197.8

UTS = Upper Third of the Slope, LTS = Lower Third of the Slope, SOM = Soil Organic Matter

Sampling the deeper layers resulted that soil layers have originated from the upper slope sections. This is the reason of the high amount of nutrients in the deeper soil horizons (Table 2). P_2O_5 content of the soil was reaching 2455 mg*kg^{-1} at the depth of 120-140 cm and remains above 2000 mg*kg^{-1} until the depth of 200 cm on the intensively cultivated slopes of Galgahévíz. The high amount of K_2O, however, does not mean nutrient overload as does the P_2O_5-content. The NH_4-N and NO_3-N has an interesting abrupt in its growth at the depth of 80 cm in both the western and eastern samples. In the eastern samples there are more abrupt changes because the depth of the sediment is thicker.

All the aforementioned data proves that there were different amounts of nutrients in the upper soil layer when erosion occurred or it might as well prove the rainfall erosivity of the given period when the sediment was deposited.

Table 2. Laboratory results of the shallow drilling east of the cooperative

Code and depth (cm)	pH (KCl)	pH (H_2O)	SOM %	Ca %	P_2O_5 mg*kg^{-1}	K_2O mg*kg^{-1}	NH_4-N mg*kg-1	NO_3-N mg*kg^{-1}
W0-20	8.1	7.4	2.0	ND	ND	ND	ND	ND
W20-40	8.1	7.2	2.6	1.3	1266.0	383.0	6.9	6.9
W40-60	7.7	7.2	5.4	1.3	1283.0	430.0	6.9	6.9
W60-80	8.0	7.2	2.4	1.1	1371.0	272.0	10.3	10.3
W80-100	8.0	7.2	1.7	0.8	1540.0	294.0	3.4	6.9
W100-120	7.9	7.2	1.8	1.0	1304.0	392.0	3.4	3.4
W120-140	8.3	7.6	1.3	1.0	392.0	407.0	6.9	6.9
W140-160	8.2	7.5	ND	1.2	660.0	424.0	3.4	3.4
W160-180	8.4	7.7	ND	2.1	669.0	478.0	6.9	10.3
W180-200	8.5	7.8	0.3	3.4	1012.0	438.0	13.7	17.2
W200-220	8.5	8.0	0.9	6.1	863.0	329.0	<KH	10.3
W220-240	8.5	8.2	1.0	7.3	895.0	246.0	3.4	24.1
E0-20	8.0	7.3	3.1	2.3	1944.0	334.0	6.9	3.4
E40-60	8.0	7.2	1.8	1.7	1968.0	295.0	6.9	6.9
E60-80	8.0	7.1	2.7	1.2	2247.0	283.0	3.4	6.9
E80-100	8.1	7.3	2.4	1.3	1950.0	277.0	6.9	3.4
E100-120	7.8	8.4	1.0	0.9	2221.0	320.0	3.4	3.4
E120-140	8.0	7.3	ND	1.0	2455.0	357.0	6.9	3.4
E140-160	7.5	8.1	0.2	1.4	2284.0	353.0	3.4	3.4
E160-180	8.1	7.3	1.0	0.7	2204.0	379.0	<KH	<KH
E180-200	8.2	7.4	1.9	0.7	2040.0	355.0	10.3	6.9
E200-220	8.3	7.5	0.8	0.8	1291.0	312.0	3.4	3.4
E220-240	8.1	7.4	0.0	1.8	941.0	262.0	10.3	10.3
E240-260	8.3	7.4	ND	2.7	834.0	253.0	3.4	<KH
E260-280	8.3	7.4	ND	2.2	706.0	217.0	<KH	6.9
E280-300	8.3	7.5	ND	2.3	502.0	222.0	10.3	6.9
E300-320	8.6	7.6	0.2	7.5	182.0	107.0	3.4	3.4

ND = no data, W = west of the cooperative, E = east of the cooperative, KH = limit of measurability

Nutrients are known to move down the slope with soil erosion. In Galgahévíz, Hungary, high amounts of nutrients were found both at the upper and the lower sections of the intensively cultivated slopes of Galgahévíz.

Table 3. Laboratory results of the soil analyses in the Sósi Creek watershed

No.	Vegetation	Slope third	pH(H_2O)	pH(KCl)	$CaCO_3$ (%)	SOM (%)	AL-P_2O_5 (mg/kg)	AL-K_2O (mg/kg)
1	Alfalfa	Upper	7.8	7.3	11.70	1.51	98.8	137.4
		Middle	8.4	7.3	9.26	1.54	128.4	153.0
		Lower	8.2	7.1	3.28	2.22	119.6	171.5
2	Deciduous forest	Upper	7.1	7.1	3.41	3.25	215.4	353.8
		Middle	7.1	7.1	4.14	3.48	159.1	444.2
		Lower	7.2	7.2	7.87	2.26	205.5	377.3
3	Arable land	Upper	7.1	7.1	1.55	1.49	160.1	230.6
		Middle	7.3	7.3	15.60	1.37	156.1	191.5
		Lower	7.2	7.2	7.41	1.76	169.9	235.6
4	Deciduous forest	Upper	8.1	7.2	4.97	3.07	47.4	175.1
		Middle	8.2	7.4	12.92	4.06	61.3	196.5
		Lower	8.0	7.3	10.77	2.83	110.7	248.4

SOM = Soil Organic Matter, AL = ammonium-lactate

Erosion risk and soil deposition volume in Mountain Penteli are illustrated in the form of G.I.S. generated maps. Figure 3 shows the spatial distribution of erosion and deposition zone. As expected, erosion is more intense on more inclided slopes.

The map representing erosion risk (on a 100x100 m grid – Figure 4) reveals that areas with greater slope inclination are more susceptible to erosion. It also demonstrates the effectiveness of contour log terracing. The areas where contour log terracing was applied show medium to low erosion risk. The qualities of soil movement overall, reveal that altitude is not the main decisive factor. The morphological attributes (surface runoff, aspect, slope) affect the soil path greatly. However, contour log terracing has proven to be very effective if applied with caution.

5. CONCLUSIONS

The two different study area resulted different soil loss results. On the Hungarian site severe erosion could occur – as it is proven by the high amount of nutrients in the layers of the shallow drillings –, on the Greek study site the parent material and the steep slopes did not yield thick soil layers, so that much erosion could not be seen since there is only little soil layer on the area.

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Figure 1: Metering devices, Mountain Penteli, Greece.

Figure 2: Shallow drilling, Galgahévíz, Hungary.

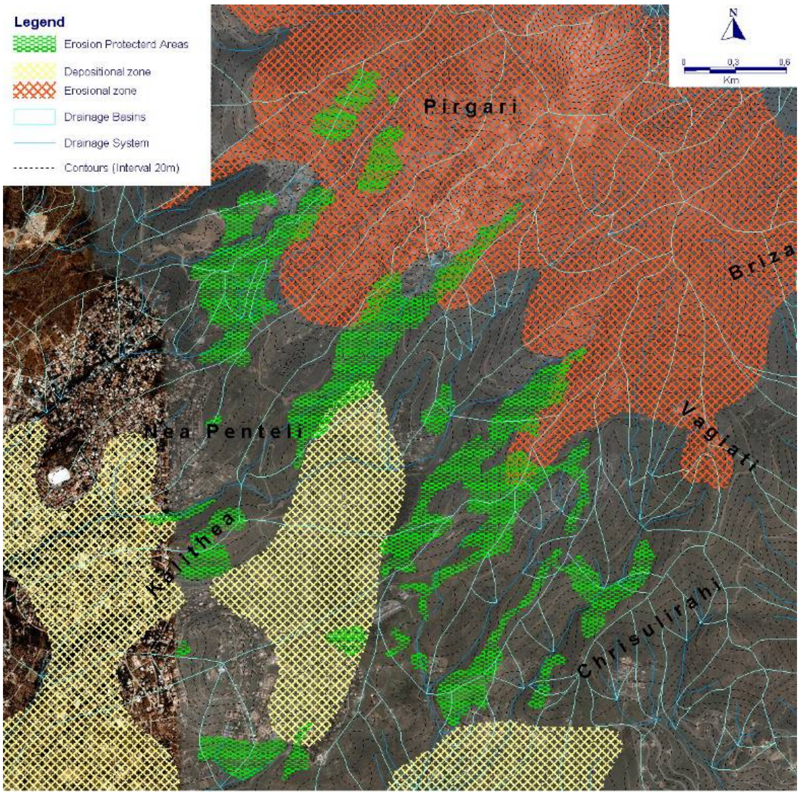

Figure 3: The spatial distribution of erosion - deposition zones in the burned area and the zones with the tree trunks for the protection from erosion.

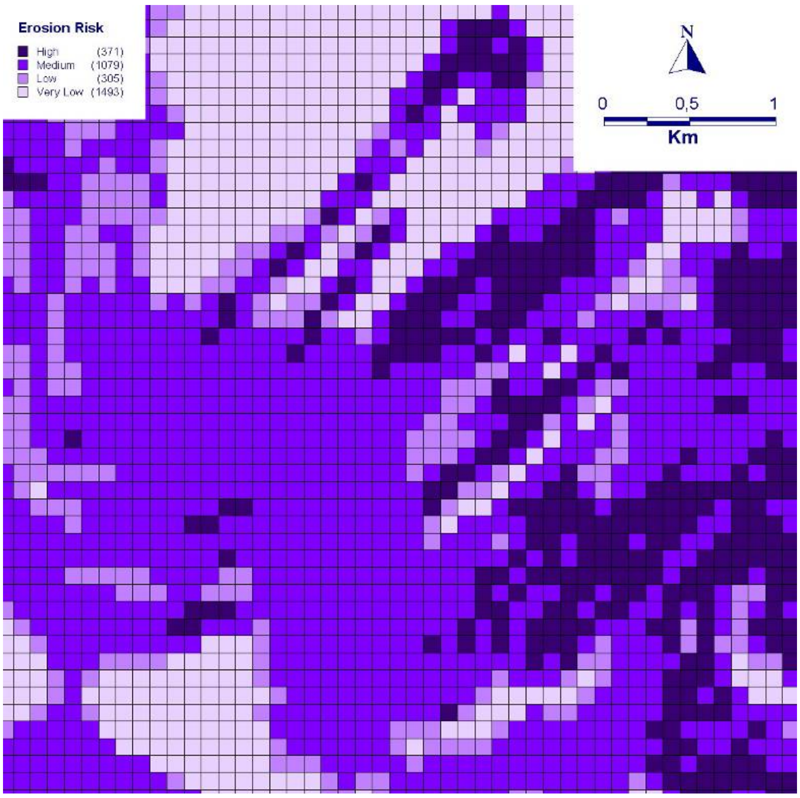

Figure 4: The highest erosion risk areas have been calculated at the East part and the erosion protected areas now have medium to low erosion risk.