ASPECTS REGARDING THE SIRET RIVER DIRECTION-CHANGING IN THE BACAU COUNTY REGION, ROMANIA

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Abstract

Rivers are active agents on the Earth's crust which lead to specific geological formations. This process of river flow shaping the landscape is a continuous and dynamic one. The study's objective, as presented in this paper, is that of identifying the course of the Siret River in the Bacau region, with the purpose of assessing the new route's impact on agricultural lands and human settlements near its vicinity. Therefore, three cadastral maps have been digitized (maps were realized in different periods of time, 1954, 1980 and 2010).For a more precise identification of the differences between the routes of Siret River in these three time intervals chosen, the river courses obtained by digitalization were overlapped at 2x2 juxtaposition: the course of 1954 with the one in 1980 and the course of 1980 with the one in 2010. Through this overlapping we were able to identify the soil surface which was subject to margins' expansion, presented with negative values and the margins' reduction process, presented with positive values. From the graphic representation obtained we can note that there is no specific area subjected only to margins' expansion or only to margins' reduction, these processes take place along the entire length of the river. The greatest value of the margins' expansion and/or reduction were obtained between 1980 and 2010 courses with $-8900007m^2$ value on the left margin and $5289474m^2$ on the right margin. The data analysis show that the margins' expansion is wider than the margins' reduction process, which leads to the enlargement of the water surface and affects the surfaces boarding the Siret river course.

Keywords: Siret River; Specific geological formations; River margins' expansion and reduction; Preserving the riverbed.

Introduction

Water is the main agent that shapes the Earth's surface, creating different geographical formations. The erosion by water is one of the most significant processes of environmental degradation [1]. Within the flowing process, the rivers energy dislocates the soil particles from an initial position and transports them to other places. Due to this process, the rivers are continuously transforming [2]. Because of this process, the river's shape changes continuously, thus obtaining meanders. Every river has its own features. These meanders can have dangerous effects upon human life, because great parts of human settlements are along the river courses and they can also influence the decentralized water and wastewater infrastructure [3, 4].

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In order to be able to identify the course modifications of rivers, we must elaborate a data basis containing the following aspects [5-19]:

- The nature and the manner in which the human activities are carried out, activities that can directly or indirectly influence a river's evolution;

- Weather conditions;

- The structure of the soil crossed by the river.

In many specialized papers the mechanisms that lead to changes in the course of a river are described. These studies focused on:

- performing practical studies from a series of digital maps or from different GIS data [1, 2, 9, 15];

- performing the theoretical studies using the mathematical apparatus, creating mathematical models or performing deferred simulations [10, 13].

Romania, due to both relief and geographical position, is a territory bordered by many rivers. Romania's territory is divided into 20 river basins and sub-basins.

In this article, reference will be made to the Siret basin, which has a surface area of 28,116km^2 in Romania.

This study's objective is to identify the changes occurred on Siret river bed, analyzed only on Bacau region. The purpose is to understand the mechanism of the Siret river course modification and to predict the evolution of the Siret river bed.

Material and methods

The study area is located in Bacau county (Region of Moldova – Romania), with the following coordinates: 45^0 03' and 47^0 58' Northern latitude and 24^0 49' and 28^0 02' Eastern longitude, with a total surface of study of 6,603km^2 (Fig. 1) [20-22].
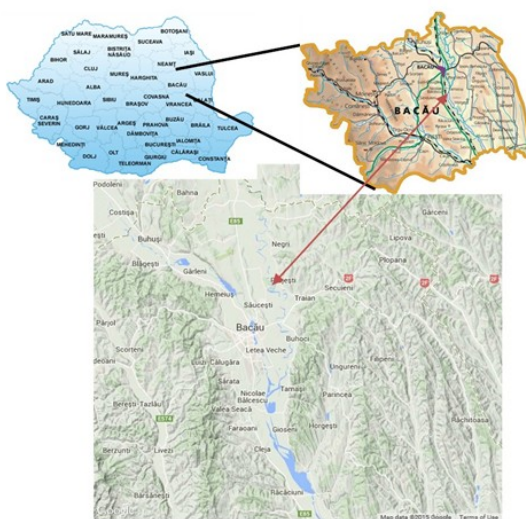

Fig. 1. Identification of the studied area

These coordinates correspond to the Siret river course that traverses the county, with a total length of 92.2km. The area that is the subject of this study is part of the Siret river basin and geographically, as relief, is part of the central plateau of Moldova.

Within this study, in order to identify the changes of the Siret river bed, plans and orthophoto maps have been chosen from three different time intervals: 1950, 1980 and 2010.

These were used to obtain the longitudinal profile of the Siret River. The standard work method was used, the maps being scanned and then digitized. After the digitalization of the Siret River, in those three periods of time, we obtained the coordinates corresponding to the two axes, OX and OY, which helped to realize the graphic representation of those courses.

After the individual analysis of the Siret's profile, it was identify the differences between two routes of the river. Thus, we have analyzed the route of Siret River for the time intervals 1958-1980 and 1980-2010. In order to achieve a more accurate measurement of the differences of shores, we chose an individual analysis for each margin: the right margin in 1958 and in 1980 or in 1980 and 2010 and the left margin in the same years.

Using the *Measure Area* function of the *Bentley* program, we were able to determinate the surface differences between the two margins. As result of such analysis, we could identify and measure the areas in which we have:

- Soil erosion – when the new margin (in 2010) is moving away from the river axis;
- Soil deposition –when the new margin is coming closer to the river axis.
  Following this analysis, we can determine:
- The number of intersection between the two margins of the same part of the river;
- The determination surface values of the difference between the two river beds:
  - We denote by – the river margins' expansion (surface in square meters);
  - We denote by + the river margins' reduction (surface in square meters).

Results and discussion

The final results of digitization are presented in the Figure 2.

After analyzing the water surface profiles, it is found that these are not identical, which shows that the Siret river has suffered a series of transformations. These changes of the water route are better visualized by overlapping two streams of the same river, in different years (Fig. 3 and 4).
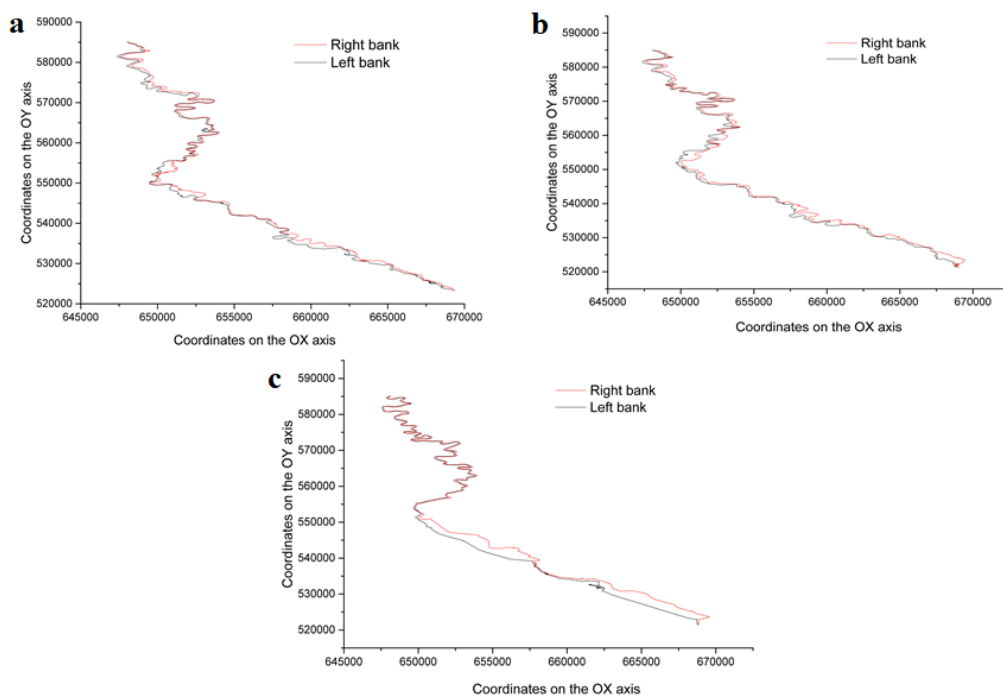

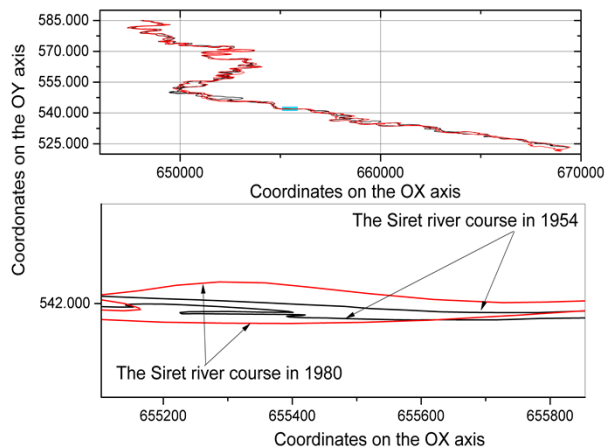**Fig. 2.** The Siret river course in: a – 1954, b – 1980, c - 2010

Fig. 3. The differences between the Siret river stream in 1954 and in 1980
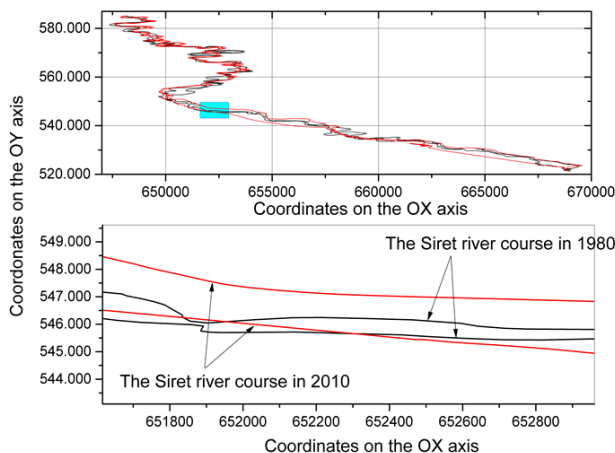

Fig. 4. The differences between the Siret river stream in 1980 and in 2010

For each analyzed period (1958, 1980 and 2010) we have established a series of features with in order to emphasize that the Siret River is continuously changing. These shape features of the river characteristics are shown in Table 1.

Table 1. The surfaces characteristics of the Siret river

Year of the map	Water surface, km²	The margin's length		Total surface of the existent islands
		Right, km	Left, km	
1954	24.01	125.8	119.12	79
1980	31.3	111.43	120.37	72
2010	42.51	104.97	106.17	66

By analyzing the data of the table, we can conclude that the water surface has been through major transformations and we note a constant enlargement of it, from 24.01km² (from 1954) to 42.51km (from 2010). Also the length of the right margin reduced between 1958 and 1980 with 11.42% and between 1980 and 2010 with another 5.73%.

The situation is different with the left margin. Between 1958 and 1980 it enlarged with 1.25km, but between 1980 and 2010 it reduced with 14.2km.

A decrease of the number of islands existent in the county of Bacau, along the Siret river, from 79 in 1954 to 66 in 2010.

Following the individual analysis of the Siret River profile, it was intended to identify the differences between two routes of this river. Thus, an analysis of the Siret River route for the years 1958 - 1980 and 1980 - 2010 was made.

In order to be able to measure as accurately as possible the difference between the banks and the Siret river route, it was chosen to analyze each bank: the right bank from 1958 and 1980 or from 1980 and 2010, and the left bank for the same cases.

With Bentley's Measure Aria function, surface differences between two banks could be determined.

The results obtained from the two studies:
A. The river margins' expansion and reduction for period 1954 to 1980 (Figs. 5 and 6).
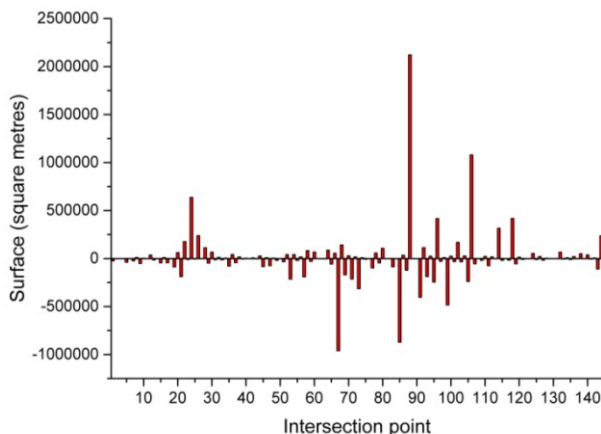B. The river margins' expansion and reduction for period 1980 to 2010 (Figs. 7 and 8).

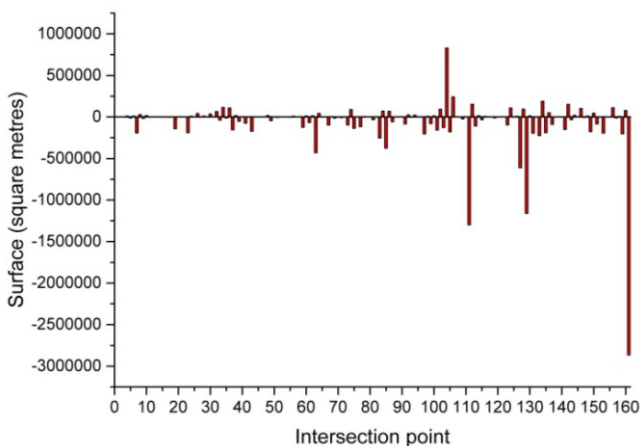**Fig. 5**. The value of the changes of the right margin

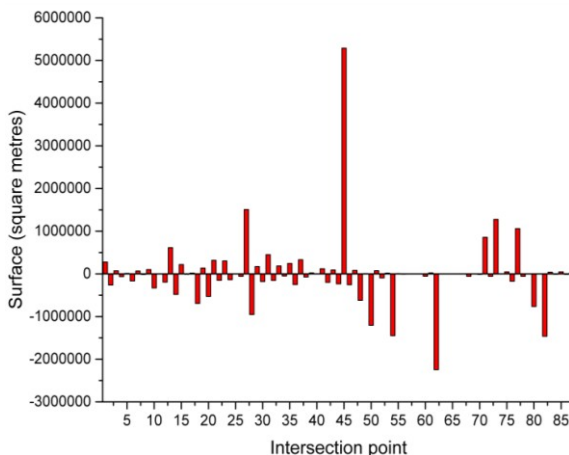**Fig. 6.** The value of the changes of the left margin

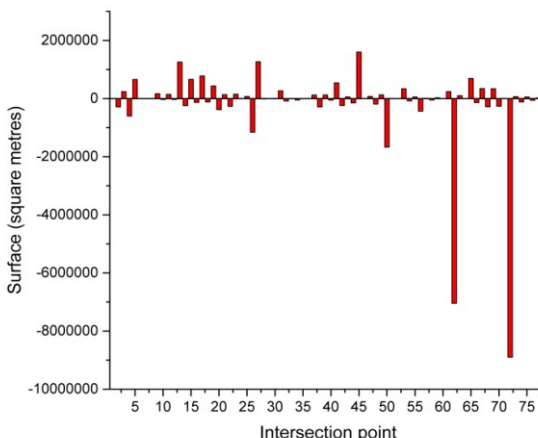**Fig. 7**. The value of the changes of the right margin

Fig. 8. The value of the changes of the left margin

Totalizing all the values obtained, we can establish the modifications occurred on the route of the Siret River:
- Between 1954-1980:
  - Left margin: $|-8,339,445.734|m^2$;
  - Right margin: $1,127,363.73 m^2$;
- Between 1980 -2010:
  - Left margin: $|-12,135,364.79|m^2$;
  - Right margin: $376,489.89 m^2$.

After obtained values analyze, by calculating their sum, we note that the obtained value is negative for the two studies:
- For the period 1954-1980 we get a value of $|-7,212,082|m^2$;
- For the period 1980-2010 we get a value of $|-11,758,875|m^2$.

The negative value shows that the main process that occurs on the Siret River represents a margins' expansion process. This process is emphasized in Table 1 (analyze of the water surface).

If an analysis of the changes is performed, for the groups of analyzed periods, on the same bank, it is found that:

     - For the left bank, there is a gradual increase of the latter, the difference between the two analyzed groups is -37,879,919,056m^2.

     - For the right bank, there is a reduction of this, the difference between the two analyzed groups is 750873.84m^2;

     - Between the two positions of the Siret River, from the beginning of the study (1954) to the final year, 2010, it was found that the left bank had a cumulative expansion of -20,474,810.52m^2 and the right bank had a cumulative reduction of 1,503,853.62m^2.

     Making the difference between right bank and left bank of the Siret River corresponding areas, for two positions, beginning from 1954 to the end of 2010, there is a general increase in surface of the banks with -18,970,956.9m^2 and 18.9km^2 respectively. These values are approximately equal to that shown in Table 1 (the difference between the water surface existing in 1954 and 2010).

     Also, from the obtained values analysis it can be concluded that the trajectory of Siret River has undergone a series of modifications, which led to:

     - Increase of the water surface;

     - A trajectory moving, predominantly to its left bank.

Conclusions

     As any other rivers, the route of the Siret River has a dynamic evolution, suffering constant changes.

     To emphasize the changes occurred in the Bacau region, we have used maps and ortho-photo maps from 1954, 1980 and 2010.

     After the digitalization of the maps, following the river's evolution, we realized graphic representations.

     Using the Bentley soft, we were able to measure the differences between the Siret River's route between 1954-1980 and between 1980- 2010.

     The measurements showed that the water surface enlarged from 24.01km^2 – the surface it had in 1954, to 42.51km^2 - as it was in 2010. Also, the number of island decreased by 13 in comparison with the first reference year of the study.

     By analyzing the surface differences of the two margins, on the two study groups, namely for 1954-1980 and 1980-2010, it is found that the main process affecting the Siret river's margins were in margins' expansion. It is also ascertained that the margins' expansion process, for the last time interval, increased with 63% in comparison with the first one.

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