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QUANTITATIVE CONSIDERATIONS CONCERNING THE SOURCE-AREAS FOR THE SILTING OF THE RED LAKE (ROMANIA) LACUSTRINE BASIN

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Abstract
The Red Lake is part of the natural barrage lakes category, and has been a major part of the landscape since 1837. The silting is specific to hidrographic basins and can be accelerated in specific conditions, which are associated to the negative, anthropic intervention. The long lifespan of the like is due to a very low silting rate and the durity of the body of the landslide. A very important static factor that reduces the quantity of solid material, that is transported in the lake, is represented by the small area of the hydrographic basin, from which the lake recieves its sediments. Through our work, we have analysed the source-areas for the sediments and the origin of the transported material. The origin of the sediments varies, depending on the distribution and size of the areas with differentiated land use, the granulometric size of the particles, the type of plants and their size, soil types etc. The hydrologic network of the Red Lake concentrates the sediments, from the 41 km^2 of the drainage basin, therefore generating maximum silting rates which vary between 1cm/year and 3.77 cm/year, while the overall average for the entire lake is recorded at 1.23 +/- 0.6 cm/year. A special attention has been given to the deforestation processes that take place in this drainage basin, which lead to the exposure of the soil towards greater erosion, because of the vegetation that has been cut down. In this case, we can talk about an accelerated erosion and silting process, which are well differentiated along the drainage basin, therefore the human factor intervening decisively in shortening the lifespan of the Red Lake.
Keywords: deforestation, detritic material, erosion, silting, source-areas

1. INTRODUCTION

The Red Lake is the most well known natural barrage lake in Romania, being formed in 1837. There are 2 hypothesis that explain the causal origin of the lake. The first refers to an earthquake that took place in 1837, which weakened the structure of the slope, located at the eastern side of the current lake location. Therefore, the original landslide occured between the limestone layers and the wildflysch, dating from the Cretaceous period. The second theory involves the presence of heavy rainfall, which infiltrated inside the wildflysch deposites, destabilising the hillslope, generating a landslide at the footslope of the Ucigasul Peak.

One of the most important, current aspects concerning the evolution of the lake is the silting process, which significantly affects the very existence of the lake. Several calculations depict a few, estimative years, after which the lake is expected to completely fill up with sediments, and will eventually disappear. The most optimistic predictions state that, without human intervention, the lake will disappear in 236 +/- 70 years, while the most negative assessments display a 181 +/- 30 life span. The main causes that determine the silting process are continuously affecting the quantity of sediments being transported by the river network. First of all, the naturally occuring, surface erosion plays a significant role in the silting process of the Red Lake, along with eutrophication, the rise in annual rainfall, and lastly, but not least, illegal deforestation. In our study, we have tried to apply the USLE method for calculating soil erosion, both for 1989, and 2007, to estimate the influence of deforestation on the production of sediments, and silting process.

2. METHODOLOGY AND DATA

The purpose of our study was to mathematically estimate the erosion values during an 18 year period (1989-2007), by creating 2 different USLE models for these 2 years. The software which we have utilised were Microimages, TNT Mips, version 6.9, ArcGis 9.3 and SAGA GIS. The materials used were topographic maps, at a 1:25000 scale, from which we have extracted the contour lines. These were integrated into a Numerical Terrain Model (MNT: 1 pixel = 10x10 meters). This was the base layer, that was used to generate the slope and slope length layers. One of the biggest issues we have encountered during our analysis, was to obtain the Slope Length layer, which could not be automatically generated in TNT Mips, therefore necessiting an export in an ArcGis compatible format. From here, it was exported again as an .ASC file, which could be handled by SAGA GIS. Here, we managed to automatically generate the Slope Length layer, with the integrated algorithm offered by SAGA.

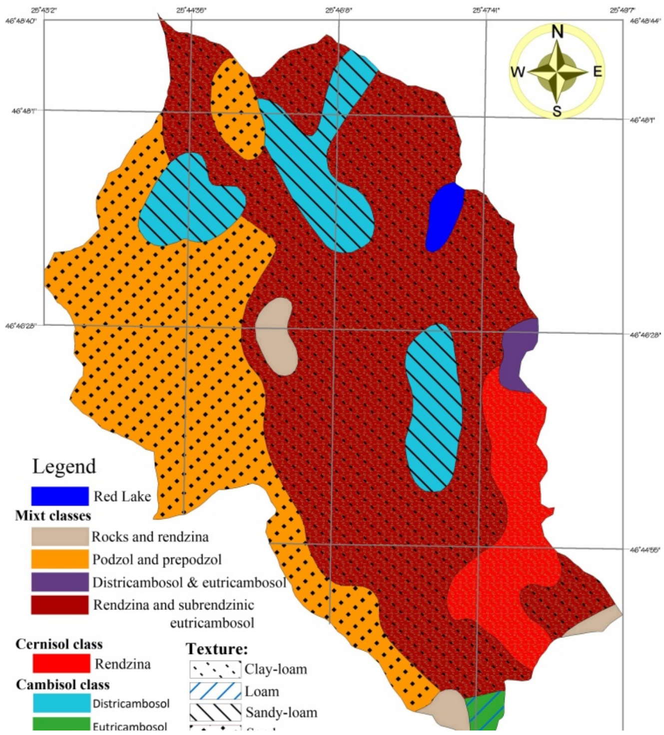

Fig. 1 - Pedologic map for the Red Lake drainage basin

After exporting the file to a TNT Mips-compatible format, we have overlaid the Slope Length over the current terrain model. Another problem was the slight misoverlaying of the two layers, which caused the imposibility of multiplicating the final rasters. Therefore we had to regenerate the MNT, by matching the raster to the Slope Length. The newly obtained MNT was used to create the Slope layer (in percents). Both of these two layers had one, final, similar issue: the presence of numerous flat surfaces and a dens river network determined the occurance of "zero" values on the raster. This would drastically alter the final result (1/5 of the total number of pixels had the "zero" value), so we had to reclasify, using the integrated Spatial Manipulation Language (SML) of the TNT Mips software, the Slope and Slope Length layers. We had attributed for all these problematic pixels, the value of "1", so they would give a neutral impact, at the final USLE multiplications.

The soil layer (Fig. 1) was classified with values from national studies (Motoc, 1975) on different soil types, and the resulting raster was associated with a 0.9 coefficient, except for the highest, rocky areas (which were attributed with a 0.1 value). In order to identify the deforested areas, we have used sets of satellite images downloaded from Global Land Cover Facility. In order to properly view the extents of the areas with vegetation, the images have been chosen from the summer period, when the vegetation is very abundant. We obtained the final satellite rasters, by mixing several RGB channels, including near and thermal infrared. Despite the poor resolution (1 pixel = 30x30 m), it was possible to detect and measure the extents of the deforested areas. We have created the vector with the deforested areas (1989 and 2007), by making the difference between the surface that were not covered with forests in 1989 and 2007. Afterwards, we have rasterized this vector, according to the 3 different soil coefficients (and the original one, from 1989). The new layers were used to calculate the difference between the classes of soil degradation (maximum = 1,2), after the forest protection had dissapeared. The occurance of deforestations meant that the vegetation index had risen in value, from 0,01 to 0.1, the forest offering 10 times more protection to erosion, comparing to the newly formed pastures. This coefficient change was applied only to the areas suffering from deforestation, in the USLE geoformula. From the current indicators, we generated 5 USLE models (1 for 1989 and 4 for 2007). The geoformula we have applied (according to Motoc, 1975, and updated value for pluvial aggressiveness), in order to obtain these raster layers was:

$$EROSION = Pluvial\ Aggressiveness * Slope^{1.5} * Slope\ Length^{0.3} * Vegetation\ Index * Soil\ Coefficient$$

By applying a Raster Substract Function to the newly generated USLE models, we could isolate the deforested regions, with the calculated Added Erosion Rate. Therefore, we were able to identify the approximated influence (increased erosion rate) values for each soil degradation state (from original state: 0,9 - up to the highest, potential, erosion state: 1,2).

3. RESULTS AND DISCUSSIONS

In order to correctly asses the results of the deforestation, we have generated several USLE models, specific for 4 different soil coefficients. Therefore, we could have a comparative view of the current situation, still associated with a reduced increase in the soil erodability, and the maximum potential situation, the added values of erosion oscillating from 0,83 tons/ha/year, up to 1,14 tons/ha/year. These extra erosion values only apply to the deforested areas. These areas have been calculated by substracting the regions with no forests in 2007, from the equivalent layer in 1989. The resulting layer has been used to create a vector which eventually held all the area and erosion information. The initial extents (18th august 1989) of the areas without forests were calculated at 5,52 km^2, while on the 27th July 2007, this value has doubled (11,04 km^2).

After obtaining the Added Erosion Rate (Fig. 2), we have applied this rate to deforested areas, and then cumulated this new raster, with the general USLE model, for each soil coefficient.

In Fig. 2, we can see the large range of erosion rate values, which peak at 114 tons/ha/year. These extreme values are, on the other hand, isolated and very rare, and do not influence the overall erosion rate (5,28 tons/ha/year).

It can easiliy be seen that the general tendency for source areas of deforestation is around next to the main rivers in the drainage basin. This is due to the fact that cut down trees are transported by dragging the logs through the water courses, to reduce effort and costs. But such practice is illegal, and authorised logging companies should not apply this kind of techniques. This is another argument that states the illegal character of the deforestation, along with the isolated areas where these practices take place (upstream, hidden from sight), and the fact that the drainage basin is part of the "Cheile Bicazului – Hasmas" National Park.

The drainage basin of the lake has a total surface of 40,59 km^2 (4059 hectares), from which, the deforested areas expand over a 571 hectares area (14% of the total drainage basin area).From the 2007 examples, we decided to analyse the difference without changing the soil coefficient (we kept the 0.9 value - Situation 0), in order to determine the isolated influence of the land use change (from forests to pastures). The result consisted in an extra 40% erosion rate. The four situations in which we determined the difference between soil coefficients (Fig. 3) did not reveal any major changes. In this case, the added quantity of sediments represents approximately 2.5 - 3% of the total mass of eroded sediments. The mean erosion rate increases from 2.78 tons/ha/year (calculated for 1989), up to 4.6/5.28 tons/ha/year. This implies that 14% of the entire basin suface determined a change of almost double the erosion rate values, during 18 years of deforestation.

Local authorities have noticed the high risk of silting, and have devised plans to construct retaining reservoirs for the alluvium. They have built 3 such reservoirs, from 1960, in the south, on the Oaia, Piatra Rosie and Licas streams. However, these reservoirs turned up not to be a long term solution, because the relatively small retaining capacity, compared to the Red Lake, meant that they would severely suffer from silting. Bojoi I. has calculated an impressive silting rate of 8,2 cm/year, for the Oaia brook reservoir, which is currently completely clogged. The one on Vereschiu (Piatra Rosie) is 90% clogged.

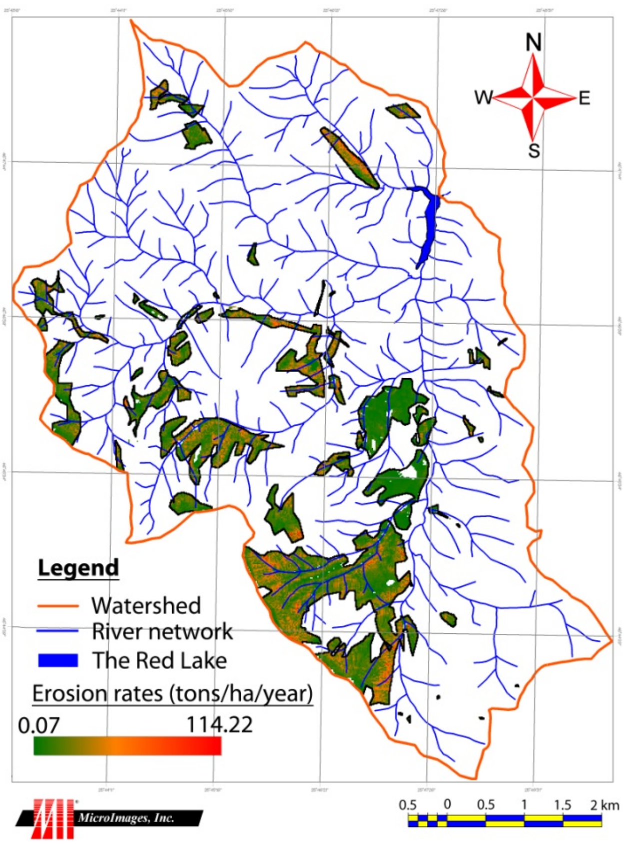

Fig. 2 – Added Erosion Rate for deforested areas (2007), for a soil coefficient of 1.2

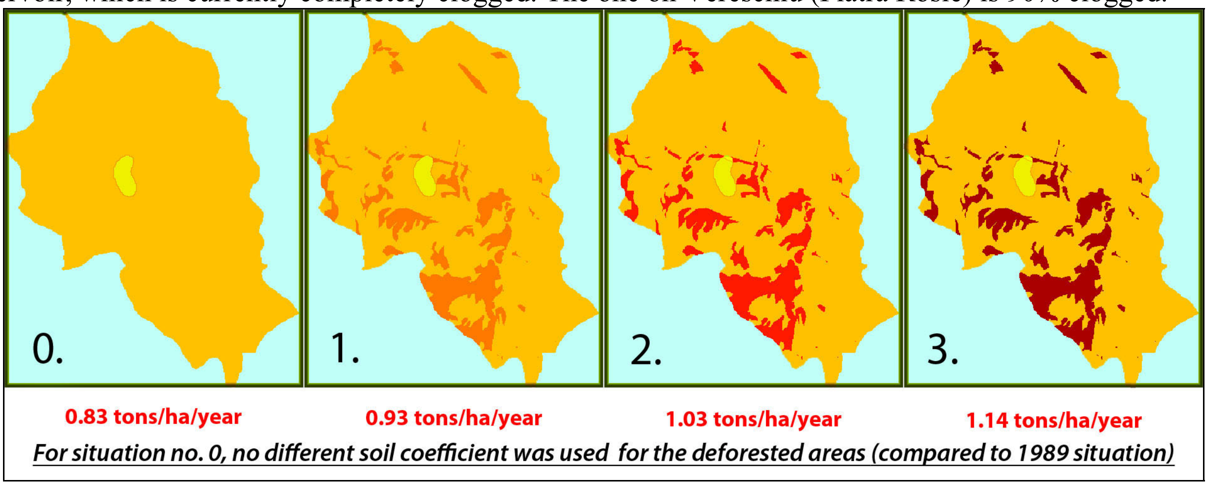

Fig. 3 - Comparative view of the added erosion in 2007, for different soil coefficients

Year	SC	MER	TSM (tons)	AER	ASM (tons)	PI (%)
1989	0.90	2.78	11284.02	-	-	-
2007 - Situation 0	0.90	4.60	18671.40	0.83	472.08	2.53
2007 - Situation 1	1.00	4.82	19564.38	0.93	530.99	2.71
2007 - Situation 2	1.10	5.05	20497.95	1.03	589.89	2.88
2007 - Situation 3	1.20	5.28	21431.52	1.14	648.80	3.03

Table 1 - Erosion indicators applied for different soil coefficient values (for the 2007 forest distribution)

Indicator	Definition
SC	Soil Coefficient
MER (tons/ha/year)	Mean Erosion Rate
TSM (tons)	Total Sediment Mass
AER (tons/ha/year)	Added Erosion Rate
ASM (tons)	Added Sediment Mass
PI (%)	Percentage Influence

Table 1 reveals all the indicators, we have calculated for the 4 situations, associated with different soil coefficients. The overall deviation between the minimum and maximum values is not very significant (0,5%), even in the context of severe soil degradation, which is not the case yet, after only 18 years of evolution.

The most significant differences in erosion occur, due to the already mentioned land use change. Therefore, the very well distributed erosion rate in 1989 has been concentrated in the deforested regions, as is visible in Fig. 4. The most affected areas are in the southern sector, upstream, on one of the most important tributaries of the Red Lake (Oaia Brook). While the soil layer influenced the final USLE models by only 2-3%, the Vegetation Index layer influenced the total erosion by approximately 40%.

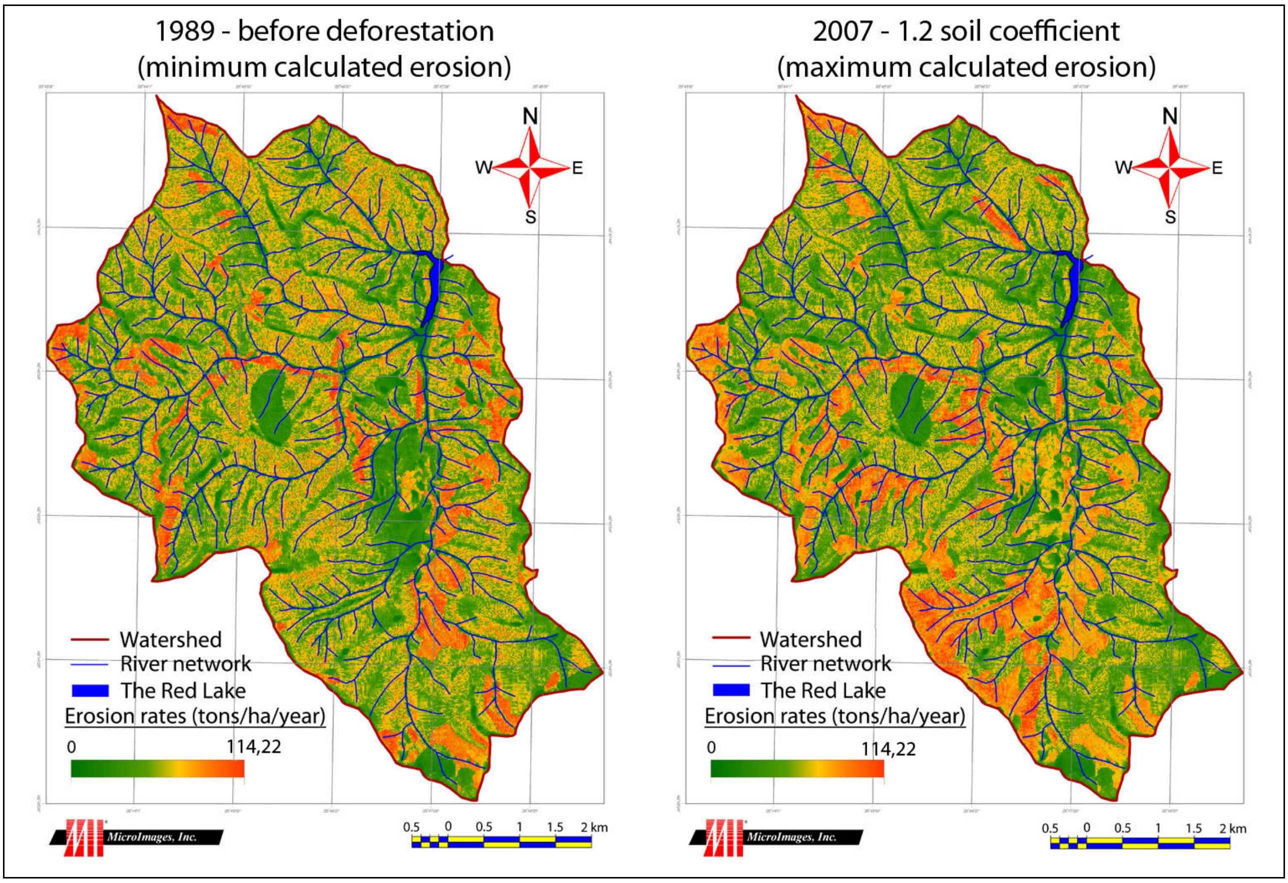

Fig. 4 - A side-by-side view of the source areas for the highest recorded erosion rate in the Red Lake drainage basin

Another downside of the current situation of the Red Lake is the increasing antropic impact. The touristic attraction of the region, through the beauty of the lake and surrounding areas, has determined the appearence of several inns and cottages, with accomodations and numerous services for tourists, including boat rides on the lake. All the calculations and numbers point out to one, concerning, conclusion. The erosion rate is rising (natural erosion, eutrophication, rainfall aggressiveness, deforestations), and the total quantity of sediments that end up on the bottom of the lake is also increasing, and all the human intervention has proved to be without any clear, long-term, positive effect.

4. CONCLUSIONS

Despite the known tendency of the natural barrage lakes to dissapear in a matter of a few years, the Red Lake has managed to survive in the landscape up until present. The main factors of the prolonged existence of the lake are the hard-to-erode landslide body, the relatively small drainage basin area, that has not created sufficient sediments to completely clog up the lake, and the large area of the lake, itself.

The mean erosion rate, generated using the USLE model, for 2007, is calculated at 4,6 - 5,2 tons/ha/year, compared to the value for 1989, of 2,78 tons/ha/year. The ever increasing deforested areas, along with the inefficient hydrotechnical solutions, applied to retain the sediments, reveal the real threat that the Red Lake could have a much shorter life span than even the most precise values, calculated through radioisotope measurements.

Taking into consideration the fact that the Red Lake has already recorded increasing silting rates, and the reservoirs designed to retain the silt have already gone out of service, the added effect of the illegal deforestation, on such a large scale, inside the drainage basin area, can only point out the negative effect of the human factor, leading to the disappearance of the lake.

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