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Assessment of the filling regime and variability of morphometric characteristics of ponds and reservoirs of small rivers of the steppe zone of Ukraine using data from remote sensing of the Earth (on the example of the Velykyi Kuyalnyk River)

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SUMMARY

In the paper on the example of 9 artificial reservoirs (7 ponds and 2 reservoirs) in the basin of the Velykyi Kuyalnyk River using the geodetic online tool USGS LandLook and the archive of space images radiometers Landsat 1-8 and Sentinel-2 for the period from 1989 to 2021 defined all the years in which these artificial reservoirs were filled with water or were dry. It was found that the filling of ponds and reservoirs (including those that periodically dried up) occurred during rain floods in spring and summer (sometimes in autumn) for several days (from 2-3 days to 1 week). The results of the study (on the example of Severinov Reservoir) are presented on chronological graphs of variability of the main morphometric characteristics (values of water surface area and length) for the period from 1989 to 2021. It is determined that there is a close unambiguous relationship between the water surface area and the length of reservoir (R2 = 0.997), and the arithmetic mean of the relative deviations does not exceed ±5%. It is recommended to use the above method to establish morphometric characteristics and assess the filling regime of artificial reservoirs according to remote satellite sensing of the Earth during preliminary (reconnaissance) studies and diagnostic monitoring of small rivers. Based on the results of research on the example of the Velykyi Kuyalnyk River, practical recommendations are provided to reduce the existing volume of regulation of runoff of small rivers in the steppe zone of Ukraine. Their implementation will contribute to the future restoration of the hydroecological regime in the Velykyi Kuyalnyk River basin.

Keywords: Remote Sensing, environmental monitoring, satellite images, artificial reservoir, filling regime, water surface area, reservoir length, Velykyi Kuyalnyk River

Introduction

At present in Ukraine there are still no official and reliable data on the regime and frequency of filling ponds and reservoirs in the catchments of small rivers. The catchment area of the small Velykyi Kuyalnyk (V. Kuyalnyk) River in the Odesa region is no exception. However, the lack of control over the filling regime and other characteristics of these artificial reservoirs (length, water surface area, water cut-off coordinates, etc.) leads to many abuses in the use of both ponds and reservoirs, and areas of coastal protection strips around them (Loboda et al., 2020).

Today there are 162 significantly changed and artificial massifs of surface waters on the catchment area of the V. Kuyalnyk River, including cascades of channel ponds and reservoirs, dug ponds (Loboda et al., 2018). The total volume of all these artificial reservoirs is 15.6 million m^3, which is 76.5% of the river runoff (20.4 million m^3) in the average water year (Loboda et al., 2016). Such significant regulation of runoff has led to the deterioration and degradation of the ecosystem of the V. Kuyalnyk River and the Kuyalnytskyi Lyman into which it flows (Loboda et al., 2017). It should be noted that according to the Law of Ukraine "On declaring the natural territory of the Kuyalnytskyi Lyman of Odesa region as a resort of state importance" of December 5, 2018 № 2637-VIII the natural territories of the Kuyalnytskyi Lyman were recognized as a resort of state importance – Resort of Kuyalnik, and the entire catchment area of the Kuyalnytskyi Lyman and the V. Kuyalnyk River were entered to the boundaries of zones 2 and 3 and the district of sanitary protection of this resort.

In addition, in order to effectively manage of water resources and achieve their "good" environmental status in 2020, the preparation of a draft Management Plan for the Black Sea Rivers Basin (including the basins of the V. Kuyalnyk River and Kuyalnytskyi Lyman) was launched, taking into account the requirements of the Water Framework Directive 2000/60/EC and the provisions of the updated Water Code of Ukraine.

Taking into account the above, the purpose of this work was to estimate the frequency of filling artificial reservoirs in the basin of the small V. Kuyalnyk River by decoding and analyzing data from remote sensing of the Earth (satellite images). It should be noted that the method used in this work is one of the most effective for the study of seasonal and perennial changes in water surface area, length, width of channel ponds and reservoirs, where there are no stationary hydrological observations (Hryb et al., 2018). In addition, the use of remote monitoring data is extremely important if the performance of periodic field surveys and instrumental measurements is physically complex and financially expensive.

Method of investigations

The methodology for estimating the frequency of filling existing ponds and reservoirs in the V. Kuyalnyk River basin is described below. For the study were used space images obtained from Landsat 1-8 and Sentinel-2 radiometers for the period from 1989 to 2021. Deciphering and analysis of remote monitoring data was performed using the online viewing tool USGS LandLook. This software product was developed by the United States Geological Survey to provide free access, viewing and working with the archive of space images and various digital maps of the Earth. The following is a procedure for exploring artificial reservoirs using the online viewer tool USGS LandLook.

First, run the USGS LandLook (follow the link: https://landlook.usgs.gov/). Then click "Start LandLook Viewer". If you need to select another digital map, click the "Base map gallery" icon, which is located on the toolbar in the upper left corner of the screen (Figure 1). Then a window will appear on the right side, where you can select another topographic map, for example, "Open Street Map". Then search for the reservoir on this map or click "Search" (Figure 1) and enter the name of the settlement near which the reservoir is located (for example, the village of Kuyalnyk, Podolsk district, Odesa region).

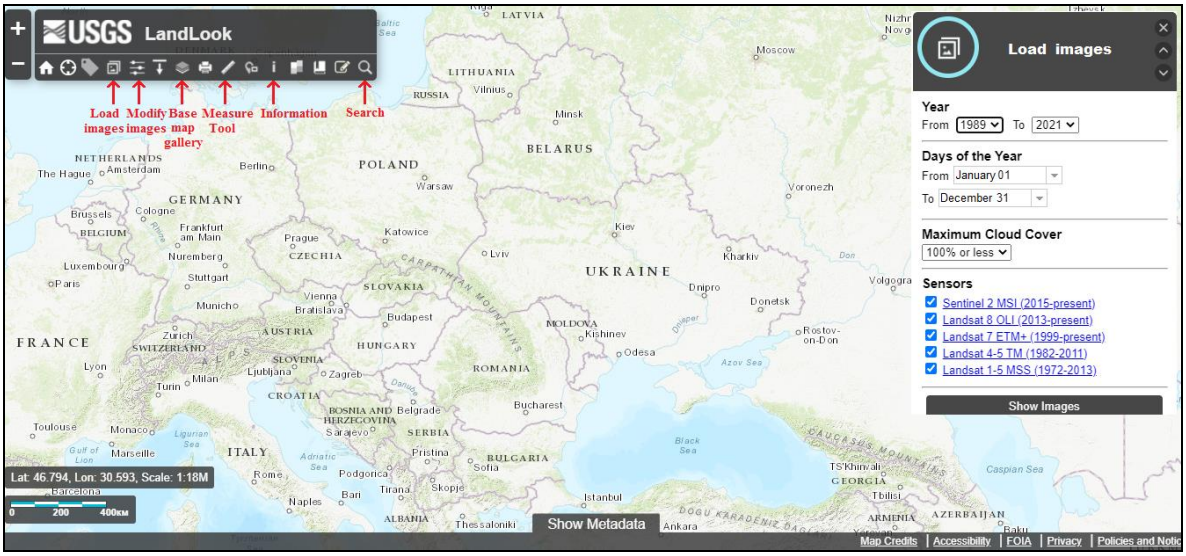

Figure 1 *USGS LandLook online browser window and explanations of the main icons*

After that, a digital map will open, on which you can see the artificial reservoir, its position relative to settlements, roads and other objects, etc. In addition, the "Load images" window opens on the right side of the screen (Figure 1). This window sets the necessary search criteria for monitoring data (years, months, start and end days of the study period and other data) and clicks on "Show images" (Figure 1) to download the archive of space images.

When you have finished uploading images using the arrows in the "Modify images" window that appears on the right side of the screen, you can view and analyze images of water bodies in satellite images taken on different dates during the selected period. If the pond was with water, then its color in the space image will almost always be black-blue or dark blue, ie on this date and this year the pond was filled with water. In addition, in this window you can improve the image, configure dynamic image updates, change the transparency of the space image, and more.

To determine the length, width, area of water bodies, and point coordinates (latitude / longitude), click the "Measure Tool" icon (Figure 1) on the toolbar in the upper left corner of the screen. A window with virtual geodetic tools for performing these measurements will then appear on the right side of the screen. To view and analyze the space images obtained for other dates, click the "Modify images" icon (Figure 1) on the toolbar in the upper left corner of the screen.

You can learn more about other features of USGS LandLook and learn more about additional reference information by clicking on the "Information" (Figure 1) icon and selecting, for example, "Help" or other items in the window that opens on the right side of the screen.

Results of investigations

The following are the results of the analysis of more than four thousand space images of 9 artificial reservoirs in different parts of the V. Kuyalnyk River basin for the period from 1989 to 2021. This period of time was chosen to determine the mode of filling ponds and reservoirs (variability of the length and area of the water surface of reservoirs, duration and dates of filling reservoirs and periods when they were without water) in the context of climate change in Ukraine (including basins of the V. Kuyalnyk River) began in 1989 (Loboda et al., 2016).

In this work, 7 ponds and 2 reservoirs were investigated: 3 ponds – in the V. Kuyalnyk riverbed; 3 ponds – in the basin and in the Sukha Zhurivka (S. Zhurivka) riverbed; 1 pond and 1 reservoir – in the basin and in the Silivka (otherwise – Targar) riverbed; 1 reservoir – in the Koshkova riverbed.

It was established that all ponds in the V. Kuyalnyk riverbed (near the village of Kuyalnyk, the urban-type settlement of Shiryaeve and the village of Yarinoslavka) were always with water.

The Severinov Reservoir, which is located in the lower part of the Koshkova River (on the north side of the village of Ruska Slobidka and at a distance of 2.1 km southwest of the village of Lizynka), was 29 years with water and only 4 years (in 1993, 1995, 2011, 2020) was without water.

In the S. Zhurivka riverbed, one pond (north of the village of S. Zhurivka) was constantly with water, and the other pond (near the village of Novooleksandrivka) was dry for 4 years (in 1995, 2015, 2019, 2020).

In most cases artificial reservoirs were dry in the basin of the Silivka River. It was established that the pond within the village of Anatolivka was with water for 23 years, and 10 years (in 1994, 1995, 2009, 2011, 2013, 2016-2020) – without water. The Siliv Reservoir (near the village of Silivka) was filled with water only for 19 years, and 14 years (in 1991-1993, 2009-2011, 2013-2020) it was dry.

During the analysis of space images, it was found that the filling of artificial reservoirs (including those that periodically dried up) occurred during rain floods in spring and summer (sometimes in autumn) for several days (from 2-3 days to 1 week). Below (Figure 2), as an example, are two chronological graphs of the variability of the main morphometric characteristics (values of water surface area and length) of the Severinov Reservoir for the period from 1989 to 2021, and shows the relationship curve of lengths and water surface area of this reservoir. Using the results of measurements, it was determined that the average length of the reservoir is 1.24 km, the average value of the water surface area is 387.4 thousand m^2. The largest values of the length and area of this reservoir were measured on 04.09.1997 and are, respectively, 3.67 km and 1417.7 thousand m^2. In addition, it was found that there is a close unambiguous relationship between the water surface area and the length of the reservoir (R^2 = 0.997), and the arithmetic mean of the relative deviations is ±4.9%.

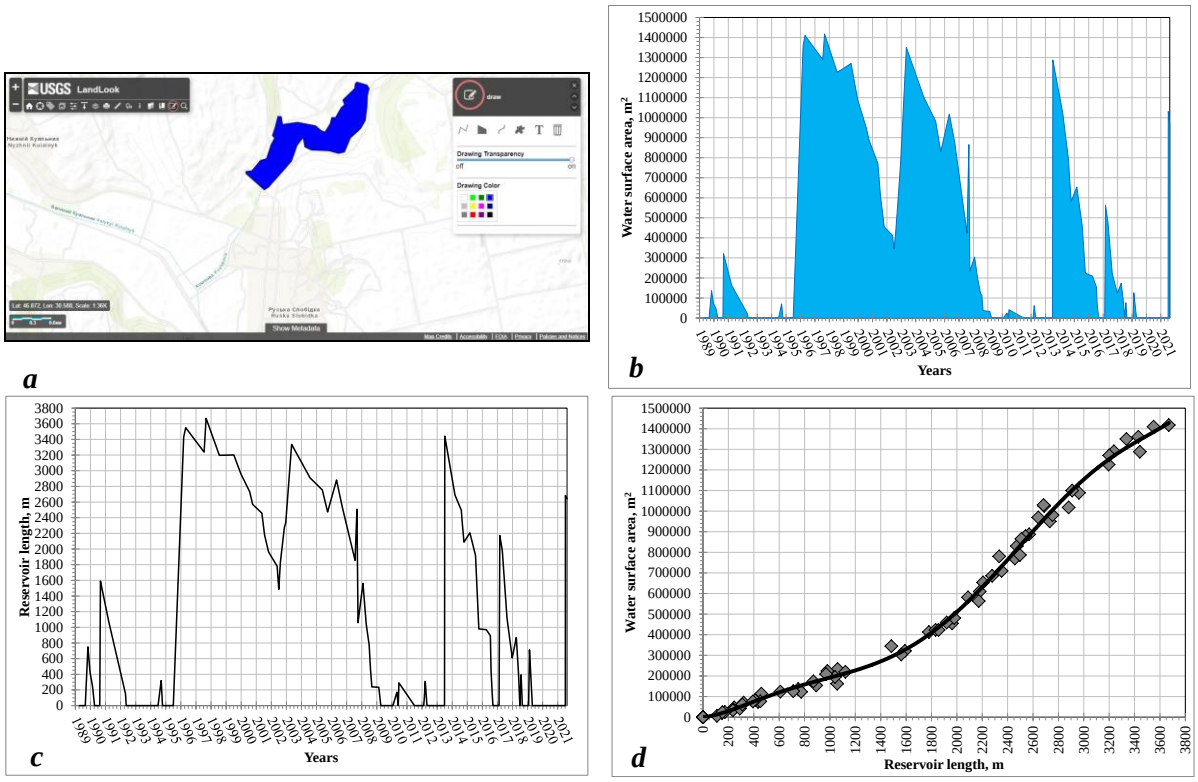

Figure 2 *Location (**a**), variability of water surface areas (**b**) and length (**c**) of the Severinov Reservoir and the relationship curve of lengths and water surface areas (**d**) for the period from 1989 to 2021*

It should be noted that the data on the filling regime and morphometric characteristics of ponds and reservoirs can be taken into account to substantiate the recommendations for the elimination of "extra" artificial reservoirs in order to reduce the volume of regulation of small rivers. According to the Water Code of Ukraine (Article 82. Regulation of river runoff, creation of artificial reservoirs) for any size of rivers "it is prohibited to build reservoirs and ponds in their basin with a total volume exceeding the runoff of the river in the estimated low water year, which is observed one every twenty years". Thus, taking into account the fact that the volume of runoff of the V. Kuyalnyk River in the estimated low-water year, which is observed once in twenty years, is equal to 0.0 million m^3 (Loboda et al., 2018), so no artificial reservoir to regulate the flow of rivers in the basin should not be.

Conclusions

In the work on the example of 9 artificial reservoirs (7 ponds and 2 reservoirs) in the basin of V. Kuyalnyk River using the online tool USGS LandLook and the archive of space images from radiometers Landsat 1-8 and Sentinel-2 (for the period from 1989 to 2021) all years are defineds, in which these artificial reservoirs were filled with water (or were dry).

In addition, the mode of their filling was determined, variability of the main morphometric characteristics (water surface area and length) and recommendations for further reducing the existing volume of regulation of small river runoff.

According to the results of the research, it is possible to recommend the use of the method of analysis of retrospective data of remote sensing of the Earth using the online tool USGS LandLook to assess the frequency of filling artificial reservoirs in small river basins, where there are no stationary hydrological observations.

In addition, the above method of determining the morphometric characteristics and mode of filling of artificial reservoirs can be recommended for preliminary (reconnaissance) studies and diagnostic monitoring of artificial and significantly altered surface water bodies.

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