ANALYSIS OF THE HISTORICAL TREND OF THE RIGHT BANK OF PRUT RIVER IN THE TERRITORIAL ADMINISTRATIVE UNIT OF PRISACANI, IASI COUNTY USING THE DIGITAL SHORELINE ANALYSIS SYSTEM (DSAS) SOFTWARE

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Abstract

The planimetric position of the river banks is a main parameter in detecting the areas affected by erosion and sediment deposition, but also for studying the morph dynamics of the river bed. In order to measure, quantify, calculate and monitor the statistics of the modification rate of the shore line, many researchers have used the software Digital Shoreline Analysis System (DSAS) which works as an extension of the software Environmental System Research Institute (ESRI) ArcGIS and which is using for this kind of statistics the multiple lines of the shore recorded at different dates in time and obtained from different sources. Taking into account that the DSAS software uses polyline layers as a representation of a certain shoreline at a certain time, we have used the polylines which represent the geographical position in time of the right bank of the river Prut. The resulted statistics are the following: Net Shoreline Movment (NSM), Shoreline Change Envelope (SCE), End Point Rate (EPR) and Linear Regression Rate (LRR). This provides a thorough analysis of the change in time of the right bank of the river Prut, but cannot establish the force of the morpho dynamics of the river bed.

Key words: ***GIS, River bank, Historical Trend Analysis, DSAS, Remote sensing***

The dynamic of the river channel represents a direct response of hydrologic, hydrogeologic, geomorphologic and anthropic factors, and it has a useful scientific and practical importance, especially for the regions where the rivers play the role of state border.

The erosion and deposition phenomena are considered challenges for the communities from the riverside of Prut and for the infrastructure in the area and, also, are of particular importance given the fact that, as of 1948, the state border between the Union of the Soviet Socialist Republics and, later on, between Ukraine and Republic of Moldova was established on the river Prut.

The modifications in time of the geometry and the planimetric position of the river banks are base indicators used in evaluating the modification in time of the river bed but also of its morpho dynamics. Therefore, the quantitative analysis of the modification of the river banks in different periods is very important in order to comprehend and establish the processes that lead to erosion and sediment deposition (Sherman *et al*, 1993), to identify the hazardous areas (Lawrence, 1994), as a base to shape the morphodynamics (Maiti *et al*, 2009) and to manage the hydro technical works to regulate the river beds.

In order to investigate the dynamics of the modifications of the geographical positions of the right bank of the river Prut between 1949 and 2017, the Digital Shoreline Analysis System (DSAS) software was used (Thieler *et al*, 1994; Thieler *et al*, 2009; Temitope *et al*, 2014). Including bigger periods, such as decades or centuries, during which major events took place, can be useful in order to analyse the morphodynamics of the river bed. Therefore, analysing the hystorical trend is a key way to address the analysis of the modifications during time periods (decades), in order to identify the past events and to anticipate their evolution.

The Digital Shoreline Analysis System (DSAS) is available free of charge and runs under ArcGIS (Thieler *et al*, 2009) and is a GIS tool which can be used to analyse the hystorical trend in order to examine the planimetric position of the shoreline of the right bank of the river Prut in the past or in present times. One of the great advantages of using DSAS for such analysis is the ability to calculate the modification rate in time of the planimetric position of the shoreline of the

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right bank of the river Prut for a certain period of time.

The study area is situated in the southern sub-sector of the middle sector of the Prut River at a distance of about 600 km from the rise, in an area characterized by a floodplain with widths of 4 to 8 km.

The channel of the Prut river in the study reach is 26 km long, it widths ranging between 41 and 102 m with an incline ratio of about 0.02 % *(Figure 1)*

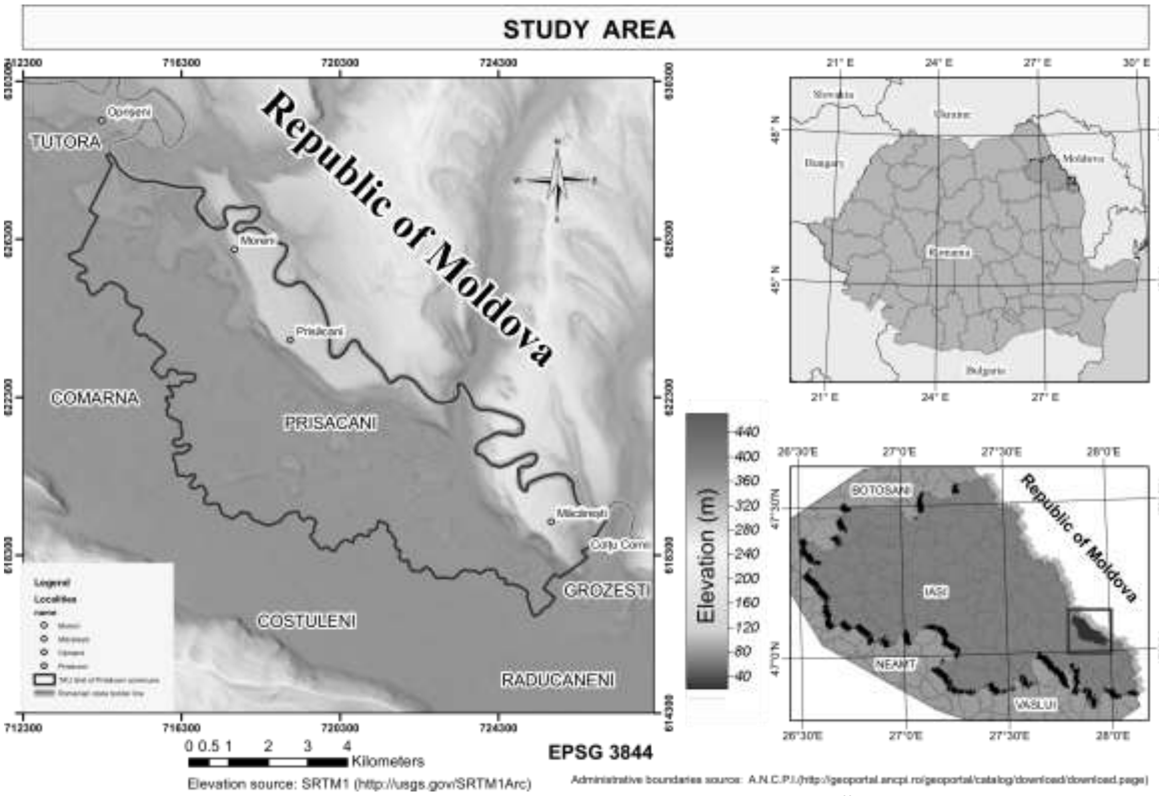
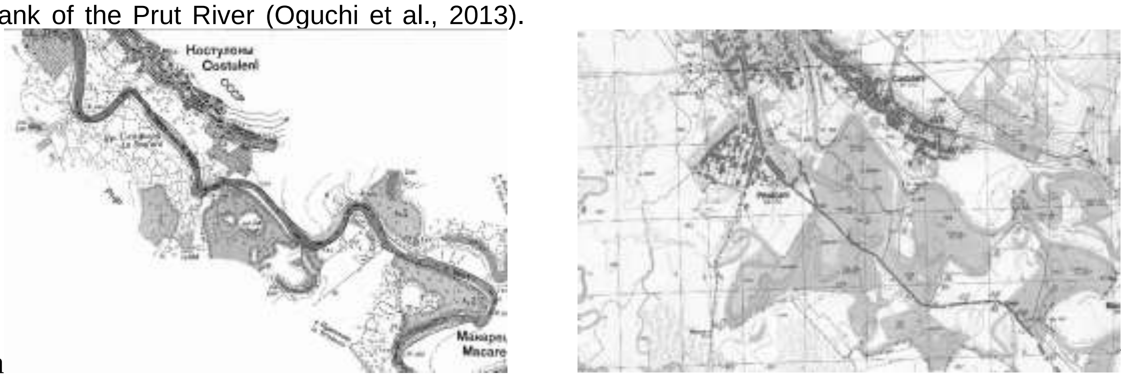


Figure 1 **The study area – Prut River channel in the Prisăcani LAU**

This article presents a Historical Trend Analysis of the dynamic of the right Prut River bank for the last 70 years, focused on a 26 km sub-sector of the Prut River, which represent the north-eastern limit of the Territorial (Local) Administrative Unit *(LAU 2nd order)* of Prisacani Commune, Iaşi County, and also a part of border between Romania and Republic of Moldova.

MATERIAL AND METHOD

The various topographic and Remote Sensing (RS) spatial data were used to digitize the right bank of the Prut River (Oguchi et al., 2013). Topographic maps were georeferenced by third degree polynomial transformation method to optimize local accuracy (Imbroane, 2012). In a first stage, the topographic maps (at 1:25,000 scale) 1949, 1960 and 1985 editions, were georeferenced using the planimetric rectangular Gauss-Krüger coordinates of trapezoids corners and intersection points of the kilometric grid (84 – 104) points transformed into planimetric rectangular coordinates in the Romanian Stereographic Projection System (Pulkovo 1942 Geodetic Datum), using the Matlab programming language (Moca et. al. 2012). *(Figure 2).*



a b

Figure 2 **Topographic maps used for right bank of the Prut River extraction: a) 1949 edition, b) 1985 edition**

Beside the topographic maps, various RS images were used: LANDSAT images acquiered on 17th of August 2000, SENTINEL 2A images dated 9th of August 2016 and 16th of May 2017, ortophotomaps realized in the year 2005 and between 2008–2010, 2010 – 2013 and 2013 – 2015 periods, LiDAR DEM (acquired in 2012), and Google Earth® high resolution optical satellite images collection. All RS images were transformed in Romania Stereographic Projection System (Pulkovo 1942 Geodetic Datum) by using the ArcGIS software. For the last three years, the right bank of the Prut River dynamic was validated and completed using GPS measurements performed with Leica 1200 GPS System.

DSAS Method

By using the DSAS application within ArcGIS software, after setting up the basic parameters and possible editing of the base line or of the transect lines, it will calculate the modification rate in time of the line which represents the right bank of the river Prut based on the measurement of differences between the planimetric positions of the shorelines associated to specific periods of time. When inputting the parameters, there are made specifications referring to the distance between two transect lines (50 meters in this study case), the minimum number of lines of the right bank which must intersect and the length of the transect lines established in such a way that it will intersect all the lines which represent the shoreline of the river Prut for the analysed period, thus the specific transect lines will not be used to calculate the statistics *(Butnariu, 2017*). The vector lines which represent the right bank of the river Prut for the period 1949 – 2017 and the transect lines are presented in figure 3.

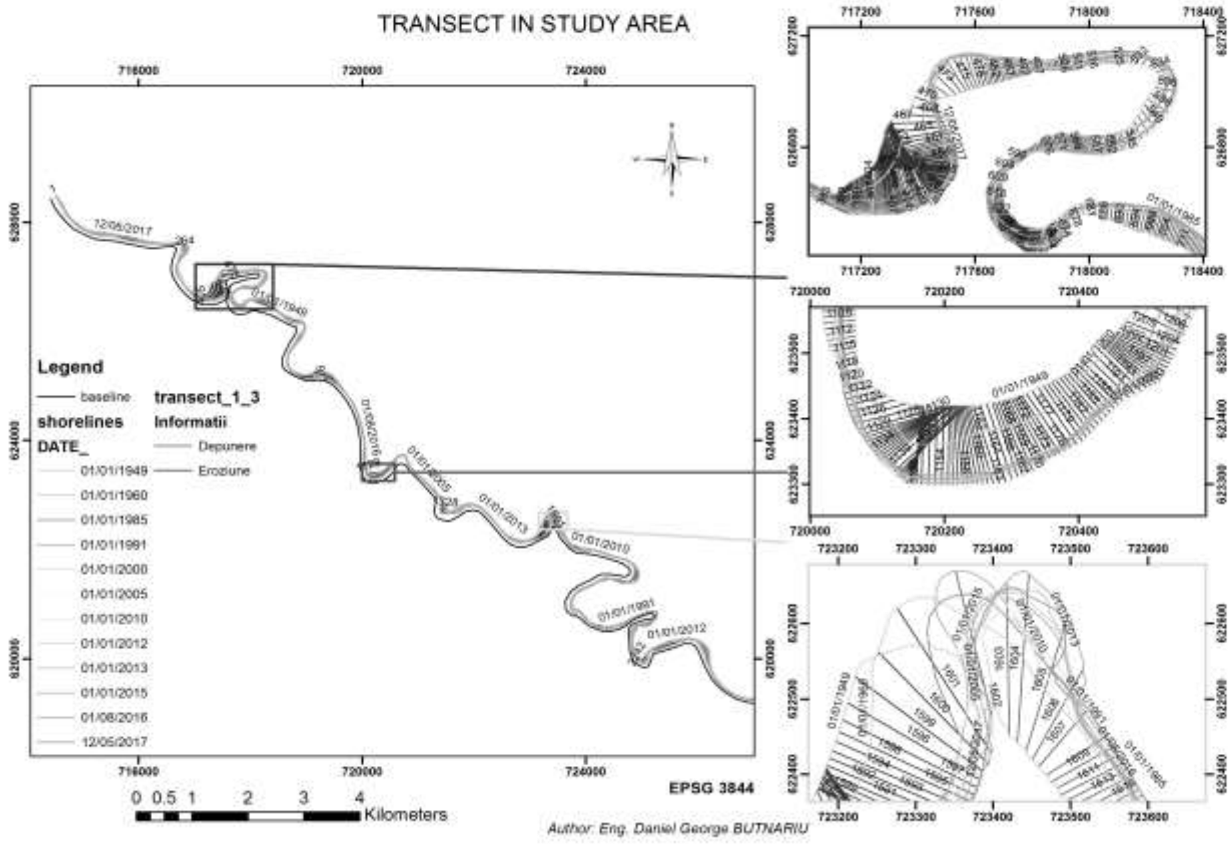


Figure 3 **Transect Lines in the study area**

The following statistical analysis are possible (Thieler et. al., 2009):

a) Shoreline Change Envelope (SCE): a distance wich represents the total change in the right bank line of the Prut River movement considering all available right bank lines positions and reporting their distances, without reference to their specific dates *(Figure 4);*

b) Net Shoreline Movement (NSM): report a distance, not a rate, between the oldest and youngest right bank line of the Prut River. The NSM is associated with the dates of only two right bank lines, oldest and youngest right bank lines for each transect line *(Figure 4);*

c) End Point Rate (EPR): is calculated by dividing the distance of the right bank line movements by the time elapsed between the oldest and the most recent right bank line.

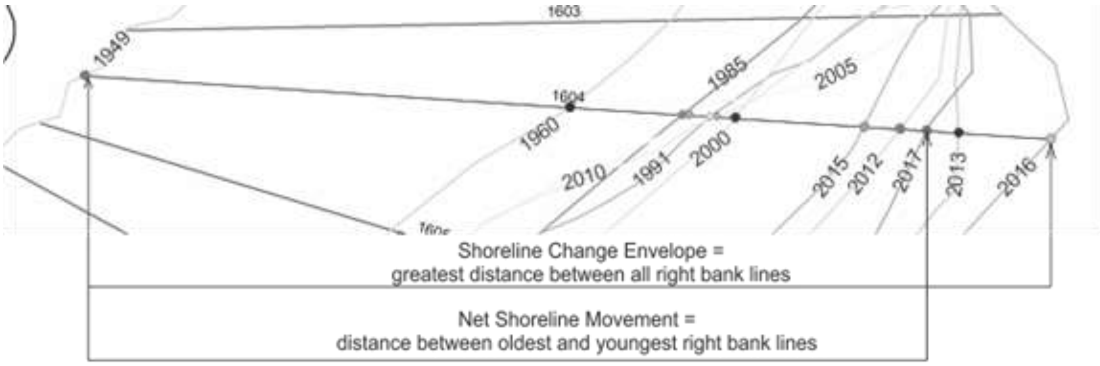


Figure 4 **Graphic representation of the SCE and NSM distance**

d) Linear Regression Rate (LRR): determines a rate-of-change statistic by fitting a least square regression to all shorelines at a specific transect *(Figure 5).* Further statistics associated with LRR include Standard Error of Linear Regression (LSE) and R-Squared of Linear Regression (LR2).

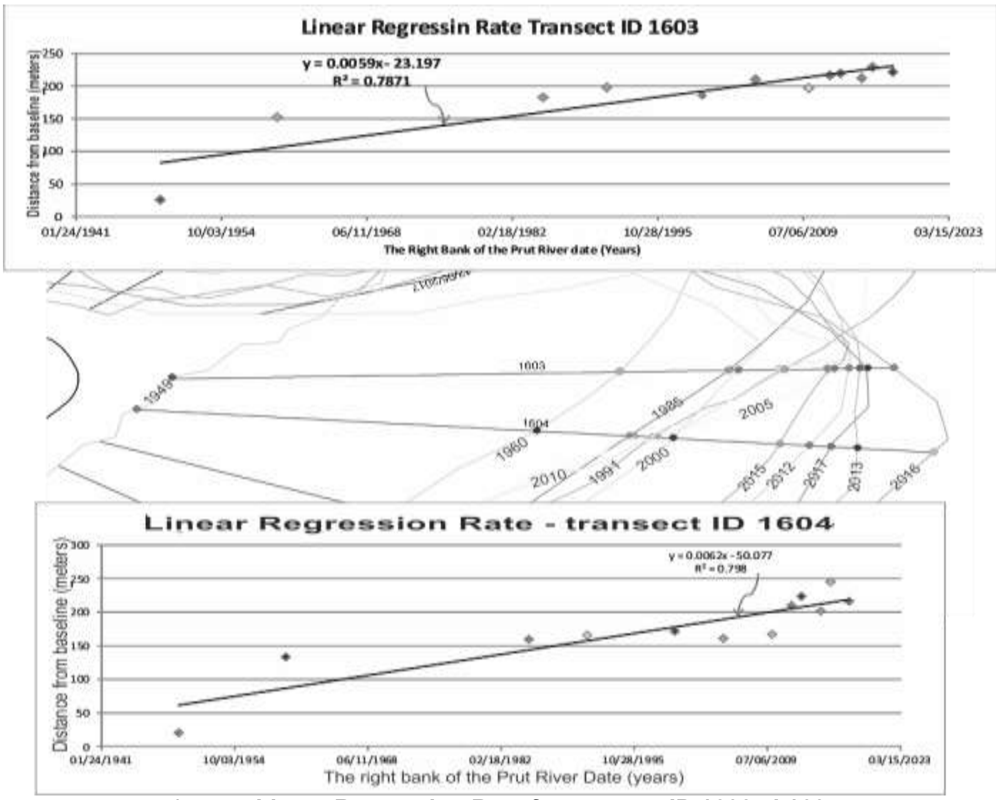


Figure 5 **Linear Regression Rate for transect ID 1603 și 1604**

The standard DSAS shoreline change measures – Net Shoreline Movement (NSM) and End Point Rate (EPR) were calculated. Net Shoreline Movement (NSM) reports the distance between the oldest right bank line of the Prut River (1949) and the youngest (2017) right bank line of the Prut River, wich presents the overall change in right bank of the Prut River position for the 68 yer period. The End Point Rate (EPR) converts this distance (NSM) into an annual rate of right bank of the Prut River change, dividing the distance (NSM) from the earliest to most recent right bank of the Prut River by time period passed.

RESULTS AND DISCUSSIONS

Table 1 presents an excerpt of the database generated by the calculation of the statistical data by using the DSAS application. It can be observed that the maximum values of the distances between the lines which represent the right bank of the river Prut, the oldest (year 1949) and the most recent (year 2017) were obtained at the transect lines with ID 424 and 426 (the value of -310.63 meters) and with ID 1603 (the value +195.85 meters). In addition, for the same areas (transect lines), the modifications rate of the right bank of the river Prut had maximum values of -4.51m/yr (transect

ID 424 and 426) and +2.84m/yr (transect ID 1603 and 1604).

For the transect line 1603 the equation of the linear regression rate is y=0.0059x-23.197 and R-Squared of Linear Regression (LR2) is 0.7871.

Table 1

The results of the statistics

OBJECT ID	Transect Id	TCD	EPR	ECI	SCE	NSM	LMS	LRR	LR2	LSE
1	1	0	-0.09	0.09	44.85	-5.86	-0.11	-0.32	0.38	9.84
…	…	…	…	…	…	…	…	…	…	…
424	424	4230	-4.51	0.09	328.08	-310.63	-0.39	-4.22	0.84	43.27
425	426	4250	-4.51	0.09	334.53	-310.63	-0.39	-4.25	0.84	44.56
…	…	…	…	…	…	…	…	…	…	…
1600	1603	16020	2.84	0.09	203.45	195.85	1.23	2.15	0.79	26.72
1601	1604	16030	2.84	0.09	224.68	195.79	1.55	2.28	0.8	27.37
…	…	…	…	…	…	…	…	…	…	…
2524	2527	25260	-0.98	0.09	78.27	-67.79	-0.46	-1.04	0.84	11.01

Figure 6 summarises the scale and rates of change in right bank of the Prut River position in the study area (Butnariu, 2017).

It can be noticed a bigger mobility of the right bank of the river Prut between 1949 and 1980, the river bed turning under natural conditions. After the regularisation works of the river bed, the built of the Stanca Costesti dam between 1974 – 1978 and especially after the consolidation works of the right bank of the river Prut from 1977 close to Moreni and Prisacani settlements, this mobility is reduced.

A centralized account of the modification in time and the evolution trend of the right bank of the river Prut is presented in Table 2.

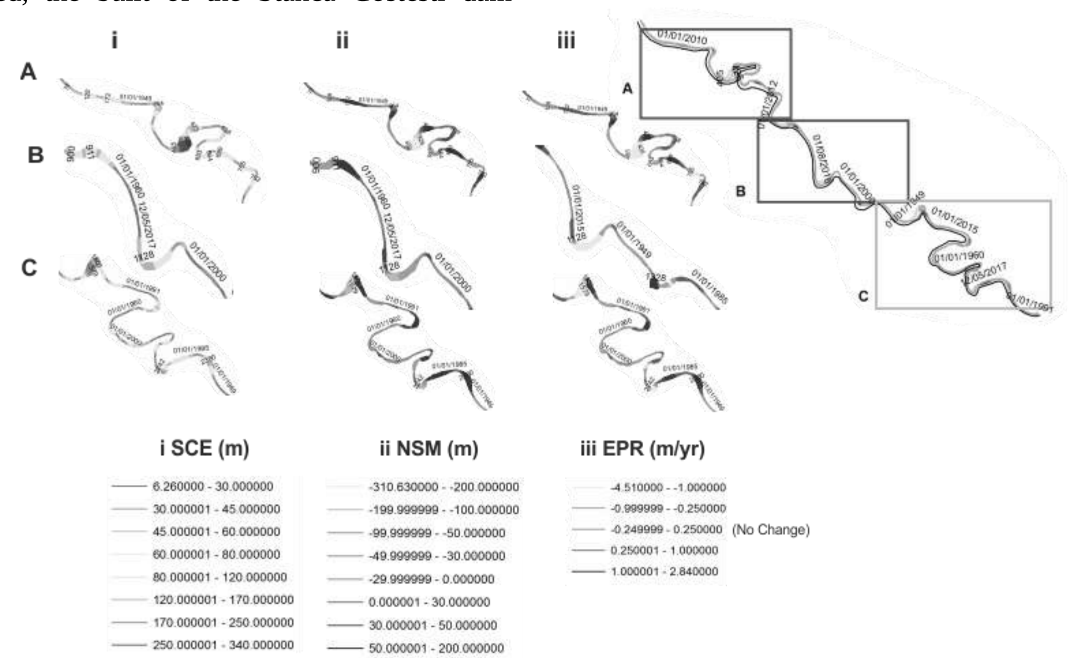


Figure 6 **Shoreline Change Envelope (SCE), anual rate of change (EPR) and Net Shoreline Movement (NSM) for the right bank of the Prut River**

Table 2

Summary of the right bank of the Prut River movements and trends

The right bank of the Prut River	No of Transects	% of Transects	Change rate (m/yr)	Total erosion/deposition change (m) Minimum to Maximum
Retreat	907	35.9	-0.01 to -4.51	-0.01 to -310.63
Advance	870	34.5	+0.01 to 2.84	+0.06 to +195.85
No Movement	747	29.6	-	-

CONCLUSIONS

Generally, after year 1948, the river Prut shows a great mobility in a buffer area of ±300 meters but, after the built of the Stanca – Costesti dam (1974 – 1978) and after the regularisation works of the river bed of Prut, the evolution in time of the geographical position of the right bank of the river Prut faced a significand reduction with only modifications of up to 50 meters and, exceptionally, up to 80 meters.

The evolution in time of the geographical position of the river banks is of a significant importance in evaluating the morphodynamics of its river bed. The importance is also provided by the communities living in the close vicinity and especially due to the fact that the river Prut represents the state border between Romania and the Republic of Moldova in the territorial administrative unit of Prisacani.

Although the DSAS extension of the ArcGIS software was created in order to calculate the modification rate of the shoreline, it also proves to be applicable for the banks of one river and, in general, for any characteristics which can be represented by a line at a certain date with the accuracy of the results being given by the input values.

The application can be used to identify the areas affected by erosion/sediment deposition, their mapping, to measure the modification of the banks during long periods of time and their modification rate (values between -4.51m/yr and +2.84m/yr for the study area), but it cannot provide data about the surface of terrain affected by erosion or by sediment deposition.

This case study shows that the DSAS extension within ArcGIS environment can provide valuable information related to the morphodynamics of the river bed of Prut, as regards the modification in time of the geographical position of the banks of the river and to identify the areas affected by erosion or sediment deposition.

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REFERENCES

Lawrence PL., 1994. *Natural hazards of shoreline bluff erosion: a case study of Horizon View, Lake Huron.* Geomorphology, Volume 10, 1- 4, 65 – 81.

Butnariu D., **2017**.*Tehnici de achiziție și prelucrare a datelor pivind traseul și solurile de pe malul drept al râului Prut în zona de studiu. Research Report*, Technical University Gheorhe Asachi Iaşi.

Butnariu D., **2017**.*Rezultate parțiale ale cercetării privind modificarea în timp a malului drept al râului Prut în zona comunei Prisăcani, județul Iași. Research Report*, Technical University Gheorhe Asachi Iaşi.

Imbroane, A. M., 2012. *Sisteme informatice geografice, Volumul I, Structuri de date.* Presa Universitară Clujeană, ISBN 978-973-595-417-8, Cluj-Napoca,

Maiti S., Bhattacharya AK., 2009. *Shoreline change analysis and its aplication to prediction: a remote sensing and statistics based approach.* Marine Geology, 257, 11-.23.

Moca, V., Oniga, V. E., Cardei, M., 2012. *Georeferentiation of the graphic fund for topographic plans drawn up on geodesic trapezia at general cadastral works. Scientific symposium with international participation "Horticulture science, quality, variety, harmony", U.S.A.M.V. Iasi.*

Oguchi T., Wasklewicz T., Hayakawa Y.S., 2013. *Remote data in fluvial geomorphology: characteristics and applications. In: Shroder, J. (Editor in Chief), Wohl, E. (Ed.), Treatise on Geomorphology. Academic Press, San Diego, CA, vol. 9, Fluvial Geomorphology, pp. 711–729,*

Sherman DJ., Bauer BO., 1993. *Coastal geomorphology through the looking glass*, Geomorphology, 7, 225 – 249..

Thieler ER., Danforth WW., 1994. *Historical shoreline mapping (II) Aplication of the Digital Shoreline Mapping and Analysis Systems (DSMS/DSAS0 to shoreline change mapping in Puerto Rico*, Journal of Coastal Research, 10(3), 600 - 620

Thieler ER., Himmelstoss EA., Zichichi JL., Ergul A., **2009.** The Digital Shoreline Analysis System (DSAS) Version 4.0 – An ArcGIS Extension for calculating Shoreline Change. Open file Report US Geological Survey Report No. 2008 – 1278, available on-line http://woodshole.er.usgs.gov/project-pages/dsas/version4.0

Temitope D., Oyedotun T., 2014. *Shoreline Geometry: DSAS as a Tool for Historical Trend Analysis,* Geomorphological Techiques

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