# NATURAL AND ACCELERATED SILTING IN THE RED LAKE BASIN (BICAZ)

**Enea Andrei[1], Romanescu Gheorghe[2]**

**Abstract:** The Red Lake (Hăghimaş Mountains, Romania) was formed in 1837, after the natural blocking of the Bicaz river, when a massive landslide was triggered by two main factors (heavy rainfall and an earthquake). Many analysis have been made, ever since it was discovered (in 1857), and it has been proven that the lake is undergoing a continuous process of silting. Its 41 km$^2$ drainage basin feeds the lake with sediments. This process gives birth to other, related phenomena, such as eutrophication. One of the most important silting causes is represented by the heavy deforestations in the Red Lake drainage basin. Until 1989, satellite images have shown the main areas where illegal deforesting has taken place which is an important factor for the accelerated silting. Our findings show that this contributes to the overall silting process, which might lead to the disappearance of the Red Lake.

***Keywords:*** *accelerated, deforestation, drainage basin, natural, red lake, silting*

## 1. Introduction

The Red Lake was formed in the fourth decade of the 19$^{th}$ century, as a consequence of a landslide of great proportions. Two hypothesis stand as the reason for which the Red Lake was formed. The first identifies as main factor heavy rainfall, that infiltrated between the limestone layers and the Cretaceous wildflysch. The second theory states that the main reason for the formation of the lake was an earthquake that weakened the integrity of the rock layers, therefore contributing to the occurrence of the massive landslide.

The Red Lake has been the object of study in numerous writings, such as: Bojoi, 1968, Cărăuşu, Ghenciu, Timofte, 1969, Dobrescu, Ghenciu, 1970, Ghenciu, 1968 a,b, Ghenciu, Apăvăloaie, 1969, Gîştescu, 1971, Grasu, Turculeț, 1980, Mihăilescu, 1940, Pandi, 2004, Pandi, Buzilă, 2004, Pandi, Magyari, 2003, Pelin, 1967, 1971, Pişota, Iancu, Buga, 1976, Pişota, Năstase, 1957, Popescu, Dimitriu, 1950, Popp, 1941, Preda, 1967, 1971, Preda, Pelin, 1963, Preda, Puşcariu, 1939, Romanescu, 2009, 2010 a,b,c, Udrişte, 1963 etc.

## 2. Geographical location and limits

It is situated in the central group of the Oriental Carpathian Mountains, as part of the Hăghimaş mountain range.

[1] "Al.I.Cuza" University of Iasi, Faculty of Geography and Geology, Department of Geography, Bd.Carol I 20A, 700505, Iasi, Romania, andy_chrome_bike@yahoo.com
[2] "Al.I.Cuza" University of Iasi, Faculty of Geography and Geology, Department of Geography, Bd.Carol I 20A, 700505, Iasi, Romania, geluromanescu@yahoo.com

The main tributary waters of Bicaz river are: Vereşchiu, Licoş, Suhard şi Oaia (Oii). Its drainage basin is situated between $46^{0}$ 48' 44" northern latitude (in the north), and $46^{0}$ 43' 27" (in the south). On a east-west axis, the basin is located between $25^{0}$ 43' 04" eastern longitude (in the west), and $25^{0}$ 49' 13" (in the east). The lake is situated in the north-east sector of the drainage basin (Figure 1).

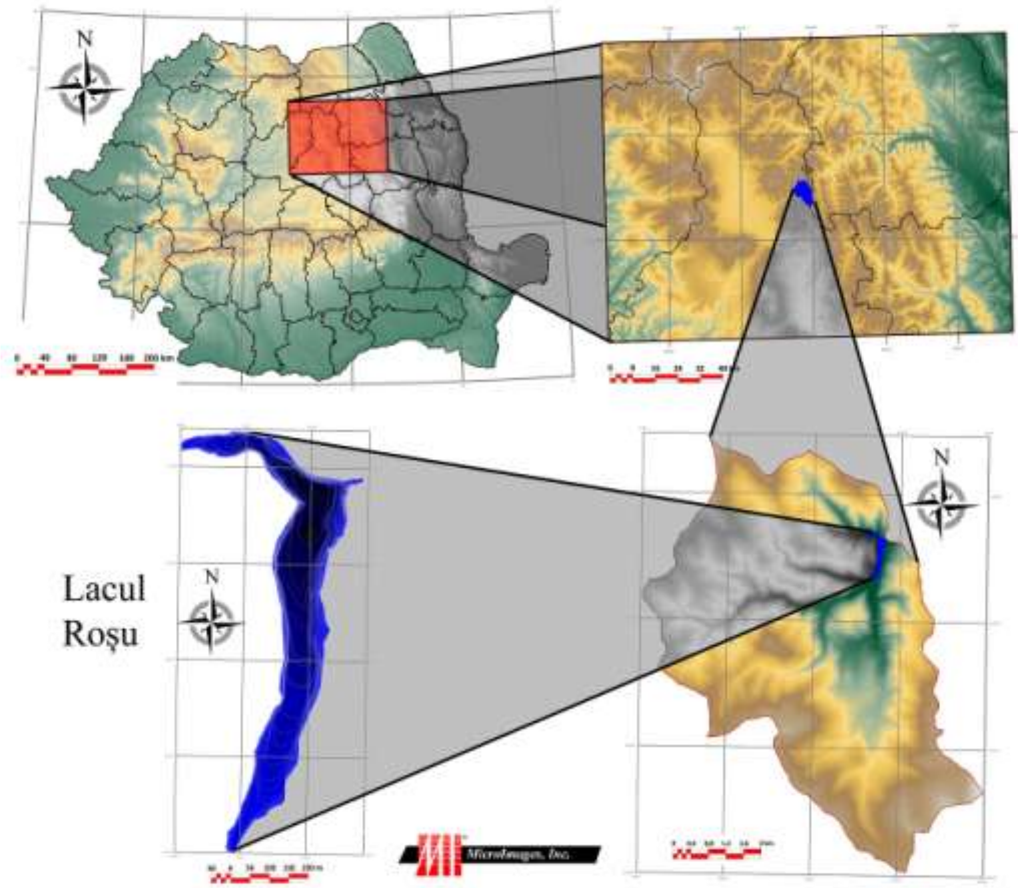


*Figure 1: The geographical location of the Red Lake in Romania*

It is located at the foothills of the Ucigaș ul Mountain (from which the landslide took place) and it is Romania's best known natural barrage lake.

It is called the „Red" Lake, because at sundawn, the Sun's rays fall directly on the red clay of the western slope (Piciorul Licoş), which mirrors in the relatively calm waters of the lake.

**3. Methodes and techniques**

In order to analyse the silting process that takes place in the lacustrine basin of the Red Lake, several techniques were used.

First of all, in order to measure the silting rate of the lake, we have made a comparison between the bathymetric transects made by Piș otă and Năstase (1957) and the bathymetric transects that derived from the numeric landscape model (MNT) generated in

2010, based on topographic maps, at a scale of 1:25000, from 1982 (they were taken in exactly the same geographic locations, as the ones in 1957).

Second of all, we calculated a deforestation rate (based on satellite images[3]), from different years, between 1989 and 2007. For each year, vector files of the deforested areas have been made, and then compared between them, in order to find out how many $km^2$ of forest have been cut down in between each interval (therefore, calculating an annual deforestation rate for each interval).

**4. The silting analysis of the Red Lake**

Silting has one of the most negative impacts for the Red Lake. It is a slow, but continuous process, that affects the existence of the lake. Some optimist calculations (G. Pandi, 2004), state that the total fill up of the lake will occur in approximately 243 +/- 70 years, whilst other calculations[4] fear that the lake will disappear in 184 +/- 30 years. In the same analysis (based on Pb-210 and Cs-137 radioisotopes), the overall silting rate was calculated at approximately 0.5-1.54 cm/year.

Pișotă and Năstase calculated an initial volume of 680,084 $m^3$. By Bojoi's calculations, after 130 years from its formation, the lake accumulated a total of approximately 480.000 $m^3$ of sediments. The current water volume (in 2010), calculated with the equipment supplied by the Laboratory of Geoarcheology (with the "Valeyport Midas" eco-sonar) is 721.404,8 $m^3$, and the volume calculated through GIS methods is 693,175.7 $m^3$.

Therefore, by using modern techniques, we have discovered that the initial volume of water that was calculated, must have reached higher numerical values than the one presented by Bojoi Ion, knowing that the silting process has been taking place uninterruptedly ever since 1837. Evidence to this finding is the known fact that the body of the original landslide, that keeps the entire water in place, is suffering a continuous process of erosion.

Taking into consideration these aspects, we can conclude that the overall volume of water can only have one general tendency: to reduce itself (with minor fluctuations during the rainy months).

Ghenciu V. states in his PhD thesis that the initial maximum depth of the Red Lake was around 25 meters. He also mentioned that, in its early years of existence, the lake stretched south up to the current road. Thus, in this southern sector, today's tributaries did not make any confluence, but flowed directly into the lake. Based on these pieces of information, we have managed to create a map with a simulation containing the original extents of the Red Lake.

The initial lake perimeter would have been roughly 6 kilometers long, and the total area of the water body would have reached over three times the current surface (originally, the lake stretched for 40 ha, compared to the current extents of just 12 ha) (Figure 1).

This is clear evidence to the fact that the silting process affects the lifespan of the Red Lake, on and on. This occurs because the lake had a very large surface to spread the entire mass of sediments coming from upstream, carried by the main tributaries. The area of the drainage basin has not seen any major changes in the 174 years of the existence of the lake, so that the sediments from the same surface (the drainage basin of the Red Lake is 41 $km^2$) have

[3] Global Land Cover Facility - http://glcf.umiacs.umd.edu/

[4] Begy R., Cosma C., Timar A., (2009), "*Recent changes in Red Lake (Romania)sedimentation rate determined from depth profile of 210Pb and 137Cs radioisotopes*", Journal of Environmental Radioactivity.

to accumulate in a third of the original area. This contributes to the rapid rise of the silting rate for the Red Lake. It is this relatively small drainage basin area that favored the long lifespan of this lake, because it is known that natural barrage lakes do not usually tend to have such a prolonged existence.

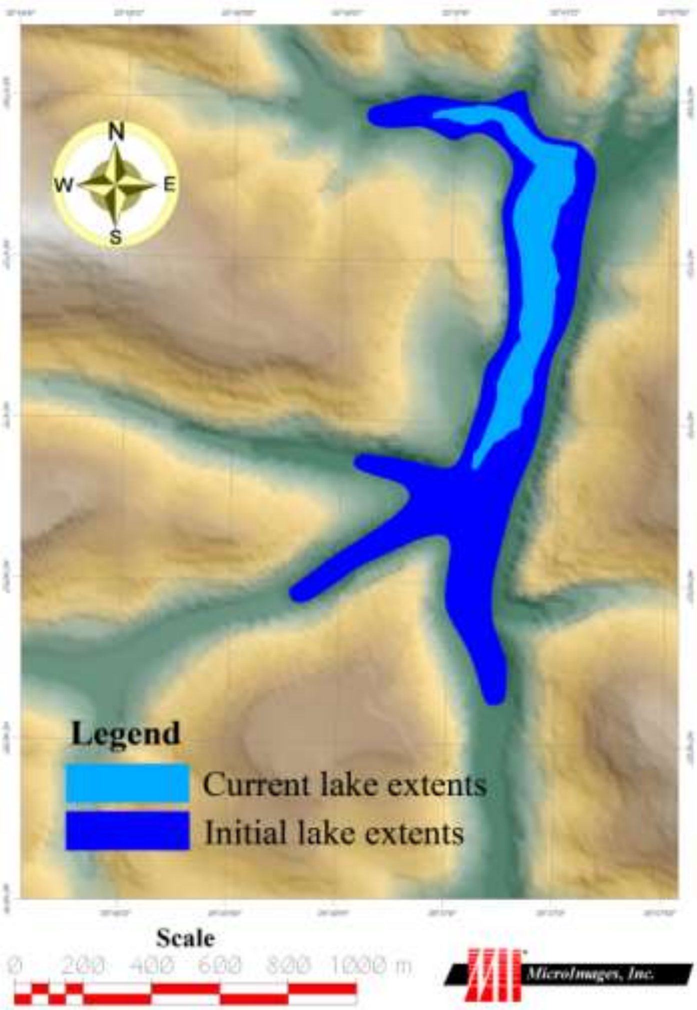


*Figure 2: A side-by-side comparison of the original and current extents of the Red Lake*

Vegetation coverage throughout the entire basin has a major role in the sustainability of the Red Lake. It protects the soil from erosion processes such as surface erosion, linear erosion or raindrop erosion. Much of the surface of the basin is situated on limestone, thus dissolving the particles rather than disintegrating them.

Within the last decade, the silting rate has grown substantially; in some places, the recorded values have even doubled. Bojoi's calculations have emphasized the shrinking of the lake by 2 - 5 meters / year. The sediments reach a thickness up to 5 - 6 meters. He has also mentioned the vegetation as having a negative impact too, because it contributes to the silting in the southern sector of the lake.

The average silting rate, calculated by Begy R., Cosma C., Timar A., at approximately 0.5-1.54 cm/year, does not apply for the whole lake, because tributaries carry different quantities of material. Besides them, there are a few lateral alluvial cones (Figure 3).

In general, the soil texture is clay, which favors the relatively even spread of the sediments throughout the limnic basin. The bathymetric transects stand as evidence of the constant and even silting.


*Figure 3: Lateral, temporary, brook that formed an alluvial cone*


*Figure 4: The most evolved silting sector (south)*

In order to asses our own silting rate, we have made a comparison between the bathymetric profiles, that were made in 1957, by Pişotă şi Năstase, and the ones from 2010, made by the team from the Laboratory of Geoarcheology, from the Faculty of Geography and Geology, "Al. I. Cuza" University, Iasi (Figure 5).

In the 53 years between the readings, we can see areas where the silting has added at least 1 meter to the bottom of the lake. Even if the fidelity of the bathymetric profile from 1957 is not as accurate as the one in 2010, it is still a good and reliable source of information.

The lowest maximum silting rate, of about 1.69 cm/year, has been measured along the A-A1 transect. This is normal, taking into consideration that the sediments have to travel the furthest, in order to settle down in this sector (Figure 6).

In the B-B1 sector, the maximum silt thickness is 1.5 meters. This would be the average situation over these transects, determining a maximum silting rate of 2.83 cm/year. On the steeper slopes of this profile, the lowest rate is recorded, of under 1 cm/year (Figure 7).

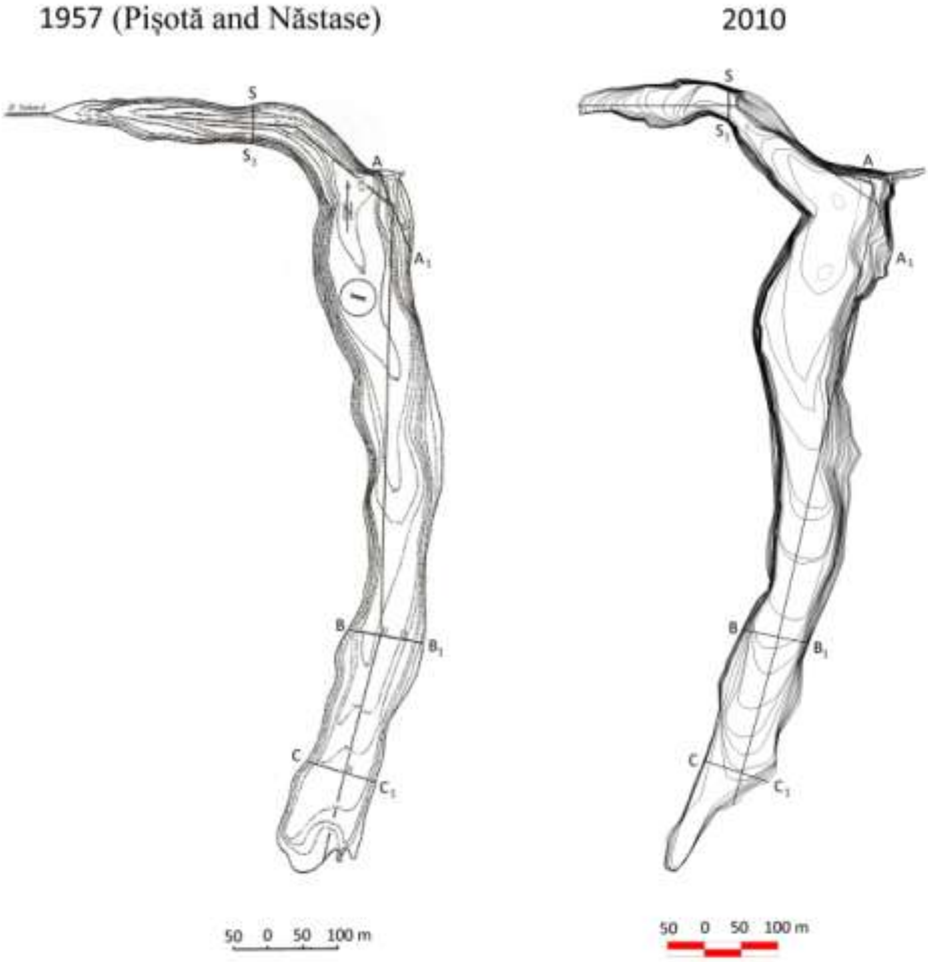


*Figure 5: Bathymetric comparison between 1957 and 2010*

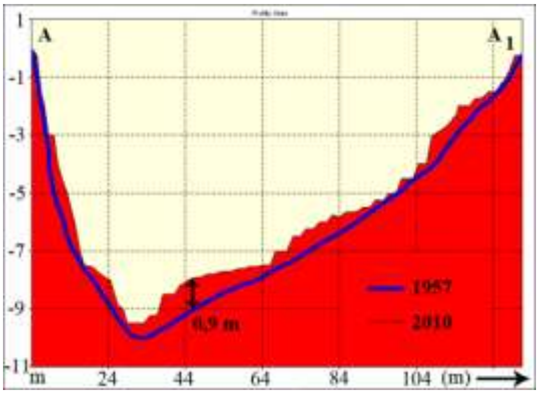


*Figure 6: Bathymetric transect A-A1*

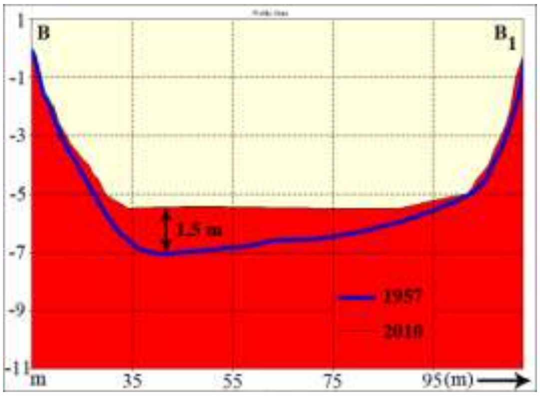


*Figure 7: Bathymetric transect B-B1*

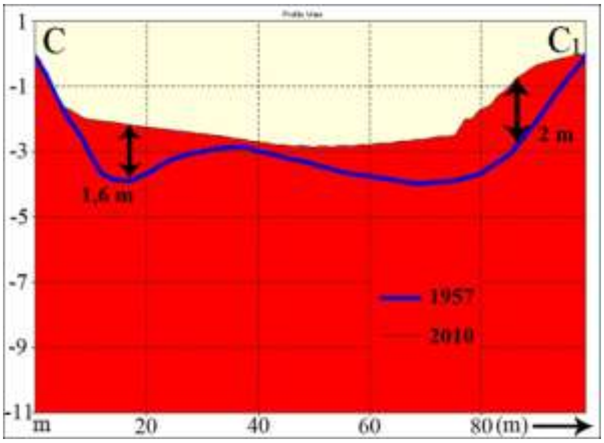

*Figure 8: Bathymetric transect  C-C1*

Most of the sediments have accumulated at the southern tail of the lake, where a total of almost 2 meters have gathered up in 53 years. These would generate am impressive 3.77 cm/year, as a maximum silting rate for this C-C1 sector (Figure 8).

After noticing the high risk of complete disappearance of the lake due to silting, local authorities have drawn plans to build retaining reservoirs for the sediments. Three dams were built for this purpose, beginning with 1960. They were built to collect the silt from the three, main, tributaries, in the south: Oaia, Piatra Roşie and Licaş (Figure 9).

These reservoirs, however, are not a long term solution, because their holding capacity is insufficient. The one built on Oaia brook is currently completely clogged (Bojoi calculated an impressive silting rate of 8.2 cm/ year). It can no longer retain silt, which is transported from upstream. The one on Vereschiu (Piatra Rosie) is 90% clogged.


*Figure 9: The sedimentation reservoir on Vereschiu brook*

However, the rapid surface reduction of the lake is not the only factor that influences the silting rate. Deforestation is another, very important factor that shortens the life of the lake. It exposes the soil, directly to external erosion agents, such as deflation, raindrop impact, linear erosion etc.

The method used to analyze this phenomenon, was the photo interpretation of the satellite images downloaded from Global Land Cover Facility[5]. There are 5 sets of images, taken for different years, starting with 1989 (1989, 2001, 2002, 2005 and 2007). Unfortunately, there are no images available for the years in between these 5 sets. In order to properly view the extents of the areas with vegetation, the images have been chosen from the summer months, when the vegetation is very abundant.  In order to obtain the final images, several RGB mixed channels have been used, including near and thermal infrared. Even though the resolution is not very high (1 pixel = 30x30 m), it is usable, in order to detect and measure the extents of the deforested areas. These deforestation actions have most probably been illegal, as the Red Lake has been included in the Cheile Bicazului - Hăşmaş Natural Park.

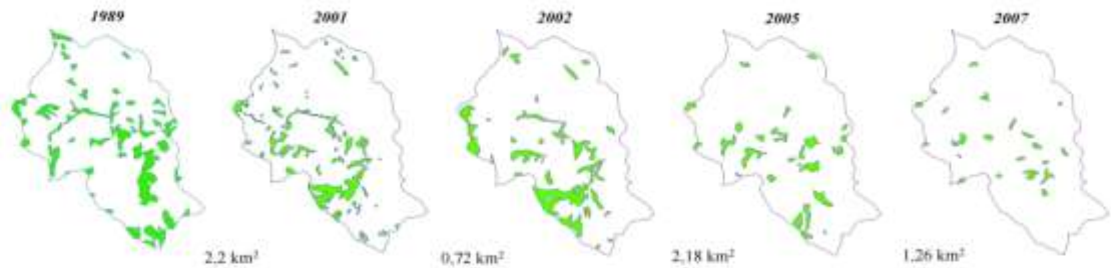


*Figure 10:  The geographical location of the deforested areas between 1989 and 2007*

On an annual basis, the figures show the general tendency of diminishing the deforestation phenomena, mainly because there are very few areas left to deforest, except for the ones that are very near to the tourist attractions. As the map in figure 11 shows, the majority of the deforesting actions take place in the highest, most remote places, in the southern half of the drainage basin. By analyzing the map above, it is clear that the direct exposure to the erosion agents can only enhance in the areas with few trees left, which can only cause one thing: the acceleration of the silting process. Other immediate effects are destabilizing the slopes, increased linear erosion, landslides, stronger high floods etc. The average rate of deforestation varies between 0.2 and 1 $km^2$ / year.

## 4. Conclusions

The Red Lake is an attractive natural lake and tourist area in Romania, but its lifespan is endangered by the silting process that takes place inside its limnic basin. The silt take its sources from all of the 41 $km^2$ drainage basin area and it is transported through the tributary river system. The rivers that flow into the lake have undergone several constructions (silting reservoirs), to reduce the overall silting rate of the Red Lake, but they prooved not to be a long-term solution. Deforestation plays as an enhancer because it accelerates the silting of the lake. Despite all of the other factors (eutrophication, the rise in annual rainfall, anthropic intervention etc.), one fact is clear. The Red Lake will eventually dissapear in 200 years at most, as long as there are no coordinated efficient solutions that reduce or stop the silting process, or, why not, improve its current state.

[5] Global Land Cover Facility - http://glcf.umiacs.umd.edu/

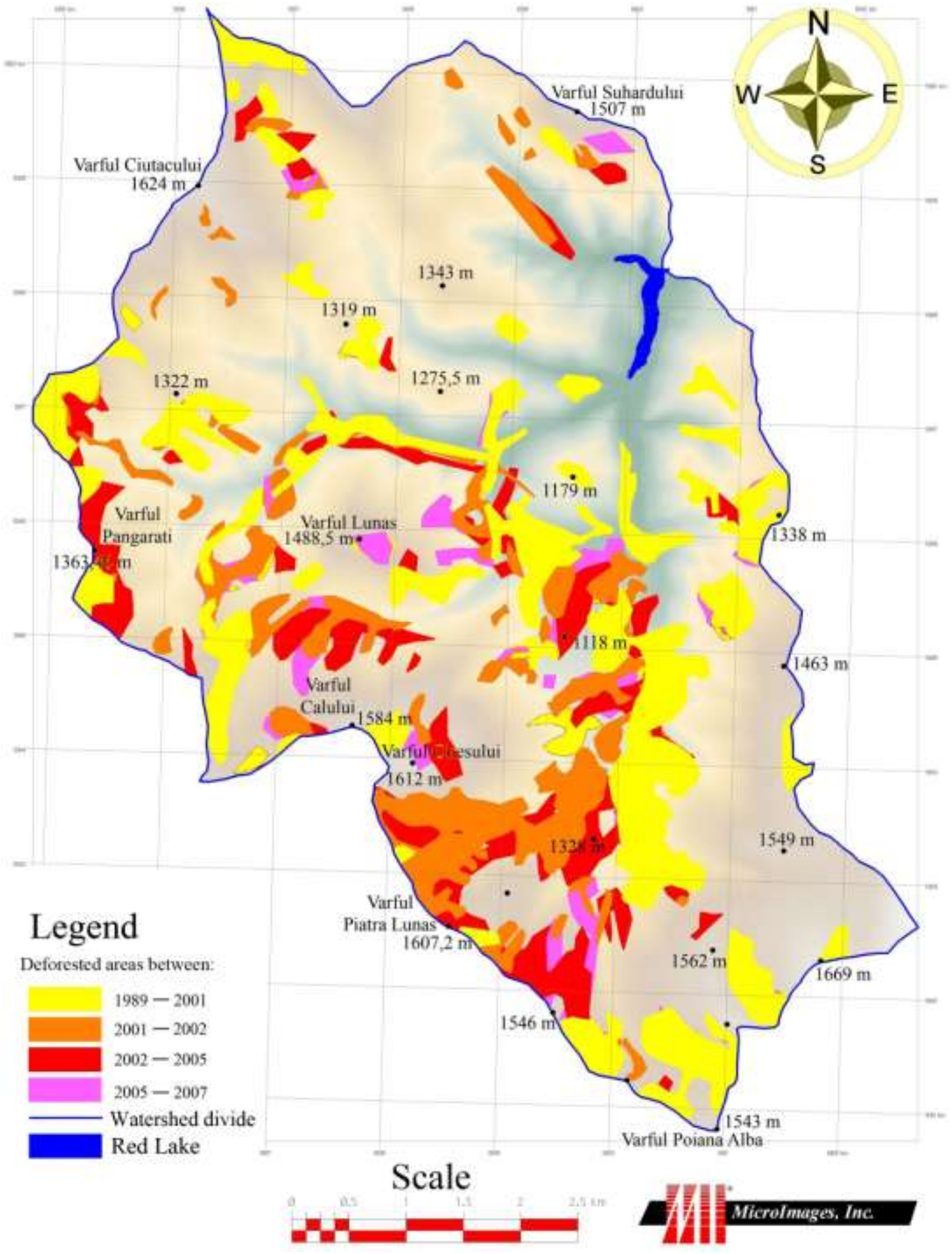


*Figure 11: Evolution of deforestation between 1989 and 2007*

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