Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIII, 2024
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ESTIMATION OF RIVERBANK SOIL EROSION RATE - A CASE STUDY

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Abstract

Erosion of riverbanks is a natural phenomenon, which leads to the loss of important agricultural land areas. At the same time, riverbank erosion can be considered a natural risk that can cause major damage to road and railway infrastructure, flood management infrastructure, biodiversity and even the population located in flood risk areas. This phenomenon is generally more pronounced in the meanders of the rivers and in regions with higher flow rates, but it can be accentuated due to climate change which can lead to changes in watercourse flows. This study aimed to estimate the net annual soil loss due to riverbank erosion on the Siret River, Romania, using aerial photogrammetry and GIS analysis.

Key words*: climate change, riverbank erosion, soil erosion.*

INTRODUCTION

Erosion of riverbanks is a natural phenomenon, which leads to the loss of important land areas, but also to the accumulation of sediments in rivers and to the damage to aquatic biodiversity. At the same time, riverbank erosion can be considered a natural hazard, when the riverbank erosion rate is higher than normal, and this phenomenon is causing major damage to infrastructure. Riverbank erosion can affect the local community, in some situations, residents are forced to move to safer areas (Mahmoodzada et al., 2023), with higher altitudes.

Riverbank erosion has a short-term impact on local communities through the loss of housing and land, but also an indirect long-term impact on the living conditions and health of the displaced population, especially in areas with high population density and low economic development. At the same time, in areas affected by riverbank erosion, local authorities can impose certain restrictions on the use of land, thus affecting the economic development (Leng et al., 2023).

Considering the above, it is necessary to predict the magnitude of the erosion of the riverbank, to prevent the occurrence of certain damages caused by this phenomenon. Tracking and forecasting the evolution of riverbank erosion phenomena can help to improve water management practices and the use of spatial analysis can help to study larger areas (Benavidez et al., 2018).

Riverbank erosion is a natural geological process that can occur slowly or with a higher erosion rate, which depends on several factors such as: hydraulic characteristics of the watercourse, soil properties, soil erodibility or soil resistance to erosion (Nur et al., 2024). The phenomenon of riverbank erosion is accelerated with rising water levels and the loss of soil matric suction, or the force with which the soil holds water, which occurs in soils that are partially saturated with water (Nardi et al., 2012).

The severity of the consequences of riverbank erosion can be correlated with the hazard exposure of the potentially affected areas, being higher in areas exposed to flood risks with a high population density and in built-up areas (Tha et al., 2022).

Riverbank erosion rates increase greatly during periods of high river flow, when high flow of water hits the riverbank with force, causing the riverbank to collapse due to pressure differences (Hasanuzzaman et al., 2023).

The importance of roughness induced by the topography of the watercourse in limiting the phenomenon of riverbank erosion must also be considered (Darby et al., 2010). Riverbank erosion varies greatly over time, with the shape of banks changing radically, especially after floods, increasing the likelihood of riverbank erosion. For example, by doubling the duration of bank flooding from 10 to 20 days, leads to a 50% increase in the probability of riverbank erosion (Vietz et al., 2016).

According to a study carried out over a period of 3 months, which investigated the lateral erosion rate of riverbank using the erosion pins method, the erosion rate was between 0.05-0.51 cm/day, and was influenced by the flow velocity of water, and the degree of vegetation coverage of the riverbank (Nur et al., 2021).

Riverbank erosion is higher on unvegetated riverbanks than on vegetated riverbanks, so the presence of vegetation increases the stability of the riverbank, thus reducing riverbank mass failure, and decreasing the water velocity in the bank area (Li et al., 2023).

Climate change significantly impacts riverbank erosion, exacerbating the natural processes that cause it. Future climate changes will affect the rainfall pattern in certain areas of the world; thus, they will play a significant role in increasing the risk of floods in the coming years, and at the same time in intensifying the riverbank erosion rate. That is why assessing the impact of climate change on bank erosion is essential for planning the timing of climate change mitigation actions (Aktar, 2023). Riverbank erosion protection strategies must consider the vulnerability of the population and infrastructure to flood risk. Protection measures against riverbank erosion in flood risk areas can be combined with measures to reduce river flows during floods such as the construction of lateral non-permanent accumulations (polders).

MATERIALS AND METHODS

A growing trend in the research community is to use various high-tech techniques to identify and solve the problems of people. GIS is an important tool which can be of assistance in the identification of river changes and bank erosion situations. To study the fluvial geomorphology of a river, the identification of the channel migration pattern of rivers from satellite images of different years using GIS and remote sensing technology is found to be very useful.

This study aimed to quantify the riverbank erosion rate using aerial photography and GIS analysis, on a 1 km long sector of the Siret River, Galati County, Romania. On the right bank of the river there is a flood protection dike that protects important areas of agricultural land and several different localities. The riverbank erosion rate analysis can be used as an argument in decision-making by the competent authorities for water management.

There are several methods for quantifying bank erosion: high-resolution traditional photogrammetry, SFM photogrammetry, UAV photogrammetry, satellite imagery (with certain cost limitations), highly accurate total station measurements, direct measurements with erosion probes, terrestrial laser scanning, airborne laser scanning and dendrogeomorphological studies (de Souza Dias et al., 2022).

Aerial photograms publicly available on the website of the National Agency for Cadastre and Land Registration were used to carry out this study (N.A.C.L.R. Romania, 2024), from 2005, 2016, as well as an aerial photogram made with a drone in 2023. These data were processed in GIS to calculate riverbank areas lost through erosion. To calculate the daily rate of riverbank erosion, the riverbank length in centimetres lost through erosion obtained between different years were divided by the number of days between the years of study.

All the figures were made in QGIS, and the photos are original.

RESULTS AND DISCUSSIONS

The study was carried out on a 1 km sector of the Siret River, Galați County in Romania, the location being presented in Figures 1 and 2. Galaţi County is in the eastern part of Romania on the border with Moldova. The Siret River originates in the forested Carpathian Mountains (Ukraine). The Siret River has a length of 559 km, a catchment area of 42890 square km, and the sinuosity coefficient is 1.86. In practical terms, it is the river basin with the highest hydro-energy potential and with the largest supply of fresh water in the country. The total theoretical water resource of the Siret river basin is 6,868 million m^3/year, which is above the average for Romania (Ministry of the Environment, 1992).

This study aimed to identify the riverbank daily erosion rate in the study area, in the period 2005-2023, to serve as a basis for decision-making regarding the implementation of works to prevent riverbank erosion phenomena in the area.

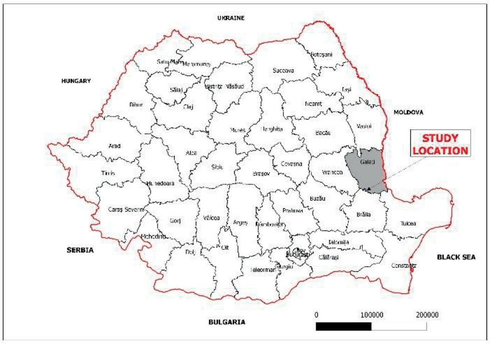

Figure 1. Study location in Romania

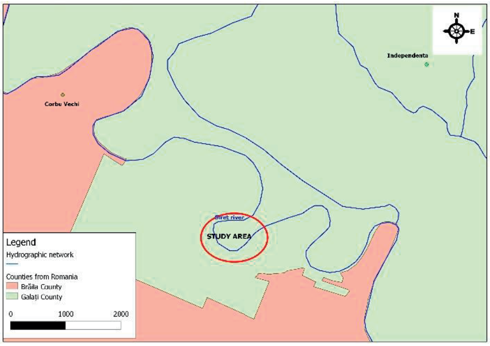

Figure 2. Study location

Taking the construction decision of riverbank erosion prevention works must balance the need to secure the Nămoloasa-Măxineni flood protection dike (Figure 3) to prevent the risk of floods.

Figure 3. The flood protection dike Nămoloasa-Măxineni

In Figures 4 and 5 present the riverbank erosion from Siret River.

Figure 4. Riverbank erosion in the study area (original)

Figure 5. Riverbank erosion in the study area

As a result of this study, the riverbank surface lost due to erosion in the study area was calculated, and it was found that during the period 2005-2016, approximately 3,313 hectares were lost (approx. 0.3 hectares/year) (Figures 6, 7 and 9). In this interval, riverbank erosion was between 10.5 and 81 meters, resulting in an erosion rate between 0.26 cm/day and 2.02 cm/day. The land areas lost through erosion were calculated by measuring the areas lost in the interval between the study years using the QGIS software, and the results obtained were divided by 11 years between the study intervals. To calculate the daily riverbank erosion rate, the distances by which the erosion advanced between the years of the study were measured, and the results obtained in centimetres were divided by the number of days between the years of study (approx. 4015 days).

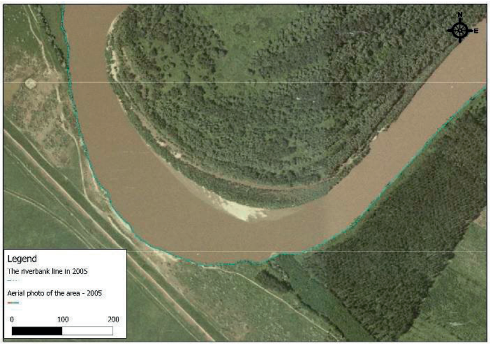

Figure 6. The riverbank line in 2005

Also in this interval, the water management authorities carried out a lower-bank riprap erosion prevention construction, which stopped riverbank erosion on a section on a section of 380 m (Figure 8). Following the evolution of erosion in the period 2016-2023, it was found that the erosion phenomena continued upstream and downstream of the riverbank anti-erosion construction, while in this area the phenomenon of riverbank erosion stopped (Figures 9 and 10).

Figure 7. The riverbank line in 2016

Figure 8. Anti-erosion works carried out in the area

During this period, approximately 1.328 hectares were lost (approx. 0.19 hectares/year) (Figure 10). In this interval, the erosion of the riverbank advanced by 1 to 32.5 meters, thus resulting in an erosion rate between 0.04 cm/day and 1.27 cm/day. The riverbank surfaces lost through river erosion were calculated by measuring the areas lost in the interval between the study years using the QGIS software, and the results obtained were divided by 7 years between the study intervals. To calculate the riverbank daily erosion rate, the distances by which the erosion advanced between the years of the study were measured, and the results obtained in centimetres were divided by the number of days between the years of study (approx. 2555 days).

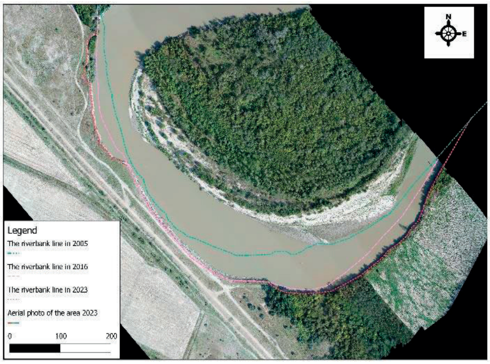

Figure 9. The riverbank line in 2023

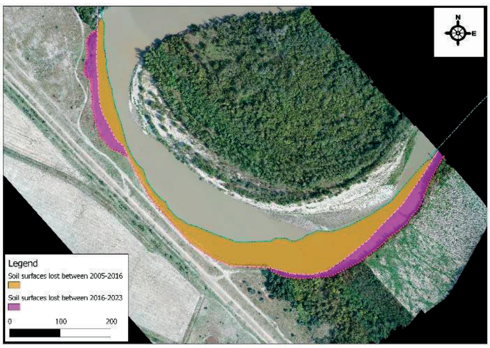

Figure 10. Riverbank surfaces lost between 2005 and 2023

CONCLUSIONS

This study aimed to identify the riverbank daily erosion rate in the study area, in the period 2005-2023, to serve as a basis for decision-making regarding the implementation of works to prevent riverbank erosion phenomena in the area. After carrying out this study, it was found that the vegetation on the riverbanks protects the riverbank against erosion, and that the areas most exposed to this phenomenon are those without riparian vegetation and those in the meanders of the watercourse, where an erosion rate between 0.04 and 2.02 cm/day. At the same time, it was found that the erosion prevention construction of the lower-bank riprap type was effective and that it should be extended upstream and downstream to protect the flood protection dike in the area.

At the same time, an accelerated increase in the areas with sediment deposits was observed in various areas of the watercourse, which exerts additional pressure on the opposite riverbank, contributing to the accentuation of the erosion phenomena, but these were not quantified in this study and can be the subject of further research.

The study confirmed that the flood protection dike is at risk due to the intensification of erosion phenomena and that urgent measures must be taken.

Riverbank monitoring using aerial photograms is a simple and easily accessible method, the accuracy of which depends on the quality of the images used. This method does not require complicated calculations and can be quickly applied to large areas and can be used to monitor the evolution of riverbank erosion phenomena over time and to make quick decisions.

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