50 YEAR'S DETERMINATION OF RESERVOIR SEDIMENTATION RATE USING TOPOGRAPHY MEASUREMENTS AND GIS. CASE STUDY: STRÎMTORI-FIRIZA RESERVOIR, BAIA MARE, ROMANIA

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Ciurte Dan Lucian [1]
Alin Mihu-Pintilie [2]
Paveluc Larisa Elena [1, 3]
Cristian C. Stoleriu [1]
[1] Department of Geography, Faculty of Geography and Geology, Alexandru Ioan Cuza University of Iasi, Iasi, **Romania**
[2] Institute for Interdisciplinary Research, Science Research Department, Alexandru Ioan Cuza University of Iasi (UAIC), **Romania**
[3] Siret Water Basin Administration, Bacau, **Romania**

ABSTRACT

The Strîmtori dam, on the Firiza River, was designed and executed between 1960 and 1964 with the main purpose of ensuring the necessary flows of potable and industrial water from the Baia Mare mining micro-region and the production of electricity. As the reservoir proposed exploitation expired in 2014 (50 years after its construction), the sedimentation rates give an estimation on the reservoir's remaining time for exploitation. Digitization of the 1960's topographic maps of the Firiza Valley former riverbed (in the reservoir covered area) was compared in ArcGIS to recent measurements of the reservoirs bed. The results emphasize the accumulated sediments layers, their height, length and volume. The results were compared with the previous estimated sedimentation rates and the obtained differences will be used to run and validate the Firiza Reservoir sedimentation model.

Keywords: GIS, bathymetry, sedimentation, erosion, Strîmtori-Firiza Reservoir.

INTRODUCTION

Sediment accumulated in reservoirs creates costly problems for dam operation and ultimate decommissioning. Many of the dams on the landscape can be viewed as future maintenance problems, which will become more urgent as they fill with sediment and lose capacity [1-10]. Given that most reservoirs have not been surveyed for sedimentation, managers could benefit from an assessment so that the problems can be anticipated and countermeasures can be explored and implemented such as installation of upstream sediment traps, sediment pass-through, flushing, or mechanical removal.

In the design and maintenance of most reservoirs, little thought has been given to sustaining reservoir functions as capacity is progressively lost to sedimentation. Loss of reservoir capacity from sedimentation is difficult to offset with construction of new reservoirs because reservoirs have already been constructed at most viable sites in the developed world [2]. Even before reservoirs fill completely with sediment, sediment within the reservoir can reduce usable capacity, interfere with outlet works, damage turbines, and cause backwater flooding upstream. The sedimentation problems are often dealt with in existing reservoir with mitigation measures applied only sometime after commissioning of the dams [3]. The mean age of existing reservoirs is between 30 and 40 years, and it is estimated that 0.5–1% of the worldwide water storage capacity is lost annually to sedimentation [3].

STUDY AREA

The Strîmtori-Firiza Reservoir is located in the north of Romania, Maramureș County, in Baia Mare Municipality on the Firiza River, just 10 km north of Baia Mare City, in the Ignis mountainous area (Fig. 1). The Strîmtori Dam, on the Firiza River, was designed and executed between 1960 and 1964 with the main purpose of ensuring the necessary flows of potable and industrial water from the Baia Mare mining micro-region and the production of electricity. The site of the dam was chosen in the narrowest part of the valley, where the geological conditions were most favourable. The cross section of the valley has an asymmetrical shape.

The left slope and the riverbed are made of andesite. The right slope has a heterogeneous geomorphological structure. The andesite base bed is covered with a layer of agglomerates of 25-30 m thick, over which there was a delluvial deposit layer of 3-8 m thick. The water flow of the Firiza river in the section of the site, known at the time of design, led to an estimated flow of 1% of 165 mc/s and 0.1% of 278 mc/sec.

The dam is a 51.50 m high-strength concrete barrage and 260 m long at the top level and is the first dam in Romania with permanent contraction joints. The work created a retention of 17.6 million cubic meters of water, allowing an average annual volume of about 50 million cubic meters of water and production of about 9.5 GW / h of electricity. As the reservoir proposed exploitation expired in 2014 (50 years after its construction), the sedimentation rates would give an estimation on the reservoir's remaining time for exploitation.

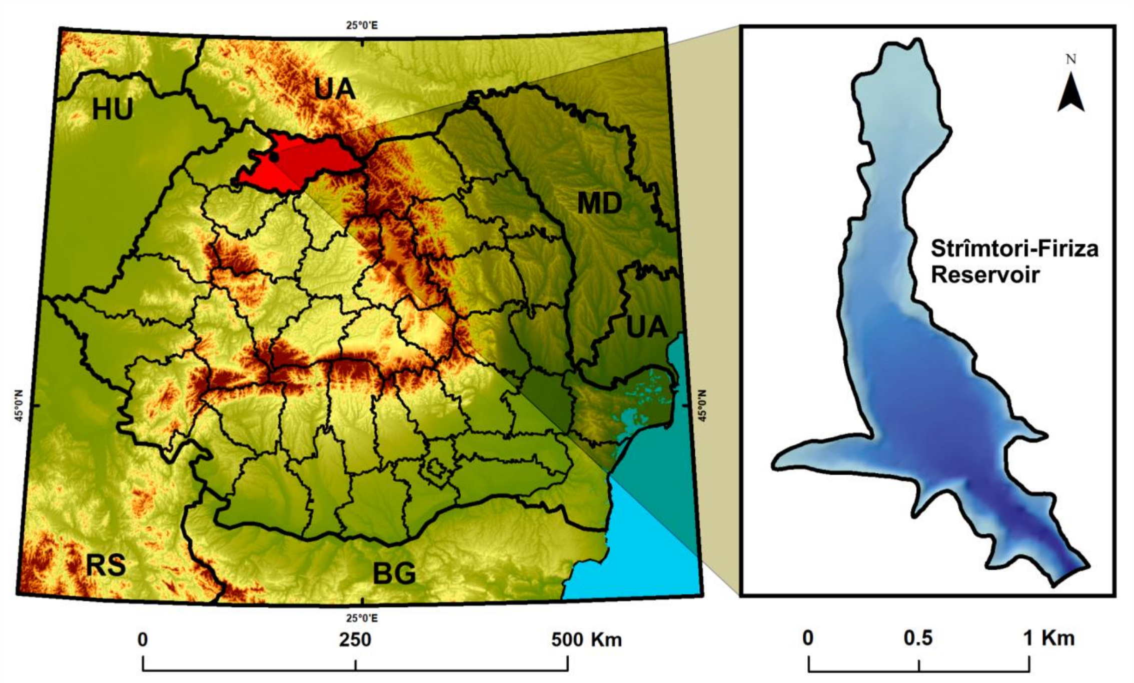

Figure 1. Location of Strîmtori-Firiza Reservoir in Maramureş County (red polygon), NW Romania

MATERIALS AND METHODS

For comparing the sedimentation rate in the past 50 years, two digital elevation models were used. For 1960 data, a 1:5.000 scale topographical map was used by digitizing the elevation isolines in ArcGIS 10. A bathymetry field trip form 2011 collected points that were interpolated to generate a contour map of the bottom of the reservoir. Both shapefiles were then converted to digital elevation models and triangular irregular networks. For the volume calculation, the 3D Analyst Tools-Functional Surface-Surface Volume ArcMap extension was used, with the water surface at 370 m for both surfaces. For calculation of the reservoir bottom and surface difference, the difference between the two rasters was made using the Raster Calculator function in ArcGIS (Fig. 2).

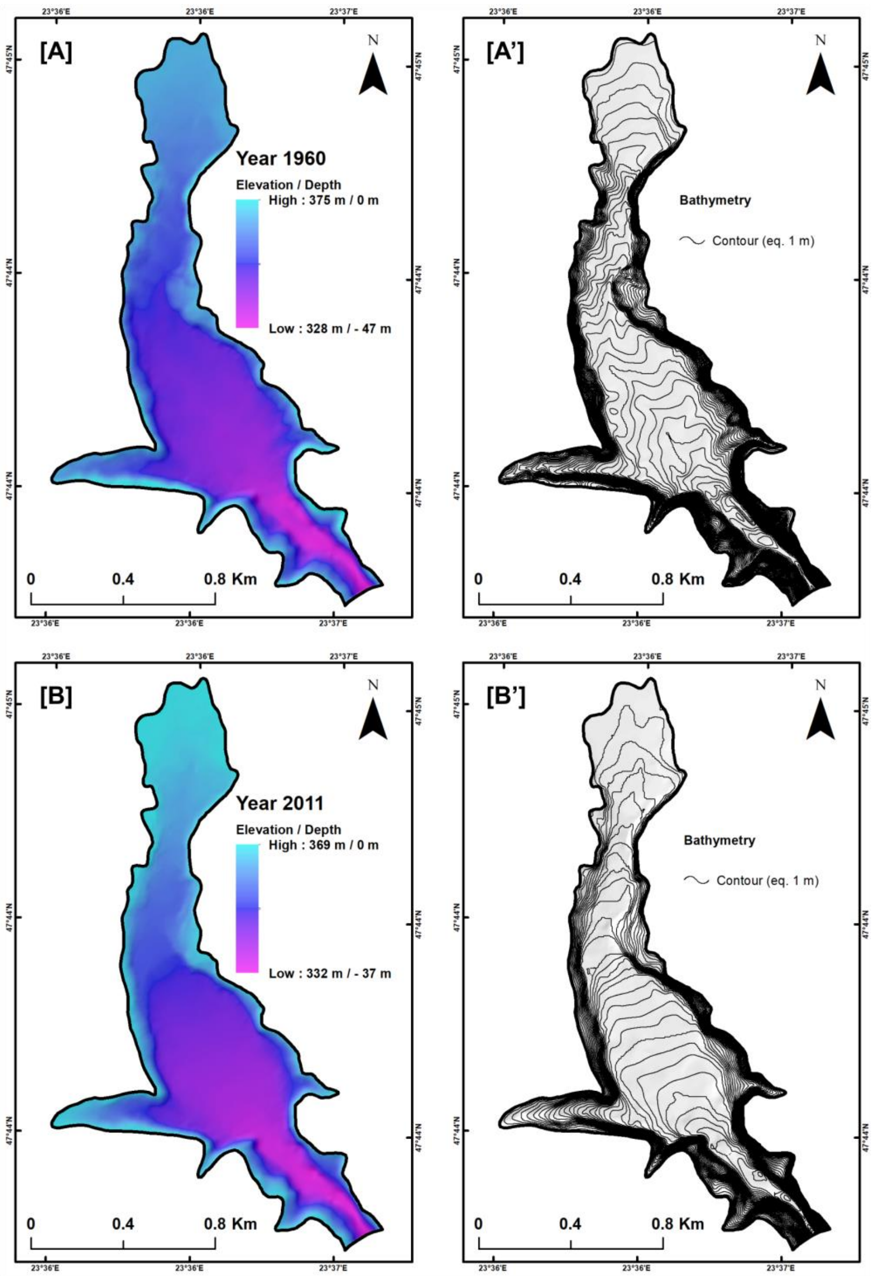

Figure 2: The bathymetric maps of Strîmtori-Firiza reservoir in the [A-A'] year 1960 an [B-B'] year 2011.

RESULTS AND DISCUSSION

The difference between the initial volume (before the construction of the dam) and the one in 2011 resulted in a volume of 1358363 m^3 (7.85% of the initial volume), which represents a very slow sedimentation rate (27.162 m^3/year). This low value can be explained by the dominance of andesite rock, cambisols, and broadleaved forest within the Firiza Catchment [4]. The reservoir bottom depth difference is shown in Fig. 3.

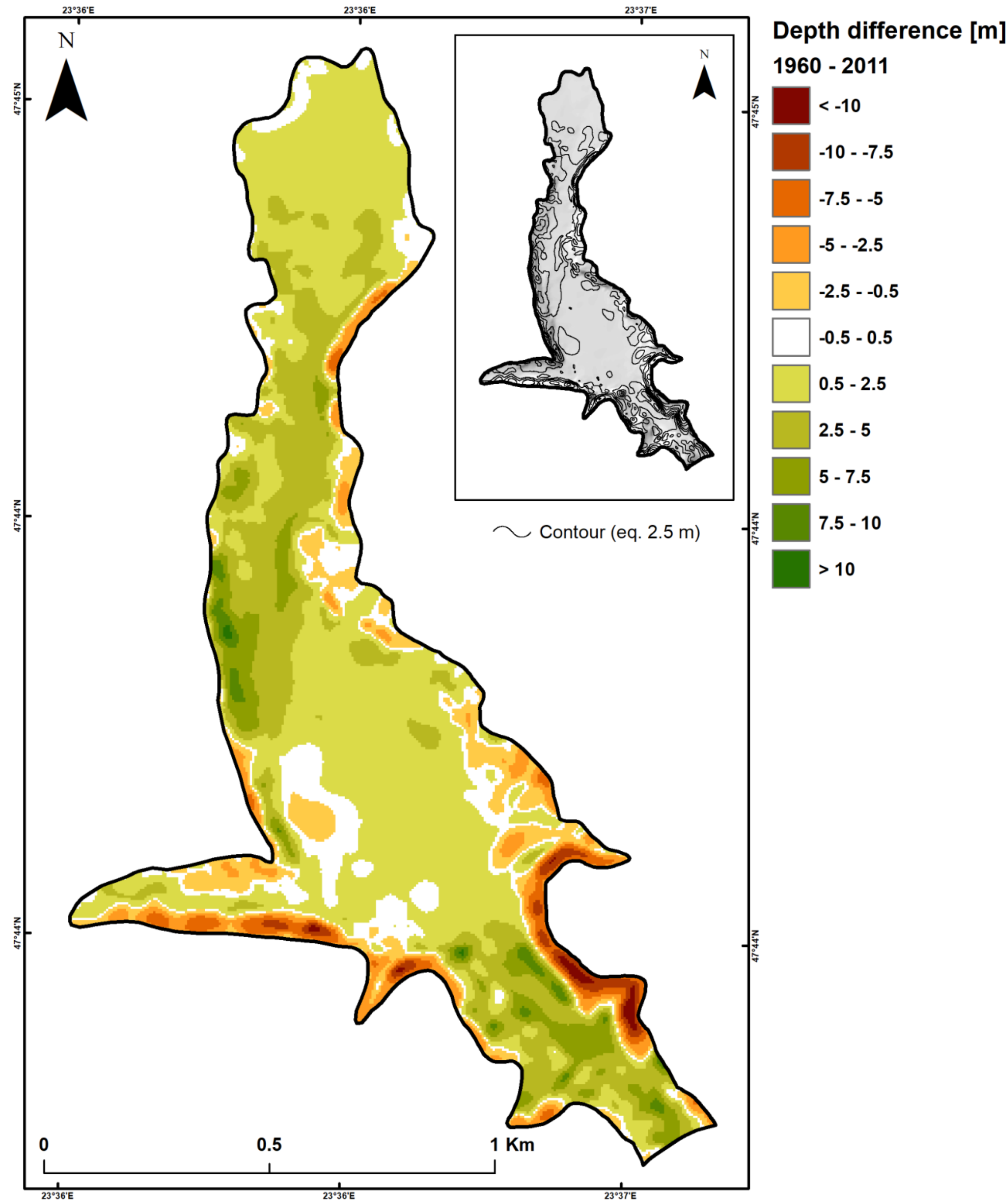

Figure 3: Erosion and sedimentation areas in Strîmtori-Firiza Reservoir between 1960-2011

Erosion areas are highlighted in green whereas sedimentation areas are shown in yellow, orange and red, according to sediments depth. The sediment yield produced in the reservoir is mainly due to the direct contribution of subaerial and subaqueous landslides originating in the reservoir banks and subaquatic slopes [5]. The largest sediment deposits (> 5m) are located in the western and southern slopes of the reservoir. In the south-east there are large sediment deposits probably caused by a subaqueous landslide (which would explain the large erosion in that bank).

Depending on the sediment supplied and on flow velocity and turbulence, rivers usually carry sediment particles with a wide range of sizes in the form of bed or suspended loads. In the reservoir, coarser sediments tend to be deposited in the upstream regions of the reservoir, advancing downstream steadily but slowly in the form of a delta; whereas fine sediments reach the reservoir in the form of suspended load [2]. The Firiza River (which enters the lake in the north) and Valea Romana River (in the west) are the largest sediment tributaries in the reservoir. Coarser sediments originating from Firiza River are situated in the north-center area of the lake (orange color) whereas those coming from Valea Romana River are spread in the southern areas. Also, the reservoir currents circulation is strongly influenced by the rivers and amplify the rates of erosion/deposition. These results will be used to generate, run and validate the Firiza Reservoir sedimentation model.

CONCLUSION

The sedimentation rate in Firiza Reservoir is about twenty-seven thousand cubic meters per year. This low sedimentation rate is mainly due to the catchment's geology, soil and land cover characteristics. The major sediment deposits are located in the centre of the lake and near the reservoir outlet, due both to the river tributaries and subaqueous landslides.

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