Using Gis Tools in Niraj River Fluvial Morphodynamics

Sanda ROŞCA[1], Ioan RUS[2], Dănuţ PETREA[3]

Abstract. Lately, the role of computerization has increased thus to the existence of software and its use has become indispensable as a result of its applicability to all Earth sciences. The Niraj minor and major riverbeds present a varied morphology and instability in some sections; due to rainfall intensity and flashfloods growing frequency the potential erosion of the river has increased, 28 settlements being situated in proximity of the river. Thus, we have used GIS technologies to identify the relations of interconnection and interdependency between causative factors, relying upon measurements of changes; in this way we want to emphasize the advantages and disadvantages of using the tools provided by GIS technologies.

Keywords: fluvial morphodynamics, meander, vulnerability, G.I.S., Niraj river

1. Introduction

The analytical, quantitative and qualitative approach of this paper, based on available data and information wants to serve to a better understanding of the possibility of using GIS technologies in the study of fluvial morphodynamics as a geographic phenomenon which induces a potential risk. Thus we have studied the genetic factors, qualitative and quantitative characteristics and also its consequences in the geographic environment. From the category of morphodynamics effects of the Niraj River we concentrated our attention to lateral migration of the riverbeds.

By GIS (Geographic Information System) technology we understand the ensemble of calculus equipment (hardware), software, information, persons and design, update and exploitations of the maps' rules which contain both the territorial repartition and the descriptions of identified elements and phenomena. Because of this I consider that GIS technology is a viable method to analyze and identify the phenomena reviewed in this study.

This working method allows the user to store maps, whose entities can be represented as vector form (point, line, polygon), but also as raster; it also allows to create a descriptive and/or numeric database, the main advantage being given by analyzing facilities based on spatial criteria or alphanumerical querying. (Băduț, 2007)

As a result of the erosion interchangeability, transport and accumulation processes in the drainage basin, the minor and major riverbeds of the Niraj river show a varied morphology and in some places unstable, and for this reason time evolution required a special analyzing method, one that would allow not only cartographic representation of the phenomena, but also one that achieves interconnection and interdependence between causal factors based on actual measurements of the riverbed changes.

Due to its positioning at the contact area of the main morphostructural units, mountains and Carpathian foothills, the area is characterized by break of slopes, changes in the river flow and important contribution of solid flow. The alluvium of the floodplain is intense. The resulting morphology will have a dynamic aspect, comprising in the interior sector numerous changes of the watercourse, abandoned channels, river and floodplain deposits in various stages of development, all this indicating that the action of the river is to achieve a dynamic balance in accordance with the system changes. The geographic components mentioned above give unity to the analyzed territorial ensemble, but some differentiations allow us to individualize two sectors: the mountain and the Sub-Carpathian sectors, represented by alternation of the hilly and depression areas differentiated by geological structure, terrain morphology, climatic and hydrological characteristics.

Thus, we processed the GIS database structured as thematic line layers for hydrography, polygon type layers for hydrographic basin characteristics (soil types, lithology etc.), grid type layers for DEM and also for the database derived from its spatial analysis (Slope, Hill shade, Aspect).

The advantage of layer type data is given by the possibility of data overlapping and by the combination made to obtain new maps. Taking advantage of the fact that the database can be updated for different intervals of time we can get layers for the same category of spatial entities for different periods. Using ArcGIS functions we obtained numerical information of different characteristics such as: catchment basin, length of the hydrographic network and average flow coefficients. Because the digital map represents a model of the geographic reality, from the informatics point of view it is made from a collection of files, so of a spatial database.

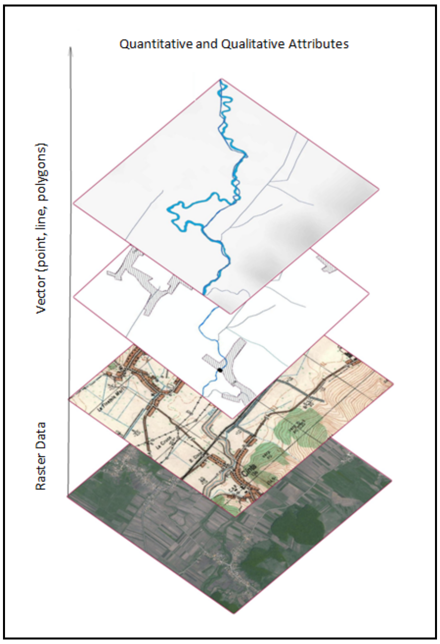


Figure 1. The database structures

2. Data Use and Methodology

The cartographic database realized for this paper can be separated into three big parts: the basic database, which consists of watershed, hydrographic network, lakes, channel systems, the built up area limits, vector information on land use, soil types, geological structure, the geographic database, which contains information such as terrain geo-declivity, land digital model, fragmentation depth, fragmentation density and the third part of the geographic database which is modeled after all other data that are reclassified in order to determine vulnerable areas to riverbed changes. Geographic Information Systems (G.I.S) offers us the possibility to identify the quantitative and qualitative characteristics of the studied geographic system now by analyzing land data, previous to the studied period using information obtained from cartographic data, but it also offers us the possibility to define areas that might have a great potential risk of recurrence and occurrence of the identified processes. So that the obtained data to be compared they were georeferenced in Stereografic 70 projection system, with the related coordinates, the specific projection system forour country. By georeferenced data (geographic referenced) we understand a data that can be linked with a position well-determined on the Earth's surface (Haidu, I., &all, 1998).

The Austrian maps, made after the third surveying campaign (NeueAufnahme), carried out since 1869, were based on St. Anne's 1840 datum, which is a reference point to Bessel's 1841 ellipsoid (adopted by the Habsburgic Empire beginning with 1869); those maps had a scale of 1: 200 000. The temporary and permanent streams, the built-up area, the river deposits, the parallel streams and neck cut-offs were digitized as well. It can be noted the impressive quantity and quality of the content, taking into consideration the technical means of that period. Landforms are represented by hatches, which in addition have contour lines for the used map sheets. The difficulty of extracting data from those sources is given by the lack of contour lines, the low resolution and the use of Hungarian language for settlements, streams and landforms.

Chronologically, the next data source is represented by the Topographic maps, with a scale of 1:25 000 edited between1961-1964. From this cartographic source we also have mapped the watershed, which represents the natural boundary used in this analysis. In order to achieve this limit it was followed both the maximum inflection of the contour lines and also the streams' source area.

SPOT satellite images from 2008, with a resolution of 2.5 m were used for mapping the streams and the built-up area limits, out of the desire to obtain the actual position of the minor riverbed and that of the urban and rural area exposed to risk. Thus it was realised a morphometric database based on major and minor riverbeds characteristics. The database was obtained by making transverse profiles and by direct measurement of the meanders from cartographic materials from different periods.

The analysis was realized in the drainage basin unit due to applied features of the hydrological and geomorphodynamic studies. In the current morphodynamics analysis, the accent was put on phenomenon and variability dimension in time and space.

3. Study Area

The studied territory represented by the Niraj drainage basin is located in the central-east part of the Transylvanian Depression, between the hydrological basin of River Mures in the North and Tarnava Mica's basin in the South. The territory has a 658 km²area. (figure 1)

With a length of 82 km, the Niraj River crosses a succession of landforms: mountain in the upper area, high hill relief in the middle basin and low hills to the confluence. That's the reason why the drainage basin has a steep slope, the floods have a higher torrentially and the river is influenced by the water volume which it receives from its tributaries.

The high density of the settlements situated in river's proximity, predominantly in the major riverbed proves the applied character of this analysis, necessary when it comes to make the inhabitants aware about the danger to which they are exposed, and it also helps to assess the most appropriate measures to protect them against these phenomena.

4. Results and Discussions

In the case of Niraj drainage basin the morphological differences are obvious between the superior and lower basin, both transverse and longitudinal profiles.

The longitudinal profile made by joining the lowest points of the minor riverbed is basically a curve with irregularities, with a downward slope from the source to shedding which sometimes has breaks of slope. The general trend is that of reducing the slope and diminishing the irregularities (Zăvoianu, 1978). In reality this rarely happens, our case showing that the differences are large across the three sectors. The upper sector, which corresponds to Gurghiu Mountains, is characterized by pronounced slope and evident structural and petrographic changes; the middle sector, that corresponds to the Sub-Carpathian area is characterized by a lower slope, with smaller and rarer slope breaks (depth erosion is diminished, the river's energy being channeled to side erosion); in the lower sector, the slope gets even smaller, thus leading to an alluvial and a pronounced lateral erosion. Slope reduction in concordance with geological and soil conditions leads to a horizontally growth of riverbed mobility making meanders and floodplains to appear.

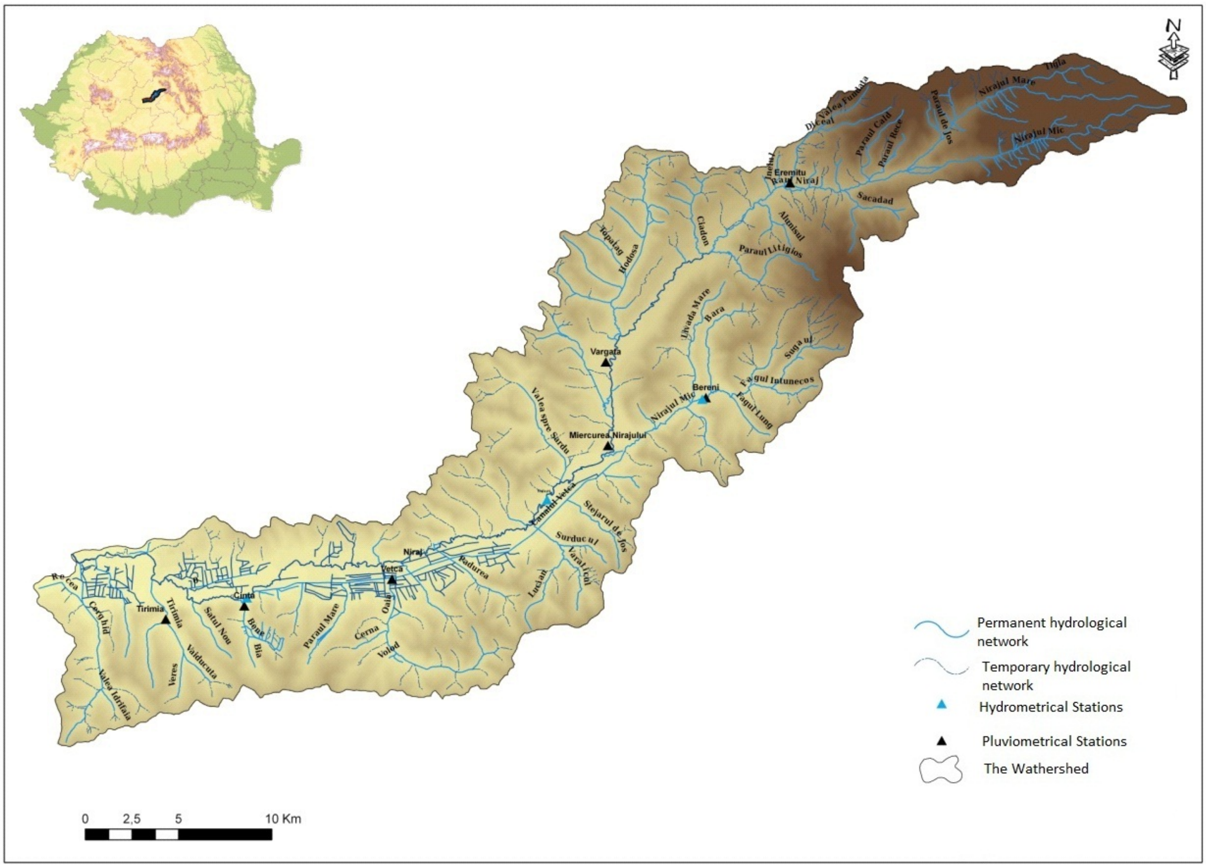


Figure 2. The geographic position of the Niraj drainage basin

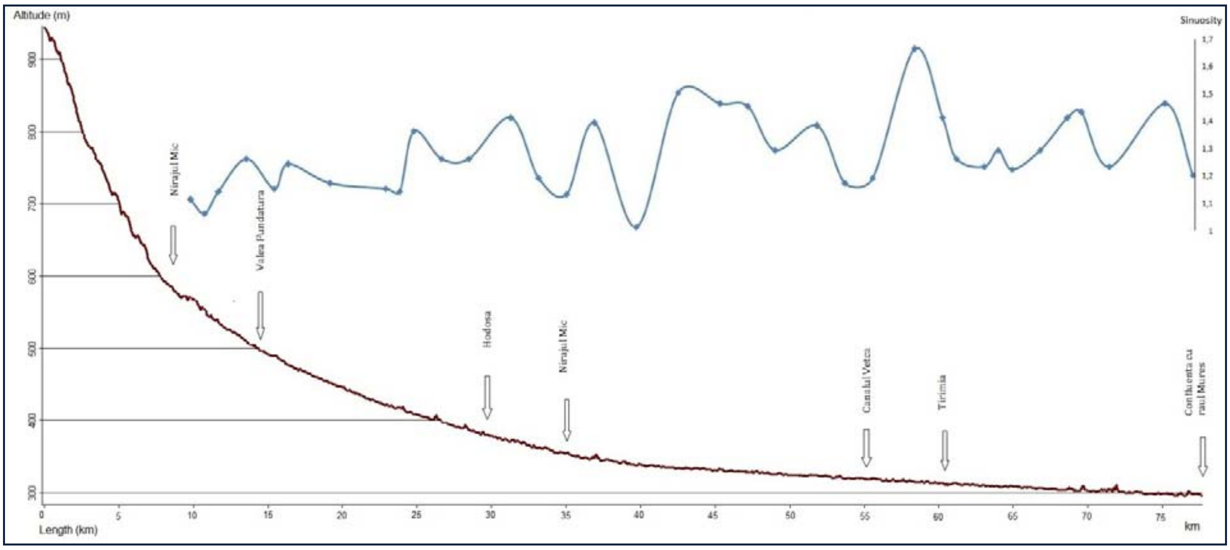
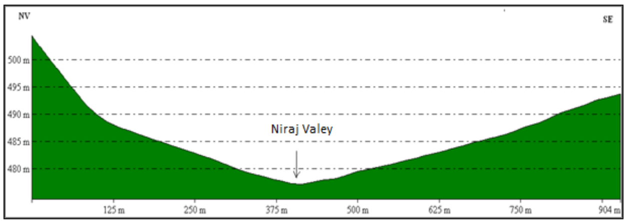
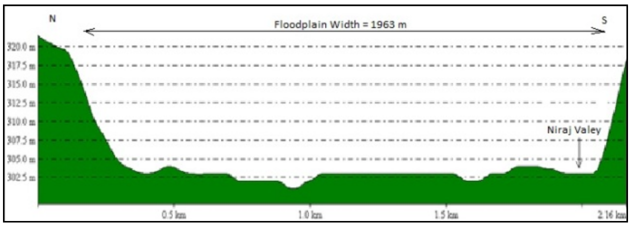


Figure 3. Longitudinal profile of the Niraj River highlighting the sinuosity variation index





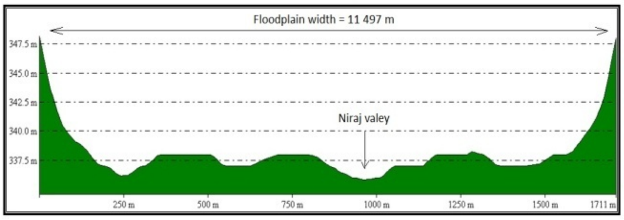


Figure 4. Transverse profile on the Niraj riverfloodplain:
a). downstream to Eremitu
b). downstream to Miercurea Nirajului
c). downstream to Crăciuneşti

The possibility of transforming transverse profiles using GIS software has a wide applicability due to large amount of information obtained through time and energy economy.

Thus it can be observed the mountain profiles with deeper areas, with steep slope and major riverbed widths reduced, sometimes with areas of expansion in the depression areas.

In the Sub-Carpathian hill area, profiles become wider from upstream to downstream, have different terrace levels on which were developed human settlements. However, due to changes in geology, the slopes have a high geomorphologic risk being susceptible to landslides, and flood activity. In the lower basin, due to slope decreasing and geological changes, rivers' energy is channeled towards lateral erosion and sediment transport, thus resulting channel deposits and alluvial fans. Based on these profiles we can identify morphological elements of scientific interest: floodplain terraces, handcuffed meanders etc.

All this aspects raise practical problems: valleys are densely populated because in this area are developed railways and roads. Facilities are subject of riverbed spatial planning, protection against settlements flood, protection of the infrastructure, agricultural land and also for exploitation of water resources from the area.

Table 1: The morphometrical parameters based on transverse profiles

Nr.	The floodplain width (m)	Left Floodplain width (m)	Right Floodplain with (m)	The river length (m)	Straight length	Sinuosity Index	Distance to the built up area (m)
1	404	358	148	1340	1215	1,10	-
2	540	20	520	2667	2513	1,06	-
3	445	189	256	1675	1495	1,12	45,24
4	1028	465	563	1776	1417	1,25	20
5	883	598	285	1278	1129	1,13	Eremitu

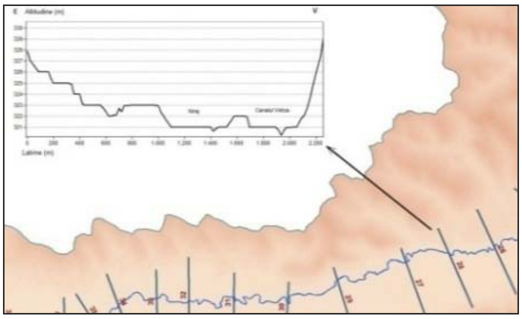


Figure 5: Location of transverse profiles

The minor and major riverbed morphometric variability was studied with the help of longitudinal and transverse profiles. In order to observe the dynamic of transverse sections along the river, morphometric measures can be used based on the principle of transverse section (Rădoane, 2008).

For analyzing the minor riverbed dynamic we have studied its basic element: the meander loop. Data mining method is to realize measurements along river's course, in relation to minor riverbed axis, over the meander loops and meanders. The resulting parameters are radius ofcurvature, wavelength,amplitude, the width of the minor riverbed and the length of the stream between the meander loops.

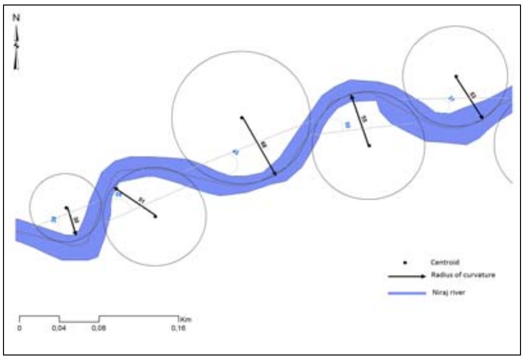


Figure 6: Meander morphometric indices

Table 2: Morphometric indices measured to the level of meander loops

Nr. of meander	Wavelength (m)	Amplitude (m)	Radius of curvature	Length of the river (km)
1	801	290	252	80,6
2	564	120	107	80,4
3	247	94	49	80,1
4	284	93	76	79,9
5	440	145	156	79,8
6	548	198	204	79,6
7	446	169	101	79,2

Overlay analysis of the temporal spatial dataset reveals the vulnerable segments of the river to the process of cut-off and down-valley migration. GIS technology allows statistical analysis of the measured indices, their graphical representation and correlations with altitude, catchment area or river length.

Meandering is the common process of the riverbed morphodynamics and is considered an expression of achieving dynamic balance between the factors that shaped the riverbed (Mac I. 1986). After we analyze the sinuosity index variation for the entire reviewed period, it can be observed its downward trend from 1.7 (specific to meander river) to 1.17 (specific to sinuosity river).

By having this database available we can identify areas with pronounced meanders along the analyzed period and those sectors that are exposed to dynamics, in conditions of extreme anthropogenic and hydrological events.

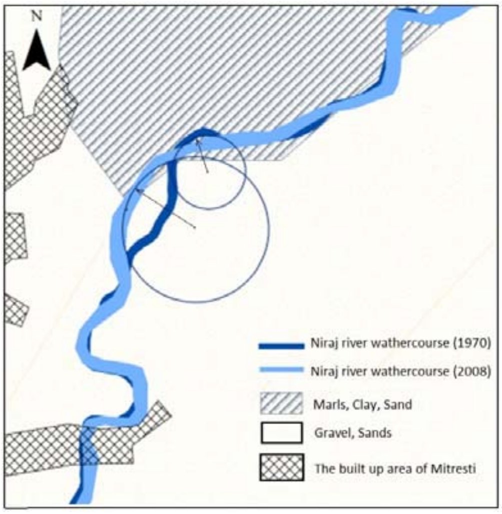


Figure 7. Meander migration in Mitresti area

In the nearby example it can be seen a complex change of the meandering (according to Hooke's classification, cited by Ichim & collaborators, 1989) next to Mitresti village. Seeking the cause of this change in the existing database it was revealed the lithology's role. The meander is positioned at the crossing zone of an area dominated by a marls clay lithology and an area dominated by a sand and gravel lithology. For a clear picture of the factors that influence riverbed dynamics it was analyzed the trend of rainfall and flow that is in a constant growth, contrary to forestation index which places the analyzed region in the weak ecological balance category, affected by human pressure.

The effects of human action in this region are felt especially in the marginal zones of the river dammed sectors. Designed to reduce the negative effects of the lateral erosion, these dams lead to minor bed handcuffing, which at high flows cause an increased erosion in the downstream sectors.

Table 3: Sinuosity coefficient variation between 1806-2008

1806 sinuosity index	1869 sinuosity index	1970 sinuosity index	2008 sinuosity index
1,7	1,67	1,59	1,17

Table 4: The evolution of the sinuosity index and that of the factors involved

Rainfall trend (1950-2008)	↗
Niraj River flow trend (1970-2008)	↗
Afforestation trend index (1970-2010)	↘
Sinuosity trend index (1806-2008)	↘

Where: ↗ represent an increasing trend and ↘ a decreasing trend

5. Conclusions

Although the river provides preliminary information necessary to its planning in order to mitigate negative side erosion, GIS is a valuable tool. This study shows that the processes involved in fluvial morphodinamics are: meander migration, meander growth with the channel cut-off being predominant. A special attention has to characterize the user of this technology because overestimation or underestimation of an indicator may decrease the accuracy of assessment.

By correlating the spatial numerical characteristics of the control factors and having the advantage of obtaining accurate spatio-temporal data, comparable with the possibility of 3D visualization, we consider the advantages of this method for morphodynamic identification and analysis as being a viable one.

BIBLIOGRAPHY

BĂDUȚ, M., GIS. (2007), *Fundamente practice*, Editura Albastră, Cluj Napoca.

BĂTUCĂ, DAN, DUMA, DIDI, ICHIM, IONIȚĂ, RĂDOANE, MARIA, (1989), *Morfologia şi dinamica albiilor de rîuri*, Editura Tehnică, Bucureşti.

FLORINA, GRECU, (2008), *Geomorfologie Dinamică*, Editura Tehnică, Bucureşti.

HAIDU, I, HAIDU, C., (1998), *S.I.G. Analiaza spatială*, edit. *H*G*A*, Bucureşti.

MAC, I., (1986), *Elemente de geomorfologie dinamică*, Editura Tehnică, Bucuresti.

RĂDOANE, MARIA. RĂDOANE, N., (2007), *Geomorfologie aplicată*, Editura Universității din Suceava, Suceava.

RĂDOANE, MARIA, RĂDOANE N., CRISTEA I. (2008), *Evaluarea modificărilor contemporane ale albiei râului Prut pe granița românească,* Revista de Geomorfologie, Vol. I.

MATIAS, KONDOLF, HERVE PIEGAY, (2003), Tools in Fluvial Geomorphology, Editura Wuley, Anglia.

SIDDAN ANBAZHAGAN, S. K. SUBRAMANIAN, XIAOJUN YANG, (2011), *Geoinformatics in Applied Geomorfology*, CRC Press, Florida.

ZĂVOIANU, I, (1978), *Morfometria bazinelor hidrografice*, Editura Academiei, Bucureşti.

[1] "Babeş-Bolyai" University, Faculty of Geography, 400006 Cluj-Napoca, Romania, e-mail: rosca_sanda@yahoo.com

[2] "Babeş-Bolyai" University, Faculty of Geography, 400006 Cluj-Napoca, Romania, e-mail: nelurus@geografie.ubbcluj.ro

[3] "Babeş-Bolyai" University, Faculty of Geography, 400006 Cluj-Napoca, Romania, e-mail: dpetrea@geografie.ubbcluj.ro