ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 3, March 2024

The Talimarjon Reservoir Capacity Monitoring Using the Google Earth Engine

M. Ikramova, Sh. Umarova, O. Ikromov, Q. Eshquvatov

Doctor of technical science, professor, Irrigation and Water Problems Research Institute
Senior lecturer, The University of World Economy and Diplomacy
PhD student, Irrigation and Water Problems Research Institute
PhD student, Irrigation and Water Problems Research Institute

ABSTRACT: Numerous scientific studies are carried out and methods developed for determining the water objects characteristics. At present the remote sensing technologies allow to conduct water reservoirs' monitoring based on satellite data. The Google Earth Engine soft is a platform designed for the analysis of geospatial data on a planetary scale. The article discusses a method for regular monitoring of the the Talimarzhan reservoir capacity using the satellite images and GIS technologies. Based on the regression equations, the monthly average indicators of water volume and water level in the reservoir were determined for 2023 using the data obtained through the GEE platform, and the deviation of the satellite data from the data obtained from the Talimarjon Reservoir Operation Department introduced in the article.

KEY WORDS: Water reservoir, Geographical information system, Modelling, Satellite Image, Google Earth Engine.

I. INTRODUCTION

The reservoirs' capacity real time monitoring is a strategic objective. At present the remote sensing technologies development makes possible to conduct reservoir monitoring based on satellite data. The Google Earth Engine (GEE) program is a platform designed for the analysis of geospatial data on a planetary scale. Many problems such as deforestation, drought, natural disasters, water resources management, climate change and environmental protection are being analyzed based on this soft platform.

Numerous scientific studies are being carried out and methods have been developed for determining the water objects characteristics based on remote sensing data [15], and analysis of various coordinate systems used in Geographical Information System (GIS) has been carried out, and special digital coordinate systems have been proposed [2, 5]. The main attention is paid to ArcGIS softs development, integration of data and technologies, features of intellectualization of GIS and decision support systems for a wide range of problems in hydrological research [4]. The research works are oriented to use GIS in mapping and selection of dam/reservoir site based on analyzing Digital Elevation Model (DEM) that allows handling and analyzing geographic information by visualizing geographical statistics through layer building maps [10]. The Reservoir Mapping Tool developed using the digital elevation model SRTM-30 which provides inundated area and dam volume and illustrated various application areas using the information in combination with other geospatial layers, which could provide key inputs towards assessing overall social impacts of dams [1]. Many challenges are associated with the integration of GISs with models in specific applications including an object-oriented method developed to link a GIS and a water resources management model for optimal water allocation in river basins [3]. A great information is available on sediment transport, deposition and erosion in reservoirs. One of the tools available to predict sedimentation in and around reservoirs is numerical models supporting the dam designers [14]. A mathematical model of reservoirs evolution is considered to study the transformation of its floor under different conditions. A combined model based on 3D hydrodynamic model together with 2DH models of suspended matter and bottom sediments transport is proposed to describe the processes of sediment transport and deposition.

The erosion model developed by the researchers of the National University of RUz includes mapping erosional and depositional shoreline segments, identifying the physical characteristics of erosional sites, determining the physical variables affecting shoreline erosion, modelling erosion susceptibility and creating hazard maps, making management recommendations based on these findings [6]. This model is designed based on the ArcGIS of the ERSI allowing to visualize large amounts of statistical data in the form of a digital map [12]. The flow model and channel sediments transport in the backwater zone was developed and variant calculations performed using full-scale hydrological data and a digital model of the reservoir bed relief. Changes in bottom elevations (erosion/alluvium) in the study area for different hydrological scenarios and an analysis of its determining factors are performed using the Global Mapper program [11].

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II. THE RESEARCH OBJECTIVE AND METHOD

The article discusses a method for regular monitoring of the water reservoirs' capacity, especially the Talimarzhan reservoir, using the satellite images and GIS technologies. The reservoir is located in Kashkadarya region of Uzbekistan with 2.3 million population, and aimed to irrigate over 402 thousand hectares of the Karshi Steppe agricultural lands. The reservoir capacity is 1525 Mio m3, area – 7735 hectares. The reservoir operation started in 1975, and at present a significant capacity has been lost due to sedimentation.

For reservoir monitoring the Earth Engine soft provides all necessary information about the reservoir from the international Global Reservoir and Dam database. As well, the GEE software has a high-performance data catalog and a large archive of the geospatial data sets. The catalog consists of data from remote sensing of the Earth, including over 50 years data from NASA's Landsat mission and an archive of data from the European satellites Sentitel with database. The geographic data consists of a space and aerial photographs taken in different bands of the electromagnetic spectrum, weather forecast models and climate parameters, maps of land and water bodies and environmental parameters, topographic and socio-economic data sets. The GEE Image collection is a data based two-dimensional raster arrays, and each image has metadata that includes the created date, the processed information, and associated metadata [11, 17]. Access and management of the system is carried out through the API interface and data processing programs in an interactive work environment using the JavaScript API using a code editor which used to create the desired scenarios and get results [13, 7, 16].

ArcGIS is used to obtain the shapefile of the watershed from the downloaded database. For this a suitable file is selected in the dialog box opened using the File –>> Add command. As a result, the water body map recorded in the database appears in the program window. Geological coordinates of the water body are entered through geocoding and a file containing geospatial data of the selected object is created (Fig.1).

In the process of studying the selected water reservoir using the GEE program, the import of the shape file with its geospatial information is carried out through the Upload Shape files from the Assets section. The data in the downloaded shape file will be placed in the Tasks section. To place the data in the shape file in CodeEditor, the parameters of the object are imported from the appropriate table of Tasks through View asset. As a result, a table of geospatial data of the reservoir appears in the CodeEditor section, and the program analyzes the data in this area [9, 8].

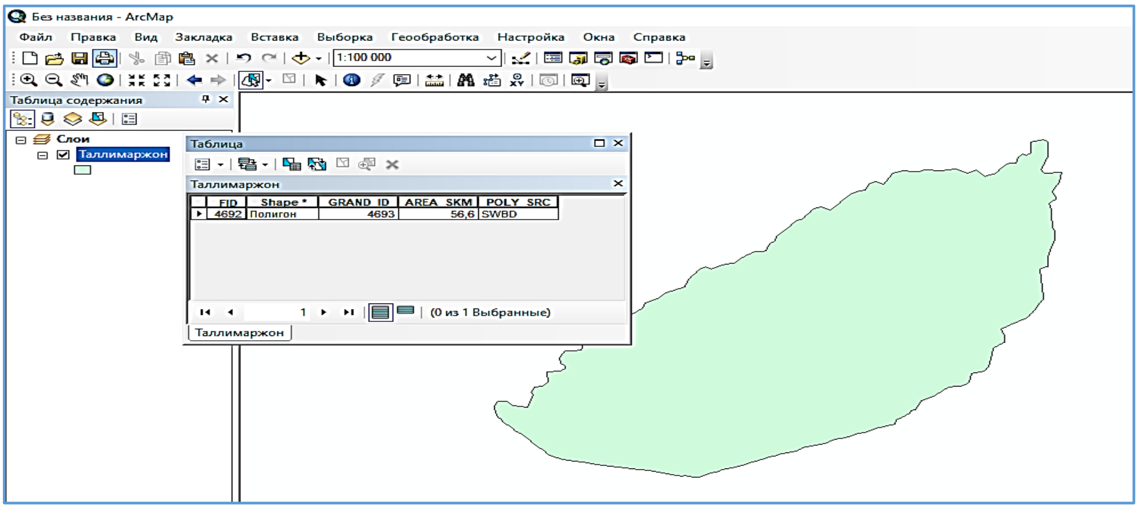

Figure 1. The Talimarjon reservoir formation at ArcGIS

Water indices were used to calculate the water surface area in the reservoir based on space photographs. By evaluating the water pixels in each image, the necessary information was obtained and a map of the change of the reservoir banks was developed. There are also cases where the images in the database do not fully cover the surface of the researched area. In order to obtain a complete detailed state of the area, an image corresponding to the geometry of the area is processed based on the mosaics function from the data of this date. To determine the water area, the water pixels in the SAR images were classified and the surface area of the reservoir was determined. The diagram obtained based on the above code is placed in the lower right part of the map (Fig. 2).

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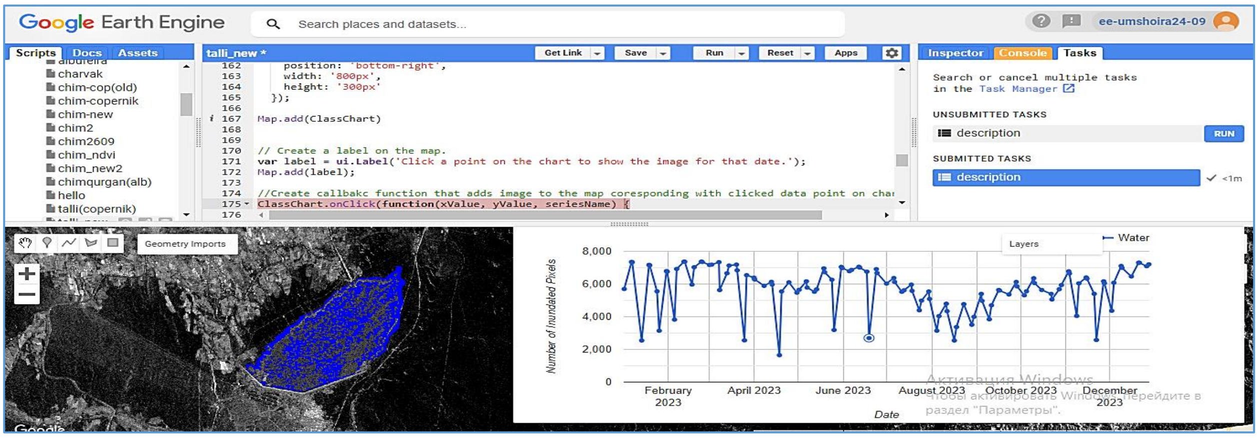

Figure 2. Reservoir time series and diagram

The diagram is mage interactive by creating a data function on the chart. This function adds the SAR image and the corresponding date and water feature to the map (Figure 3). The map displays the data date and dynamically updates as new data is entered. The appropriate SAR image and water area map were selected from the diagram, and the hydrological regime of the reservoir was studied.

The diagram shows the number of water indices. Using the layer created on the basis of imported geospatial data of the water reservoir, it was determined the area covered by water, and the results were exported to a file in csv format.

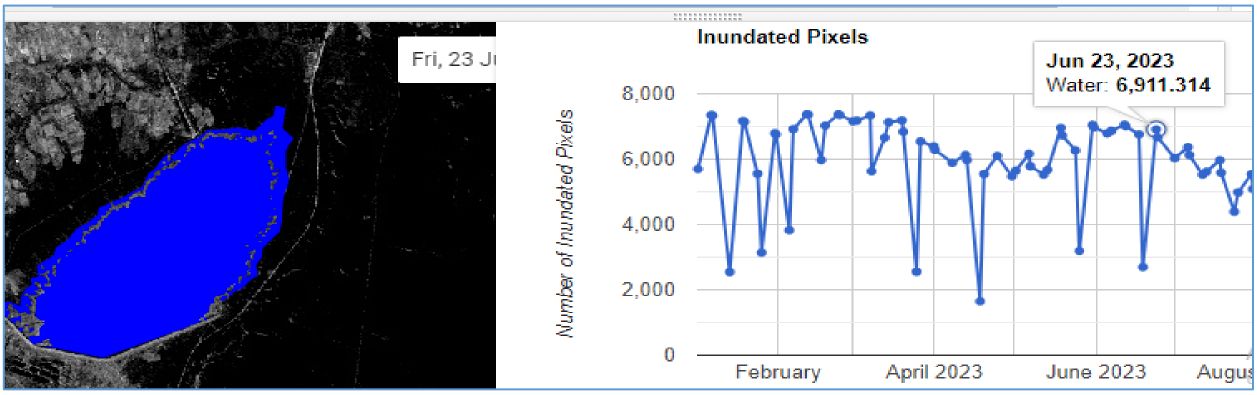

Fig. 3. Loading of data, corresponding to the selected dates

III. RESEARCH RESULTS

The results of determining the reservoir volume based on satellite and GIS technologies were compared with previously measured reservoir volume data. For this, the results of bathymetric measurements conducted in the Talimarjon reservoir in 2019 and 2023 were used. Regression equations were analyzed to form the relationship equation between water level and water volume, and results were obtained for the change of the water level surface in 2023 for the Talimarjon Reservoir

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(Fig. 4).

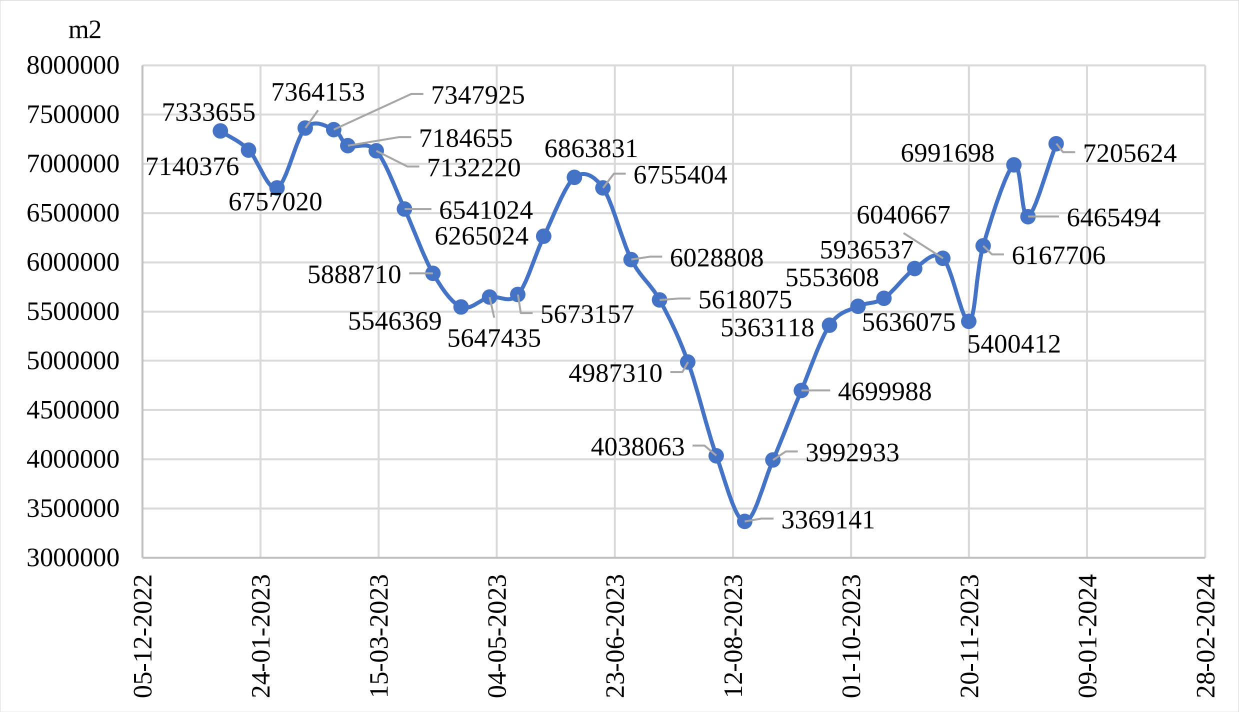

Fig. 4 The Talimarjon reservoir water surface area changes during 2023 (Sentinel-1)

Based on the above research, only the water surface area of the reservoir is determined. To calculate the volume of water, the data measured in a certain period are necessary. The results of bathymetric measurements conducted in the Tallimarjon reservoir in 2019 and 2023 were used in the research process. Regression equations were analyzed to reflect the relationship between water table surface and water volume (Fig. 5).

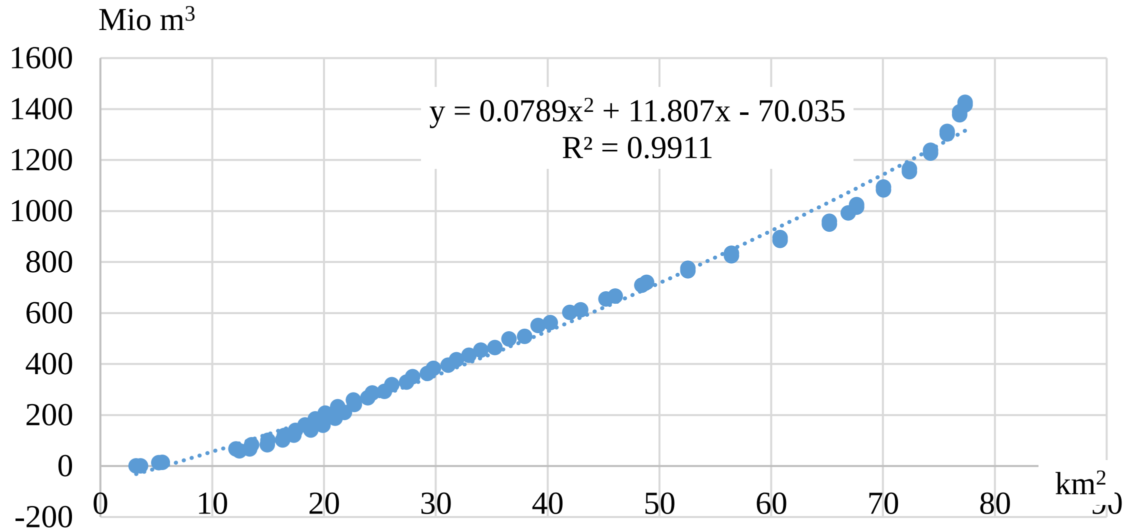

Fig. 5 A graded function between reservoir volume and water surface area

It was determined that the coefficient of determination in the linear regression equation is equal to 0.98, and in the regression equation using the 2nd-order function, it is equal to 0.99. Therefore, 99% of the change in water volume can be explained by the change in water level. To calculate the volume of water in the reservoir, the following equation can be used based on the surface area of the water:

$$V = 0{,}0789x^2 + 11{,}807x - 70{,}035$$

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Also, based on the available data, a regression analysis was conducted between the water level and the water surface, and the relationship equation between them was obtained (Fig. 6).

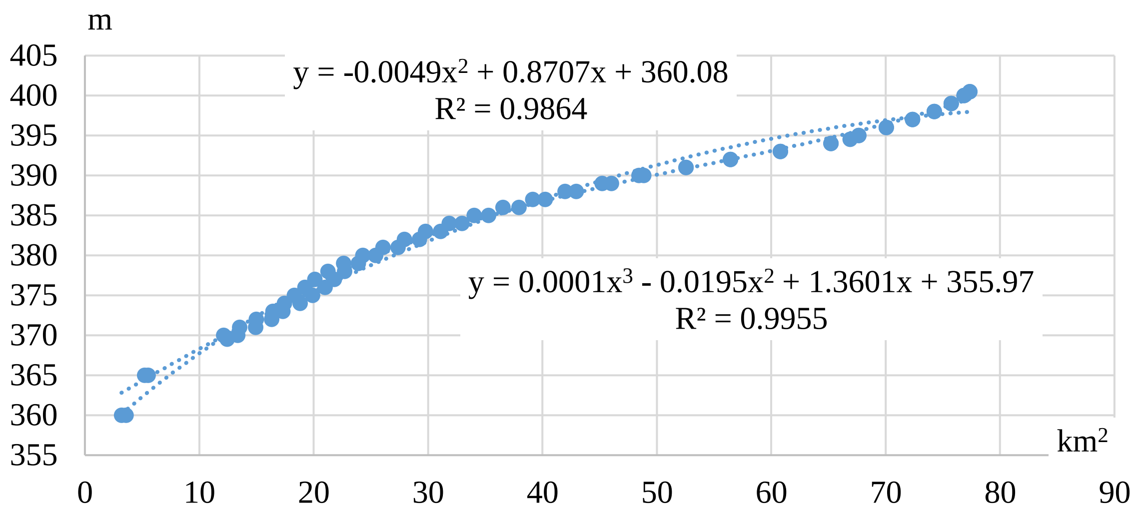

Fig. 6 A graded function between water level elevation and surface area

In the graph, the relationship between water level and surface area is shown to be more accurate when expressed by second- and third-order functions. The coefficient of determination in the second order regression equation is equal to 0.9864, and in the third order this indicator is equal to 0.9955. The following regression equation was used to represent the water level gradient by surface area:

$$H = 0{,}001x^3 - 0{,}0195x^2 + 1{,}3601x + 355{,}97$$

Based on the regression equations, the monthly average indicators of water volume and water level in the reservoir were determined for 2023 using the data obtained through the GEE platform, and the deviation of the satellite data from the data obtained from the Talimarjon Reservoir Operation Department introduced below (Table 1). The data determined by the satellite data and the data of the Talimarjan Reservoir Operation Department were compared, and the difference between them varied from 0.3 to 7.4%, with an average of 2.94%

Table 1. Water level and volume data in the reservoir

2023	Water level elevation (m)	Surface area (km^2)	Volume (Mio m^3)	Measured* (Mio m^3)	Deviation %
January	390,07	71,4	1175,69	1011	0,45
February	389,95	70,27	1149,70	1277	2,32
March	390,06	71,32	1173,84	1558	1,19
April	389,08	61,02	944,58	939	-0,59
May	389,23	62,65	979,75	1171	2,12
June	389,69	67,55	1087,98	1556	-0,18
July	388,94	59,64	915,14	990	7,56
August	386,45	43,41	591,42	432	6,42
September	388,59	56,37	846,57	678	3,58
October	388,91	59,36	909,20	954	4,70
November	389,36	63,99	1008,97	890	7,43
December	390,24	72,98	1212,36	996	0,30

*Official data of the Talimarjan Reservoir Operation Department.

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The average monthly indicators and values of water level and volume for 2023 are presented in Figure 7. The study of the annual operating mode of the reservoir showed that in January-March, the water level reaches 390 m, and the volume of water in the reservoir varies between 1150-1176 Mio m3. In April-May, the water level decreased to 389 m, and the volume was between 945-980 Mio m3. In June, the water flow increased, and as a result, the level increased to 390 m, and the volume increased to 1088 Mio m3. Then, due to a sharp increase in the demand for irrigation, the amount of water taken from the reservoir increased sharply, as a result, the water level in the reservoir decreased to 386 m in August, and the water volume was equal to 591 Mio m3. In September-December, the water level reached 390 m, and the volume of water increased from 847 Mio m3 to 1212 Mio m3.

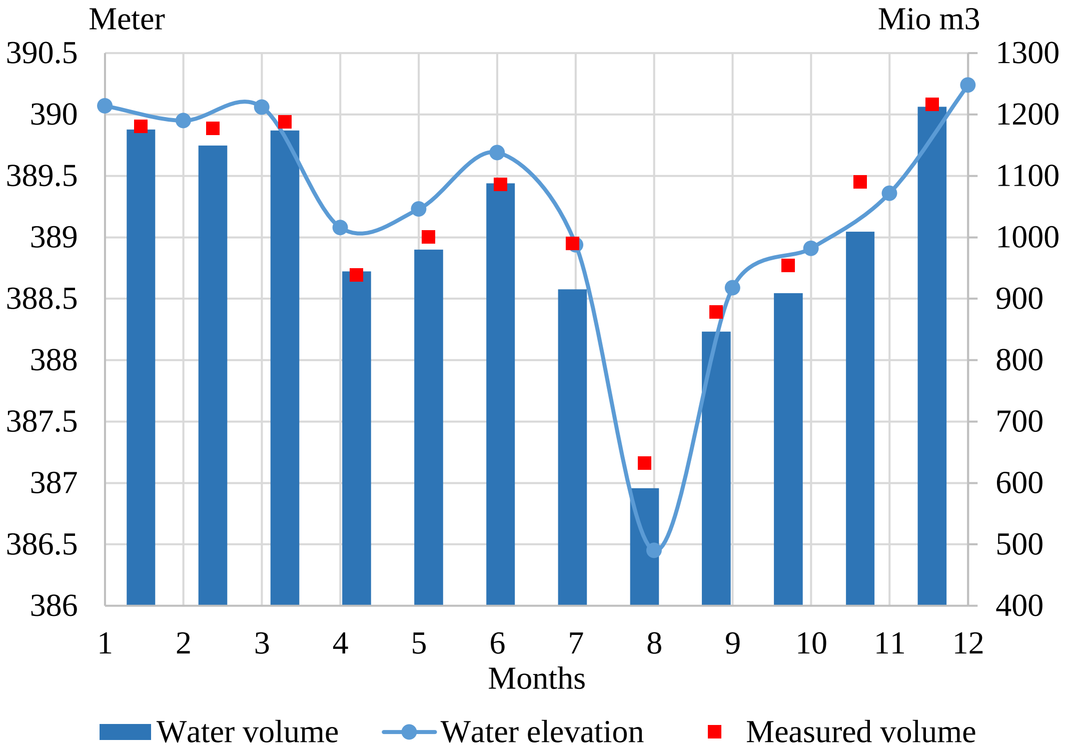

Fig 7. Comparison of calculated and measured water volumes in the reservoir

IV.CONCLUSION

Based on this research, a method for determining the water volume in the reservoir was developed using the GEE water surface area data. The satellite images from the GEE platform on the reservoir surface data at the ordered dates allow to determine the volume of water on this date, and the reservoir capacity change trend over the years can be determined as a result of the correct evaluation of the relationship equation with the water surface area. The GEE platform has become an important part of this research because of its satisfactory data accuracy, cost-effectiveness, and user-friendly interface.

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