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DATABASE SEARCH IN A GIS APPLICATION INTENDED FOR MAPPING THE USE CATEGORIES AND ANTI-EROSION SYSTEMS IN ANTOHESTI WATER CATCHMENT AREA, BACAU COUNTY

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Abstract

There is no news that the use of GIS technique in the engineering field takes place at high level, and has a very well defined place in environment engineering.

This paper shows a sequence of a GIS application in the field of quantification of soil loss as a result of water erosion. The GIS application is exemplified in a water catchment of approximately 4000 ha in Berheci Superior of Bacau County, with intensive water erosion processes, both at the surface and in gullies.

After the development of databases (graphic and alphanumeric), the determination of connections (keys) between them is very important, in order to enable interrogation. Interrogation ensures the value of GIS application, and in this application we can notice 2 interrogation methods. The development method of the interrogations, as well as the response manner in the own designed concept, with a relational alphanumeric database are shown.

This paper shows the importance of correlated databases in the context of statistical analyses for large areas. Following these analyses and by means of the GIS, the most intelligent ecologic and anti-erosional management solutions can be taken in torrential hydrographic water catchments.

Key words: database, interrogation, erosion, GIS, agricultural management.

INTRODUCTION

The use of Geographic Information Systems technique for the management of certain parameters on the environment became a current usual fact. These techniques are widely used both for the studies conducted on small areas (of few hectares) as well as for impact studies at regional or even national level.

The region monitoring and management operations imply a significant volume of data and processing and analysis means. In this context, the determination of the quality of soil and in particular of those impaired by erosional degradation becomes extremely important both for the agricultural owners and for the decision makers in agricultural management area.

If we refer to the determination of the erosional risk, particularly for large areas, this implies the thorough knowledge of all factors that intervene in the performance of the degradation process, namely the parameters which characterize the climate, landscape, soil, use of lands, agricultural operating technologies etc. However, considering that all these parameters

have a spatial distribution, namely receive a certain value at each point in space, the complex monitoring action can only take place within a Geographic Information System

The implementation of these techniques also enables an integrated ecological monitoring, through which the competent bodies can permanently monitor the status of natural resources, generally of the environment factors and anthropic impact, based on the spatial and temporal parameters and coverage indicators, which ensure the information framework required for the strategy and tactics on the prevention of consequences of environment and human activity factors, for the development of forecasts and for the exercise of the operative control on the actions concerning the recovery (improvement) of the ecological status.

In the activity of fight against soil erosion, the purpose of a GIS consists of ensuring the data acquisition, storage and processing. But the most important part is that of providing information (results) which can synthetically characterize, at all times, the status and progress of the degradation process of lands as

a result of torrentiality, drainage and sedimentation, in order to take decisions in due time (Statescu Fl., Zauca D.C., Pavel V.L., 2013).

The use of GIS is required and justified in particular as a result of the provided opportunities related to the review of the multitude of spatial distribution factors which intervene in the triggering and performance of the erosional processes, high costs and long time required for the monitoring thereof through other methods, in particular with respect to large areas.

One of the main components of a Geographic Information System is the database which consists of a graphic database (layouts or georeferenced maps in a projection system) related to an alphanumeric or attribute-type (non-graphic) database (Renard K.G., Foster G.R., 1996).

MATERIALS AND METHODS

Study area

This paper sets out a study, performed through GIS techniques, concerning the evolution of land degradation process through erosion in the reception basin of Antohesti water catchment area, of Berheci river higher water catchment area, Bacău County (Figure 1).

The reception area is of 3963 ha, with a highly fragmented relief, hilly type and average slopes of more than 15 %. The slopes are affected by surface erosion, deep and. The sloping land was affected by sheet erosion, gully erosion and by active landslides.

Dominant soils are chernozems and brown soils, and the most extended uses are: arable land – 47.2%, pasture land – 26.78% and forest – 16.8%, (Biali and Popovici, 2003).

Data and methodology

In order to determine the soil loss following the surface erosion we used the Universal Soil Loss Equation (USLE) in the form used in Romania – ROMSEM (Moțoc M., Tuhai A., 1998.) and which includes the parameters of spatial distribution concerning: the pluvial erosivity (K), the soil erosivity (S), the gradients and length of discharge on versants (i, L), the purposes of the land (C) and the existing anti-erosion arrangements (Cs).

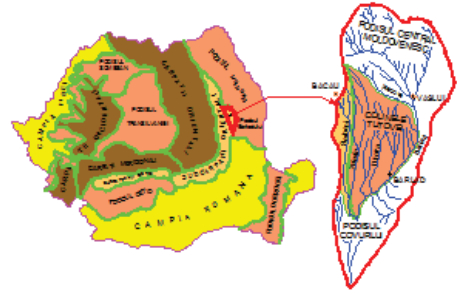


Figure 1. Location of research (Berheci catchment)

In order to develop the geo referenced database and an attribute-type database, respectively, required for the storage and processing according to the algorithm of the above mentioned equation, the raster procedure was used, which consisted of the overlap of the cartographic documentation (site plans 1:25.000) of a rectangular grid with the cell / pixel size of 25 x 25 m. The USLE equation was successively applied within GIS project, in order to determine the potential soil loss (potential risk) and the actual soil loss (actual risk) corresponding to each cell.

The GEO-GRAPH Geographic Information System, a GIS - type software, developed by Suceava IT Service Company was used in this application for the implementation of techniques of the Geographic Information Systems.

The GEO – GRAPH system is distinguished as an open system through the structure of the ASCII format input data. This structure enables the access to the drawing information located outside the system, thus facilitating the data integration with other systems or with files generated by the user by means of own software. The user is able to generate own software which will generate input data recognized by the GEO – GRAPH system, such as: data taken over from the total stations as files of coordinates and outline or data from files such as *.dxf* type, generated following vectorization (Biali Gabriela, Cojocaru Paula, 2015).

The GEO – GRAPH Geographic Information System contains the following primary modules:

- CAD module for the representation of vectorial drawings and raster images.

- The alphanumeric data interrogation module with spatial graphic localization.
- The import / export module of vectorial drawings.
- The module for generation of symbols and representation of cartographic elements on digital plans.
- The module of “drivers” for the connection with input / output peripherals.
- The module of background raster image vectorization.
- The interrogation module

The interrogation module of this GIS application performs the interrogation of alphanumeric data by means of SQL controls, both in xBase data management system and in relational S.G.B.D. in the client / server system. This module enables powerful facilities provided to the user in order to develop the own application. In this context, we could mention:

- definition of the database structure;
- definition of the index keys for access to the database;
- definition of relations between the tables (joins);
- definition of views (hypothetic tables defined by the user);
- definition of the connection relation between the graphic information and the alphanumeric information (rule setting);
- SQL controls editing by the user.

The alphanumeric database was developed and managed with FoxPro 2.6 in Windows. This S.G.B.D. is a relational system for the management of databases. In a simple meaning, a relational system implies several databases (commonly referred to as “tables”) opened at the same time, connected by means of common fields. The number of databases and common connecting fields define the complexity of the Satabase management system. Figure 2 shows the number of tables which set out the alphanumeric database in the application.

The *.dbf* tables of the database were automatically generated following several processing actions (except for “Coef S” table, which refers to the soil characteristics according to the soil unit sheets, based on which the S erodability coefficients were determined).

Name	Ext	Size
CoefS	DBF	65,422
Cote	dbf	1,877,480
Directii	dbf	1,877,480
Eroziune	dbf	1,877,480
Folosint	dbf	2,743,996
Pante	dbf	1,877,480
Sisteme	dbf	2,743,996
Soluri	dbf	2,743,996

Figure 2. “.dbf” files which set out the alphanumeric database of the GIS project

For each *.dbf* table, the structure was defined first by: the names of fields, the type and length thereof, depending on the nature of data to be uploaded.

The structure defined in a first stage can be changed by the user at all times, by means of the “*modi stru*” control, but it is extremely important to remain unchanged as of the moment of defining the “connection keys” between the alphanumeric database and the graphic database, otherwise the interrogation turns out incorrect and even impossible.

The key of a GIS consists of creating the connection between the alphanumeric database and the graphic one.

In order to enable the database interrogation both by “Fox keys” and “SQL keys”, the projection of correlation between the files of the alphanumeric database and the graphic one is required in the stage following the completion of *.dbf* tables.

The *.ast* type are thus developed, based on the following rules:

- ⇒ the files with *.ast* extension should have the same name as the *.dbf* files (tables);
- ⇒ the creation in the work directory of the file referred to as “Catalog.ast” which contains the list of all tables regarding which an interrogation “connection” is intended and the fields indexed for the connection between tables (Figure 3);
- ⇒ these files should be edited by maintaining the structure of each table in FoxPro through the “*disp stru*” control, by specifying the connection fields between tables for interrogation purposes.
- ⇒ indexation of fields in the database, required for interrogation purposes (Figure 4).

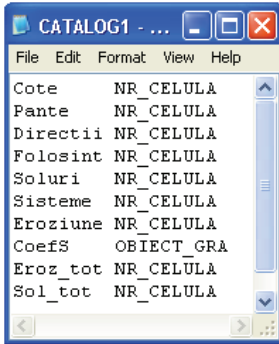


Figure 3. Sequence with the “Catalog.ast” work directory

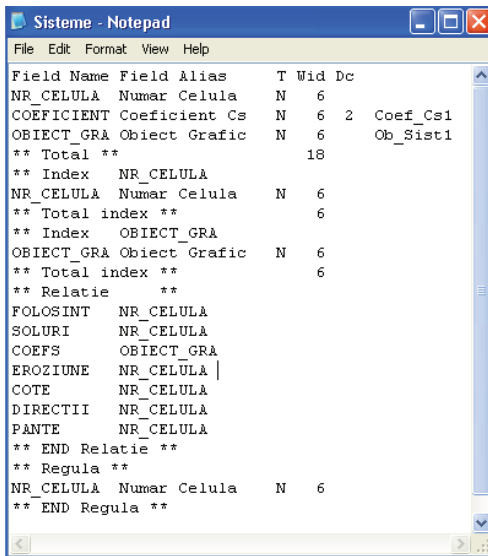


Figure 4. Editing syntax of an .ast type file

Few rules to comply with:

- ⇒ The “Field Name” should be as identical as possible with the one set out in the .dbf table;
- ⇒ “Field Alias” represents the description of fields (not more than 15 characters);
- ⇒ The “Coef_Cs1” and “Ob_Sist1” provisions mentioned on the right side mean that, upon the database interrogation for the two fields, supporting tables, called dictionaries, shall be displayed; these dictionaries are developed by the user, with no specific format requirements, in order to provide additional and extremely fast information for interrogation;
- ⇒ For each separate table there should be specified the indexed field, as well as the “Relation” of the relevant table with the other

tables of the database (by means of the field description).

RESULTS AND DISCUSSIONS

Two types of interrogation were used in the GIS project contemplated herein: through “Fox Keys” and through “SQL language”.

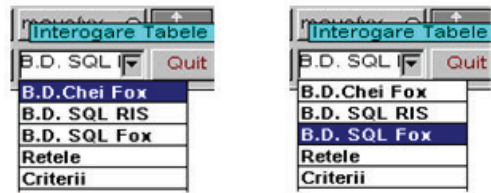


Figure 5. Sequence of the potential interrogation types of the application

The main menu of the Geo – Graph system enables the user to select the interrogation options.

In the first option, *Relation – Fox keys*, the interrogation takes place from the graphic database towards the alphanumeric database (as in the example set out by Figure 6).

The interrogated graphic object (cell in this case) shall be highlighted compared to the rest of the graphic background (the chosen selection color is white).



Figure 6. Interrogation of the database by means of “Fox Keys”

Immediately after the click, the first table of the Catalogue shall be displayed in the screen area (Figure 7) with the information computed and saved in the database.

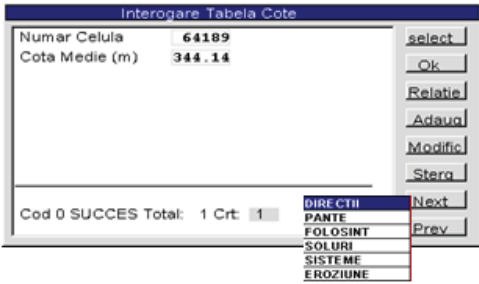


Figure 7. Answer of the interrogation by means of the function "Relation – Fox keys": first "Cote" table

By accessing the "Relation" button, a window will be opened next to the table, which enables the selection for interrogation of the other tables with which the active table has connection keys defined by the index; thus, the other elements may also be displayed for the same cell, solely by switching from one table to another (Figure 8 - 13).

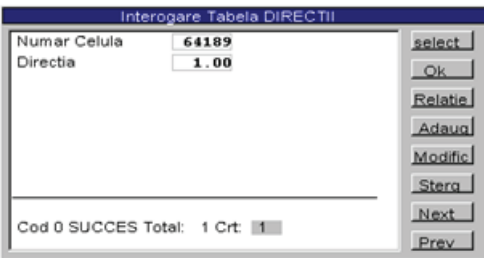


Figure 8. Answer of the interrogation by means of the "Relation – Fox keys" function with the "Directions" table

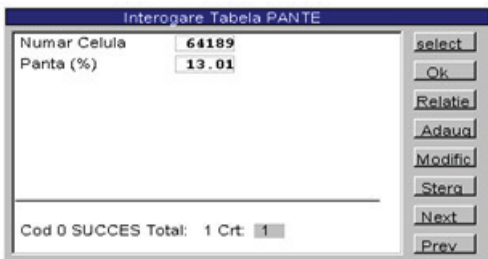


Figure 9. Answer of the interrogation by means of the "Relation – Fox keys" function with the "Gradients" table

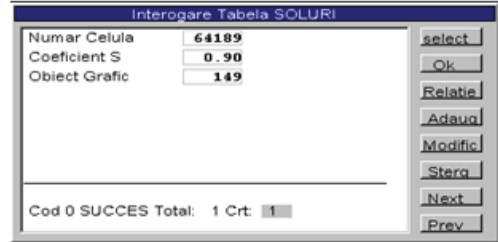


Figure 10. Answer of the interrogation by means of the "Relation – Fox keys" function with the "Soil" table

The update of the alphanumeric database can be easily performed by clicking the "Add", "Change", "Delete" buttons.

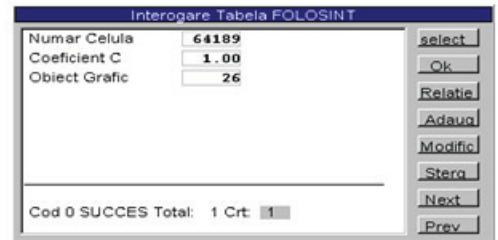


Figure 11. Answer of the interrogation by means of the "Relation – Fox keys" function with the "Purpose" table

The "Next" button enables the user to view, one by one, the interrogated graphic objects.

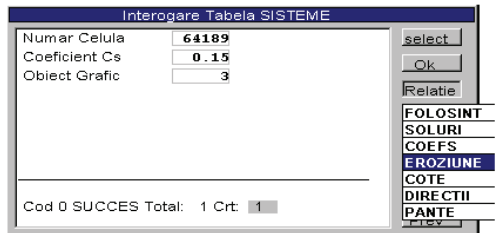


Figure 12. Answer of the interrogation by means of the "Relation – Fox keys" function with the "Systems" table



Figure 13. Answer of the interrogation by means of the "Relation – Fox keys" function with the "Erosion" table

In case of interrogation through the SQL language, click on the “Table” button in order to select the intended interrogation topic, either by selecting a table of the database, or by selecting a virtual table, (the „views” can be recognized based on the contents of the “underline” character of the name thereof). Following the selection of the table or view, the interrogation key is automatically selected. The key represents a group of fields which will receive values in order to meet the interrogation requirement, and afterwards the system performs the search of entries in the database. Figure 14 shows an example of answer of the interrogation in a virtual table, namely “Tabel Eroz_tot”. Thus, when the interrogation topic is selected, the system tries to fill-in values that meet the set out requirements, the fields defined through the “Eroz_tot.ast” file, by

using the name of the selected object (cell) as input data.

The second interrogation type based on SQL keys can take place by clicking the “Select” button and setting out, with the keyboard, numeric values, the cell or cells which meet the interrogation requirement following to be displayed (Figure 14). Thus, the “Select” button enables the performance of an interrogation from the alphanumeric database towards the graphic database (Biali Gabriela, Statescu Fl., 2013).

The following example shows another SQL interrogation: it aims at identifying the areas of the water catchment with the “non-productive” use category (Wischmeier W.H., Smith D.D., 1978); thus, only the “C coefficient” field is filled-in by specifying the interrogation requirement (Figure 15).

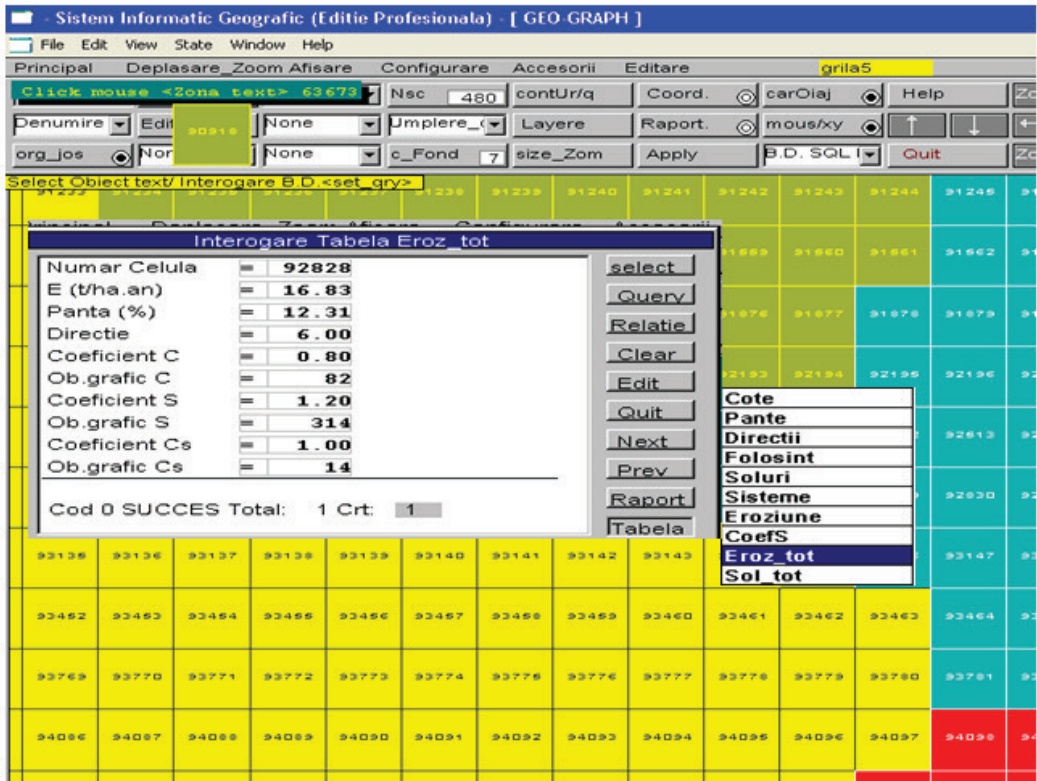


Figure 14. Answer of the SQL interrogation on the information layer of purposes in Antohești water catchment; List of interrogation selection possibilities

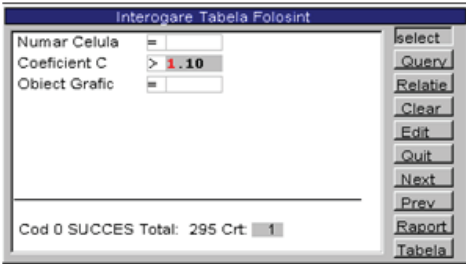


Figure 15. Example of interrogation based on SQL keys

The answer of the interrogation brings in the center of the screen the first cell that meets the requirement, as well as the interrogated table. The lower part of the interrogation shows the total number of cells which meet the interrogation requirements, and the fields are filled-in with the values of the first cell which was identified in the list (Figure 16). The answer consists of 295 cells, which represent $295 \times 25 \times 25 \text{ (m}^2\text{)} = 18.4375 \text{ ha}$.

By clicking the “Next” button, the entire list is displayed, both graphically and alphanumerically.

Within the GIS application, the system was designed so as to enable the user to generate their own criteria by means of the SQL language, by clicking the “Edit” button or operating changes in the window, through the selected interrogation controls (Figure 17).

The interrogation is performed by means of SQL controls, and does not require the existence of the key in the database (as in the case of the previous interrogation). It should also be mentioned that the Client / Server databases do not use interrogation keys, but only SQL controls.

The following example shows a criterion-based interrogation by means of editing an own SQL control. The interrogation has two requirements, namely: it is intended to identify the area of the water catchment occupied by plough land (which means $C > 0.8$) and no protective anti-erosional systems apply ($C_s=1.0$).

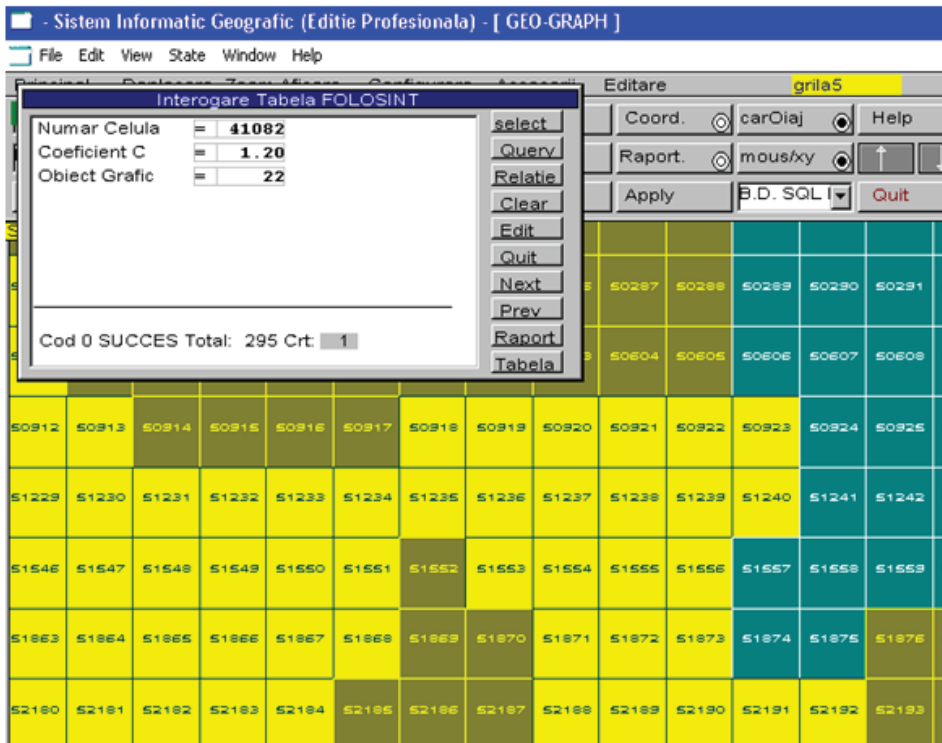


Figure 16. Criterion-based interrogation by means of SQL language; answer of the interrogation

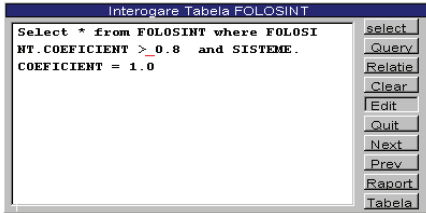


Figure 17. Syntax of the criterion-based interrogation SQL control

The answer of the interrogation in a graphic form is showed in Figure 18. All colors were deactivated and only the areas that met the interrogation requirements are highlighted.

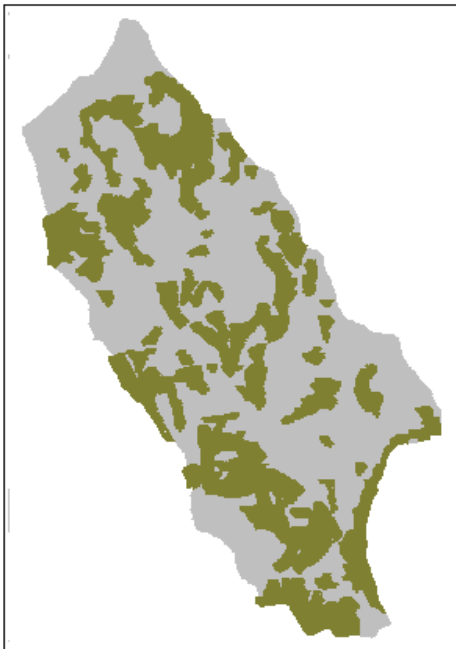


Figure 18. The answer of the interrogation in a graphic form

CONCLUSIONS

The implementation of the Geographic Information Systems (GIS) in the analysis of erosional processes for large areas ensures the possibility to perform a complex monitoring on the quality of versant soil and enables the timely performance of the most appropriate protection and preservation actions concerning the fertility thereof.

The use of GIS for the analysis of land degradation processes and for the forecast of the time progress thereof is possible for both the relatively small plots of certain holders, located more or less uniformly within a territory, as well as for larger areas, water catchments or regional and administrative units.

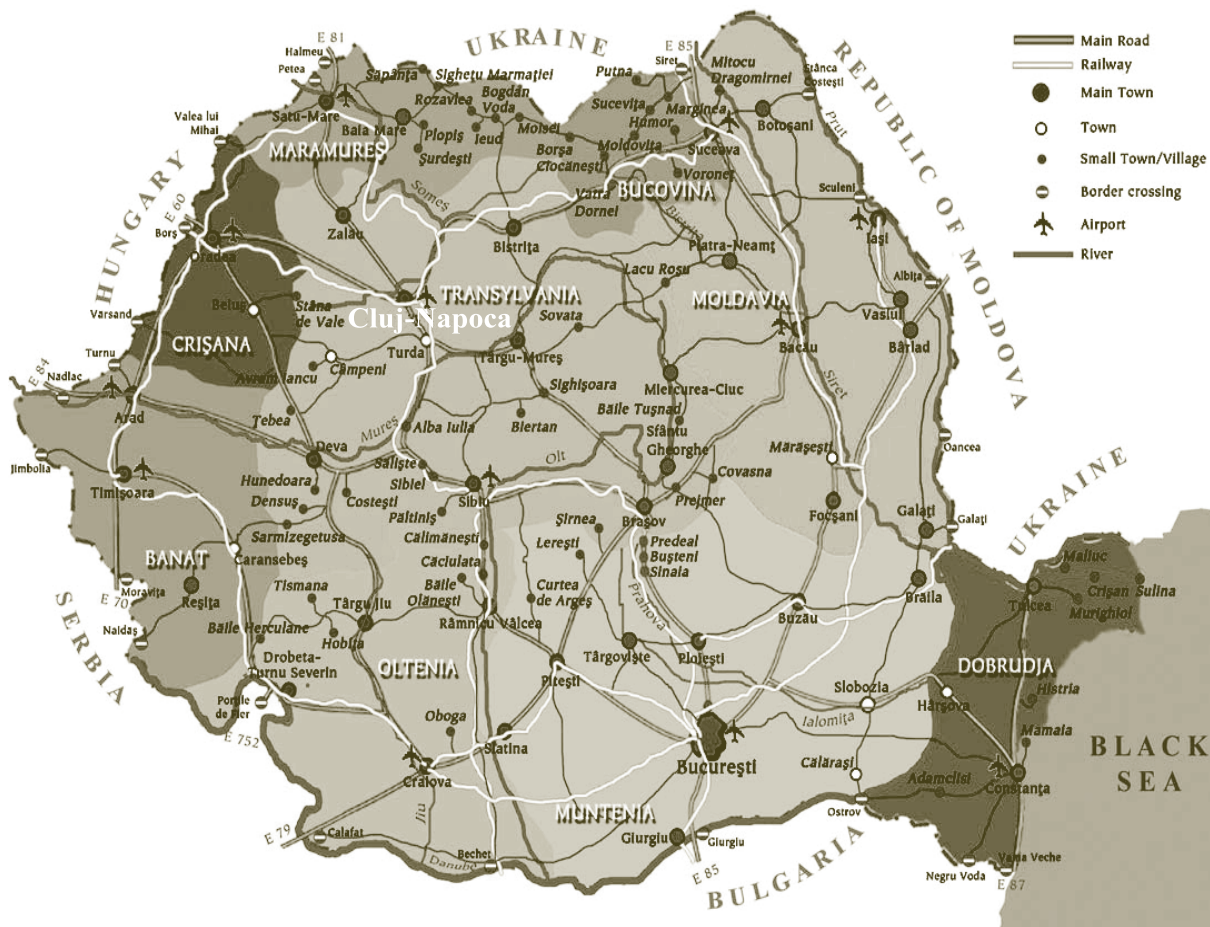
A major advantage of the GIS consists of the possibility to perform an interrogation on any uploaded information layer, the database being a relational one.

The possibility to conduct statistics based on the information obtained after processing such. If, for values of C, S, Cs coefficients, one could have determined with a certain approximation the related areas, directly from the site plans, in case of landscape parameters (gradient, flowing directions) and erosion, in case of the analyzed water catchments, this would not have been possible.

One should note the facilitation of the criteria analysis due to the existence of virtual tables within the project. The criteria analysis enables us to obtain information from different layers.

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MONITORING THE EFFECTS OF EXCESSIVE USE OF CHEMICAL FERTILIZERS ON UNDERGROUND WATERS BY USING THE GIS TECHNIQUE

GABRIELA BIALI¹

ABSTRACT. – **Monitoring the Effects of Excessive Use of Chemical Fertilizers on Underground Waters by Using the GIS Technique.** This paper highlights the increase of nitrates and nitrites content in the underground waters, in correlation with the levitation to the underground of the nitrogen quantity on the agricultural lands, by using a modelling method through the GIS technique.

The research is conducted for the underground waters of an area of Prut River catchment, and for the assessment of NO₂, NO₃ concentration, water samples are taken from a limited number of boreholes (44 boreholes). These boreholes are randomly distributed in the area and only some pieces of information are acquired from the laboratory tests. Based on this source data, by means of an interpolation method under software Surfer 8.1, the maps of NO₂, NO₃ concentration distribution were created. The spatialisation is made on 1880 cells and the results set out herein are at the level of a 2015 survey year.

The Romanian Law on fresh water sets out that although the nitrites and nitrates are within the admitted maximum limits 0.5 mg/l and 50 mg/l, respectively, another indicator should also be taken into consideration:

$$\frac{\text{Nitrates}}{50} + \frac{\text{Nitrites}}{3} \leq 1$$

Thus, in the application, the mathematical modelling generated a map of the above mentioned indicator distribution. One can notice that, under certain circumstances, although the NO₂ and NO₃ indicators are within the admitted maximum limits, this indicator is still exceeded. This leads to the conclusion that in certain areas of the analyzed region there is significant chemical pollution, fact that leads to safety actions concerning the use of well water.

Keywords: *modelling, underground waters, spatial distribution.*

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1. INTRODUCTION

The incorrect irrigation and drainage, associated with other inappropriate practices (monoculture or short term cropping systems, excessive loosening of the soil, especially through numerous superficial works etc.) to which are sometimes added the inexistence of anti-erosion systems of culture on the agricultural versants, determine the appearance and intensification of physical and chemical degradation of lands.

Both the physical pollution through processes such as: water or wind erosion, the destructuring, compacting etc. and chemical pollution through the alluvial transport with significant pesticide quantities, contribute in this manner even more to sensitizing, favouring and emphasizing the degradation of the quality of underground waters, considered as being "*the last hope of drinkable water*".

The activity of knowing the quality of underground waters is carried out at the level of large hydrographic basins, on morphological units, and within them, on aquiferous structures (underground), through the hydrogeological stations, comprising one or more observation forages.

The probable causes for which in the majority of cases the groundwater do not correspond to the requirements to use them in potable purposes:

- The pollution of surface waters;
- The conditions and natural hydro geochemical processes that favour the passage to solution of different anions and cations;
- The intensive development of agriculture in the last decades with the excessive use of chemical fertilizers based on azoth and phosphor and of pesticides, led to their accumulation in the soil (or the accumulation of degradation products);
- The effects of the passivity of former zootechnical complexes of high capacities regarding the measures for the conservation of environment factors;
- The climatic, hydro geological particularities and the exploitation of irrigation systems that contributed to the mineralization of organic matter from the soil and the migration of substances resulted from these processes.

A special problem regarding the quality of underground waters is represented by their content in nitrates -NO₃ and nitrites -NO₂.

In order for the underground waters to be considered appropriate from the qualitative point of view, it is necessary that the quality indicators belong to the maximum admitters-MAC concentrations, imposed through the Law of Potable Water no. 410 /2002 modified and completed with Law 311/2004. In addition, the assessment of underground water quality supposes a complex action of interpreting

all the quality indicators, of correlating the values obtained in the laboratory for different indicators, even in the situation that, by comparison with MAC, we ascertained that the concentrations were situated within these limits.

The main sources of accumulated nutrients are represented by the direct evacuations from agriculture, drains and erosion, and by the effluents of the localities' sewage stations.

We estimate that the largest part of the quantity nutrients is due to the sources from agriculture (diffusion sources). For the underground waters to be considered potable, the value of indicators NO_3 and NO_2 must be situated within MAC, imposed by the Law of potable Water (NO_3 -50 mg/l, NO_2 -0,5 mg/l). On the other hand, although the values of NO_3 concentrations, respectively NO_2 do not exceed MAC, a certain condition for which the following formula is applied, must be complied with:

$$\frac{\textit{nitrates}}{50} + \frac{\textit{nitrites}}{3} \leq 1.$$

In which the nitrates and nitrites concentrations are expressed in mg/l.

2. STUDY AREA

The underground waters from the Prut River catchment area are quartered in porous-permeable deposits of Quaternary and Tertiary age disposed over older Cretaceous, Silurian and Presilurian formations, situated at different depths but which, because of climatic and layer conditions generally have reduced debits and high content of salts.

The underground waters within the Moldavian platform, in relation with the natural possibilities of drainage, respectively of their connection with the surface waters are: under pressure (depth) and phreatic (free).

In the category of free underground waters, we include the aquiferous waters without pressure, where we notice a supply area and an unloading area; therefore, they are naturally drained.

The phreatic waters are accumulated in the first horizon of permeable rocks and are supplied from precipitations, from the hydrogeological neighbour units and locally from the overflow of rivers.

The waters under pressure are accumulated in permeable deposits intercalated between the loamy-clay layers distributed on several levels are encountered in the areas sectioned by the valleys of rivers. The supply of this type of aquiferous is ensured from the hydrogeological superior units through the higher end of the layer and the drainage occurs through the lower end.

Most of the times, the deposit conditions are favourable to the water mineralization; to these, the salts from the soils washed from the infiltrated precipitations are frequently added, and as a result the phreatic waters have a higher mineralization degree.

In the Prut catchment area (Fig. 1) the groundwater are quartered in sandy deposits of quaternary age, with clay intercalations of small hydrogeological importance and gypsum horizons. In these conditions, the exploitable conditions are encountered in the rivers' meadows, in weakly permeable and sulphated deposits. Generally, we notice the sulphated waters with mineralization and high hardness with a reduced debit degree.

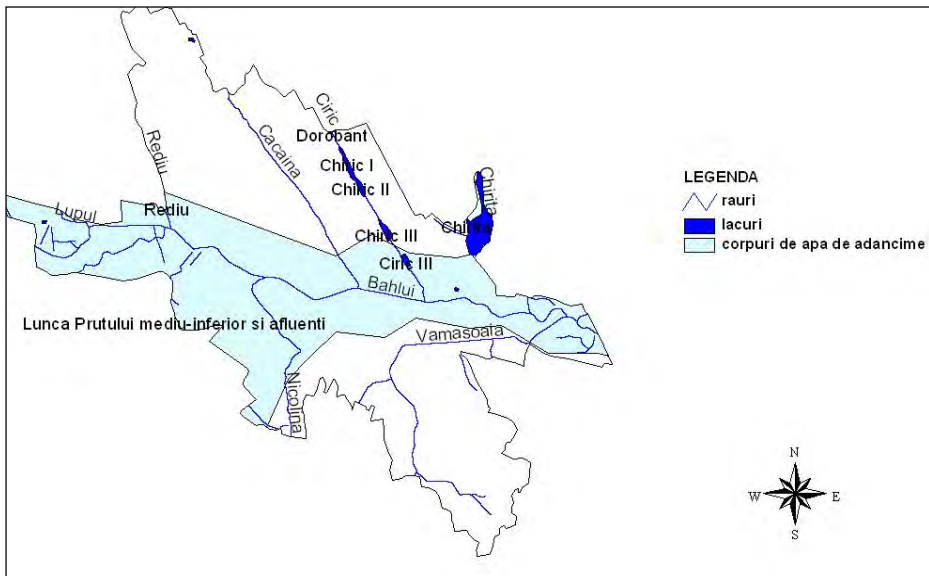


Fig. 1. Study area: Iași City

3. METHODS OF THE RESEARCH

3.1 Entry data

As entry data, we used the values NO_2 , NO_3 (mg/l) determined in the Laboratory Water Quality belonging to the Prut Water Direction at the level of 2015. The analyses were made on water samples assayed from 44 observation forages from the Prut hydrographic basin (located through the STEREO 70 coordinates) belonging to the National System of underground waters quality Surveillance, e.g. (Table 1).

Then we calculated the value of the indicators assessing the water potability:

$$\frac{\textit{nitrates}}{50} + \frac{\textit{nitrites}}{3} \leq 1$$

Table 1. Drilling parameters of the study area

Forage no.	Plan coordinates in the STERO 70 projection		NO ₂ (mg/l)	NO ₃ (mg/l)	INDICATOR: $\frac{\textit{nitrates}}{50} + \frac{\textit{nitrites}}{3}$
	X (m)	Y (m)			
1	634150.562	751325.439	0.026	5.065	0.1100
2	633863.404	750817.791	0.42	44.67	1.0334
3	658289.763	722926.687	0.803	19.621	0.6601
4	667731.251	701856.350	0.0385	97.695	1.9667
5	667133.890	701741.096	0.016	0.8	0.0213
6	665339.264	701495.313	1.022	261.53	5.5712
7	696082.457	653053.352	0.570	5.80	0.3060
8	693880.402	653097.634	0.240	8.30	0.2460
9	690868.400	653521.559	0.05	3.70	0.0900
10	691156.982	650027.408	1.40	46.90	1.4030
11	691159.514	649927.431	0.37	5.75	0.2367
12	710883.965	637421.058	0.10	3.80	0.1095
13	706655.705	634513.032	0.38	5.55	0.2360
14	720455.610	622856.785	0.12	1.80	0.0743
15	717542.139	619381.882	0.15	1.00	0.0700
16	740100.524	589639.041	0.006	30.55	0.6130
17	747776.891	570825.278	0.0495	27.075	0.5580
18	743885.527	538616.078	0.008	27.385	0.5504
19	739858.249	611963.055	0	17.225	0.3445
20	615773.355	714936.515	0.0785	3.865	0.1035
21	646264.066	708012.499	0.023	3.35	0.0747
22	646069.205	707807.432	0.041	0.59	0.0255
23	645874.343	707602.365	0.052	16.275	0.3428
24	659898.363	683348.529	0.098	9.36	0.2199
25	658908.750	682923.178	0.169	9.715	0.2506
26	637665.861	688184.548	0.055	3.05	0.0793
27	646075.989	683997.085	0.0735	0.2975	0.0305
28	646222.338	658591.021	0.05	1.50	0.0475
29	711030.507	631622.380	0.09	8.80	0.2062
30	711249.593	634829.224	0.195	4.40	0.1530
31	649494.205	651871.758	0.03	2.25	0.0552

Forage no.	Plan coordinates in the STERO 70 projection		NO ₂ (mg/l)	NO ₃ (mg/l)	INDICATOR: $\frac{\text{nitrate}}{50} + \frac{\text{nitrite}}{3}$
	X (m)	Y (m)			
32	655811.718	647330.530	0.07	1.25	0.0488
33	655421.985	646920.496	0.02	1.20	0.0292
34	657439.168	646271.449	2.02	1.54	0.7045
35	657113.880	647263.549	0.45	43.50	1.0200
36	637851.363	720103.554	0.066	2.65	0.0750
37	670722.327	674719.812	0.38	3.85	0.2020
38	748618.872	557241.570	0.467	48.65	1.1287
39	746724.431	556993.839	0.0085	11.615	0.2351
40	745319.914	580868.538	0.015	1.06	0.0262
41	745945.104	546232.553	0.043	2.675	0.0678
42	745845.131	557225.907	0.021	0.275	0.0125
43	749219.143	602851.455	0.06	0.775	0.0355
44	746924.780	592018.866	0.03	0.97	0.0294

3.2 The creation of thematic layers regarding the distribution of NO₂, NO₃ concentrations

Because their evaluation is made by assaying water samples from a limited number of forages distributed randomly in the territory, according to the laboratory analyses, only punctual information is obtained (Biali et al., 2013).

Starting from a limited number of forages and respectively samples, it is only possible to approximately assess the quality of underground waters from the entire territory, being difficult to elaborate in due time the most adequate intervention measures.

Starting from this source data, the concentrations of different pollutants (in the case of our application) represented in MNT are generally derived with the help of an interpolation. For this application GIS we used the Surfer 8.1 software (method of interpolation – Kriging) (Fig. 2).

Among the 12 interpolation methods put at the disposal by Surfer we chose in order to space the punctual information the Kriging interpolation method and obtain of thematic layers regarding the distribution of NO₂ (Fig. 3) and NO₃ concentrations (Fig. 4).

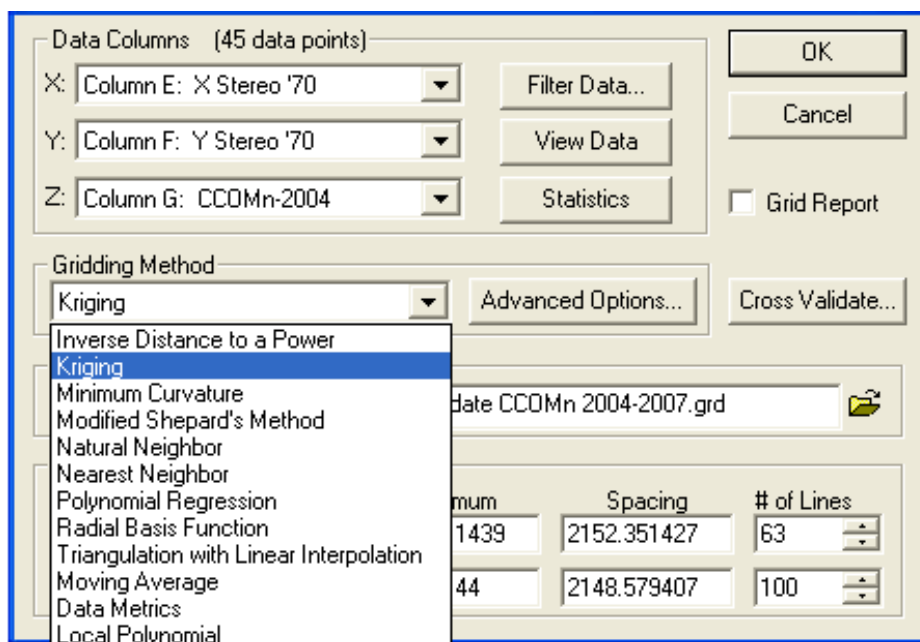


Fig. 2. Detail Surfer software; choosing the method of interpolation and setting the pixel size

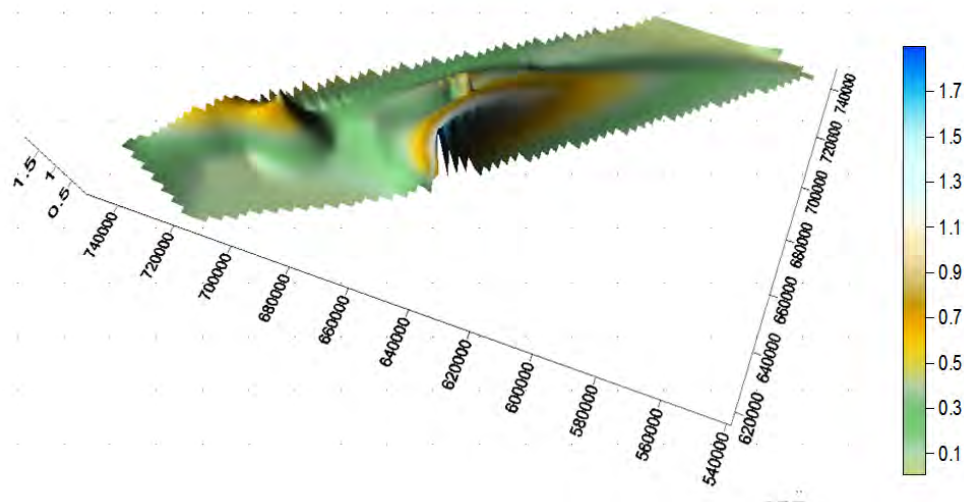


Fig. 3. The thematic layer regarding the distribution of NO₂ (mg/l) in the territory studied in 2015; 3D representation

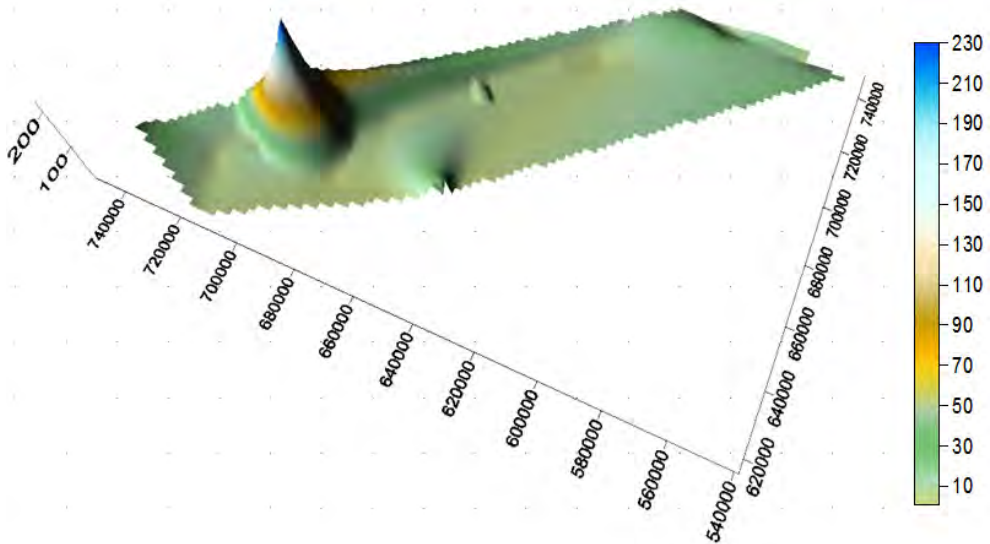


Fig. 4. The thematic layer regarding the NO_3 (mg/l) distribution in the territory studied in 2015 3D representation

4. RESULTS AND DISCUSSIONS

Starting from the values of concentrations determined in the laboratory on water samples assayed from the 44 forages, after the interpolation, we obtained concentrations in 1880 points.

Also we will achieve a spatiality of the indicator $\frac{\text{nitrites}}{50} + \frac{\text{nitrites}}{3}$.

The values obtained afterwards in all the raster points (located through the X and Y coordinates) after interpolation, in each point situated in the centre of a cell (Table 2).

With Surfer software one obtains the thematic layer regarding the distribution of the values of the indicator $\frac{\text{nitrites}}{50} + \frac{\text{nitrites}}{3}$ (Table 2) and (Fig. 5).

Table 2. The values obtained after interpolation with SURFER, in each of a cell

Cell No.	X (m) Stereo '70	Y (m) Stereo '70	NO ₂ (mg/l)	NO ₃ (mg/l)	$\frac{\text{nitrate}_5}{50} + \frac{\text{nitrite}_3}{3}$
1	742762.1	542913.2	0.031926	23.3845	0.478331865
2	740609.7	545061.8	0.035238	24.0515	0.492776112
3	740609.7	547210.4	0.051815	22.16654	0.460602676
4	742762.1	547210.4	0.041741	18.80309	0.389975532
5	742762.1	542913.2	0.031926	23.3845	0.478331865
.....					
1465	652363.3	691165.2	0.245243	49.75168	1.076781388
1466	654515.7	691165.2	0.296957	63.04128	1.359811051
1467	656668	691165.2	0.352662	77.70399	1.671633735
.....					
1500	676039.2	693313.8	0.388856	44.77624	1.025143427
1501	678191.5	693313.8	0.505746	29.65145	0.761611042
1502	628687.5	695462.4	0.066127	3.256486	0.087171995
.....					
1568	671734.5	699759.5	0.396986	49.84778	1.129284183
1569	673886.8	699759.5	0.55154	29.90772	0.782001106
1570	624382.8	701908.1	0.070366	3.463758	0.09273046
.....					
1614	669582.1	704056.7	0.466425	45.10777	1.057630446
1615	622230.4	706205.3	0.07223	3.654572	0.097168085
1616	624382.8	706205.3	0.069843	3.942739	0.102135922
.....					
1879	637296.9	744879.7	0.257995	19.82124	0.482423055
1880	635144.5	747028.3	0.290876	28.09792	0.658916941

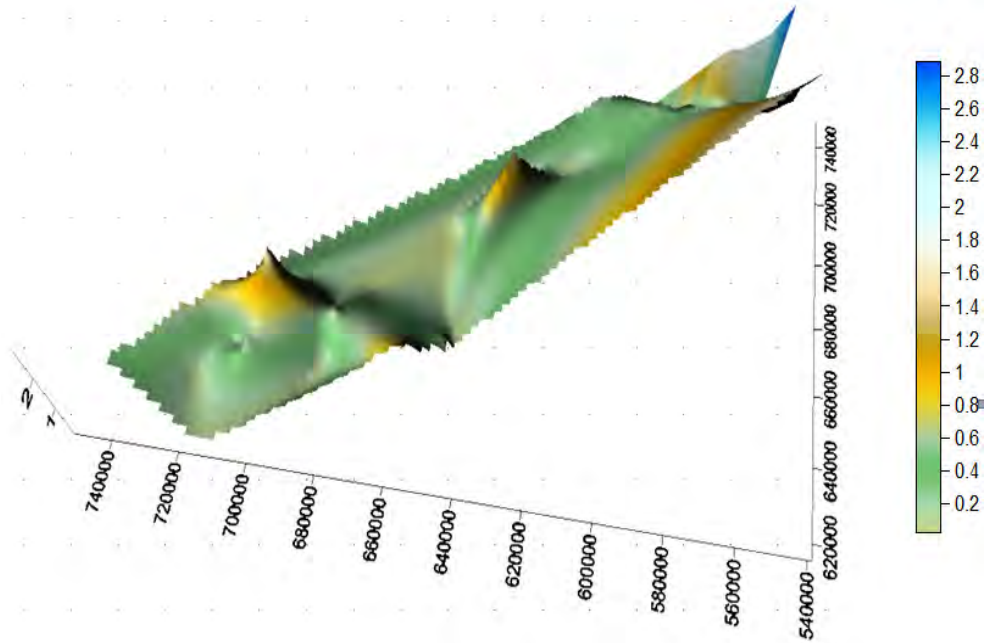


Fig. 5. The thematic layer regarding the distribution of the values of the indicator $\frac{\text{nitrates}}{50} + \frac{\text{nitrites}}{3}$ in the territory studied in 2015 (3D representation)

4.1. The interpretation of results obtained

For the results interpretation, we compared the values of NO_2 and NO_3 measured in the laboratory on water samples taken in 2015 from the 44 surveyed boreholes of Prut catchment area, with the maximum admissible values of Law no. 458/2002, as amended and supplemented through Law no. 311/2004.

The maximum admitted concentration for NO_2 is of 0.5 mg/l, and for NO_3 is of 50 mg/l. The value of indicator $\frac{\text{nitrates}}{50} + \frac{\text{nitrites}}{3}$ should be lower or equal to 1 (Table 3).

Table 3. Summary of the results

Range of values	Indicator
Range of values	NO ₂ (mg/l)
0 mg/l - 0,5 mg/l	93,5 %
>0,5 mg/l	6,5 %
Range of values	NO ₃ (mg/l)
0 mg/l - 50 mg/l	93,2 %
>50mg/l	6,8 %
Range of values	$\frac{\text{nitrates}}{50} + \frac{\text{nitrites}}{3}$
0-1	89,65 %
> 1	10,35%

5. CONCLUSIONS

1. Monitoring the underground water quality implies a complex action of assessing all quality indicators and of performing the existing correlations between indicators. It is not enough to compare the determined value of each quality indicator with the CMA required by the Law on fresh water, being required to interpret, from a chemical point of view, the existing correlations between various quality indicators.

2. The activity of knowing the quality of the underground water at the level of large catchment areas can only take place within a GIS, where the punctual pieces of information acquired following the laboratory tests in a limited number of profiles are subject to spatialization within a MNT, in order to conduct a complex analysis at each point of the analyzed area.

3. The NO₂ concentration exceeds CMA in up to 6.5 % of the analyzed area and the NO₃ concentration exceeds CMA by 6.8% (according to Table 3).

4. The indicator: $\frac{\textit{nitrates}}{50} + \frac{\textit{nitrites}}{3}$ exceeds the maximum admitted value by 10.35 % (according to table 3).

5. The use of GIS enables the spatialization of these indicators in the area, and thus the knowledge of areas with exceeded concentrations is important. Through permanent monitoring, the potability sanitary bodies can classify the water sources based on the concentration of nitrates and nitrites in the water, compared to CMA, so that these would not be used, in order to prevent the occurrence of diseases.

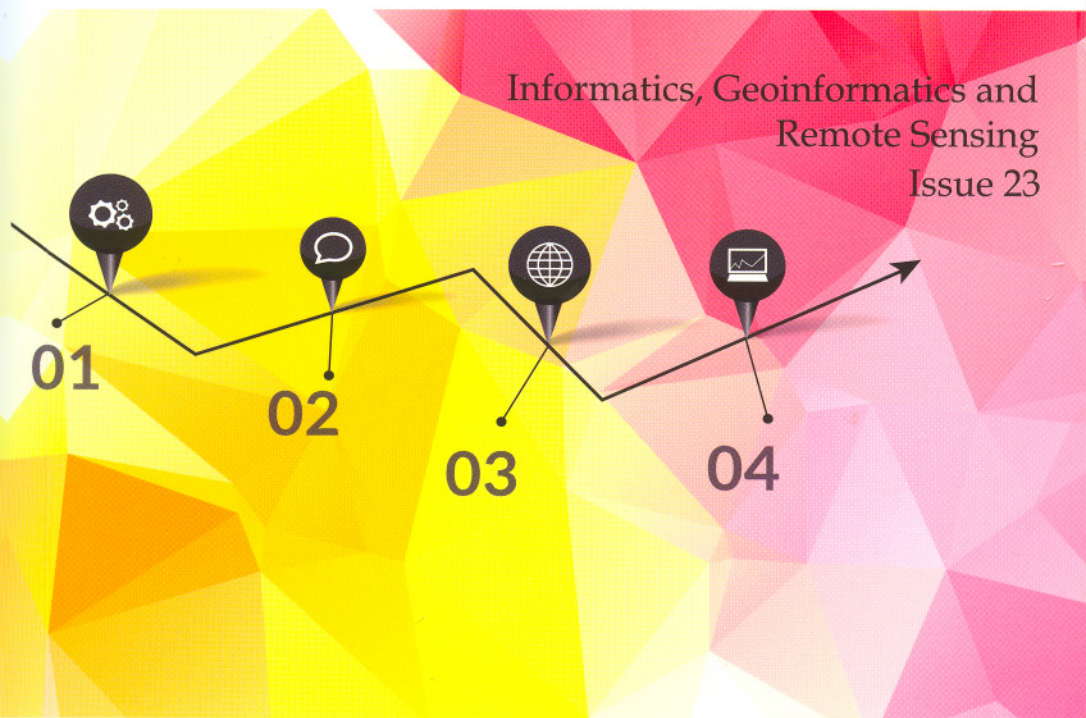
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MONITORING THE EVOLUTION OF GULLIES IN A WATER CATCHMENT BY GIS TECHNIQUES

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ABSTRACT

This paper presents a case study regarding the GIS applications on the slopes with frequent erosion processes in depth. Monitoring the gullies consists in identifying them in the land, their positioning on the map, their classification and recording according to several indicators and following their evolution in time.

The study is carried out in a water catchment area of 4,665 ha in Berheci Superior, Bacau county, Romania. By using orthophotoplanes, satellite images or air-photograms (in some cases) and the documentation in the land, it was possible to map the gullies 72 gullies are taken into account.

By GIS techniques, we model and create informational layers regarding the following parameters in the studied water catchment: the way of using the lands, the lithology, elevation, orientation of slopes, the land slope, and the density of relief fragmentation (Rus M.,2015, Kerekes A.H.,2016).

The work method suggested in this study is applying the model of frequency ratio (Frequency Ratio Model) in ArcGIS. The most important layer resulted contains information about the susceptibility of the lands to gully formation, when natural factors are taken into account. In this application, the (negative) contribution of the anthropogenic factor is not under study.

The GIS analysis in this paper regarding the susceptibility of the slopes to gully formation has indicated a relatively high share of the stable lands (62.4%). By this study, we want to suggest the best measure to fight erosion in depth, in order to protect agricultural lands affected by ravine formation.

Keywords: gullies, GIS, modelling natural factors, digital maps

1. INTRODUCTION

The study of gullies is a preoccupation of both geographers and engineers. Following and monitoring gullies in the water catchments in Romania are highly important, because gullies and streams participate by 29% to the total erosion, which means 37 million tons of eroded soil. Among these, 18.5 million tons reach rivers as deposits, accounting for 37% of the deposits which are being transported annually in the country. The surface taken out of the economic circuit of Romania annually, only because of the gullies, is about 23,000 ha (Popovici N., 2000). Summing up all their activity, streams produce important damage to various sectors of the national economy, both by erosions, floods and clogging.

Designing stream formations is appropriate and justified, because these forms of land degradation produced by water erosion are widely spread on the territory of Romania, and their negative effects are enhanced by the areas taken annually off the economic circuit. The solid material transported from slopes is deposited at their bottom and mainly in the areas of stream discharge; it is transported in riverbeds, aggravating the danger of flood and intense dam clogging (Patriche C. V., 2015).

The opportunity of this study (and of the studies presented at conferences in recent years) shows that in the case of agricultural water catchment areas, the proposed agricultural-forestry anti-erosion measures and works play an important part. These also make the division of the land into categories of use, in view of preserving the soil, improving and recovering its fertility.

2. MATERIALS AND METHODS

2.1. Study area

The water catchment area under study is called Gaiceana. It belongs to the upper water catchment area of the river Berheci, in the Unit called Colinele Tutovei, and it is located in the Eastern part of Romania, in Bacau county (Fig. 1). The reception area is of 4,665 ha, with a highly fragmented relief, hilly type and average slopes of more than 17%. Absolute altitudes ranging between 545.5 m and 150 m in the dam accumulation, resulting an energy relief 395.5 m. The area under study is strongly fragmented and affected by ravine formation. The lands are mainly agricultural and have relatively steep slopes. That is why these lands are affected by sheet erosion, gully erosion and active landslides [1]. We have identified and studied 72 gullies of different forms (linear, compound, continuous and discontinuous), with a total area of 218 ha, which account for 0.47% of the surface of the water catchment area. The frequency of the gullies is 1.5 gullies/100 ha.

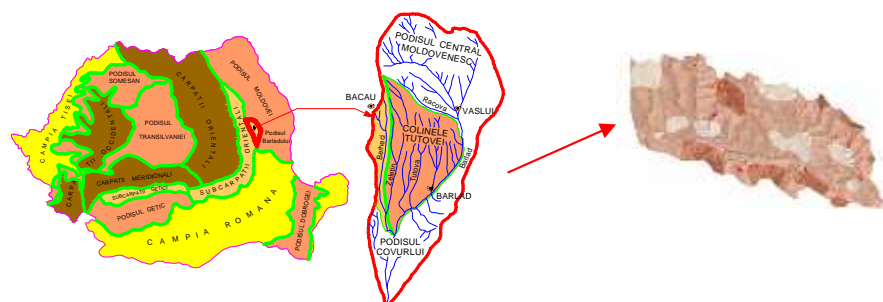


Fig.1. Location of the study area (Gaiceana catchment)

2.2. Method of research and input data

In view of reaching the target aimed by the research, namely creating the susceptibility map of lands to ravine formation in the water catchment area called Gaiceana, we used the software ArcGIS by applying the Frequency Ratio Model. The model is based on the relations between the distribution of gullies and each factor that determines their occurrence, in order to underline the relation between gully location and the factors that control their occurrence (Biali G., 2016). The frequency ratio is calculated by dividing the percentage of the area occupied by gullies for each factor taken into account by the percentage of the total area corresponding to each factor.

[Type text]

According to the previous study in the land, if the value is above 1, it results a higher correlation, while the values less than 1 show a lower correlation. The input data in this model were obtained in the land and from maps. The map model of this study was made based on six factors (the use of lands, lithology, elevation, exposure, slope, depth of relief fragmentation), to which we added the inventory of gullies. The recording of the gullies was done on topographic maps at scale 1: 5000 (to identify the gullies with forests) and on orthophotoplanes with a resolution of 50 cm, which enabled the obtaining of highly accurate information.

3. RESULTS AND DISCUSSION

In this subchapter of the paper, we present the factors studied and their digital maps, which resulted by using the GIS techniques.

3.1. Land use (coverage with types of vegetation)

How lands are used and covered with vegetation is one of the basic factors in stabilizing the slopes. By his activity, man influences directly and indirectly the processes that occur on slopes, by his direct influence on the natural vegetation, but especially on cultivated ones. The anthropogenic interferences represent a start in the production and intensification of slope instability processes.

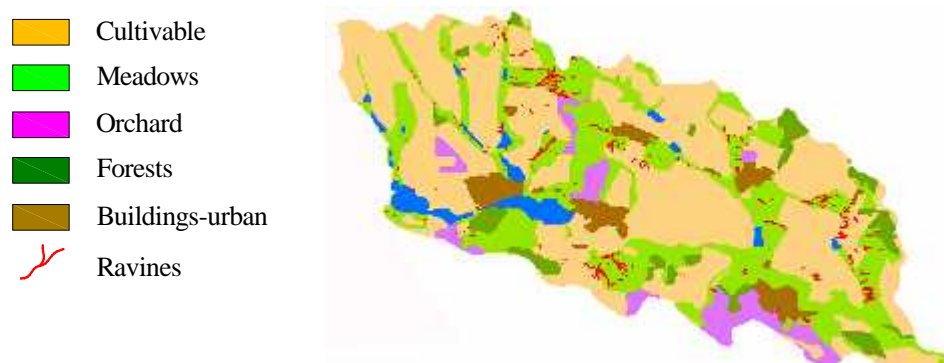


Fig.2. Digital map of how lands are used

The agricultural lands have a high percentage, over 90 % (Fig. 2), out of which almost half are lands that can be ploughed (51.28 %), (Table 1) shows the fact that the area studied is mainly agricultural, which can have effects on the stability of the slopes. About 70% of the surface of the gullies are on the lands used as meadows; they have the highest frequency ratio, 2.49 (Table 1).

Table 1 – Study on the factor “Land use”

Type of vegetation	Percentage of the total surface (%)	Percentage of the total surface of the gullies (%)	Frequency ratio
Cultivable	51.28	29.23	0.57
Meadows	28.63	71.25	2.49
Orchard	11.25	8.59	0.76
Forests	4.02	1.25	0.31
Buildings - urban	4.81	2.13	0.44

3.2. Lithology factor

In the studied water catchment area, the study of lithography shows obvious differences in gully distribution. Over 65% of gully area are slopes made of clays (Fig. 3).

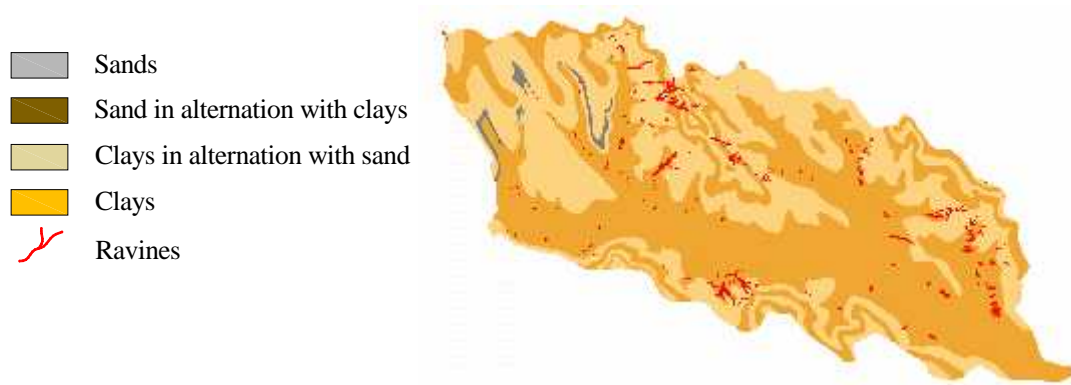


Fig.3. The digital map with lithology structure

They are also the most susceptible, having a frequency ratio of 1.16. On slopes, with a lithology structure different from the clay structure, the probability of gully occurrence is much reduced. The frequency ratio is higher than 1, for slopes with a lithology structure, is explained by the fact that rainfall water and thaw infiltrates only soil surface and do not reach groundwater level.

Table 2 – Study on the “lithology” factor

Lithology type	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
Clays	56.12	65.28	1.16
Clays in alternation with sand	41.18	38.25	0.93
Sands	2.42	1.84	0.76
Sands in alternation with clays	0.28	0	0.00

3.3. Elevation (altitude) of slopes

In the area studied, in the lands with low altitude of less than 250 m, about 80% of the gullies surface has been formed, on the lands with altitude between 250 m and 300 m very few gullies are found, and in the lands with altitude higher than 300 m do not have gullies (Fig. 4).

The most susceptible are lands under 250 m altitude, with frequency ratio of 1.12. The increase of the relief altitude decreases the probability of gullies occurrence. This fact is explained by the intensification of linear erosion to slope bottom, as a result of the rainfall water concentration at the slope bottom.



Fig.4. Digital map with the elevation (hypsometry) of slopes

Table 3 – Study on the “elevation” factor

Altitude interval (m)	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
150 – 200	15.23	38.74	0.96
200 – 250	51.08	38.95	1.12
250 – 300	26.17	19.57	0.86
300 – 350	7.25	3.12	0.43
350 – 400	0.18	0	0
400 – 550	0.09	0	0

3.4. Exposure (orientation) of slopes

In the basin studied, slope orientation has a direct influence on time of solar exposure, factor which on conjunction with the slope itself generates different temperature ranges. Soil humidity influenced directly, which leads to various degrees of geo-morphological processes.

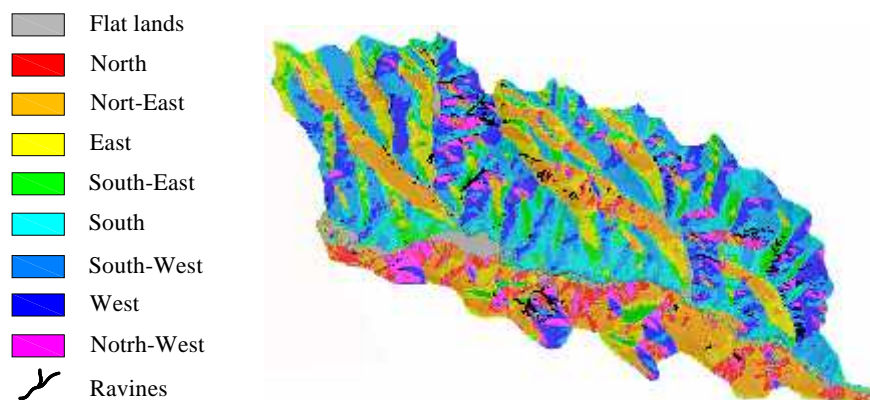


Fig.5. The digital map with slope exposure

The division of the slopes with different orientation is relatively heterogeneous (Fig. 5). The most susceptible slopes in gully formation are those with exposure to west, north-west and north. The slopes with north-west and north orientation retain better the humidity in the soil. Another important phenomenon is spring, during the thaw, the inferior horizons of the soils being frozen; on these slopes concentrations of important erosion flow are formed.

Table 4 – Study on “exposure” factor

Orientation	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
Flat lands	3.09	1.55	0.50
North	9.57	9.25	0.97
North-East	12.88	11.51	0.89
East	14.81	8.95	0.60
South-East	8.52	6.32	0.74
South	10.96	6.28	0.57
South-West	21.36	16.88	0.79
West	13.47	29.81	2.21
North-West	5.34	11.49	2.15

3.5. Slope (declivity of the slopes)

In the area studied, slope gradient is the most important morphometric variable for the erosion processes, and slope classification is relevant to appreciate the susceptibility of gully formation processes. Slope inclination reflects the geologic constitution and structure, and also the stages of slope evolution.

From the stand of the conditions that favour the installation of gullies, lands with slope gradient higher than 5° are the most exposed. Lands with slope gradient from 5 to 15° account for 54.33% of gully surface (Fig. 6) and have a frequency ratio >1.

Putting roads on slopes leads to their transformation within a short period of time in ravines and gullies.



Fig.6. Digital map with the slope declivity

Table 5 – Study on the factor “Slope”

Slope interval (°)	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
1-3	16.21	11.58	0.71
3-5	39.71	31.28	0.79
5-10	14.62	21.77	1.49
10-15	26.33	33.58	1.28
> 15	3.12	1.29	0.41

3.6. Slope susceptibility to gully formation

By overlapping of resulted topic maps and the reclassification according to obtained values, we obtained the synthesis map of land susceptibility to gully formation (Fig. 7). According to the map obtained, the lands with low and very low susceptibility account for 16.0% of the area. About 77% of lands have altitudes of 200-300 m and are used mainly as cultivable lands (47 %). Lands of average susceptibility account for 15.8% of the total area and 51.6% of their surface is used as agricultural lands. Lands of high susceptibility account for 33.1% of the surface and have 57.3% of meadow areas. 29.5% of the lands have the slope gradient higher than 10°. Lands of very high susceptibility account for 36.5% of the total area studied, and 40.17% of their surface is exposed to West, North-West and South-West and these lands are used as meadows (84.7%).



Fig.7. Digital map with slope susceptibility to gully formation

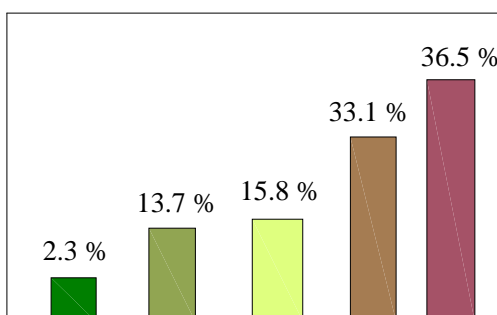


Fig. 8. Share ravines on lands with different levels of sensitivity in Gaiceana basin

The last stage was to validate the obtained results, which was done by overlapping the representation of susceptibility classes with the gully layer, in order to obtain their frequency within each class of susceptibility. The results obtained are presented in figure 8 and show the fact that the highest incidence of gully formation is in class 5, which means very high susceptibility. Gully frequency ratio in this class is 36.5%. A high frequency is recorded also in the high susceptibility class (33.1%).

4. CONCLUSIONS

The GIS analysis of the slope susceptibility to ravine formation in the water catchment area Gaiceana showed a relatively average percentage of stable lands (31.8%). However, these lands can lose balance by deforesting, excessive pasture, practising inappropriate agricultural techniques, which can be conducive to new geomorphological processes.

Following the study, we can conclude that the analysis of land susceptibility to gully formation involves a degree of uncertainty because of the limitations imposed by the data used. Still, this method provides the opportunity to identify areas prone to gully formation processes, information which is useful for institutions to take measures of reducing negative effects.

Designing streams is a measure to regulate the flow on slopes and in the discharge network, to prevent slope erosion and to avoid the damage produced by floods, for an efficient and integral use of the catchment area.

The design needs to be complex and integer in order to ensure an efficient water and soil control on the whole surface of the catchment area, which would restore eventually the synergistic hydrological and ecological balance of the area.

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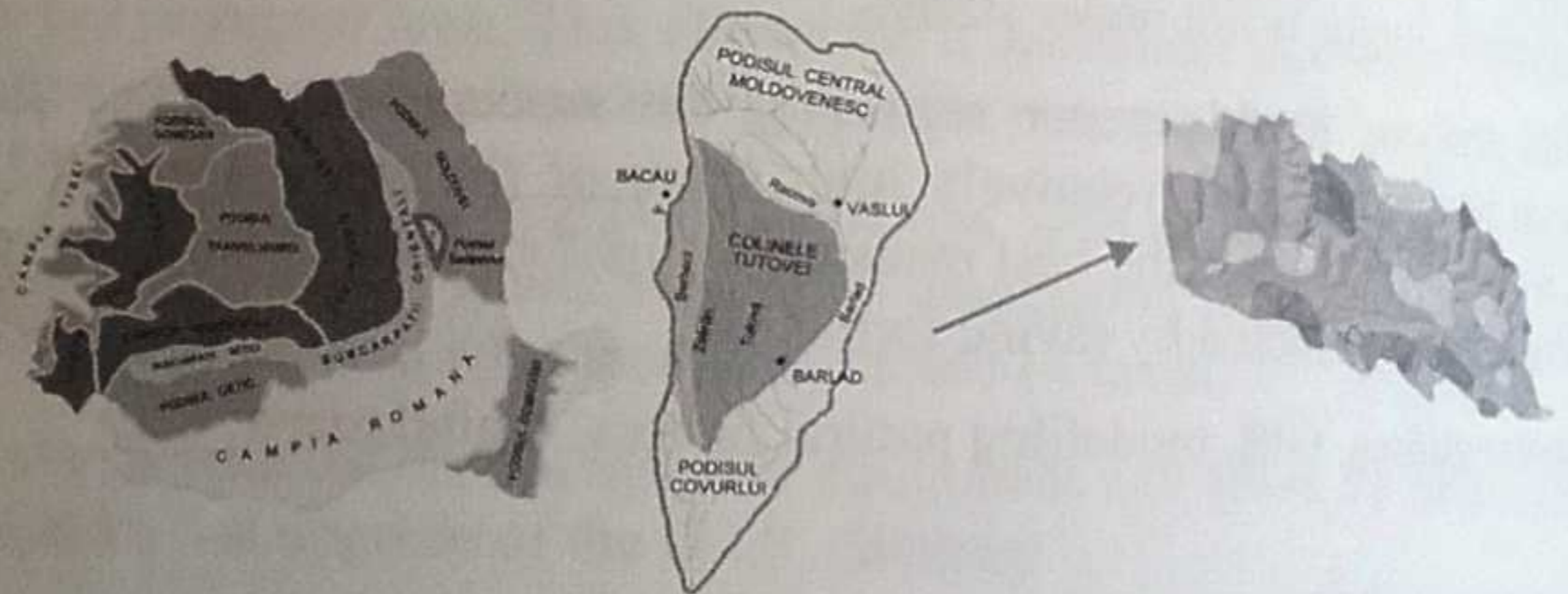


Fig.1. Location of the study area (Gaiceana catchment)

2.2. Method of research and input data

In view of reaching the target aimed by the research, namely creating the susceptibility map of lands to ravine formation in the water catchment area called Gaiceana, we used the software ArcGIS by applying the Frequency Ratio Model. The model is based on the relations between the distribution of gullies and each factor that determines their occurrence, in order to underline the relation between gully location and the factors that control their occurrence (Biali G., 2016). The frequency ratio is calculated by dividing the percentage of the area occupied by gullies for each factor taken into account by the percentage of the total area corresponding to each factor.






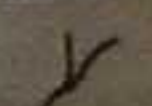
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-  Cultivable
-  Meadows
-  Orchard
-  Forests
-  Buildings-urban
-  Ravines

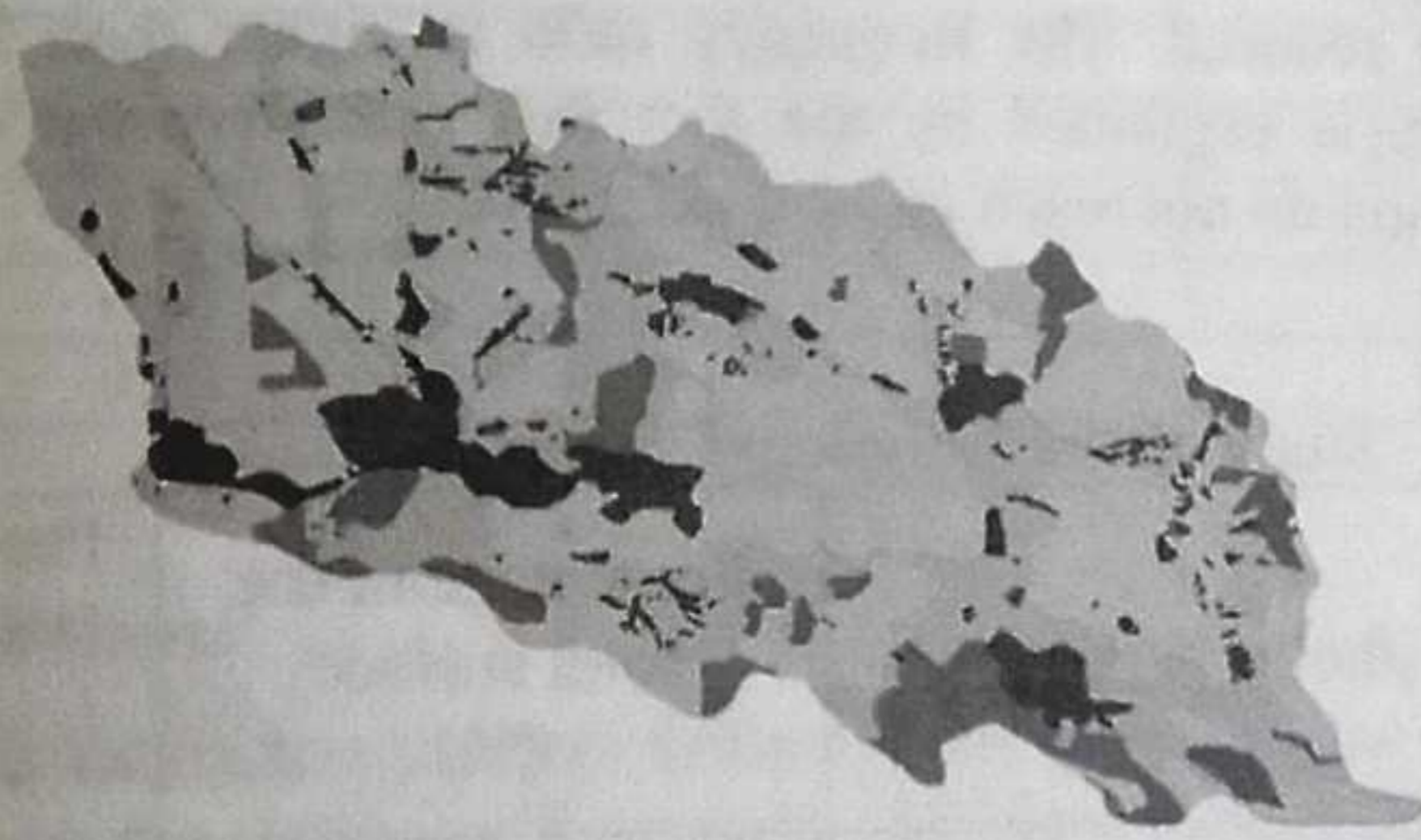


Fig.2. Digital map of how lands are used






The agricultural lands have a high percentage, over 90 % (Fig. 2), out of which almost half are lands that can be ploughed (51.28 %), (Table 1) shows the fact that the area studied is mainly agricultural, which can have effects on the stability of the slopes. About 70% of the surface of the gullies are on the lands used as meadows; they have the highest frequency ratio, 2.49 (Table 1).

Table 1 – Study on the factor “Land use”

Type of vegetation	Percentage of the total surface (%)	Percentage of the total surface of the gullies (%)	Frequency ratio
Cultivable	51.28	29.23	0.57
Meadows	28.63	71.25	2.49
Orchard	11.25	8.59	0.76
Forests	4.02	1.25	0.31
Buildings - urban	4.81	2.13	0.44

3.2. Lithology factor

In the studied water catchment area, the study of lithography shows obvious differences in gully distribution. Over 65% of gully area are slopes made of clays (Fig. 3).

-  Sands
-  Sand in alternation with clays
-  Clays in alternation with sand
-  Clays
-  Ravines

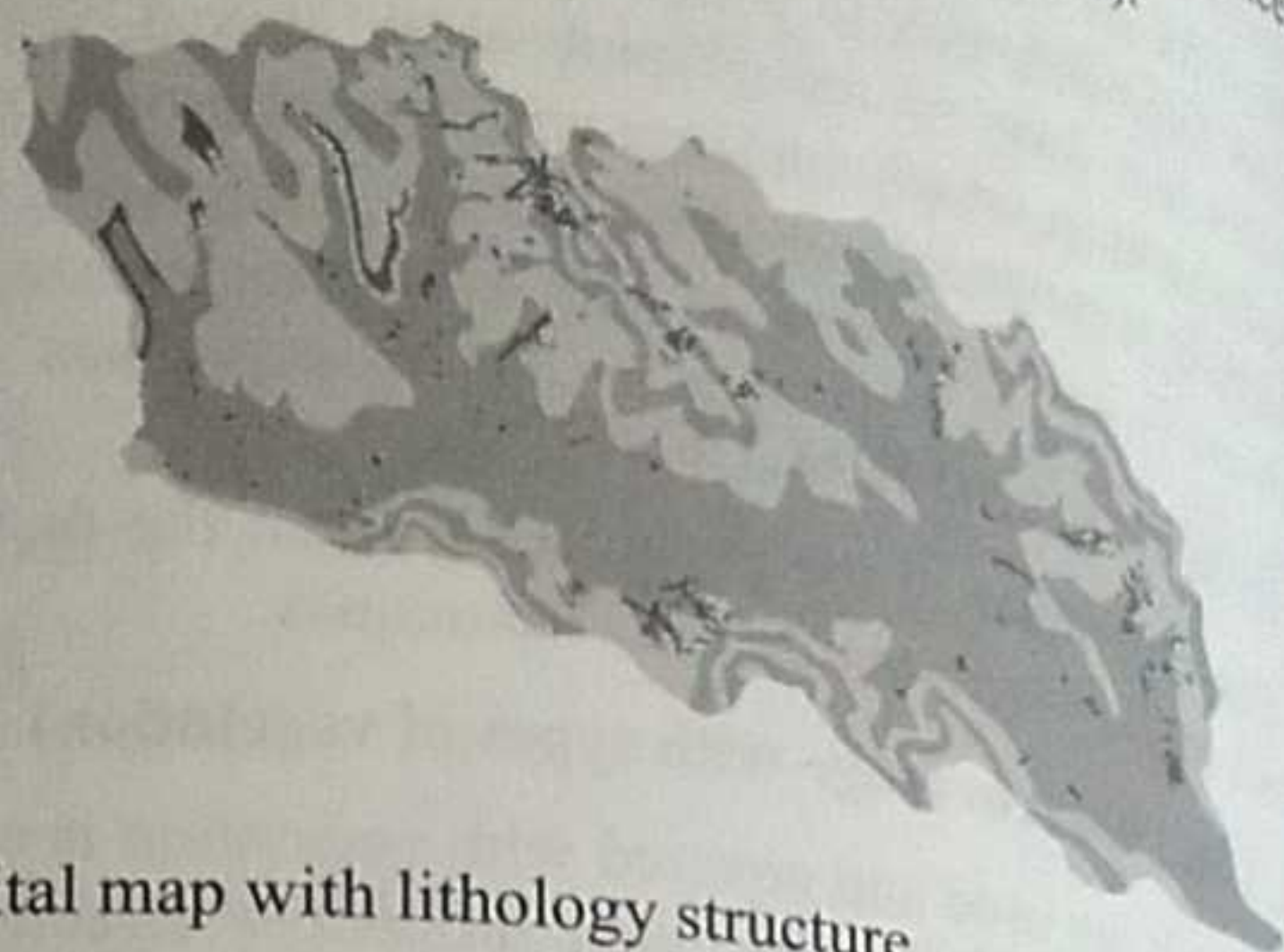


Fig.3. The digital map with lithology structure

They are also the most susceptible, having a frequency ratio of 1.16. On slopes, with a lithology structure different from the clay structure, the probability of gully occurrence is much reduced. The frequency ratio is higher than 1, for slopes with a lithology structure, is explained by the fact that rainfall water and thaw infiltrates only soil surface and do not reach groundwater level.

Table 2 – Study on the “lithology” factor

Lithology type	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
Clays	56.12	65.28	1.16
Clays in alternation with sand	41.18	38.25	0.93
Sands	2.42	1.84	0.76
Sands in alternation with clays	0.28	0	0.00

3.3. Elevation (altitude) of slopes

In the area studied, in the lands with low altitude of less than 250 m, about 80% of the gullies surface has been formed, on the lands with altitude between 250 m and 300 m very few gullies are found, and in the lands with altitude higher than 300 m do not have gullies (Fig. 4).

The most susceptible are lands under 250 m altitude, with frequency ratio of 1.12. The increase of the relief altitude decreases the probability of gullies occurrence. This fact is explained by the intensification of linear erosion to slope bottom, as a result of the rainfall water concentration at the slope bottom.

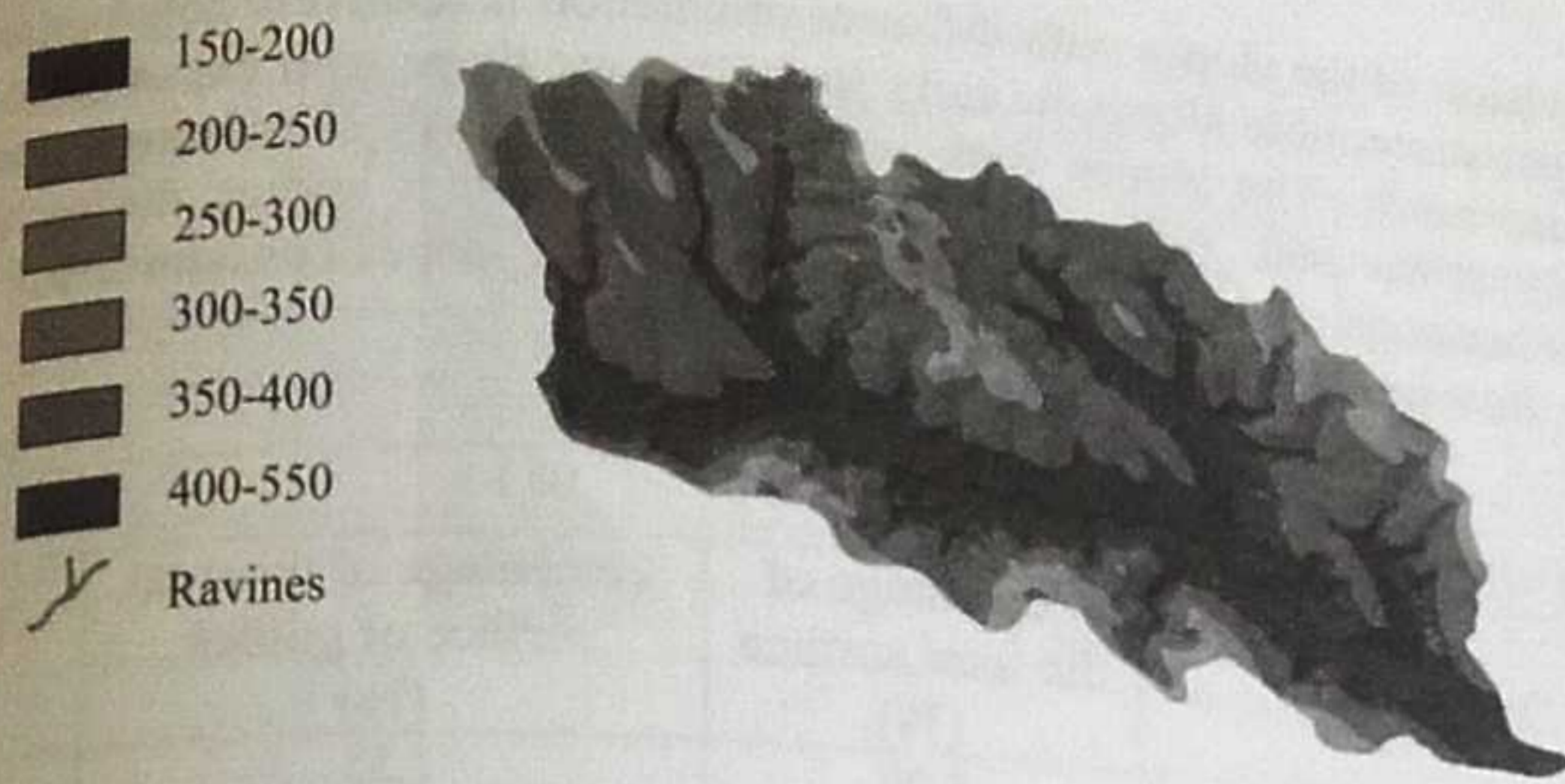


Fig.4. Digital map with the elevation (hypsometry) of slopes

Table 3 – Study on the “elevation” factor

Altitude interval (m)	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
150 – 200	15.23	38.74	0.96
200 – 250	51.08	38.95	1.12
250 – 300	26.17	19.57	0.86
300 – 350	7.25	3.12	0.43
350 – 400	0.18	0	0
400 – 550	0.09	0	0

3.4. Exposure (orientation) of slopes

In the basin studied, slope orientation has a direct influence on time of solar exposure, factor which on conjunction with the slope itself generates different temperature ranges. Soil humidity influenced directly, which leads to various degrees of geo-morphological processes.

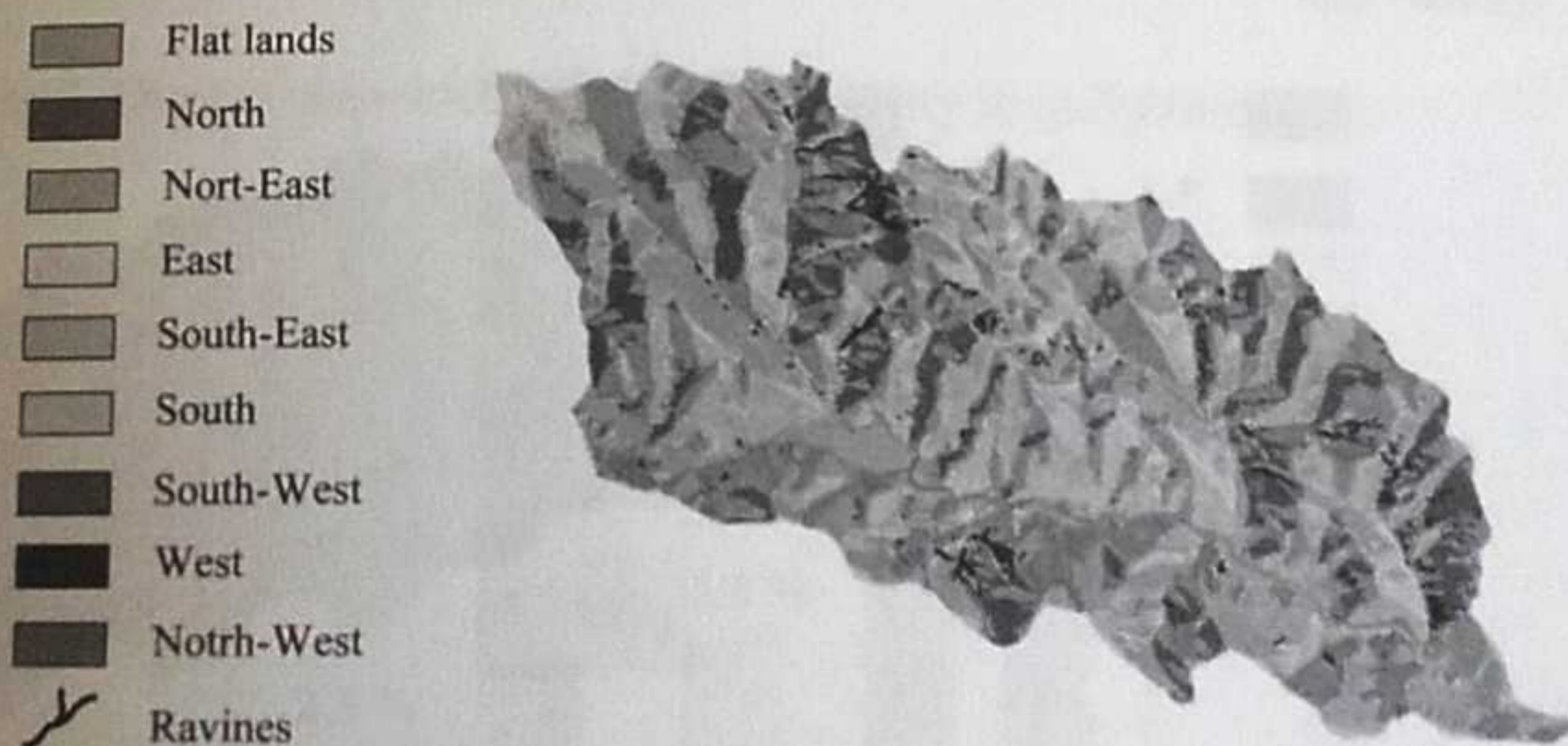


Fig.5. The digital map with slope exposure

The division of the slopes with different orientation is relatively heterogeneous (Fig. 5). The most susceptible slopes in gully formation are those with exposure to west, north-west and north. The slopes with north-west and north orientation retain better the humidity in the soil. Another important phenomenon is spring, during the thaw, the inferior horizons of the soils being frozen; on these slopes concentrations of important erosion flow are formed.

Table 4 – Study on “exposure” factor

Orientation	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
Flat lands	3.09	1.55	
North	9.57	9.25	0.50
North-East	12.88	11.51	0.97
East	14.81	8.95	0.89
South-East	8.52	6.32	0.60
South	10.96	6.28	0.74
South-West	21.36	16.88	0.57
West	13.47	29.81	0.79
North-West	5.34	11.49	2.21
			2.15

3.5. Slope (declivity of the slopes)

In the area studied, slope gradient is the most important morphometric variable for the erosion processes, and slope classification is relevant to appreciate the susceptibility of gully formation processes. Slope inclination reflects the geologic constitution and structure, and also the stages of slope evolution.

From the stand of the conditions that favour the installation of gullies, lands with slope gradient higher than 5° are the most exposed. Lands with slope gradient from 5 to 15° account for 54.33% of gully surface (Fig. 6) and have a frequency ratio >1. Putting roads on slopes leads to their transformation within a short period of time in ravines and gullies.

- 1-3
- 3-5
- 5-10
- 10-15
- > 15
- ⚡ Ravines



Fig.6. Digital map with the slope declivity

Table 5 – Study on the factor “Slope”

Slope interval (°)	Percentage of the total surface (%)	Percentage of the total surface of gullies (%)	Frequency ratio
1-3	16.21	11.58	0.71
3-5	39.71	31.28	0.79
5-10	14.62	21.77	1.49
10-15	26.33	33.58	1.28
> 15	3.12	1.29	0.41

3.6. Slope susceptibility to gully formation

By overlapping of resulted topic maps and the reclassification according to obtained values, we obtained the synthesis map of land susceptibility to gully formation (Fig. 7). According to the map obtained, the lands with low and very low susceptibility account for 16.0% of the area. About 77% of lands have altitudes of 200-300 m and are used mainly as cultivable lands (47 %). Lands of average susceptibility account for 15.8% of the total area and 51.6% of their surface is used as agricultural lands. Lands of high susceptibility account for 33.1% of the surface and have 57.3% of meadow areas. 29.5% of the lands have the slope gradient higher than 10°. Lands of very high susceptibility account for 36.5% of the total area studied, and 40.17% of their surface is exposed to West, North-West and South-West and these lands are used as meadows (84.7%).

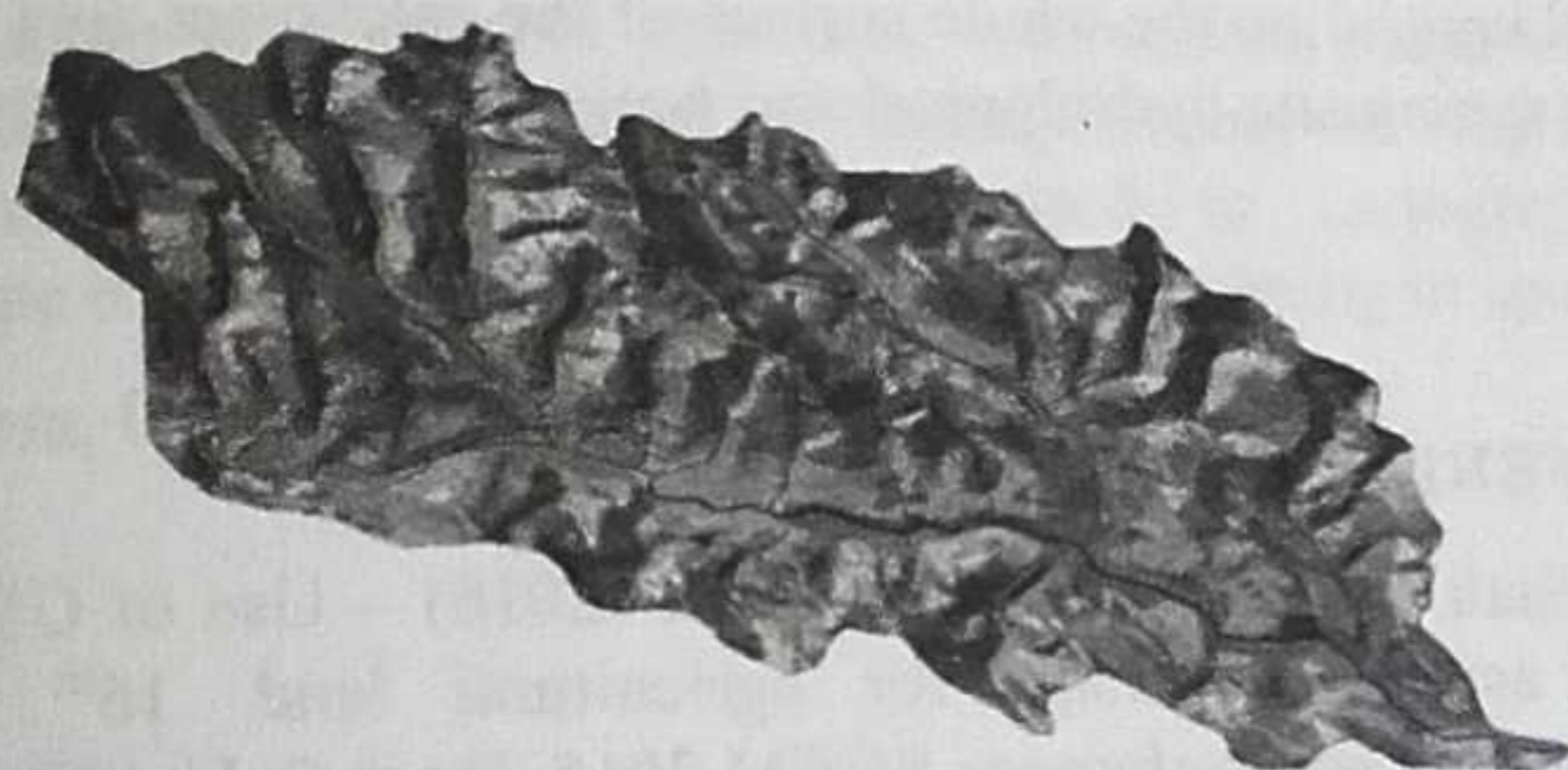
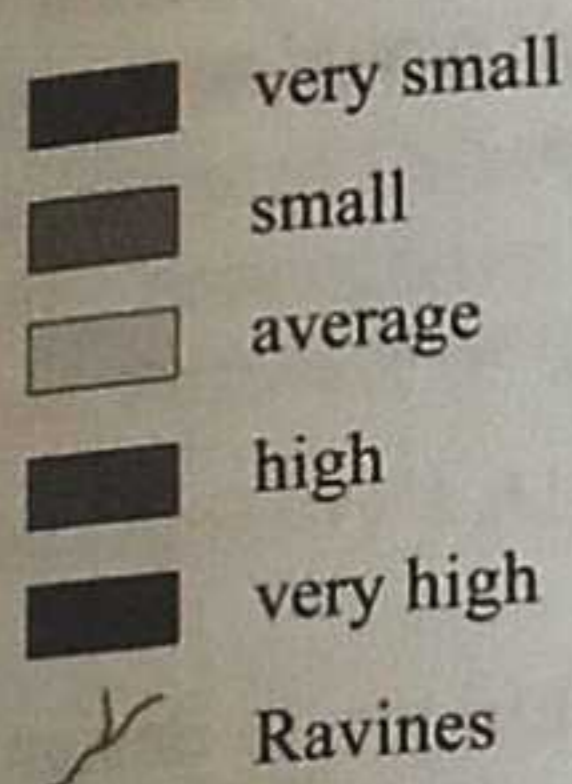


Fig. 7. Digital map with slope susceptibility to gully formation

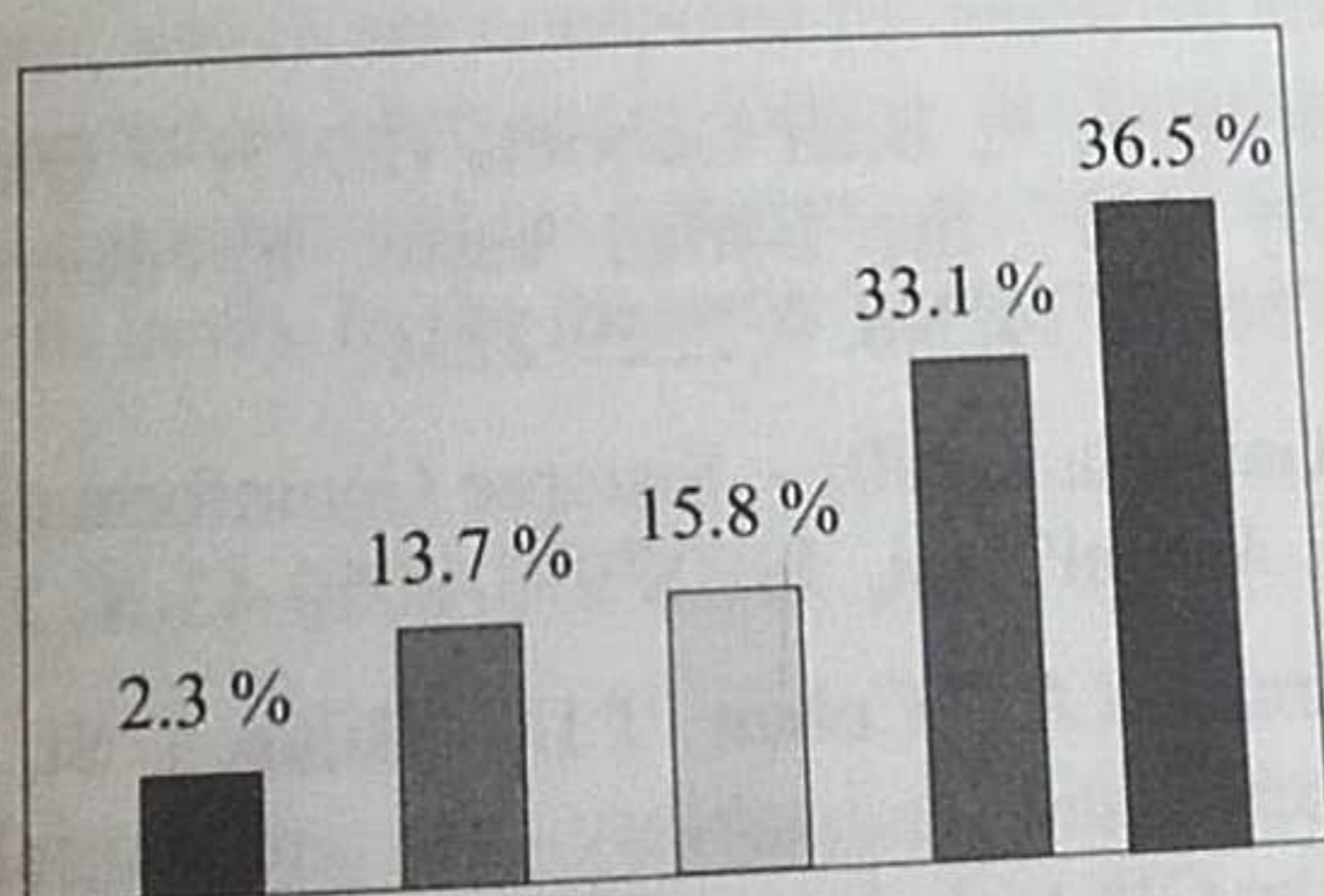


Fig. 8. Share ravines on lands with different levels of sensitivity in Gaiceana basin

The last stage was to validate the obtained results, which was done by overlapping the representation of susceptibility classes with the gully layer, in order to obtain their frequency within each class of susceptibility. The results obtained are presented in figure 8 and show the fact that the highest incidence of gully formation is in class 5, which means very high susceptibility. Gully frequency ratio in this class is 36.5%. A high frequency is recorded also in the high susceptibility class (33.1%).

4. CONCLUSIONS

The GIS analysis of the slope susceptibility to ravine formation in the water catchment area Gaiceana showed a relatively average percentage of stable lands (31.8%). However, these lands can lose balance by deforesting, excessive pasture, practising inappropriate agricultural techniques, which can be conducive to new geomorphological processes.

Following the study, we can conclude that the analysis of land susceptibility to gully formation involves a degree of uncertainty because of the limitations imposed by the data used. Still, this method provides the opportunity to identify areas prone to gully formation processes, information which is useful for institutions to take measures of reducing negative effects.

Designing streams is a measure to regulate the flow on slopes and in the discharge network, to prevent slope erosion and to avoid the damage produced by floods, for an efficient and integral use of the catchment area.

The design needs to be complex and integer in order to ensure an efficient water and soil control on the whole surface of the catchment area, which would restore eventually the synergistic hydrological and ecological balance of the area.

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FACULTY OF LAND RECLAMATION
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IMPORTANCE OF TOPOLOGY IN A GIS PROJECT OF MONITORING THE SOILS IN AGRICULTURAL LAND

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Abstract

This paper presents the advantages of using the topology in a GIS project. The study was conducted on two watershed with mainly agricultural uses. We presented a model for creating the topology designed to monitoring the soils in the basins studied.

In the present application, we qualify the graphical objects as soil units on the map. After the topology there was possible the grouping in thematic layers depending on their type and on many other information from the attribute-type database (erodability, humus content, texture, structure, pH etc.). Topological relations were created through an own program in Fortran language under Windows). The topological structure of spatial database in this GIS project is under Geo-Graph software. The existence of topology also brings another major advantage of the project: facilitates the creation of key links between databases, the important step towards the query.

Key words: database, GIS, layers, soils, topology

INTRODUCTION

Topology is a mathematical procedure to explicitly define the spatial relations: defining connections between lines, identification of adjacent polygons, defining a polygon as a set (an aggregate) of lines. The spatial relationships between geographic objects of a map are plotted on that map, but their interpretation depends on the person that reads the map. Creating the topology in a GIS makes explicit certain relations between objects. In other words, the topology is a codification of spatial relationships between the objects of a layer that are connected or are adjacent (lines, nodes, polygons). For example, the topology of a line means knowing the start and end points (nodes) and the polygons to the left and right. The generation of topology represents the process of building topological relations between the objects of a layer (Renard K., 1996).

Explicit generation of topology may be mandatory after subsequent changes or updates of the graphical database (disconnected topology), or may be implicitly assumed by the software (dynamic topology).

As regards the mapping, the relations and functions of graphical elements will always be targeted towards the effectiveness of storage

and the location of spatial elements. In the past, the amount of mapped information and diversity of usable data sources have made it difficult to establish such functions.

Separation of spatial elements from their thematic attributes and organizational structure of these ensembles foreshadowed spatial databases used today in GIS.

Thus it appeared the topological structure (for storing data in vector model), which is based on adjacency properties and spatial relationships between different elements (objects) of a map. Lack of topological relations in a vector representation, reduces much the query possibilities, even if the user manages to deduce on his own, visually, some of these relationships (Biali G., Popovici N., 2003).

The topological model (corresponding to the numerical maps and plans where, not only the data are digitally represented in vector format, but they are also added the topological relations between objects), incorporates for a map or a plan in vector form three sets of data:

- Identifiers of characteristics of the land to be plotted in vector map or plan, and which, corresponding to their geometry, are divided in three generic types: point objects, line objects and surface objects;

- Thematic attributes of characteristics, being organized in a hierarchical classification scheme;
- Spatial data, which describe the geometric structure of vector maps or plans under three aspects: of topological relations between objects, of shape and size of objects, of their position (given by the pairs of coordinates).

MATERIALS AND METHODS

Main research of this work was editing the topology. The Geo – Graph system allows the creation of three types of topologies: dot, polygon and network. The topological structure (for storing data in vector model) is based on adjacency properties and spatial relationships of the elements (objects) of a vector plan. This allows setting up the structure of spatial data bank files, which are indispensable for the operation of the information system: keeping up to date, overlapping areas, shaping entities

by overlapping intermediary borders, generalization of the border route etc.

This paper exemplifies the creation of topology for the map of soil units in a 2 studies watershed, where through a GIS-type system there was determined the soil loss through erosion by applying “Universal Soil Loss Equation” (Wischmeier W., Smith D., 1978).

A rectangular grid of square cell was overlapped over the map with mapping of soil units, the pixel size being 25 x 25 m (Figure 1), for each graphical object being created then a primary database (“graphical object” being represented by the polygon limited by the boundaries of each soil unit).

The primary database should contain: graphical object number (unique in the drawing), the value of coefficient entering the calculation equation (soil erodability coefficient S) and the reporting as pixels of the graphical object.

The file is called *layer.tpg* and is created according to a certain type, like in the example in the Figure 2.

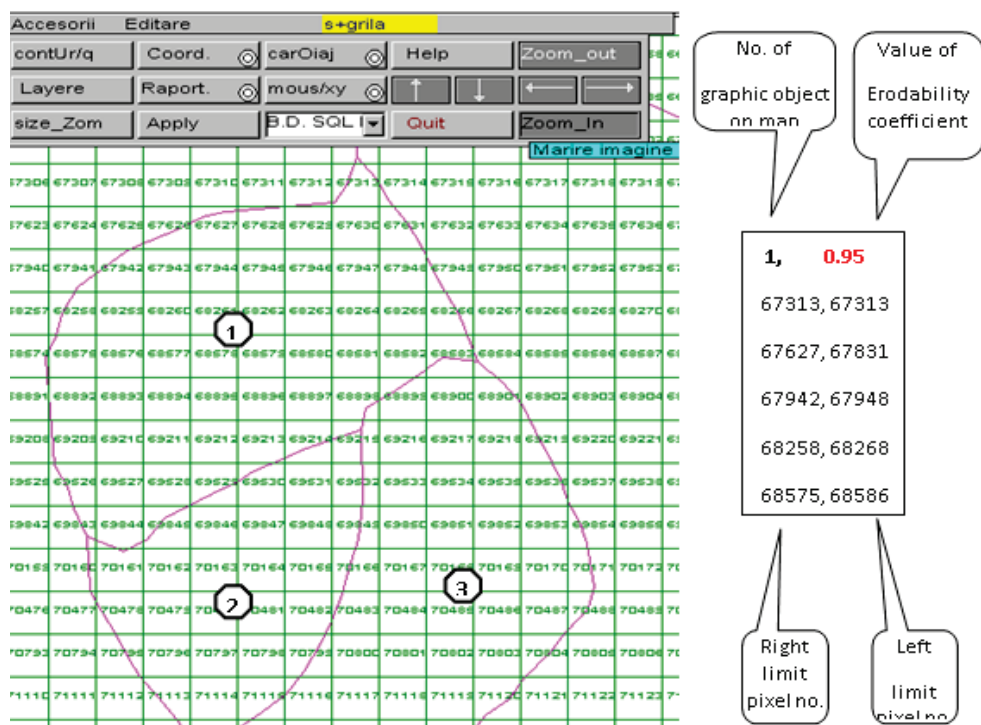


Figure 1. Detail of grid overlay over the soil unit plan in Antohesti watershed

RESULTS AND DISCUSSIONS

This operation can be done reading either on the screen, or on plotted plans, but there are some disadvantages such as: large number of graphical objects in a vector drawing (Figure 2) will lead to a long working time; the occurrence of errors due to incorrect assessment of membership of a pixel to an object or another or errors in loading the data from the keyboard.

In this context, this operation was executed automatically within the GIS project by creating the topology.

Within the Geo – Graph system by using the editing menu (fourth line from the main menu) there is possible both to prepare the plan in

order to create the topology and to create it automatically.

Editing is performed by having displayed permanently the cursor coordinates (absolute coordinates in double precision – the yellow bar under the main menu).

The flow of operations is as follows:

- Loading the vector drawing in Geo – Graph by the function from the main menu;
- Setting from the main menu the option “Serial no.” to have control of graphical objects viewed;
- Selecting with the mouse the graphical object (Figure 2);
- Resorting to “eDI_SET” key that automatically generates a window that defines the following parameters (Figure 3).

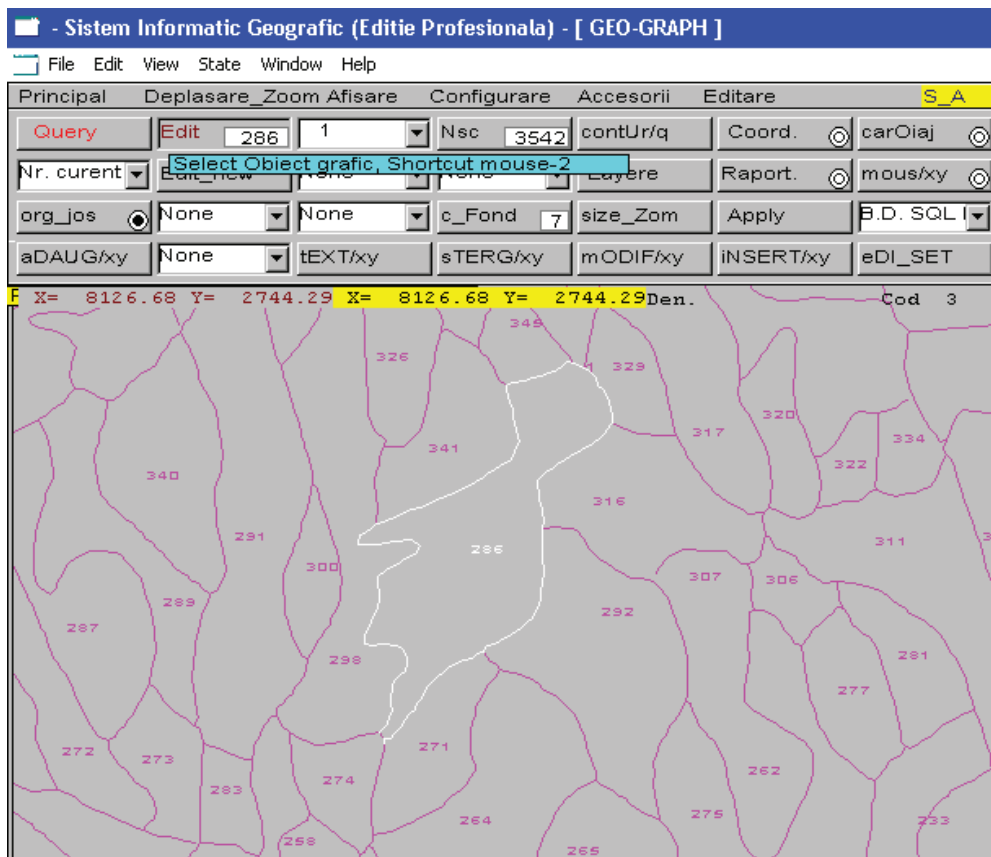


Figure 2. Selecting a graphical object in order to create the topology (in the example – soil unit in Antohesti hydrographic basin).

The dialog box that opens allows:



⇒ Name: is assigned to the soil unit, the coefficient value S;

⇒ Code no.: the window below ("Help primitive graphics") will automatically open: the code for vectored graphical object is chosen;



⇒ Layer no.: the drawing and filling color code of polygon is defined.

Figure 3. Editing the parameters for selected graphical object

The result of the process described can be viewed by selecting from the main menu the "Name" key (Figure 4).

Knowing the S factor is very important in applying equation USLE (Moțoc M., Tuhai A., 1998).

The value of erodability soils was determined for each unit of soil knowing soils physical characteristics and using the soil erodibility the nomogram (Foster G.R, McCool D.K., Renard K.G., Moldenhauer W.C., 1981).

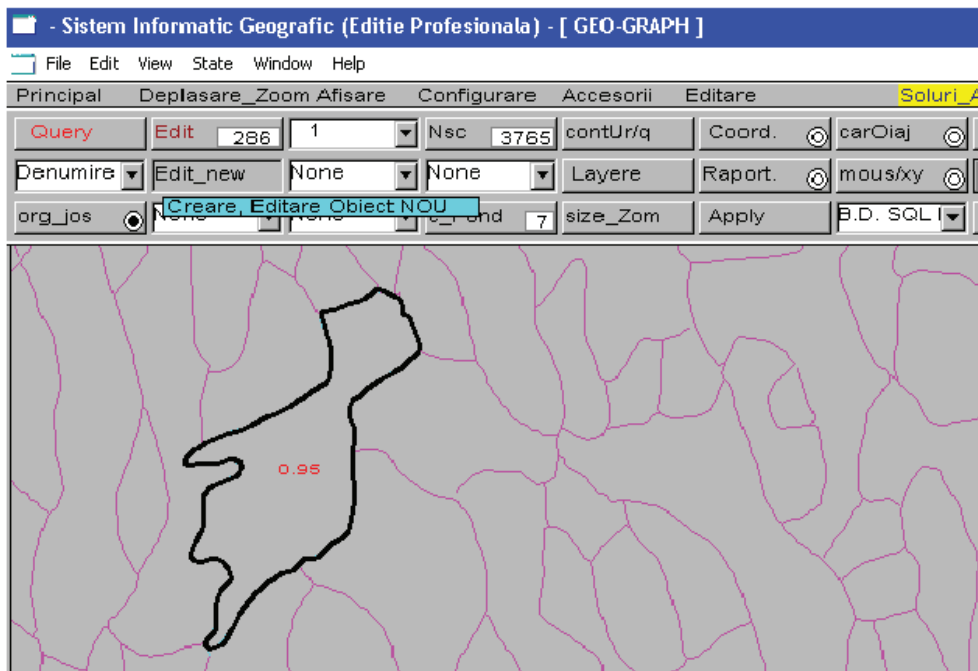


Figure 4. The result of editing operation of the graphical object and assigning the erodability coefficient "S"

It is important to know the maximum admitted limits of software when editing the graphical objects; this is possible through the “Design Information” command (Figure 5):

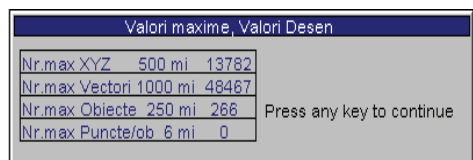
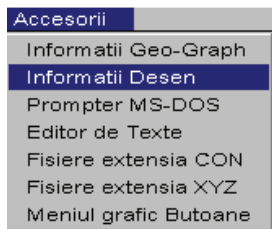
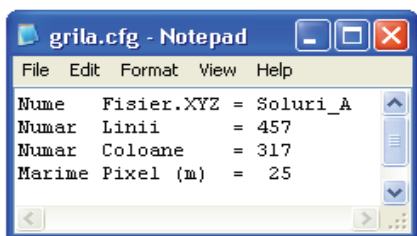


Figure 5. Vector drawing information

The window represents the maximum values accepted by the Geo – Graph system as well as the current values of the drawing.

At the end of these operations ASCII saving of vector drawing is made, the files thus obtained being necessary for the next processing. The way of creating the graphical object topology within a hydrographic basin is based on the “Topology.exe” program (Figures 6, 7).



Name	Ext	Size
grila	cfg	105
Soluri_A	CON	108.004
Topologye	exe	195.072
Soluri_A	ICX	69.664
Soluri_A	XYZ	142.170

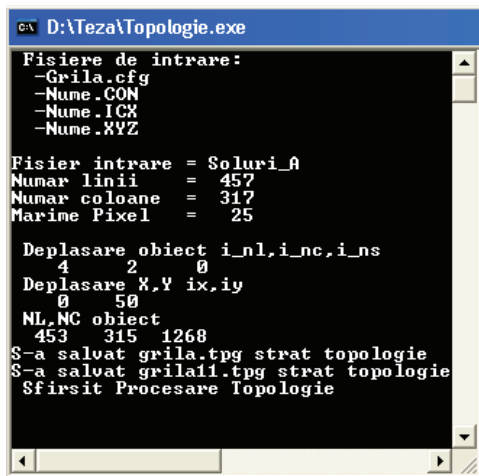
Figure 6. Configuration of input data in topology.exe program

The name of corresponding layer to be processed is set, in turn, in the “*grid.cfg*”.

The other three files (*.xyz*, *.icx*, *.con*) have resulted from the previous processing.

The principle of the program consists of a scanning line by line in the graphical object, with the step less or equal to the size of the cell. Based on the pattern recognition method, the vector line is translated on the pixel contour receiving automatically its number (according to the example in Figure 1).

The resulting file contains related intervals and values according to the topological interpretation of program input vector drawing.



a.

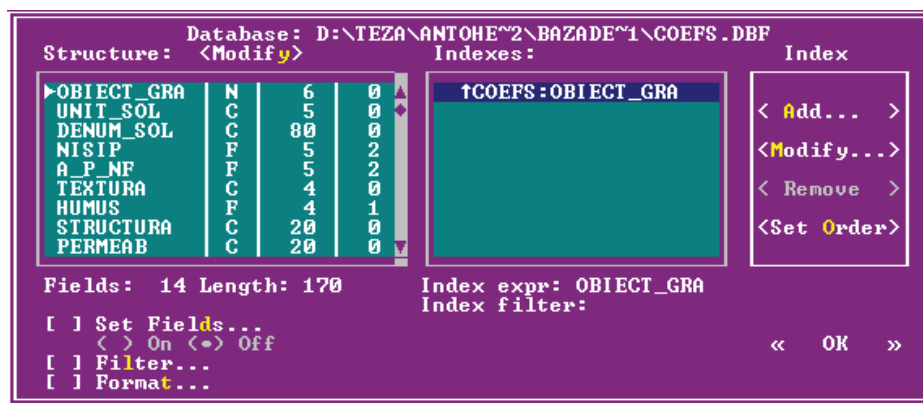
Name	Ext	Size
grila	cfg	105
Soluri_A	CON	108.004
Topologye	exe	195.072
Soluri_A	ICX	69.664
strat	tpg	122.219
Soluri_A	XYZ	142.170

b.

Figure 7. Automatic creation of topology:
 a. program running;
 b. resulting files.

The resulting file – “layer.tpg” is renamed as the number of information layer entering the next processing, according to the settings of the computer program; in the example shown, the information layer of the soil units is “layer 6.tpg” (Figure 10).

With this topology there was possible: to assign the erodability coefficient for each soil unit separately (Figure 4), to create the attribute-type databases (Figure 8), graphical georeferencing of objects on vector plans – layers of soils (Figure 9), (Biali G., Statescu FI., 2013).



Humus	Structura	Permeab	Ph	N	P	K	Coef_s
2.4	astructurat poliedr	mica	6.15	0.12	2	110	1.11
2.2	poliedrica	mica	8.25	0.07	19	195	1.11
1.0	glomerulara	moderata	8.60	0.06	4	90	1.18
1.0	glomerulara	moderata	8.60	0.06	4	90	1.13
3.1	astructurat	moderata	6.45	0.15	174	500	1.20
1.0	glomerulara	moderata	8.60	0.06	4	90	1.11
3.1	astructurat	moderata	6.45	0.15	174	500	1.20
1.0	glomerulara	moderata	8.60	0.06	4	90	1.18
2.4	astructurat poliedr	mica	6.15	0.12	2	110	1.11
1.0	poliedrica mica	mica	6.30	0.18	1	135	0.80
3.1	astructurat	moderata	6.45	0.15	174	500	1.20
1.0	glomerulara	moderata	8.60	0.06	4	90	1.18
1.0	poliedrica mica	mica	6.30	0.18	1	135	0.86
3.2	poliedrica	mica	6.35	0.14	6	250	1.15
3.3	astructurat granular	mica	7.70	0.19	115	332	1.23
1.3	poliedrica	moderata	6.85	0.08	4	195	0.95
2.4	astructurat poliedr	mica	6.15	0.12	2	110	1.11
2.2	poliedrica	mica	8.25	0.07	19	195	1.11
3.3	astructurat granular	mica	7.70	0.19	115	332	0.89
1.0	poliedrica mica	mica	6.30	0.18	1	135	0.80

Figure 8. Example database attribute soils

If it was to recap for shortprocess as follows: I started with the plans of situation with soil mapping;were driven steps: scanning, automatic vectorization software as Corel Draw, OCR Trace module, filter module coordinated with "dxfin.exe" rescue ASCII and binary forms;resulting vector plans (Figure 9).

Apply the "topology.exe" and are assigned soils units the coefficient of S erodabilityand fill color code. Resulting layers of soil information with the distribution coefficient erodability S, (Figure 10), to be applied correctly equation USLE.

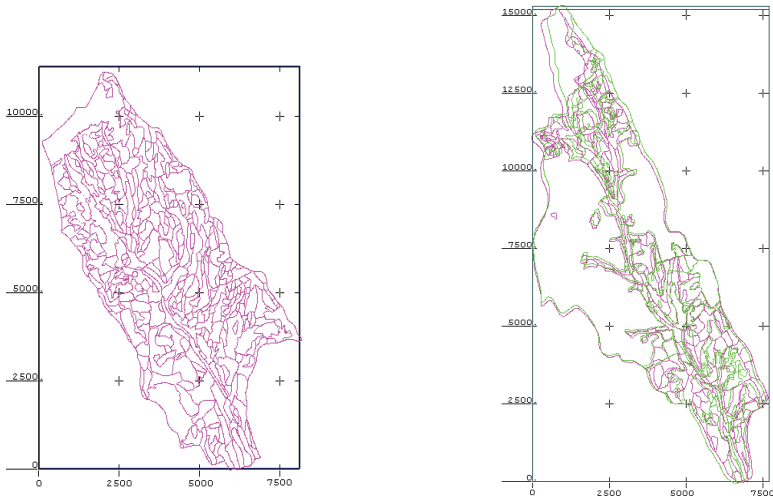


Figure 9. Vector plans of soil in the two watersheds studied

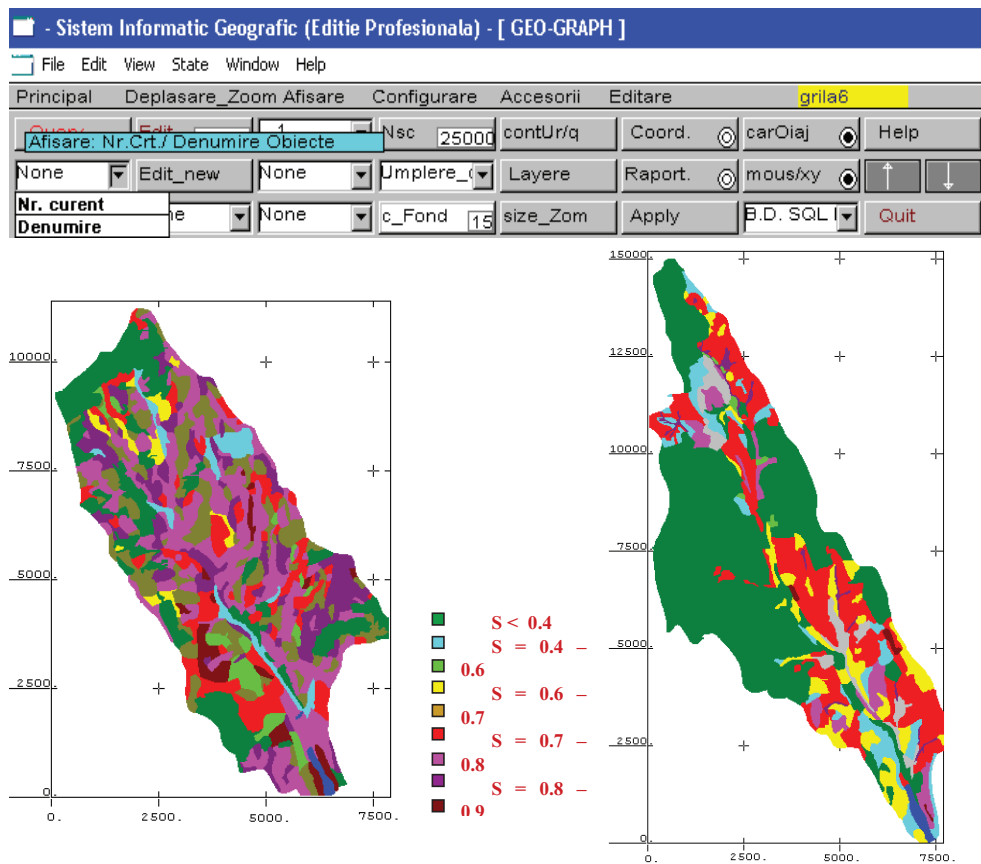


Figure 10. Layers of erodability coefficient (S) in the those two watersheds studied

CONCLUSIONS

Most GIS store topological relations as part of the data model. In this case, editing spatial characteristics of a layer alter its topology. Therefore, for this project there was necessary to reconstruct the topology in order to restore spatial relations after the graphical objects (ground units) were vectored. Phases for setting up graphical and alphanumeric databases, as well as the generation of topology, were created separately within this project, but many GIS environments allow today a quasi-simultaneous approach.

Creating and storing topological relations provided the following advantages:

- the data is stored more efficiently, and therefore it can be processed faster and it can process large data sets;
- enables to make analyses, such as modelling leakage along the connection lines in a network by combining the adjacent polygons with similar characteristics and overlapping the geographical objects;
- redundant data is eliminated;
- it helps identifying the errors resulting from digitization.

In the context of developing the GIS project the topology is of particular importance.

When designing a GIS, but, also subsequently, when adding and editing vector data within a GIS project, certain conditioning regarding both the composition of geometric entities and spatial relations between graphical elements shall be complied with.

The GIS project in this paper presents a particular case of creating topological specifications of vector entities for the soils in a hydrographic basin.

The advantages in this application are major:

- it guarantees the compliance and accuracy of graphical information;
- it creates the conditions of connection between graphical entities and associated attribute databases;
- the analysis and spatial query functions become possible.

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GIS-BASED WATER EROSION MODELLING: THE CASE OF HIGH SLOPE WATER CATCHMENT AREA, ROMANIA

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Abstract

This paper shows the results of a series of hydrographic simulations by mathematical modelling of the erosion phenomenon. The main goal is to show the importance of using the GIS technique to analyse the erosion process. Our research uses several well-known mathematical models and GIS software. Mathematical modelling was performed with the USLE model running under Geo-Graph software and the WEPP model running under ArcGIS 9.2 software. The multitude of factors involved in modelling and especially their spatialization is the main argument for choosing these two models. Finally, in order to be able to compare the results, in both cases the erosion simulation was conducted in the same hydrographic area, under the same geographical, climatic, pedological and relief conditions. The research focuses on a location with steep slopes affected by significant soil degradation processes.

This paper used five input parameters in the simulation process using the USLE model: daily weather forecasting, vegetation or food growing management, land and soil topography. The model is based on daily regulates the hydrological state of the tested soils. Since climate change has had a major impact on soil erosion, the WEPP model has proven to be an efficient tool in erosion modelling, as it allows the entry of a large set of climate data. The WEPP model has also been used worldwide due to its ability to accept a multitude of data sets of soil characteristics. In the present case, in our research, the USLE model was used first, being launched before WEPP, as it has been used worldwide, but the results obtained with the WEPP model were good in almost all our simulations. The main results of this phase of our research show that the erosion is significant and exceeds acceptable limits. Therefore, in conclusion, major support practice actions and an appropriate agricultural practice are recommended to mitigate the effects of erosion process.

Key words: GIS, modelling, runoff, soil topography, water erosion

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1. Introduction

Along with other soil degradation processes, erosion contributes to the continuous contraction of the world's agricultural land, while the dramatic increase in population worldwide requires special measures for natural resources preservation. (Burrough, 1988). One third of the ground surface worldwide is in an acute state of degradation. The fertile soil loss rate amounts to 24 billion tons per year. In Romania, this process is intensified by both natural

factors (relief, climate) and anthropogenic factors due to negative human action.

In Romania, the annual soil losses due to erosion range from 3.2 to 41.5 t/ha/year, while tolerable losses are as high as 3 to 6 t/ha/year, and about 150 million tons of soil, containing about 1.5 million tons of humus, 0.45 million tons of N, P, K, are lost on the entire agricultural land each year (Biali et al., 2014; Bilasco et al., 2018; Niacsu, 2012).

The risk of erosion can be estimated using an expert system (qualitative) or a model (quantitative)

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approach). Over the last decade, a series of initiatives have been developed to assess the risk of soil erosion at country, European and global levels. The methodologies to assess the risk of erosion are: USLE, CORINE, RIVM, GLASOD, EEAPESERA and others (Biali et al., 2019; Irimus et al., 2017).

As a result of recent studies, the scientific community has developed and extended the concept of DPSIR (Driver, Pressure, State, Impact & Response) for environmental changes (Berghoff et al., 2014). The main purpose of this concept was to transform environmental changes into information that is easily accessible for decision makers (DPSIR used by the European Environment Agency) (Haidu and Costea, 2012).

When it comes to erosion, the concept mentioned above ensures a chain of causes and effects determined by this form of degradation, which obviously also involves society in its entirety. When trying to determine and quantify all these factors on a case-by-case basis, the first step is to try to estimate the risk. The determining forces of erosion are: human population, land development, tourism, agriculture, transport, natural events and climate changes.

The pressure factors are: the degree and type of land coverage and climate changes. The pressure factors act as indicators that provide information regarding the *stage* (degree) of erosion and the *impact* of (direct or indirect) changes determined by erosion on certain systems (e.g. soil characteristics, biodiversity, etc.), to which the society will *respond* with a series of rules, policies or certain behaviours (strategies of conservation) (Biali and Cojocar, 2018).

Observing and measuring the factors that influence the susceptibility to erosion (the so-called factorial approach) is a way to determine and classify surfaces at risk of erosion. The measurement indicators generally characterize climatic conditions, soil, topography, etc. The positioning of these indicators on the map results in the drawing up of maps presenting the risk of erosion. The accuracy of the data used obviously contributes to achieving quality results, but the advantage of using the GIS technique on large areas consists of integrating these data into different mathematical-hydrological modelling patterns. However, sometimes the algorithms used to integrate these data have some shortcomings and thus simulation errors occur.

Comparisons are therefore necessary. This type of methodology deduces the risk of erosion from the current stage reached by this form of soil degradation in a specific area. Expert-type analyses estimate the risk of erosion directly from field observations and/or satellite images and aerial photography. Characteristics such as: the aerial extension and coverage of gutters, ravines and sediments deposited are parameters that ensure a real indication of the level of erosion, apart from the measurements made at plot-level in order to determine the intensity of erosion (Dumitrescu et al., 2014).

In order to derive erosion risk estimations at a national scale, experts can be consulted through surveys. A quick and easy way to estimate an erosion risk in a particular area may be the expert approach method. In this case, the experts are consulted through surveys.

A computer application creates a database that allows drawing conclusions, especially where there are uncertainties or the results are not clear from the very beginning. Such an approach is exemplified by the GLASOD Global Assessment of Soil Degradation (Fig. 1), of the UNEP project (United Nations Environment Programme).

It is based on the answers to a survey sent to renowned experts in different countries and thus depends largely on a set of expert-type analyses.

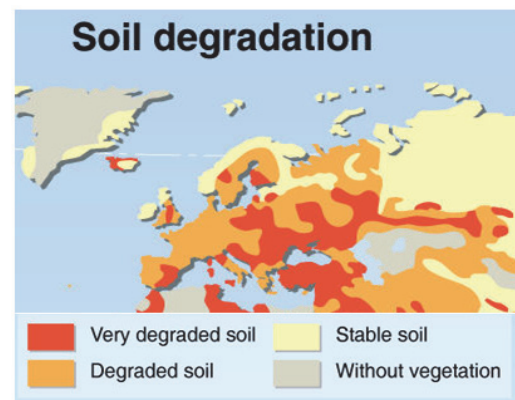


Fig. 1. Water erosion of soils in according to the GLASOD approach Source: United Nations Environmental Programme – GRID (<https://seos-project.eu/resources/resources-c01-s01.html>)

The GLASOD map can be used by: international decision makers, national decision makers, international programs and conventions, researchers, at national and international level, universities, professors and students, environmental organizations (public awareness), etc. The disadvantages of using the GLASOD map are: small scale, expert assessment (qualitative and potentially subjective), limited number of attributes, only the dominant type of degradation is represented by colour, etc. The data shown in Fig.1 are general but they suggest that Romania is positioned in an area of significant soil erosion.

The map of Western Europe presenting the risk of soil erosion is another example of such an expert-type approach. The map was drawn up by various experts who have outlined the areas that affected by erosion processes.

2. Material and methods

2.1. An empirical approach to estimate erosion

The sediment balance is the final product of erosion through the action of water and other agents.

The total volume of eroded material within a hydrographic basin constitutes the gross or total erosion. From this quantity, only a part enters the hydrographic network. A part of the material is deposited at the base of slopes in the form of alluvial cones, or in the major riverbeds in the form of alluvial ridges or fields. The quantity of eroded material transported through the hydrographic network is known as solid runoff.

In order to assess the risk of soil erosion, it is necessary to map and analyze many factors involved in the erosion process: aggressiveness of rainfall, steepness and length of slopes, erodibility of soil, vegetation and agricultural practices. Each factor has a different behavior from one area of the region to the next. A great deal of data to be mapped, stored, structured and processed rationally is thus collected.

The majority of the empirical approaches for estimating the rate of erosion are based on the following methods (Wischmeier and Smith, 1978):

- 1) The Universal Soil Loss Equation (USLE) or one of its amendments;
- 2) Sediment production calculation as a function of the receiving surface;
- 3) Sediment production calculation as a function of runoff characteristics.

The empirical modelling of erosion, in this case, applying the USLE model, implies a series of intrinsic limitations, which derive from the specificity of the model:

- model is only applicable to planar, not linear erosion;
- model was tested on plain and hill regions with slopes of 5 – 25 %;
- relation between kinetic energy and precipitation intensity;
- model is applicable only for calculating the average values of soil losses for time frames over 20 years and is not applicable to unique events;
- neglects some interactions between factors, so it is difficult to distinguish the role of each of them.

The model represents a multiplicative function of six hydrological factors (Eq. 1): climate aggression, soil erodibility, steepness and length of slopes, vegetation coverage and support practices:

$$A = R \cdot K \cdot LS \cdot C \cdot P \quad (1)$$

A —annual rate of soil erosion, ($t \cdot ha^{-1} \cdot year^{-1}$); R – rainfall erosivity (energy factor), ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot year^{-1}$); K —soil erodibility—depends on soil granulometry, on the quantity of organic matter in soil, soil permeability and structure, ($t \cdot ha^{-1} \cdot h^{-1} \cdot MJ^{-1} \cdot mm^{-1}$); LS —relief factor, dependent on the length and inclination of the slopes, dimensionless; C - vegetation cover factor, dimensionless; P – support practices factor, dimensionless (Wischmeier and Smith, 1978).

Factors R , K and C are usually determined within field research over several years in order to assess annual climate variations, requiring major time and resource investments. Empirical equations are developed using data collected from specific

geographical areas, and for this reason, the use of these equations is limited to the given areas. Consequently, several attempts have been made to change or adapt models such as USLE in order to adjust them to other conditions than those of the central and eastern United States, for which they were created. Applying the USLE model required assessing a variety of factors of the equation for the entire surface of the area studied and expressing them in the form of thematic maps. These maps were integrated in Geo-Graph GIS through the process of map digitizing. The polygons obtained for each map have their own attributive databases. The maps were overlapped using Raster Map Calculator in ArcGIS (Niacsu et al., 2015).

Among the six factors, rainfall erosivity and vegetation cover have a great variability during the year. Thus, data regarding rainfall erosivity combined with data regarding the vegetation layer and agricultural practices can be used to research soil erosion at different scales. Intra-annual variations in rainfall erosivity affect agriculture, forestry, water management and ecosystem services. Consequently, neglecting intra-annual variability of rainfall erosivity can lead to inappropriate decision-making (Wischmeier and Smith, 1978).

2.2. Expert systems

An expert system (ES) is a complex app (a software program) that explores a great deal of knowledge in order to draw new conclusions about activities that are difficult to examine, using methods similar to human experts (Popita et al., 2014).

About multi-criteria analysis, applying Geographic Information Systems (GIS) allows to manage information efficiently and to facilitate the integration of multiple layers of data with various analysis procedures. Integrating Risk Analysis, using Geographic Information Systems, with Multi-Criteria Evaluation (MCE) and with Analytic Hierarchy Process (AHP) is probably the most appropriate method to solve complex problems regarding: natural and anthropic risk distribution, land use, spatial planning, etc (Clinciu et al., 2010).

The Weighted Linear Combination (WLC) of map layers within the AHP is a strategy to evaluate multi-criteria decision-making problems. The WLC applies Eq. (2):

$$E = \sum_{i=1}^n W_i \cdot V_i \quad (2)$$

where: W_i - the importance/relative weight of factors/parameters; V_i - the relative weight of parameters i ; n - number of parameters.

In order to integrate geographic data and preferences/knowledge of decision makers into a single value, the Analytic Hierarchy Process (AHP), developed by (Moore and Wilson, 1992), is used. It is a mathematical instrument used for the systemic analysis of complex decision-making problems. AHP

is not a “correct” decision-making instrument in itself; it only allows to find, among a multitude of alternatives, one solution that corresponds, to a large extent, to the way the researcher understands to solve a given problem (Biali et al., 2018; Iacobescu et al., 2012). The program solutions implemented in GIS compare the map layers taking them two by two and determine the weight values of each. In this manner, the decision makers can select the right result by defining a hierarchy for a complex problem.

In this work, the risk of erosion was analyzed for the study area for five data sets at input (Fig. 2). In the first phase, the weights of the layers (factors/criteria) were calculated using AHP, then the map of the potential distribution of the risk was generated using the WLC (Weighted Linear Combination) analysis. For this purpose, the AHP extension for the ArcGIS program was applied for WEPP model (Cochrane and Flanagan, 1999). The WEPP (Water Erosion Prediction Project) model was

developed within the USDA/ARS-USA. It was originally presented in 1990 and has evolved continuously. It is a computerized model based on a new technology for predicting soil erosion by water, taking into account the laws of water infiltration and percolation, soil physics, hydraulics and erosion and runoff mechanisms, and the grounds of agricultural plant growing science (Cochrane and Flanagan, 1999).

This model aims to determine the hydrological parameters and the erosion potential of runoff on different areas of a slope, in various conditions of land use and in the presence of a variety of agricultural practices (Biali and Cojocaru, 2020).

The two models (USLE and WEPP) have been tested for a long time in the USA, Europe and Romania and the results confirm that both models are reliable and can be used successfully (Moțoc, 2002; Renard et al., 1997; Wischmeier and Smith, 1978).

The main input/output data of the WEPP model are present in Fig. 2.

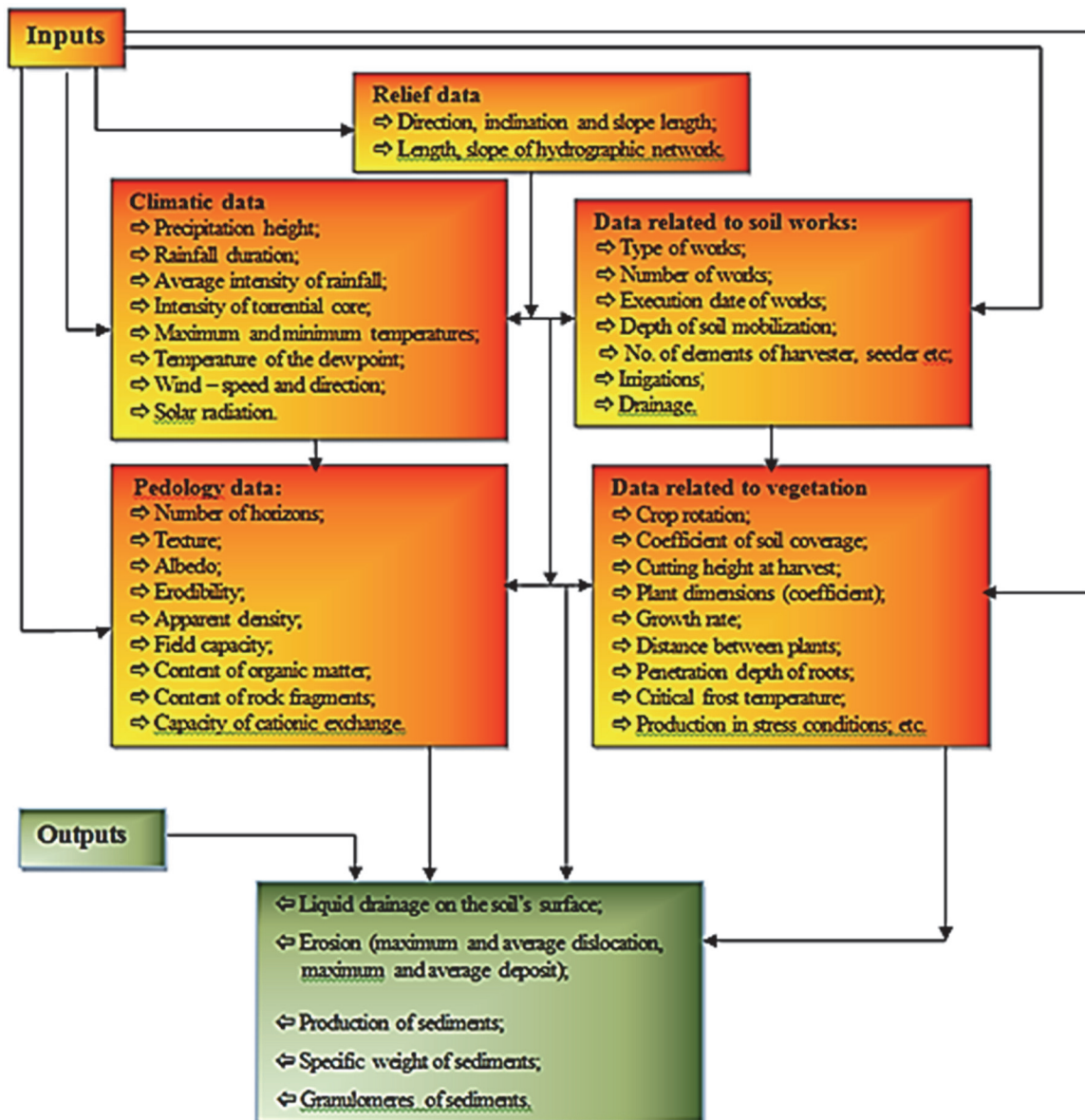


Fig. 2. The main input/output parameters of the WEPP model (Cochrane and Flanagan, 1999)

The WEPP and USLE models are among the most common in the world and they are used to simulate water-caused erosion. The research in this paper simultaneously uses WEPP simulation and the USLE model to make a comparative result analysis. The input parameters are different but erosion quantification by simulation provides the same information.

3. Results and discussion

3.1. Localization of research

Our research location has the following characteristics: the land has an area of 1,107 ha and is located in the Ghilavesti river basin, in the upper Berheci basin, in Tutovei Hills in Bacau County, in the North-Eastern part of Romania (Fig. 3).

This location was chosen for our research first of all due to the relief factor: the relief is very fragmented, with forms of deep erosion, with a relief energy of over 270 m, the average slopes have high values of over 18%. From a climatic point of view, the studied land is located in an area of Romania with high rainfall aggressiveness, where the rainfall aggression coefficient is higher than 0.100. The predominant soils in the studied river basin are chernozems and brown soils, which generally fall into high erodibility categories. The land is mainly arable land and pastures. Some of this land is affected by significant gullying and landslide processes (Biali et al., 2014).

3.2. Modelling erosion by USLE with Geo-Graph GIS

The USLE model has been modified and adapted according to the specific factors that trigger and maintain the erosion process on the Romanian territory. This model was developed by researchers from the Institute of Pedology and Agrochemical Research in Bucharest (Motoc, 2002).

3.2.1. Rainfall aggressiveness (pluvial erosion - R)

Rainfall characteristics (R on Eq. 1) such as: frequency, duration, quantity, intensity and kinetic

energy play important roles in soil erosion by water.

The R factor in the general formula USLE is recognized as being one of the most adequate parameters to predict the erosive potential of raindrops and of the potential capacity of transporting rainfall runoff, respectively. At the regional level, data on climate erosion can be used as an indicator of the potential risk of erosion. The R factor does not take into account soil losses due to melting snow, ice or to the action of the wind.

Often, the only data freely available on rainfall are the monthly and annual averages. Some authors (Ioniță et al., 2014) have developed alternative formulas that only involve monthly and/or annual average rainfall in the calculation to determine the R factor. The calculation relation R (Eq. 3) is entered in the calculation module *r.usler*.

$$R = \sum_{i=1}^n r_i \quad (3)$$

For data on rainfall, the raster of the average annual rainfall level was used. Using the *r.usler* module, R factor maps were calculated (Fig. 4).

Runoff concentration values represent the “receiving basin” from which liquid and solid runoff is accumulated (Fig. 5). Therefore, the higher the value of a cell, the more it is assumed that a larger amount of water and sediment, respectively, will pass through it. The flow direction is calculated using two models: the MFD (Multiple Flow Direction) and / or SFD (Single Flow Direction).

3.2.2. Soil erodibility (K)

It is the factor of soil erodibility - namely of its capacity to withstand/undergo erosion. K factor sizes vary between 0.1-0.9. As the value of parameter K increases, the infiltration decreases and the risk of soil erosion increases. It is obtained based on the intrinsic properties of soils, such as texture, structure, organic matter content and measures soil resistance to erosion. It represents the erosion rate determined experimentally under standard conditions.

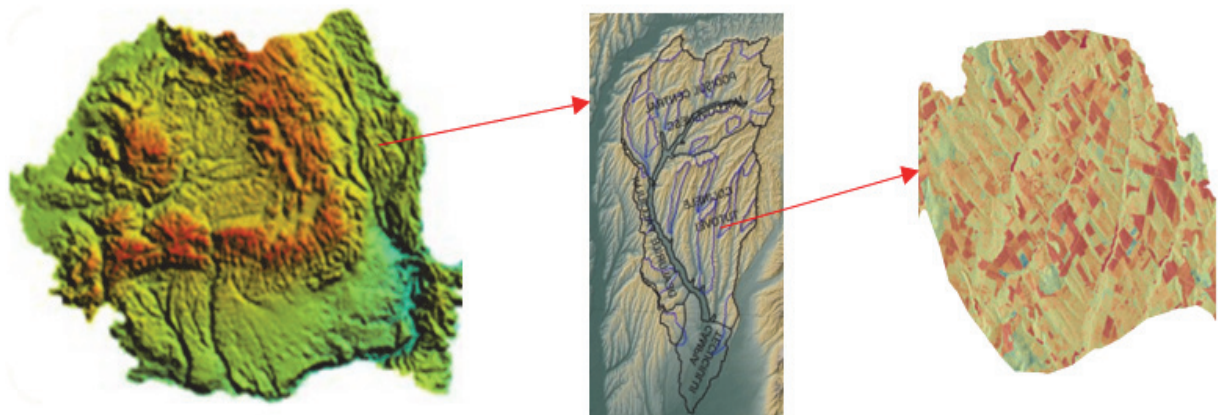


Fig. 3. Location of the study area (Ghilavesti catchment)

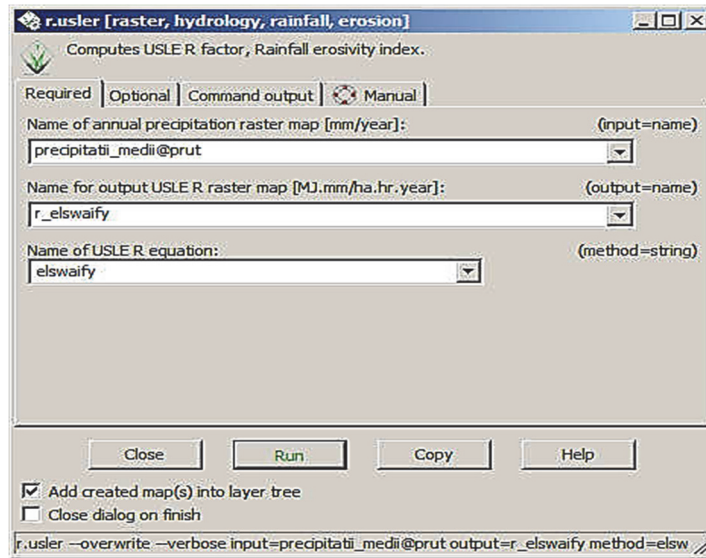


Fig. 4. Graphical interface of the *r.usler* module

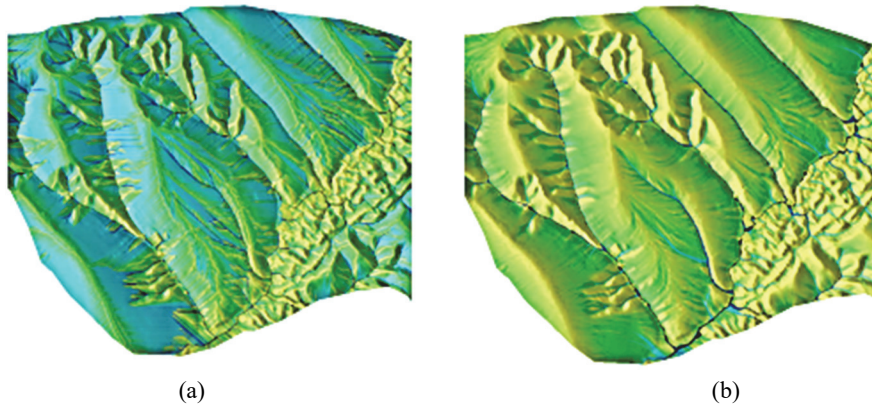


Fig. 5. Runoff accumulation: (a) multiple flow direction; (b) single flow direction

Repeating the experiments under different soil conditions has led to the development of an equation (Eq. 3) to calculate soil erodibility:

$$K = \frac{2.1 \cdot M^{1.14} \cdot 10^{-4} (12-a) + 3.25(b-2) + 2.5(c-3)}{100} \quad (3)$$

where: *M*-(sand + dust) (100 - clay); *a*-share of organic matter (%); *b*-soil structure code; *c*-soil permeability code.

In order to develop the K factor map, data from the soil map at a scale of 1:10,000 were used. Vector data were converted to raster format in order to be able to be used as input data for the *r.uslek* module, implemented in GIS, used to calculate the soil erosion factor (K) in USLE (Fig. 6). The module input includes the soil texture (psand, pplay, psilt/dust) and organic matter content (pomat) rasters. The input data was the percentage of dust, not silt. These data are available from previous research (Biali et al., 2018; Niacsu et al., 2015). The output raster represented by the soil erodibility factor (K) is determined by running the *r.uslek* module. The spatialization of this parameter (K) is shown in Fig. 7.

3.2.3. Relief factor (LS)

The length of the slope determines the concentration of water - between the two being a direct link (the longer the slope, the more water is concentrated at its base). Furthermore, the steeper the slope, the higher the erosion. The combination of the S and L factors represents the topographic factor (LS). It can be calculated according to the formula of (Eq. 4):

$$LS = \left(\frac{\lambda^t}{22.13} \right) \cdot (65.41 \cdot \sin^2 \beta + 4.56 \cdot \sin \beta + 0.0654) \quad (4)$$

where: λ - horizontal projection of slope length (m); *t* - constant depending on the size of the slope (equal to 0.5 for $s > 5\%$, 0.4 for $3\% < s \leq 5\%$, 0.3 for $1\% < s \leq 3\%$, and 0.2 for $s \leq 1\%$); β - slope in degrees.

The methods (conventionally called *r.flow*) applied to calculate the LS factor in GIS consists of the following stages:

- using the order *r.flow*, the runoff concentration raster is calculated (*flowacc*)
- using the order *r.slope.aspect*, the slope is calculated (slope)
- using the instrument *r.mapcalc*, the LS factor

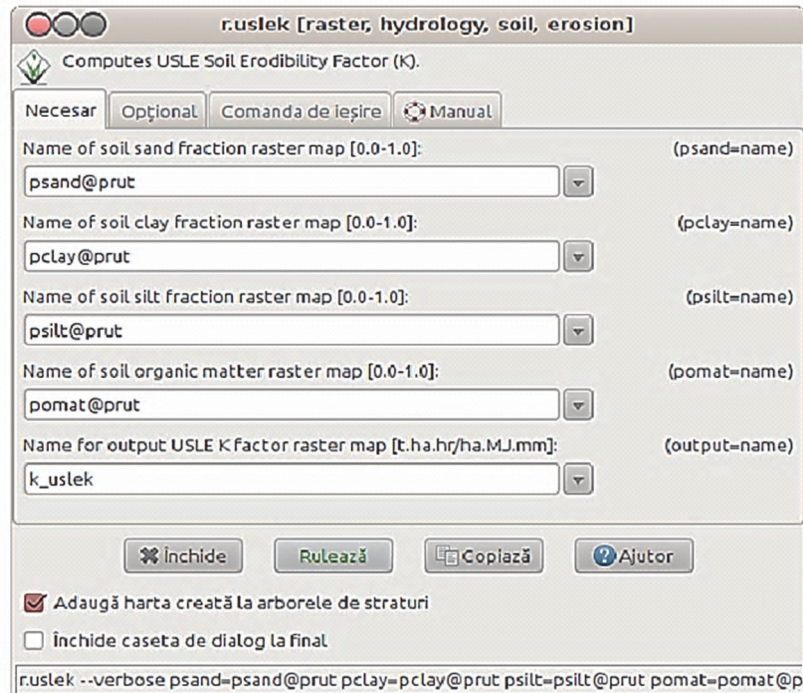


Fig. 6. Graphical interface of the *r.uslek* model

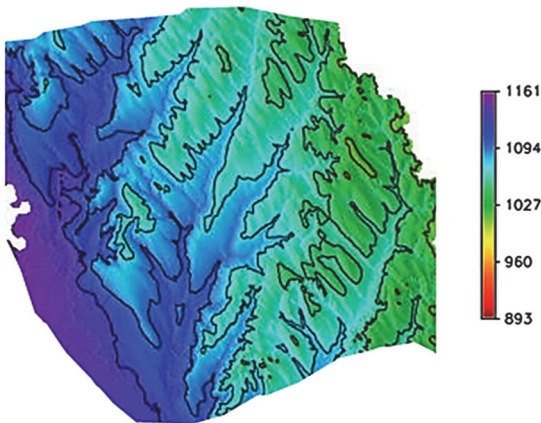


Fig. 7. Soil erodibility (factor K)

deposits, respectively, as well as to highlight potential surfaces exposed to linear erosion.

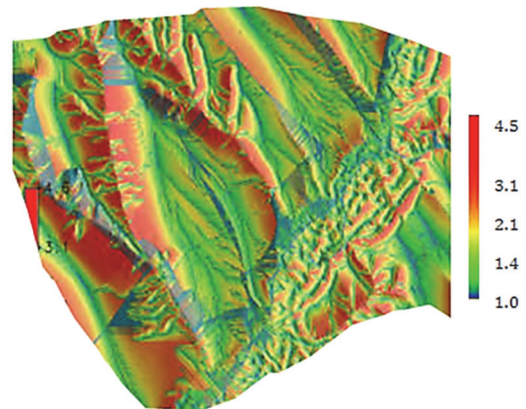


Fig. 8. Slope length factor

The *r.watershed* module in GIS provides a more efficient method to determine the LS factor. It analyses elevation for the purpose of calculating basic hydrological parameters and USLE factors. Thus, raster maps of runoff accumulation, drainage direction, watercourses and hydrographic basins, as well as LS and S factors from the USLE model can be calculated. The LS factor is obtained as a product of two components: the length factor (Fig. 8) and the slope inclination factor (Fig. 9).

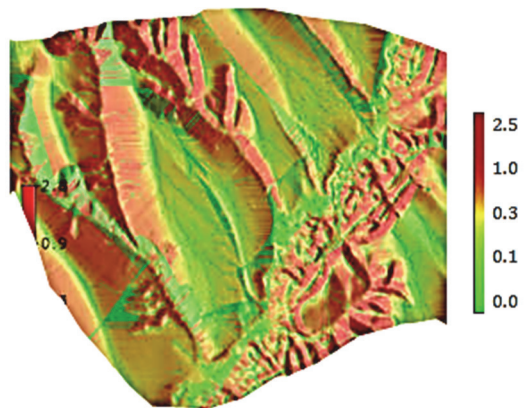


Fig. 9. Slope inclination factor

Figs. 10-11 present the distributions of LS factor values (*ls.r.watershed*) within the area studied. First of all, a different structural model of the spatial distribution for the two runoff calculation methods (MFD and SFD) can be noticed. The MFD model results in a more complicated structure, which highlights the drainage pathways, thus serving as an efficient method to determine erosion areas and

Moreover, as regards the two methods (SFD and MFD), the statistical analysis shows higher average values for SFD (0.63-0.7) than for MFD (0.29-0.32). Thus, using two methods can result in fairly different results, leading to the overestimation or underestimation of soil losses up to twice as much.

The distribution of LS values is presented in Fig. 9, which also shows the presence of higher values in case of using the SFD method.

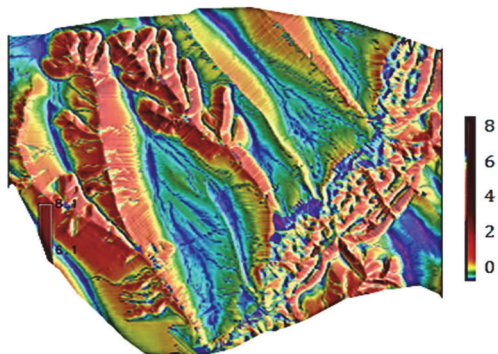


Fig. 10. LS factor (MFD)

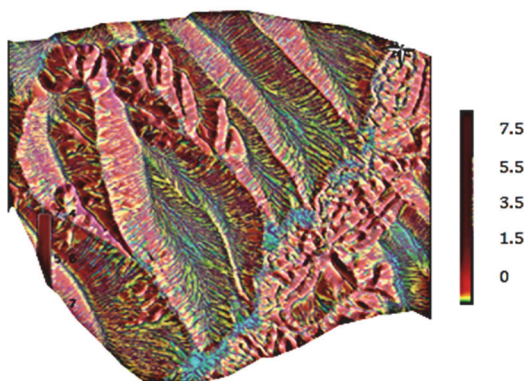


Fig. 11. LS factor (SFD)

3.2.4. Vegetation and management cover (Factor C)

One of the most important factors in the USLE (and RUSLE) equation is the vegetation and management cover factor (C) representing the effect of vegetation and of agricultural practices on soil erosion rates. It also shows the manner in which the erosive potential will be distributed throughout the year, in different agricultural, construction, etc. phases. Factor C represents the influence of vegetation on soil erosion and can take values between 0 - in forests, where due to compact vegetation, erosion is reduced to zero and 1 - in areas uncovered by vegetation, where erosion takes place without the moderating effect of vegetation.

The vegetal layer protects the soil by dissipating the energy of raindrops. Thus, soil erosion can be limited through adequate management techniques. In both models, USLE, the factor C is calculated from empirical equations containing field measurements (Eq.5):

$$C = 1.02 - 1.21 \cdot NDVI \quad (5)$$

NDVI - Normalized Difference Vegetation Index. The spatialization of this parameter (C) is shown in Fig.12.

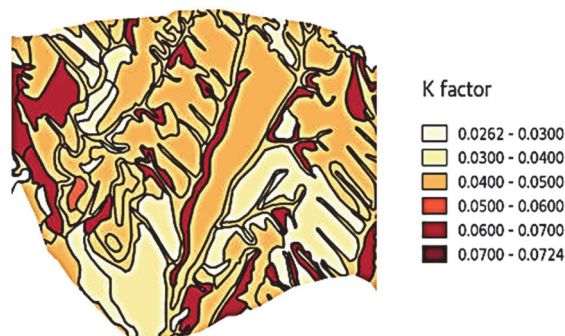


Fig. 12. Vegetation and management cover (factor C)

3.2.5. Support practices (P)

Ploughing and orienting agricultural plots parallel to contours, cultures in alternating strips or on terraces, reforestation, creating mounds and rock ridges are the most effective practices for conserving soil. P factor values are lower than or equal to 1. Value 1 is assigned to lands where no support practices are taken. For the purpose of generating the map layer of the P factor we have used the crop cover/use Map. The database with map attributes in vector format was filled in with the correspondences from interval values 0.05-1.0 (Biali, 2018) for the categories of vegetation cover/use, after which the vector layer of the map was converted to raster format.

3.2.6. Potential annual soil loss (A potential)

Soil loss maps (Figs.13-14) have been generated as a product of map layers representing the factors in the USLE model. Thus, we have generated potential soil loss maps under given conditions of rainfall, soil and relief and estimated soil loss, also taking into account the conditions of vegetation cover/use (Table 1).

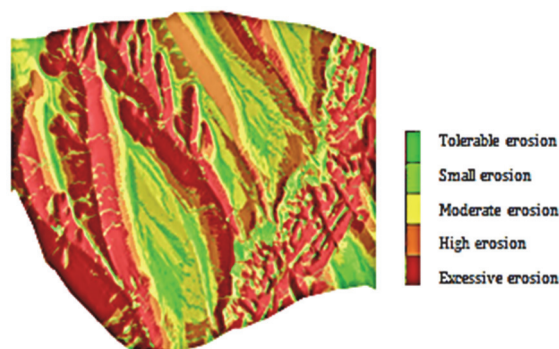


Fig. 13. Potential annual soil loss (MFD)

Potential soil erosion calculated according to the commands used in GIS, (Eq. 6), as a product of rainfall erosivity factors (R), soil erodibility factor (K) and relief factor (LS).

$$r.mapcalc = r.regresie@prm \cdot k_SI@prm \cdot length.slope. \cdot mfd.@prm \quad (6)$$

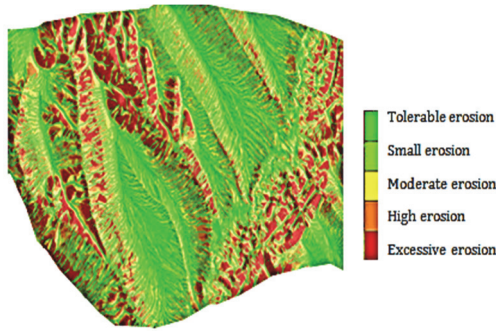


Fig. 14. Potential annual soil loss (SDF)

We have ranked erosion in 5 erosion classes based on our modelling results and SQL query analyses in the output database. The results are shown in Tables 2. We notice a high proportion of high and very high-risk classes for erosion in the case of estimation using the SFD method, compared to the MFD method, where a high proportion is recorded in low-risk classes (Table 2). Soil losses that do not exceed 4-6 (t·ha⁻¹·year⁻¹) and that occur over a 50-100

year range can be recovered if the soil has the capacity to recover. Soil losses of more than 10 (t/ha/year) can be irreversible if adequate soil protection actions are not taken.

3.3. Modelling erosion by WEPP with ArcGIS

With WEPP model was used to process sets of spatial and georeferenced data, and some essential parameters in soil losses due to erosion could be determined. The database that we have created allows different variants of erosion process simulation. ArcGIS 9.2 analysis provides a wider range of data on the phenomenon depending on the influence of each parameter. Thus, factors such as soil erodibility, rain aggression factor, positive effects of crops and agricultural practices on land, etc. can be assessed. (Biali et al., 2014).

By comparing the Geo-Graph results using USLE and the GIS analysis results, we noted that the maps looked the same, but the percentages were different (Figs. 16-19).

Table 1. Soil loss tolerance classes (Moțoc, 2002)

Soil erosion class	Soil erosion type	Soil loss (t·ha ⁻¹ ·year ⁻¹)
1	Very small (tolerable)	< 4
2	Small	4.1 – 9.5
3	Moderate	9.5 – 20.0
4	High	20.0 – 40.5
5	Excessive	> 41

Table 2. Proportion of potential erosion classes in the study area

Soil erosion class	Risk class (t·ha ⁻¹ ·year ⁻¹)	SFD model	MFD model
1	Unappreciable erosion (<4)	11.04%	9.25%
2	Weak erosion (4-10)	12.27%	13.28%
3	Moderate erosion (10-20)	23.25%	32.61%
4	High erosion (20-40)	31.02%	24.42%
5	Very high/excessive erosion (>40)	22.41%	20.41%

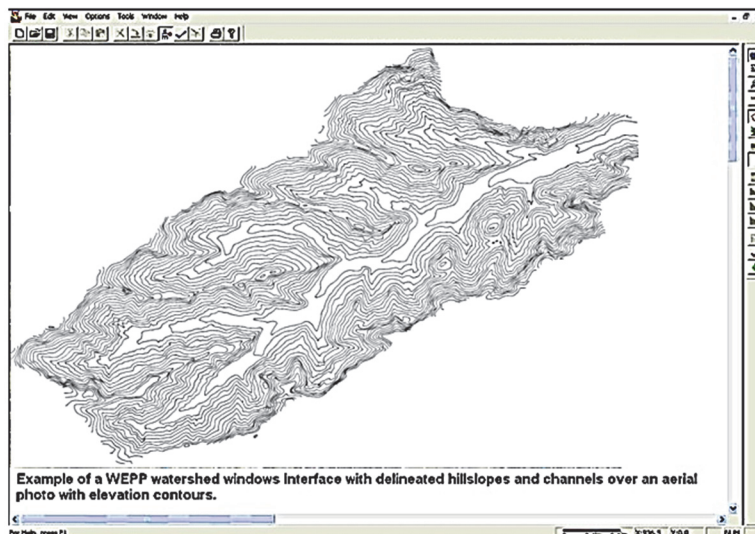


Fig. 15. WEPP watershed window in area studied

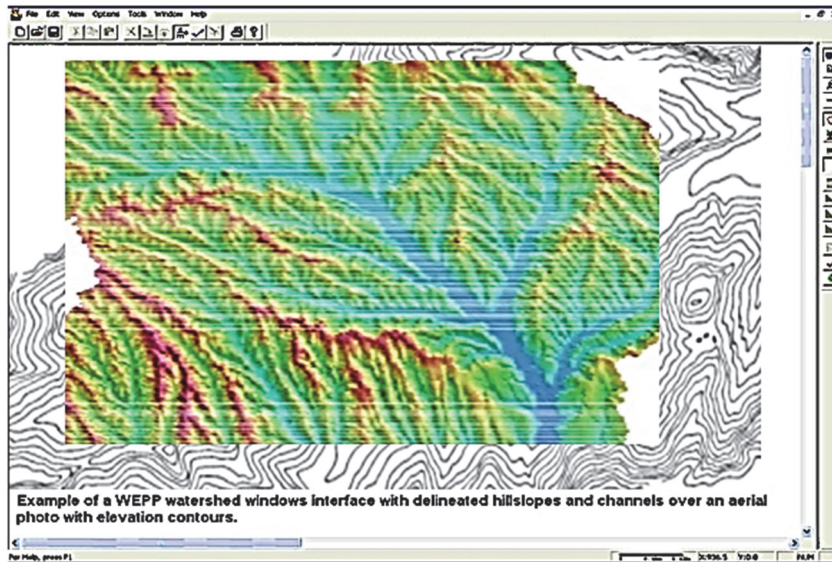


Fig. 16. Slope map (with ArcGIS)

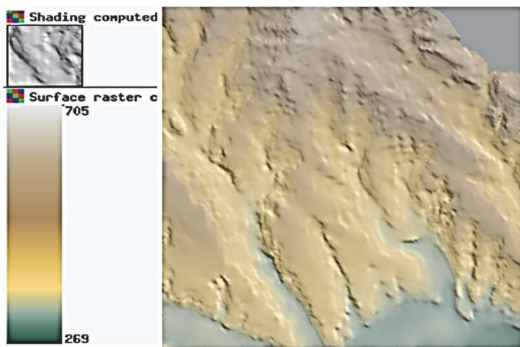


Fig. 17. Hypsometric map (with ArcGIS)

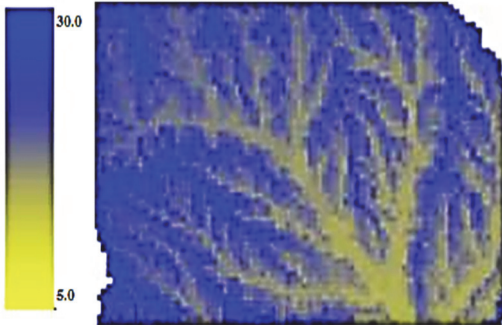


Fig. 18. Runoff concentration (with ArcGIS)

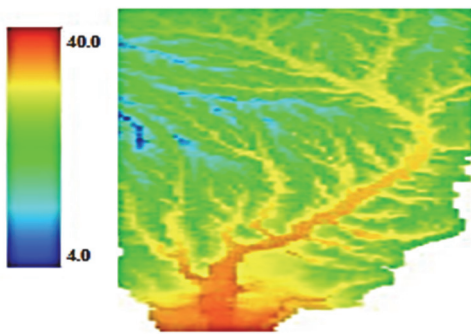


Fig. 19. Annual soil loss map (with ArcGIS)

The results obtained by both methods are similar, as it was predictable the MFD method is closer to the modelling in WEPP. By erosional modelling (both methods), the territory studied falls into the following erosion risk classes: class 1 (unappreciable erosion) - 7.15%; class 2 (weak erosion) - 11.10%; class 3 (moderate erosion) - 31.16%; class 4 (high/severe erosion) - 25.1% and class 5 (very high/excessive erosion) – 25.8%.

The results from both simulations (with USLE and WEPP) show that the erosion is high to excessive. The percentages in Tables 2-3 confirm the vulnerability of the researched area to the degradation processes (Fig. 20).

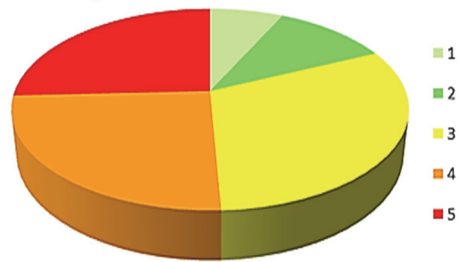


Fig. 20. Diagram of average erosion with the both models (USLE and WEPP)

Table 3. Soil loss tolerance classes in modelling with WEPP

Soil erosion class	Risk class (Soil loss) ($t \cdot ha^{-1} \cdot year^{-1}$)	Percentages of the studied area
1	Unappreciable erosion (<4)	5.05%
2	Weak erosion (4-10)	8.17%
3	Moderate erosion (10-20)	29.71%
4	High erosion (20-40)	25.78%
5	Very high/excessive erosion (>40)	31.30%

4. Conclusions

1. The novelty of our research consists of the fact that the data sets and databases created may be used in mathematical GIS modelling. This makes it possible to monitor erosion in the same river basin at different times and it allows the detection of changes/modifications in that territory. Based on these changes, methods of agricultural land management may be proposed consisting of anti-erosion practices and works.

2. Hydrological erosion modelling is a greatly researched issued. Currently, researchers have succeeded in diversifying the models of erosion, all based on: various algorithms (empirical, physical), approaches (qualitative, quantitative), characteristics (soil losses, alluvium accumulation) and factors (rainfall, relief, soil, vegetation, land use) of the erosional process, spatial (plot, slope, basin) and temporal scales (single event, average) and forms of erosion (laminar, runoff, ravine, on the bank).

3. The relatively large variability of climatic conditions results in a fairly wide range of rainfall erosion values in the study area, values ranging between 893.4 and 1161.5, at an average of 1058.2 (MJ mm ha⁻¹ h⁻¹ year⁻¹)

4. Relief factor (LS) estimation is of major importance in calculating soil loss; the estimation method used having a primary role as regards the result, which can change even twice. Thus, the SFD method provides results ranging between 0.63 and 0.7, and the MFD method – of only 0.29-0.32. Thus, selecting different algorithms for runoff does not only determine the amplitude of the resulting values but also the model of the spatial distribution of relief factor values.

5. Crop/vegetation and management factors (C) and support practices (P) are real estimation issues, requiring the mapping of vegetation cover/use and support practices arrangements. In this regards, using remote-sensing techniques and photointerpretation of satellite images and aerial photographs, using LiDAR data to create highly accurate numerical models of lands become irreplaceable.

6. Under the conditions in Romania, the soil lost by erosion is recovered through a natural process of pedo-genesis at a rate of 4-7 (t·ha⁻¹·year⁻¹). Thus, the studied area presents a major danger of water erosive degradation, it can be saved only by suitable appropriate agrotechnical practices and support practices.

7. In the context of natural and social-economic conditions from Romania, the use of GIS for the analysis and prognosis of land erosion and other associated processes represents a very modern requirement, taking into account the economic grounds and the speed of obtaining the information required for taking the appropriate decisions of improving the situation, in real time.

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STUDY ON CROP SUITABILITY AND AGRICULTURAL LAND EVALUATION USING THE GIS TECHNOLOGY

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ABSTRACT

Our research reveals the importance of GIS technology for land evaluation. The research was conducted on a piece of land of about 770 ha in Romania, which enjoys a diversity of natural factors. Land suitability evaluation, especially given limited land resources, is an important stage in the assessment of its ecological state and for land use planning.

The main goal of this evaluation is to estimate the possibilities of maintaining the optimal natural potential of the soil in the process of a certain mode of use over a long period of time. Based on the analysis of the contribution of the various land favorability parameters, we assessed the Agricultural Land Suitability Index and the findings are grouped into five classes of suitability: very good, good, moderate, medium and poor. This classification was made by superimposing several layers of information in a Geographic Information System - GIS. The research described in this paper relies on field data acquisition using a GPS and drone, and on data collected from databases of various institutions. The data were processed using ArcGIS software.

This land evaluation action/activity allows one to determine the relative value of a piece of land. The GIS technique may be used to easily compile a database (attribute and graphics) for a large territory and for a very wide range of agricultural crops, respectively. These analyses allow determining the most appropriate uses and crops in terms of profitability, as they may reveal crop yield and economic efficiency on a regular basis.

According to this paper, GIS analysis allows the practical interpretation of the natural characteristics of the studied soil in terms of both actual evaluation and technological soil characterization.

Keywords: evaluation, soils, agricultural crop suitability, GIS

INTRODUCTION

Land evaluation allows determining the relative value of a piece of land, i.e. the most suitable and profitable uses and crops for that land. These works, which may reveal crop yield and economic efficiency on a regular basis, allow the collection of the necessary data for the substantiation of technologies, investments, remuneration of agricultural work, etc.

The practical interpretation of the research on the natural features required for good crop yield distinguishes between evaluation and technological land characterization.

As the production capacity of land changes under the influence of natural factors, but more particularly due to human intervention, land evaluation must be constantly updated (in line with each stage of agricultural and economic development as a whole). Where land improvement works have been carried out, which lead, in all cases, to the substantial modification for the better of all environmental factors, the assessment of the production capacity of that land should consider them, i.e. the so-called enhancing elements should be incorporated. [2], [3], [7].

Favorability is the extent to which a piece of land meets the living requirements of a given crop plant, under normal climate conditions and rational use. According to natural bonitation score, there are ten classes of favorability for each crop and agricultural use. Natural fertility is the overall property of the soil to provide nutrients in amounts and shares appropriate to the growth of those categories of crops for which temperature and other environmental factors are favorable.

Soil quality includes all soil properties that provide it with a certain degree of natural fertility. Land quality includes both soil fertility and the way in which the other environmental factors (cosmic-atmospheric factors, such as light, heat, rainfall, etc., geomorphological and hydrological factors) influence plants. They all impact human labor productivity differently in relation to the way in which the physiological requirements of plants are satisfied. From this point of view, land quality is determined in terms of favorability and bonitation score for natural conditions for a particular use.

The land suitability unit represents the area resulting from the grouping of land units according to a particular set of specific characteristics, in order to determine use categories. The pedological study includes the grouping of productive agricultural land in classes of suitability for use (arable, vineyards, orchards, pastures, hay fields). From this point of view, land ranges from the best and easily usable in agriculture to land without agricultural value, but which can be used for other purposes, [4], [6], [9].

Land grouping in terms of suitability includes 6 land classes. These classes are defined taking into account the extent of agricultural use limitations and restrictions and are summarized in the suitability unit formula, [11].

Land suitability refers to land grouping or classifying into classes, subclasses and subdivisions for a particular purpose. Land grouping in suitability classes for different uses and developments is done according to the “Pedological Study Development Methods”, the second part, published by I.C.P.A. Bucharest in 2007, [3], [5].

Land grouping in suitability classes requires ordering the various piece of land according to their applicability for different uses and developments, and specifying the deficiencies that limit its intensive use or development for different purposes. The grouping is done in classes, subclasses, groups and subgroups, depending on the nature and intensity of the restrictive production factors. Restrictions refer to existing conditions that impact crops and to the risk of occurrence of degradations with the same effects due to land exploitation.

Restrictive factor analysis reveals the required improvement actions and operation optimization measures. In Romania, land falls into 6 classes of suitability for different uses, marked with Roman numerals, where class I has no restrictions and class VI has extremely severe restrictions. Limitations may refer to soil, climate, relief or drainage.

2. MATERIALS AND METHODS

2.1. Research methods

The physical and chemical characteristics of soils, and their use limitations and possibilities were assessed to determine land suitability. In order to identify the agricultural potential of the premises, the following characteristics were analyzed: land use/categories, soil categories, organic matter content of soils, humus layer thickness and slope. Physical parameter assessment allows collecting information on restrictions related to the agricultural use of that land. The notion of limitation is related to land quality. For instance, if the slope is considerable, the land is prone to erosion. The higher organic matter content indicates 'better soil health'. The multifactorial analysis of the suitability indicator was performed by feeding all these parameters into a GIS environment. The thematic maps obtained were drafted, all the polygons in the thematic maps were assigned particular favorability values: very good, good, moderate, medium and poor, [2], [8]. Land suitability for agricultural uses was calculated by superimposing maps and by means of the GIS calculation model. This agricultural land suitability index was calculated using the following formula:

$$\text{IPAT} = 0.2 (\text{UT})i + 0.2 (\text{CS})j + 0.1 (\text{P})k + 0.25 (\text{CO})m + 0.25 (\text{A})n$$

Where:

IPAT – agricultural land suitability index

UT – coefficient depending on land use (classes 1–6); $i=1-6$

CS – coefficient depending on soil category, assessed based on the extent of erosion (classes 1–5); $j=1-5$

P – slope coefficient (classes 1–6); $k=1-6$

CO – coefficient depending on soil organic carbon (classes 1–4); $m=1-4$

A – coefficient depending on fertile soil layer thickness (classes 1–4); $n=1-4$

Indices i, j, k, m, n are subclasses and contribute directly to suitability index calculation.

The next step was to integrate spatial data, which is done using the formula in a GIS environment. The initial information on land suitability influence parameters is shown in the form of qualitative indices with major impact on agriculture [9], [10]. In order to make quantitative assessments by means of mathematical operations and subsequent GIS analysis, the descriptive information was turned into agricultural land suitability indices. The influence of variables on agricultural land suitability was ranked in the following order of importance: organic carbon content, fertile soil depth, soil texture, land use and slope [8], [10].

The calculation model shown above reveals indicators regarding land suitability on various classes; therefore, the graphic objects (polygons representing land use on the site plan) were assigned particular values. The corresponding values were assigned based on the relative favorability or unfavorability of the land suitable for agriculture. Finally, based on the crop yield values, GIS automatically delimited land suitable for agriculture (Fig.8 and Fig.9) and the last thematic layer of the GIS application was obtained.

2.2. Description of the research area

This paper describes a research conducted on a land with an area of 687.4ha, i.e. the V-Sulița perimeter in Botoșani County, Romania (Fig.1). From the administrative point of view, it is in the Sulița and Lunca communes. From the hydrographic point of view, the V-Sulița perimeter is located in the Sitna river basin, which is part of the Prut river basin. From the geomorphological point of view, the area studied is located in the Moldavian Plain, the Jijia-Bășeu depression.

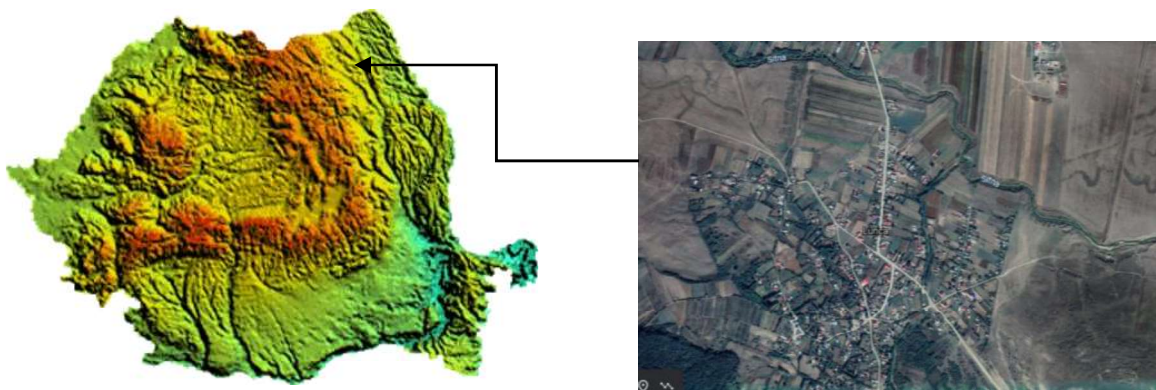


Fig. 1. Location of investigated perimeter

The relief is represented by differently exposed slopes, plateaus and valleys. For the climatic characterization of the studied area, we used meteorological rainfall data from Sulița station located within the perimeter, while the other data were collected from Botoșani station, located about 25 km away. The land in the investigated perimeter is affected by surface erosion processes, the steep slopes are sometimes affected by deep erosion materialized in ditches, gullies and ravines. Also, where coastal springs are present and the solidification rock is represented by marl and/or clay, there are active and semi-stabilized landslides. For the pedological characterization of the analyzed perimeter, the studies prepared at the Botoșani County Office of Pedological and Agrochemical Studies were used, based on which the pedo-amelioration sectioning was achieved depending on the intensity of the limitations of agricultural land use or the possible risk of degradation and subclasses depending on the nature and extent of limitations.

3. OBTAINED RESULTS

3.1. Land suitability determination database

The first stage of GIS technology application was the creation of an alphanumeric and graphic database for the studied area; this may be considered the most important stage, since the performance of the future information system depends on the quality of these data, [1]. The creation of the database with the georeferenced values of the indicators that determine the bonitation scores is facilitated by the use of the information layer superimposing model. In this project, the cartographic support includes the site plan with contour lines (with 10m equidistance) represented at 1:5000 scale (Fig. 2) and the site plan with soil unit mapping at 1:5000 scale (Fig. 3), with descriptive sheets for each soil unit (physical-chemical tests).

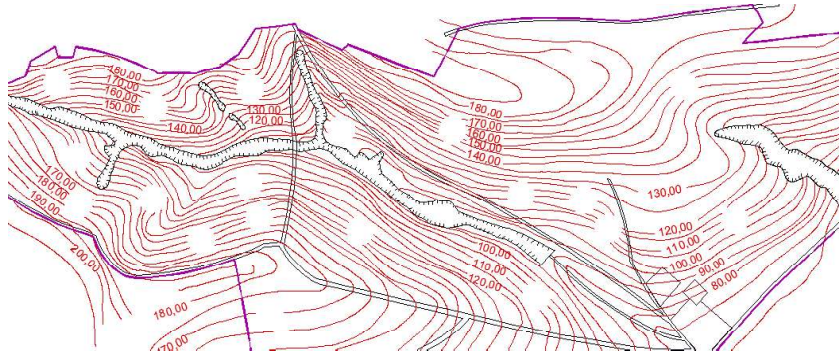


Fig. 2. Cartographic support used: site plan with contour lines

3.2. Soil map

A 1:5000 scale map was used, updated by field tests, to create the soil map (Fig.3). Depending on the genetic characteristics of the soil (texture, susceptibility to erosion and physical-chemical properties) and the morphological specificity of the land (slope, natural drainage), suitability categories were assigned to the studied land. Soils included in the very good suitability category are thick, loamy, loamy-sandy and loamy-clayey, not eroded or hardly eroded. They are represented by leached chernozems and typical poorly humifying chernozems, with the richest organic carbon content (1.51-2.63%). Soils with good suitability have a loamy-sandy and loamy-clayey structure and have the same properties as those with very good suitability, but differ in the smaller thickness of the humus layer (50 cm or less) and a lower organic carbon content (0.51-1.50%). Soils with moderate suitability include stratified alluvial soils and vertic chernozems with a thick humus layer (50-100 cm), not eroded, clayey and loamy-sandy, with poor or medium drainage. Soils with medium suitability are loamy and loamy-clayey, rather thin (25 cm), moderately eroded and with a moderate organic matter content (0.51-1.00%). Sandy-clayey thin soils, on moderately inclined slopes affected by erosion and with a relatively low organic carbon content have poor suitability. This category includes land affected by landslides and land in the hearth of localities.



Fig. 3. Soil map in the investigated perimeter

3.2. Land use map

The creation of the thematic map “Land use” (Fig. 4) was possible based on satellite images. Several classes were delimited, which were later grouped (generalized) in 6 categories of land arable, orchards, vineyards, meadows, urban and forests. According to land use, arable land was included in the good suitability category. Normally, it could

have been assigned the highest value (very good suitability), but most of this land is on slopes, which contributes erosion process activation, which diminishes land suitability. Meadows and hay fields fall into the category of land suitable for agriculture, for ecological and legal reasons, and they were included in the medium-poor suitability category. Plantations have poor suitability because, for the most part, they are located on slopes. Land occupied by urban areas, waters or roads is null and it is excluded from calculations.

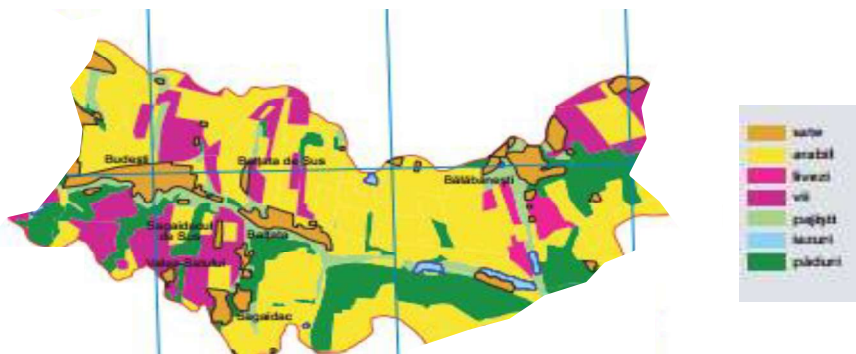


Fig. 4. Land use map

3.4. Slope

Slopes were determined based on the digital terrain model (DTM) using contour lines extracted from the topographic map at 1:5000 scale. Slopes range from 0 to 31°, with a mean value of 3.1°. Depending on slope incline, the pieces of land were grouped in 6 classes: classes 1 (0-1°) and 2 (1-3°) are assigned very good and good values, respectively, due to the almost flat relief and good natural drainage. They are more common in the eastern and northern parts of the studied perimeter and are currently used as arable land. Classes 3 (3-5° slope) and 4 (5-10° slope) are thought to be moderate and medium, respectively, due to the more rugged terrain and medium infiltration values. Class 5 (10-15° slope) has a relatively high runoff value and is therefore included in the poor category. Class 6 (>15° slope) includes unsuitable or very poorly suitable land, with steep slopes and very important surface runoff; the most rugged land is on the right side of the river (Fig. 5).

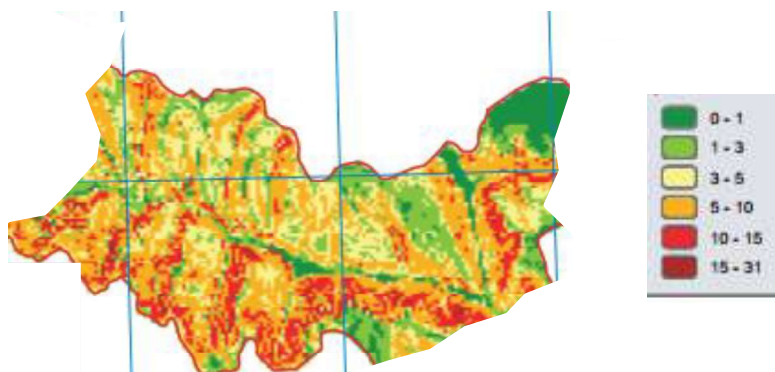


Fig. 5. Slope map in the investigated perimeter

3.5. Soil organic carbon content

The role of soil organic matter is very important. It is an ideal source of soil nutrients. The amount of humus in the soil was determined based on individual soil sheets and field samples. The value obtained was multiplied by a conversion coefficient to obtain the percentage of humus in the soil. The humus content shows soil suitability for agriculture and changes depending on the variability of its type but also on the use of land and the extent of erosion. The average organic carbon content in the studied soil is 1.4% (minimum) and 2.63% (maximum) (Fig.6).

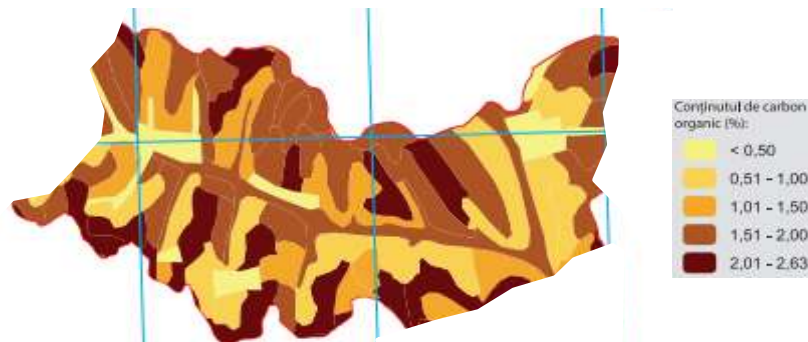


Fig. 6. Soil organic carbon content map

3.6. Humus layer thickness

The thickness of the soil humus layer is an important physical characteristic that determines the growth of the root system of plants, the available volume of water and air in the soil. Soils with shallow humus limit the growth of the root system. In order to determine the thickness of the humus layer, the profiles of each soil type were studied based on the individual soil sheets and field samples. The thickness of the humus layer changes depending on the type of soil and the presence of clay minerals (Fig.7).

This characteristic also depends on the specificity of the underlying rock and the morphology of the relief. The humus layer is thinner on steeper slopes. The texture, mineralogical composition and extent of alteration of the substrate rock are also important factors that influence soil thickness. Medium-thick soils, with high humus content and optimal aeration conditions, are the most suitable for agriculture (very good and good). High-thickness soils are assigned medium values and low-thickness soils are also assigned low values.

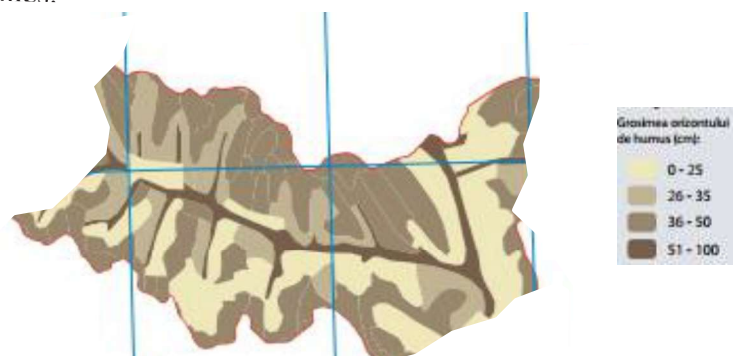


Fig. 7. Humus layer thickness map

3.7. Soil category map based on suitability

The areas of suitability for agriculture were delimited (very good, good, moderate, medium and poor) by grouping layers and polygons based on the weighted aggregation method [AA]. Land with very good suitability for agriculture represents 51.8% of the basin area (Fig.9). It has favorable pedological conditions (typical and carbonate chernozems), and the slope has low values (below 5°). It is arable land, which is recommended in such situations. Sectors with good suitability include meadow lands and some sloping areas with an incline of up to 10°. They occupy 23.5% of the basin area and are used as meadows (meadow sectors), forests and arable land. Depending on slope incline, the last type of use does not fall into the arable land category.

The thematic maps obtained were assigned particular favorability values: very good, good, moderate, medium and poor (Fig.8).

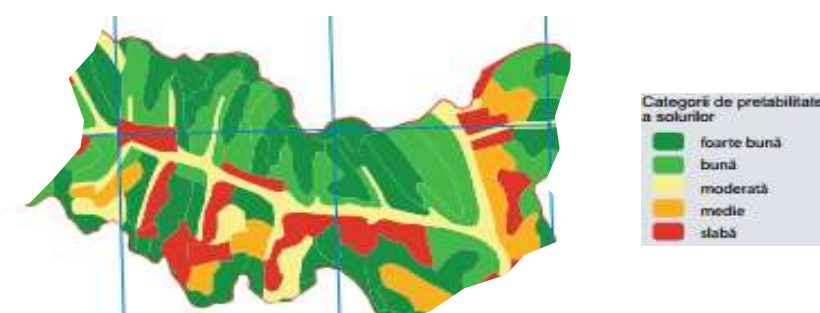


Fig. 8. Thematic maps with land suitability for agricultural on category

Therefore, it is recommended that this arable land be transformed into meadows, hay fields or orchards. Land which is moderately suitable for agriculture includes slopes with 5-10° or sometimes 10-15° incline, with carbonate and typical chernozems. It makes up 7.4% of the total area. Depending on its exposure, slope and lithology, we recommend that this land be used as meadows or orchards. Areas with medium suitability values (7.3%) are found on the slopes of the lower course of the river valley, where the incline reaches 15°. This land is used for various purposes, but orchards predominate, a category of use that is recommended in such conditions. Land with low agricultural suitability values includes areas occupied by slopes with 15-31° incline, land affected by landslides, which is stabilized or in the process of stabilization and forestation.

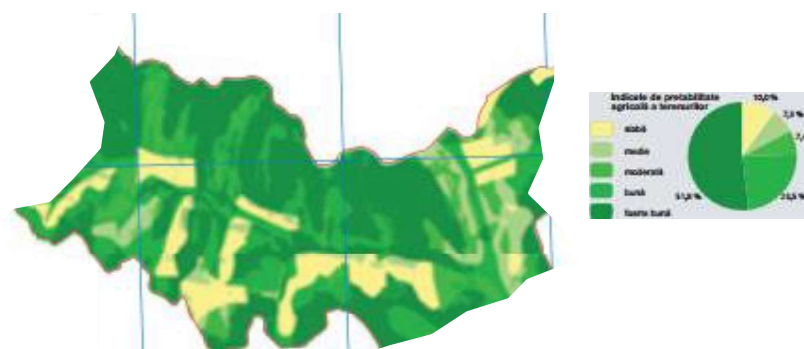


Fig. 9. Soil category map based on suitability

4. CONCLUSION

Land monitoring and management operations involve a considerable volume of data, and data processing and analysis means. Therefore, soil quality determination gains special importance both for agricultural land owners and for decision-makers in the field of agricultural management.

Based on some GIS modelling principles, the map of land suitability for agriculture was developed. Our research shows that most of the studied perimeter is suitable for agriculture, yet some areas require works to adapt them to the local morphological relief conditions. About 75% of the region is characterized by very good and good agricultural suitability. Medium and moderate suitability is characteristic for 14.7% of the basin area. Only 10% of the land in the investigated perimeter is not suitable for agriculture.

However, there are examples of improper land use that violate the regulations in force. In some cases, within the studied perimeter, the morphological specificity of the location of the various categories of land use is not complied with. According to some authors [4], arable land must be located predominantly on slopes with incline up to 5°, vineyards - on slopes with 10-30° incline, orchards - 15-40°, hay fields - 0-5°, pastures - 5-40°, constructions and roads - 0-40° (depending on lithology), while forests have no such limits.

For example, a plot of about 97 ha of arable land is located on a slope with an incline of about 15°. Such examples are also found in the studied perimeter, in total, about 10% of the entire area occupied by arable land does not meet the optimal morphological requirements of location. This land should be assigned to other uses (hay fields, orchards or vineyards).

The 107 ha vineyard in the village of Lunca is located on a slope affected by landslides. In such cases, it is recommended that the land be afforested. According to our research, 7.4% of the land in the river basin is not used according to its geomorphological and pedological characteristics.

The optimal use of agricultural land and the best possible crop yields require the continuous monitoring of soil quality and taking the necessary preservation measures. This approach is made possible by the existing site plans concerning the agricultural suitability potential of available land and water resources. All these actions are achievable with the help of GIS technology, a technology that models reality, creates and updates databases, a technology that is used successfully in many environmental areas.

Using GIS to establish and develop land quality progress and detect possible degradation processes is possible for relatively small parcels of land owners, more or less evenly spread in a territory and also for larger areas, cadastral administrative territories.

Increased accuracy for the studies undertaken on land quality can be achieved through the development and updating of databases and the use of complex mathematical models to forecast its evolution. Such models can integrate into the system a large variety of data acquired from various sources, sometimes extended by automated statistical processing, and thus obtaining information including overviews on specific time periods, graphs, maps presenting thematic degradation risk or intervention needs by agricultural - pedologic - improvement works etc.

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GIS TECHNOLOGY USED TO STUDY FLOODS ON A RIVER SECTION

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ABSTRACT

Our paper describes a case study, on a 27 km-long section of the Moldova River in Romania, on which floods often occur. Floods are some of the most disastrous phenomena caused by combined factors: atmospheric and hydrological with significant repercussions on the environment, with great material damage and loss of life.

According to this application, GIS technology is a remarkable solution that can solve rationally, intelligently and efficiently the increasingly difficult problems related to these phenomena, to the use of terrestrial resources. GIS facilitates the processing and analysis of both conventional and remote sensing spatial data, integrated in complex and heterogeneous databases.

Our paper shows real-time flood modelling by applying established mathematical-hydrological models. The identification and mapping of flooded areas are represented by field data collection and the use of radar images taken at the time of the floods, in combination with satellite images, taken before or after the events. Field data collection is often done using mobile equipment, which allows direct real-time connection to a resource center and fast information exchange.

The GIS application described in this paper shows that both field equipment use and subsequent data processing allow fast mapping of floodplains and identification of affected areas and enable one to make fast calculations to determine, for instance, the optimal path between points of interest, depending on the actual situation on the ground (inaccessible roads, damaged bridges, etc.).

This study suggests a solution for managing flood emergencies, both by directly collecting updated field information and by calibrating flood patterns by quickly mapping floodplains.

Keywords: floods, hydrological modelling, floodplains, GIS

INTRODUCTION

Floods are some of the most disastrous phenomena caused by combined atmospheric and hydrological factors with significant repercussions on the environment, with great material damage and loss of life.

Floods are hydrological runoff phenomena along riverbeds during which, temporarily, some territories are covered with water from rivers, lakes or slope runoff. River floods occur during rises in water level, if there are no retention lakes and dams. Water overflows and floods the land when the river bursts its banks and sometimes dams. Other times floods are caused by seawater due to storms, submarine earthquakes or breakage of dams.

The causes of floods are both natural and anthropogenic. Among the natural causes, those that most often cause floods are climate conditions that generate large amounts of precipitation: rains and especially torrential rains, melting snow often accompanying rainfall, excessive humidity, strong storms, earthquakes.

The anthropogenic causes of floods are man-made worldwide deforestation, hydrotechnical constructions - especially earth and rock dams, the natural breaking of river or sea dams, the deliberate breaking of dams [2],[5].

Floods may be quantified by direct and indirect economic damage, and also by their effects on social life and the environment, or by their potential ecological consequences. The impact on the population consists in the loss of human lives in the settlements totally or partially affected by floods, in the number of damaged or destroyed houses, in the loss of animals that could not be evacuated from the devastated area, in direct damages to the roads and railways networks, to the power and communication line networks due to pole damages, or to the gas, oil or drinking and industrial water pipelines. Floods also affect hydrotechnical constructions and dam lakes by completely destroying them, or by damaging or clogging them [7].

Indirect economic damage consists in the temporary or permanent interruption of production processes, delays in the delivery of products or additional transportation costs. The negative social effects are the loss of human lives and their subsequent consequences on the life of human communities and society in general, negative psychological effects, the onset of epidemics, decreased population income, destruction of cultural values of human communities [3]. The negative ecological effects are the degradation of the environment due to impairment of the quality of its factors - surface water pollution, groundwater pollution, soil pollution in flooded areas. Flood forecasting is done through weather forecasting systems and hydrometric records, which may be done more efficiently by using GIS technology [1].

2. MATERIALS AND METHODS

2.1. Research methods

This paper includes a GIS simulation using the Mathcad mathematical model where the calculation method employed is based on the characteristic equation of the phenomenon:

$$(Q-q)dt = S dh$$

The flow propagation model is the non-permanent three-dimensional motion of water in the river bed, described by the Saint Venant system of equations formed by the following system of equations [4]:

continuity equation:	$\frac{\delta A}{\delta t} + \frac{\delta Q}{\delta t} = 0$			
motion equation:	$\frac{\delta Q}{\delta t} + \frac{\delta}{\delta x} \left(\frac{Q^2}{A} \right) + gA \left(\frac{\delta h}{\delta x} \right) + gA(I_f - I_0) = 0$			
	<table style="margin-left: 100px; border-collapse: collapse;"> <tr> <td style="border: 1px solid black; padding: 2px 10px;">dynamic waves</td> <td style="border: 1px solid black; padding: 2px 10px;">diffusion waves</td> <td style="border: 1px solid black; padding: 2px 10px;">kinematic waves</td> </tr> </table>	dynamic waves	diffusion waves	kinematic waves
dynamic waves	diffusion waves	kinematic waves		

Where:

Q - flow rate; A - flow section area; h - water depth; I_0 - thalweg slope; I_f - friction slope; x - distance measured along the length of the water bed; t - time; g - gravitational acceleration.

Hydrological models and hydraulic models are based on the same physical principles, they differ only in the degree of approximation used to describe the phenomenon. Thus, hydrological models do not simulate a flood wave in each section of a river section, but the global change of the flood over an entire river section.

3.2. Applicability of the ArcGIS platform in the flooding study

Flood modelling and damage assessment in almost real time is a widely addressed issue in literature. The identification and mapping of flooded areas is represented by field data collection, which is often a difficult task, and the use of radar images taken at the time of the floods, in combination with satellite images, taken before or after the events.

Field data collection is often done using mobile equipment, which allows direct real-time connection to a resource center and fast information exchange. Mobile equipment with specialized GIS software is used both for fast floodplain mapping and damage identification, and for fast analyses, such as the determination of the optimal route between points of interest, depending to the actual situation on the ground (broken bridges, inaccessible roads, etc.). This study suggests a solution for managing flood emergencies, both by directly collecting updated field information and by calibrating flood patterns by quickly mapping floodplains [8].

Here are some examples of geoprocessing services that have been implemented in this study: geoprocessing service for calculating the optimal route between two or more points of interest, displaying it on a single updated map, together with directions for the various road sections; geoprocessing service for the fast assessment of flood damage by calculating the number of buildings, bridges, inhabitants, road kilometers, etc., which are affected by floodplains and viewing them on the map [6].

Viewing, on the map, the possible flood evolution scenarios, developed by means of specialized flood modelling software; viewing the reports directly on the map with the possibility of using spatial filters, so as to enable decision makers to have access to filtered and simple yet very condensed information. This application accesses the same map service as mobile applications and has tools for calculating the optimal route. The workflow requires field users to identify and map the floodplain, affected buildings, inaccessible communication means and report them in real-time synchronization with the central database. Synchronization with the central database automatically allows all field users to view all field records.

2.2. Analyzed area and input data

The Moldova River section studied in this application is located in the middle course of the Moldova River basin, between Păltinoasa and Cornu Luncii, belonging entirely to the sub-Carpathian region (Fig.1). The analyzed section is located on the middle course, in the major and minor riverbed of the Moldova River, within the morphological unit of the Moldavian Plateau, characterized by a hilly relief, with altitudes ranging from 400 to 600 m, decreasing from North to South.

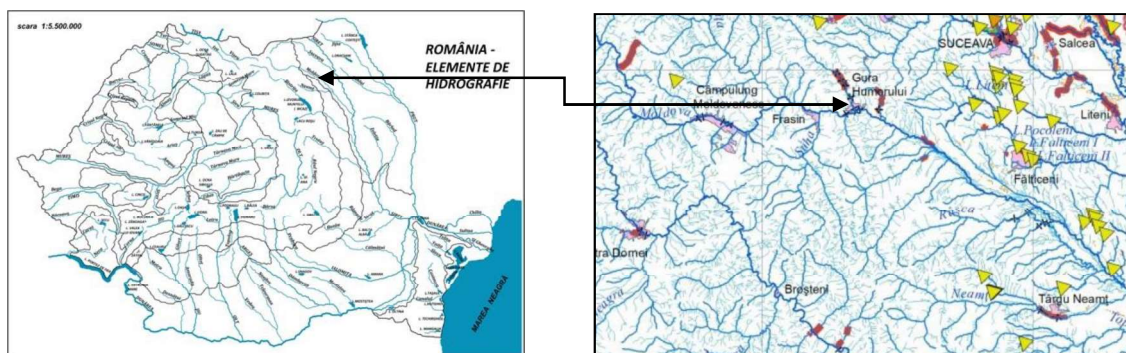


Fig. 1. Location of the studied river sector

The Moldova River Basin is located in the NE part of the Eastern Carpathians and in the NW part of the Moldavian Plateau. The Moldavian Valley looks like a depression between the Moldavian Subcarpathians and the Suceava Plateau being dug by the Moldova River. It springs from Obcina Ferdeu, crosses the counties of Suceava and Neamț to flow into Siret near the town of Roman. The Moldova River is a tributary on the right side of the Siret River, it has a wide and low meadow section up to Ciumulești, the largest width of the meadow and terraces is at Baia, where the relief looks like a depression.

Table 1. Morphohydrographic characteristics of the Moldova River basin pertaining to the analyzed section. [8]

Reference section	Water course data					River basin data	
	Length (km)	Altitude (m)		Average slope (‰)	Sweep coefficient	Area (km ²)	Average altitude (m)
		Upstream	Downstream				
(XII-1-40-31)	96	1116	435	7	1,53	1936	900

Table 2. Maximum flow rates at various exceedance probabilities corresponding to the studied river section [8]

Moldova	Section	In Romania		Highest flow rates (m ³ /s)		
		F (km ²)	L (km)	1%	20%	50%
	Bridge on DJ77C road	1950	94	1.300	-	185

The table below shows hydrological data pertaining to the analyzed section. The most important tributary streams to the Moldova River (XII-1-40) are Moldovița and Suha. Downstream of Gura Humorului, the river enters the sub-Carpathian area, suffering a slight slope discontinuity, which leads to the formation of a section with highly mobile riverbed. The slope in this section up to Cornu Luncii is 4.8‰.

3. OBTAINED RESULTS

Following the modelling within this application, it was possible to forecast flood limits using the ArcGIS platform.

Flood hazard maps are developed based on the existing floodplains, which show the potentially floodable areas in the major riverbed of the Moldova river for floods whose maximum flow rate is characterized by the following outflow probabilities: 0.1% (low probability), 1% (medium probability), 10% (high probability).

The flood hazard map is developed in an integrated system using databases, digital maps in GIS environment and specialized software. The GIS environment database pertaining to the map is developed by collecting, processing and storing the necessary information and data regarding: topographic and cartographic base of the area; characterization of the river basin from the point of view.

Mathematical modelling allowed establishing the floodplains for 3 different calculation options (Fig.2-7).

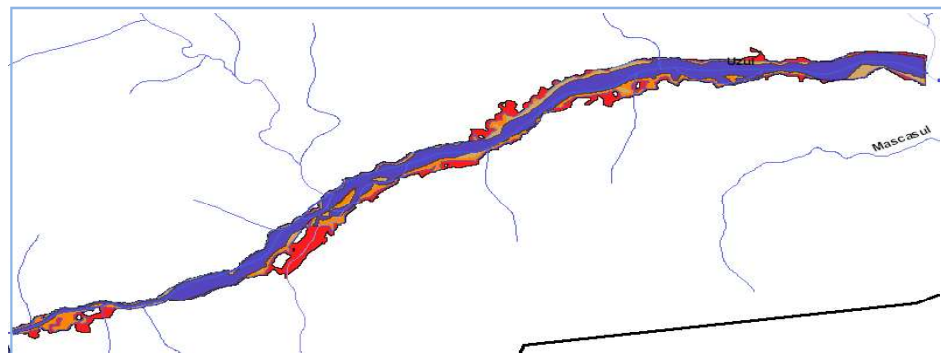


Fig. 2. Vector representation of flooded areas with 0.1% (red), 1% (orange) and 10% (blue) probabilities

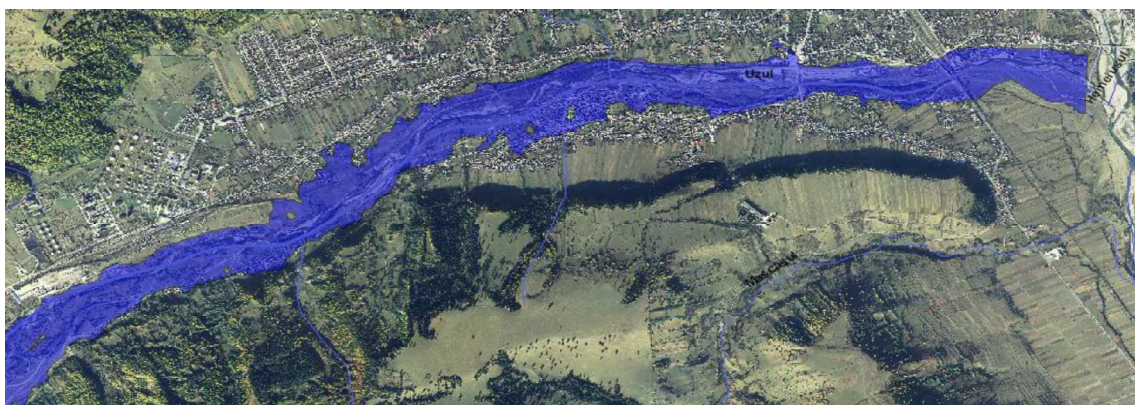


Fig. 3. 0.1% flood limit on the studied river section

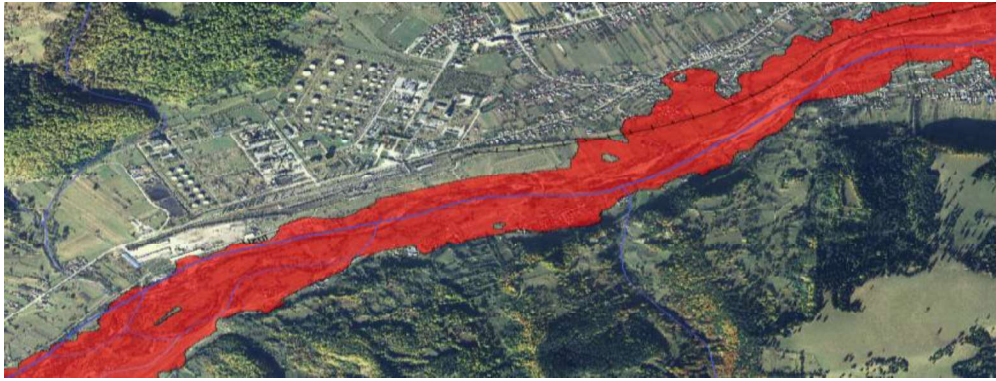


Fig. 4. Floodplain on the Moldova River, near Gura Humorului, with 0.1% probability



Fig. 5. 1% flood limit on the studied river section

This flooding probability is calculated by hydraulic modelling of data recorded at hydrometric stations every 100 years.

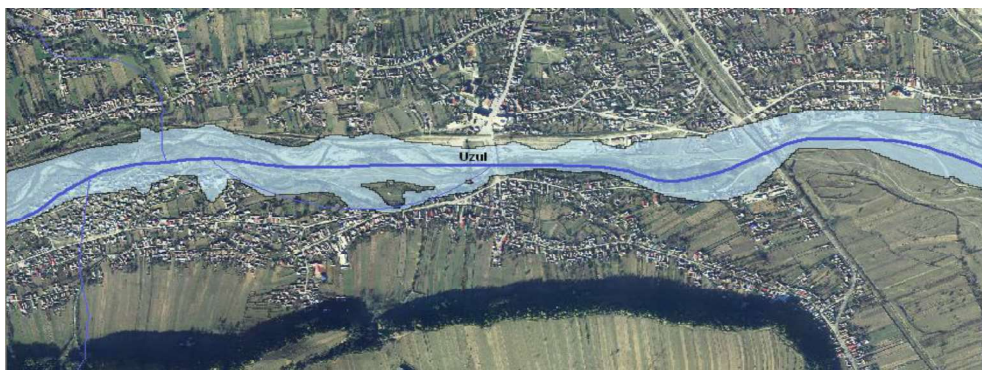


Fig. 6. 10% flood limit on the studied river section

With 10% probability floods occur on smaller areas but are much more frequent than the other 2 probabilities.

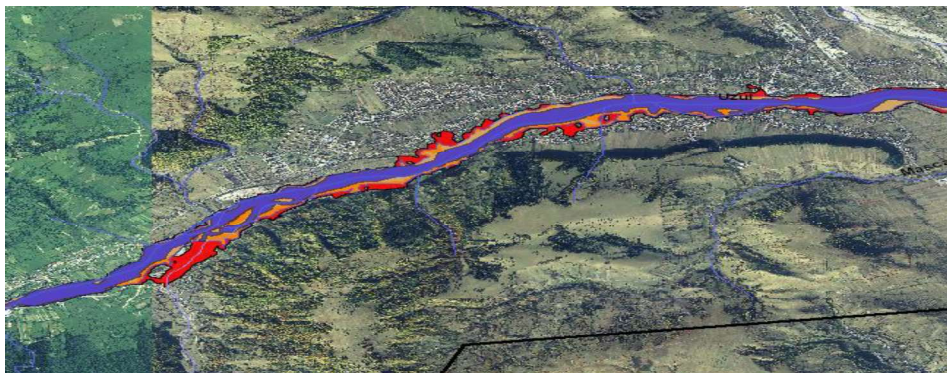


Fig. 7. Representation of the ortho plane vector of floodable areas at various probabilities: 0.1% (red), 1% (orange) 10% (blue)

The ArcGIS platform provides a series of alpha-numeric data on the location of the area of interest and, in the case of its use in the forecasting flood limits, of information on flow rates, lengths, flooded areas (Fig.8).



Fig. 8. Detail of the studied river section with floodplain near Gura Humorului, with 0.1% probability

CONCLUSION

Our paper aims to describe the modelling process, which is extremely useful in hydrology. The use of GIS technology has proven to be an extremely important contribution in the management of flood emergencies. The possibility of using the same topographic map regardless of the user's location and whether he has an internet connection or not is a major advantage for working in any environment. The possibility of synchronizing field collected data, when there is a broadband internet connection available, is an even bigger advantage in emergency management.

The floods that occurred in Romania over the last 10-15 years and the consequences that followed have led, due to improved social awareness, to a new approach, that of flood risk management, an approach in which awareness and involvement of human communities have an essential role in avoiding loss of life and reducing damage.

The direction considered for obtaining results is the one offered by specialized software on various aspects related flood wave crossing. The ultimate goal is for the results that

can be obtained by using these programs to provide operational safety. This obviously requires their calibration in reality.

The use of high-performance computer programs (such as the one used in this paper, Mathcad 14.) facilitates the creation of numerous simulation variants, starting from hydrological or constructive input data. The use of advanced computing platforms together with the creation of a database concerning the studied river basin is the first step in implementing a GIS monitoring system.

The studied river section is frequently flooded and considerable areas are affected. Figures 2-8 show the land and constructions that could be affected.

The application described in this paper was aimed at demonstrating the importance of GIS technology in flood monitoring. Databases in digital format and information layers may serve as new inputs to modelling programs and, in the future, they may be used to calibrate analysis models and improve spatial and temporal predictions.

GIS allows assessing flood hazard and collecting information about floodplains in almost real time. This is particularly important for decision makers who can intervene and mitigate the effects of floods and even save lives.

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APPLICATION OF GIS TECHNIQUE IN LAND EVALUATION FOR AGRICULTURAL USES

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Abstract

The purpose of this paper is to analyze the opportunity of GIS technique implementation for the research of agricultural lands quality. Taking into account that the factors which determine the quality of agricultural lands have a spatial distribution, we considered that the complex activities (especially on large surfaces) can be better done within the framework of an information system. Compared to other methods applied for assessing the productive potential of agricultural lands, the GIS technique use enables computer-based easy data storage and processing of complex data, geo-referenced and descriptive data coming from various sources, providing the decision makers in the agricultural / territorial management with the information they need in a short time and at a much lower cost. The new approach of this paperwork consists in drafting a new method of establishing the favorability scores for agricultural lands, a method developed in the GIS environment.

Key words: GIS, land favorability, layers, overlay

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1. Introduction

Sustainable agricultural land usage should be based on complex activities of research and quantitative understanding of the main conditions that determine plants growth and fruiting. Also establishing how suitable such conditions are for each land use and crop (as a field can be unsuitable for certain uses and crops, but suitable for others) needs comprehensive studies (Anoh et al., 2012; Bone et al., 2010; Stătescu, 1994). The production capacity of lands can significantly change under the influence of natural factors, but the most important influence is due to human interferences. Land quality should be regularly updated (to match each development stage of agriculture and the economy as a whole) (Florea et al., 1987; Gomez-Navarro and Garcia-Melon, 2011).

In the case of land improvement works leading in all cases to the enhancement of environmental factors, when assessing the land production capacity it is necessary to take into account the implementation

of the so-called enhancement elements (Barrachina et al., 2012; Fortuna et al., 2012; Karlen et al., 2013).

Monitoring and management operations for a territory require a considerable amount of data and tools for data processing and analysis. In this context, assessing soil quality becomes particularly important for both farm owners and decision makers in agricultural management (Deasules, 2013; Gruia, 2011; Iacobescu et al., 2012).

Considering that the factors influencing land production capacity are in a spatial distribution, meaning they have a particular value in a certain point in the studied area, we consider that the complex favorability evaluation action (particularly on larger areas) can only be achieved by means of a spatial information system (Lotze-Campen et al., 2010; Nejadkoorki and Nicholson, 2012).

The purpose of land evaluation in the current social-economic context is to assess its performance, which enables to maintain a sustainable agriculture for the benefit of people, and at the same time getting

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information about its behavior in relation to the environment factors. This purpose implicitly offers the decision-making support for the land management and planning, as the right decisions are based on the analysis and description of land limitations resulting from the evaluation. This objective cannot be applied without detailed knowledge and assessment of the factors influencing the evaluation process, which reveal the opportunities, possibilities and forecast of the land use and limitation. The purpose of agricultural lands evaluation can also be to draft a strict inventory of the land resource.

On international and national levels, scientific research in agricultural land evaluation is focusing its efforts on the system integration of information about the land features (Florea et al., 1987). This research starts from the hypothesis that a transition is necessary from the national methodology of agricultural land evaluation towards an information-system methodology, namely in a GIS environment.

The importance of the research is given by the fact that using the GIS technique enables objective quantifications of soil indicators in databases, and also the automated spatial distribution of indicators, coefficients and favorability scores. In this paper it is highlighted the fact that the availability of a soil indicators database and a GIS methodology of agricultural land evaluation is an important step in complying with current requirements for the sustainable development of agriculture, by maintaining/ increasing land productivity, economic viability, environment protection and food safety.

2. Case study

2.1. Short description of the area

The undertaken study was carried out on a 375 ha area located in the Șomuzul Mic catchment, Suceava (Romania) and aims to highlight the quality of agricultural land by calculating favorability scores using the Geographic Information Systems (GIS) technique. This area was chosen for research as a complex pedological system of this hydrographic basin, where we made the best use of a large amount of field data (O.S.P.A., 1988).

2.2. Methodology for agricultural lands evaluation

2.2.1. Current methodology

In Romania, the land evaluation is based on the system developed and improved by Dumitru Teaci (Teaci, 1980).

Soil favorability for different species of plants is expressed by a series of *favorability scores* under natural conditions (the first case) and by the enhancement of these evaluation scores by applying land improvement works and current improvement technologies (the second case) (Teaci, 1980).

In order to calculate the favorability scores under natural conditions, certain *favorability*

indicators are used, by applying land improvement works and current improvement technologies, using the so-called *enhancement indicators* (Stătescu, 2003).

Plant growth depends on the whole range of environmental factors. Given the large diversity of environmental conditions, in order to determine the land production capacity the most significant conditions were chosen, namely: the terrain conditions, climate resources, hydrology and soil characteristics. From these groups of environmental factors only the most significant indicators were considered, namely the most precise and easiest to measure, which are usually found in the existing mapping works, (Teaci, 1980) as follows:

1. average annual temperature - corrected values - *indicator 3C*;
2. average annual rainfall - corrected values - *indicator 4C*;
3. gleyzation - *indicator 14*;
4. pseudo-gleyzation - *indicator 15*;
5. salinity or alkalinity - *indicator 16 or 17*;
6. texture in Ap or in the top 20 cm - *indicator 23A*;
7. pollution - *indicator 29*;
8. slope - *indicator 33* ;
9. landslides - *indicator 38*;
10. groundwater depth - *indicator 39*;
11. flooding capacity - *indicator 40*;
12. total porosity of that horizon - *indicator 44*;
13. total CaCO₃ content in 0-50 cm - *indicator 61*;
14. reaction in Ap or in the top 20 cm - *indicator 63*;
15. degree of base saturation in Ap or 0-20 cm - *indicator 69*;
16. edaphic volume - *indicator 133*;
17. reserves of humus in the 0 - 50 cm layer - *indicator 144*;
18. moisture excess at the surface - *indicator 181*.

Value scales or divisions (partitions) were chosen for each indicator. The levels of the value scales or the divisions were set so as to enable the rating of their influence by coefficients.

In the case of land favorability under natural conditions, each of the above indicators, except indicator 69 which is indirectly relevant, counts for establishing the favorability scores, by a favorability coefficient ranging between 0 and 1, depending on the unfavorable or optimal state for the intended use or the plant requirements.

For nearly half of these indicators a single set of coefficients is provided. For the rest of indicators there are several series of coefficients according to their interdependence on other indicators.

To obtain the favorability score on land use and crops we multiply by 100 the product of the coefficients related to the 18 indicators directly relevant for establishing favorability scores. 1) (Teaci, 1980).

$$Y = (X_1 \cdot X_2 \cdot \dots \cdot X_n) \cdot 100 \quad (1)$$

where:

Y- favorability score (according to Table 1); X_1, X_2, \dots, X_n - values of the indicators coefficients

(example of two indicators coefficients in Table 2 and Table 3).

Therefore, when all indicators have for example, the coefficient equal to 1, so all factors are optimal and satisfying the plant requirements, the favorability score is maximum, i.e. 100. When the coefficient value is closer to 0 (zero) and more indicators are in such situation, the resulting favorability score is closer to the lower limit, i.e. 0. Even if only one indicator coefficient is 0 (zero), meaning a quite unfavorable (limiting) factor for the considered plant, the resulting favorability score is 0 (zero), because any value multiplied by 0 (zero) yields zero (0). Of course, the higher the favorability score is obtained for a given crop, the more favorable is that land to that crop.

When calculating the favorability scores on plots (land plots) or groups of parcels we should take into account that the topographic contour of a plot does not normally coincide with that given by the *Organic Homogeneous Territories* (TEO), and a plot may include two or more such different units, for which the favorability score points need to be calculated. As surfaces of TEO units of the same plot are not equal, the favorability score of the plot is calculated as a weighted average. If we consider the division of land into five categories according to the fertility level, each quality category receives 20 points (favorability scores, according to Table 1).

Table 1. Favorability scores depending on land quality categories (Teaci, 1980)

Quality category (fertility)	Favorability scores	Quality category level
I	81 – 100	Very good
II	61 – 80	Good
III	41 – 60	Average
IV	21 – 40	Weak
V	1 – 20	Very weak

2.2.2. GIS-based research method

In this research, the indicators database used for calculating the favorability score was created by using the „raster” model, which implies the overlapping of a rectangular network/grid of square cells on the area subject to research (Burrough, 1986).

The favorability indicators values are initially set for each basic cell / pixel of the network, and then stored in a relational database (Zeiler, 2003). The cell/pixel size, which will decide how detailed the research will be, mainly depends on the relief, surface and variable spread of different soil types and uses. Thus, if the surface larger, the relief is rather uneven and there is greater diversity of soil and land use, the cells will decrease in size (Biali and Popovici, 2003).

Processing of data stored in the database is performed according to the specific algorithm for calculating the favorability scores, using maps (slopes, uses, soil types, land improvement works etc.) and sometimes remote sensing digitized (electronic) images and geo-referenced data stratification (Fig. 1) (by the "overlay" technique).

That enables to finally get some very useful information, including the eco-pedologic development / monitoring on any small surfaces (at cell / pixel level).

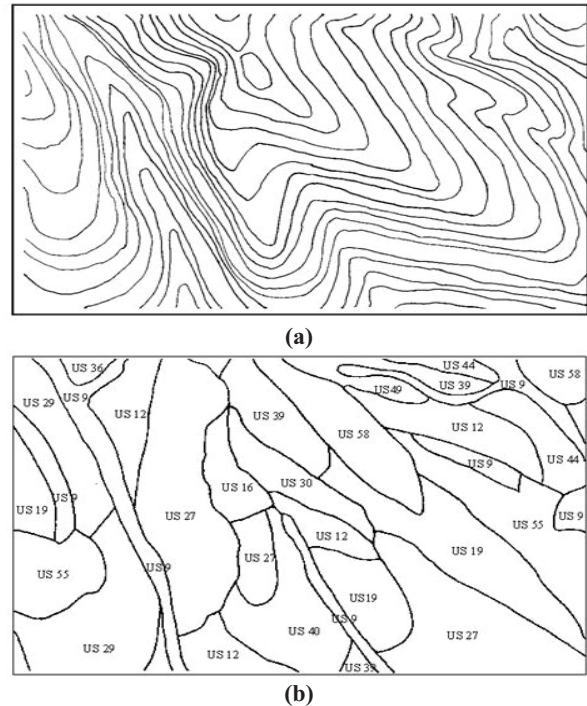


Fig. 1. Cartographic vector: a) contour map, b) soil units

Eventually, favorability scores are obtained by applying the relation (1). In this case the calculation is made by the GIS software at cell level. In this context, the application of GIS technology is necessary and justified by both economic considerations and data processing safety and speed, and thus the needed information is obtained in "real time".

To implement this technique, creating a (graphical and descriptive) database about the studied territory can be considered the most important step, as the performance of the future information system will depend on the quality of such data (Davidson et al., 1994). The setting up of the database with geo-referenced values of indicators at the basis of the favorability scores is facilitated by the use of the "raster" model, based on overlapping a square network / grid of rectangular cells over the studied area (Fig. 2).

The cartographic support consisted of contour situation plans (Fig. 1.a) at 10 m equidistance and soil units mapping (Fig. 1.b), with related records (physical – chemical tests). For each soil unit (graphical object: the perimeter within the boundaries of each soil unit) the values of land favorability indicators are initially established (stored in a relational database), and then the information layers will be created by applying the GIS calculation modules. Using the "overlay" technique, by overlapping the 18 layers, a thematic map of favorability scores will be obtained for the studied territory.

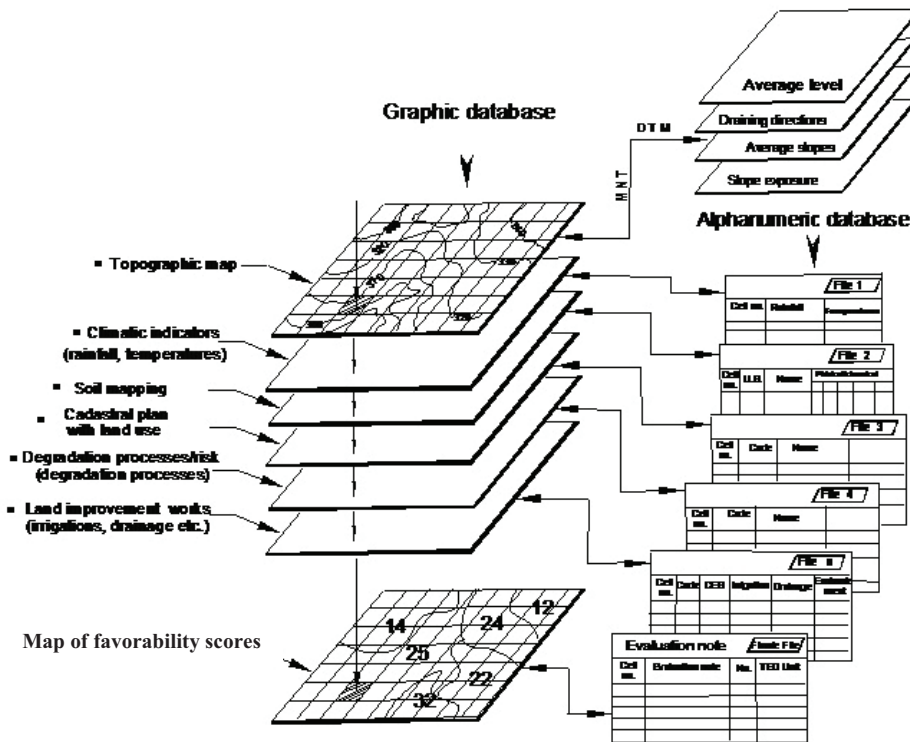


Fig. 2. Stratification scheme of geo-referenced data required by the study to determine land quality through favorability scores

Since the "relief" factor has a significant weight in assessing the land quality, setting up the *Numerical Terrain Model* (NTM) is an important step in the GIS project, generating three informational layers (Fig. 2) (average levels, drainage directions, average slope) that will count in the calculation algorithm for the favorability scores (Biali and Popovici, 2003). Thus, in this chapter we present some aspects of the NTM development, as well.

2.3. Results and discussion

2.3.1. Building the MNT

The Numerical (Digital) Terrain Model (NTM / DTM) is a mathematical tool that allows the numerical / digital representation of some portions of the earth's surface (Frank, 1995). In terms of information technology, a numerical terrain model appears as a file where the data is organized as a matrix, where each value represents the elevation of a point. Based on this altimetry database one can get a great deal of information, especially on: slope, exposure, different perspectives, profiles of different sections.

In a first stage, the contour topographic maps at the scale of 1:10,000 (10 m equidistance) were scanned at a 600 dpi resolution. The conversion raster - vector was automatically done using Corel Draw 10 software, Trace OCR module.

Using GEO-GRAPH software facilities (GIS information system) each contour was assigned its own level and the situation plan was reported in an axis system (GEO-GRAPH, 1998) (Fig. 3).

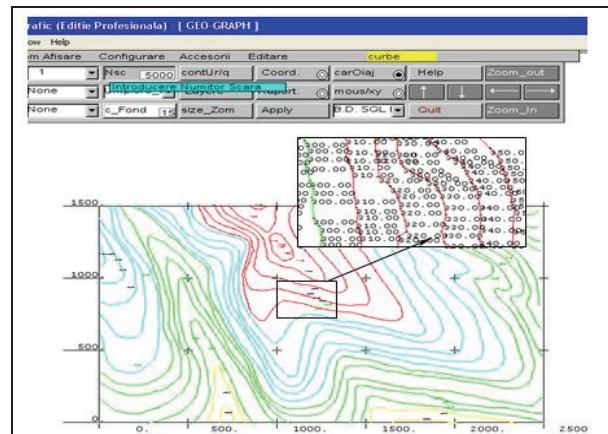


Fig. 3. Contour shapes layer in vector format, relative to the axis system, with detail on the items listed on the contour shapes

In the addressed research method, for creating the geo-referenced database the so-called "raster process" was used, which consists in overlapping a rectangular grid of square cells over the cartographic documentation (digitized plan), primarily taking into account the features offered by the raster structure of the data using the "overlay" technique. The size of a cell (usually called "pixel"), was decided to be 50 x 50 m (Biali and Popovici 2003). The correct choice of the cell size is of great importance, ensuring the accuracy of input data (and therefore accuracy of the database) and of the information obtained by applying the information system; of course the processing hardware available was also taken into account without neglecting the economic issues related to data

acquisition costs. The *Numeric Terrain Model* (NTM) was obtained by an interpolation (which is the fundamental operation to work with punctual/discrete information). A local interpolation method was adopted, namely the *weighted averages method*.

According to the principle of weighted average, the altitude of an unknown point (H_i) is derived from the measured points altitudes (H_j) by the relationship below, where x and y are the coordinates and p the weighting factor (Eqs. 2 and 3).

$$H_i = \frac{\sum p_j H_j}{\sum p_j} \quad (2)$$

where:

$$p_j = \left[\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \right]^u \quad (3)$$

The Geo-Graph system includes a calculation module designed according to the algorithm presented; the program is called "MNT.exe" in the Fortran Power Station language under Windows (GEO – GRAPH, 1998). The resulting information layers are presented in the Geo-Graph software in Fig. 4 and Fig. 5 (a,b). From a mathematical perspective, the slope and orientation (direction determined according to the cardinal points) are correctly estimated at a certain point if the surface is described by an analytical function (surface gradient); in the present case, these two parameters must be redefined for each pixel (cell).

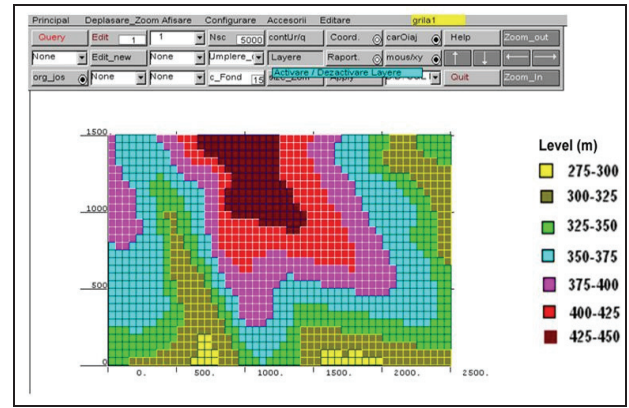


Fig. 4. Hypsometric map of the studied perimeter (spatial distribution of average pixels levels)

Land slope I was calculated from the slope value " i " (in percent, %) after, (Eq. 4) (Wischmeier and Smith (1984):

$$I = \frac{0.17 + 0.12i + 0.017i^2}{6.613} \quad (4)$$

The parameter marking the slope length on the slope direction was determined by the relationship (Eq. 5):

$$L = \left(\frac{\lambda}{22.14} \right)^m \quad (5)$$

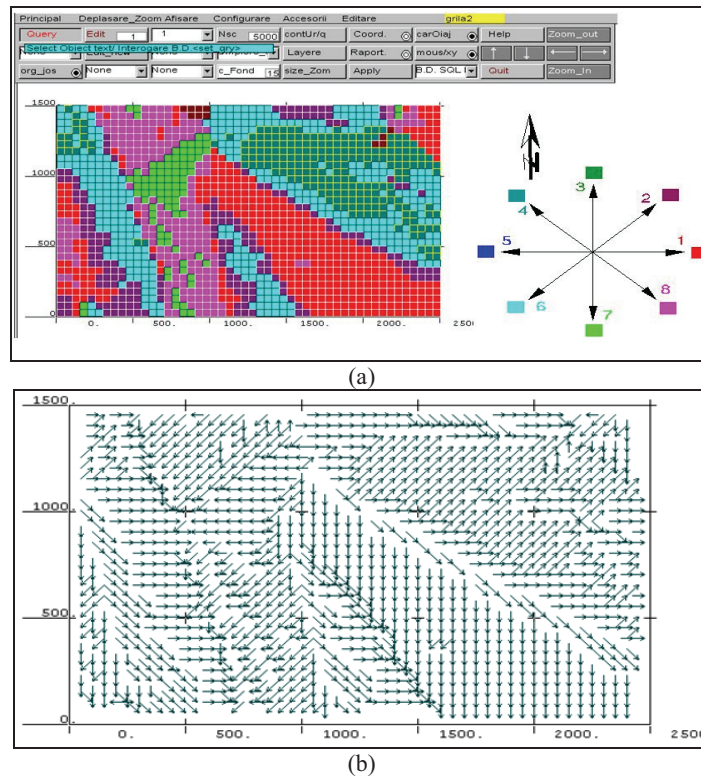


Fig. 5. Slopes exposure map; Informational layer of flow directions a) grouped by color codes associated with the cardinal points b) flow direction represented by arrows

where: λ - slope length in horizontal projection (m);
 m - parameter ranging between 0.3 and 0.6, was considered $m = 0.5$.

The average slope information layer resulting from processing is shown in Fig. 6. In the GIS project, for each indicator the related information layer was created with direct connection to the relational database. This paper presents two of the 18 indicators that were considered for calculating the favorability score, namely Ind. 33 - the "slope" (according to Table 2) and Ind. 39 - the "groundwater depth" (according to Table 3).

2.3.2. The "slope" - Ind. 33

For all uses and crops, flat or nearly flat terrains are the more favorable. Sloping diminishes suitability of such lands.

Therefore, the favorability scores for such lands will decrease, the evaluation coefficient of this indicator receiving values below 1, depending on both the slope and the land use or crop (Fig. 7).

2.3.3. The "groundwater depth" - Ind. 39

Plant growth can be influenced by the presence of groundwater at certain depths. The groundwater level (and hence its ability to influence soil properties and plant growth conditions) depends on the texture, being lower for coarse textures than in medium and fine textures. Therefore, the scale of depth where groundwater can affect soils refers to two situations: one for land with coarse texture and one for those with medium and fine texture.

Influence of groundwater depth on plant growth differs, depending not only on the texture but also on the average annual rainfall, and therefore two situations can be distinguished in terms of average annual rainfall: less than 600 mm and over 600 mm (Fig. 8). The processing of the information layers by the Geo-Graph software to determine favorability scores at pixel level was made by a program named "Bonitare.exe", in FORTRAN language, using all layers processed in previous phases as input, according to the methodology presented.

Therefore, by overlapping the 18 information layers on the favorability indicators values, we have obtained the information layer of the favorability categories on the studied area for the wheat crops, under natural conditions. In Fig.9 the graphical final product is presented, but this layer is connected to the descriptive database that enables the later query.

3. Conclusions

1. Once the favorability evaluation is performed based on indicators (such as suitability for irrigation, soil erosion control works, salinity and alkalinity prevention and decrease works etc.) a technological description can be provided now for such land in order to establish the needs and opportunities to increase production capacity. The values of these indicators, on categories and subcategories can be highlighted in alphanumeric relational databases and on specific maps with their territorial distribution.

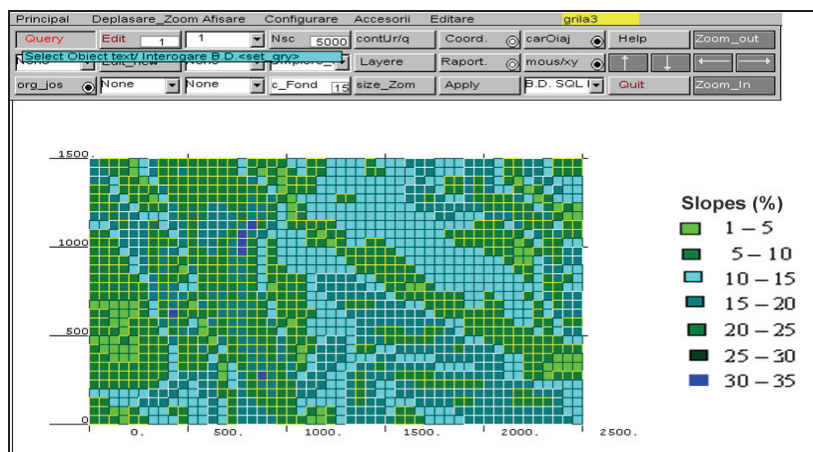


Fig. 6. Map of the landscape gradient in the studied area Information layer of average slope for each pixel

Table 2. Indicator 33 (Code assignment for – Slope groups and categories and land favorability coefficients) (Teaci D., 1980)

CODE	Slope categories	Slope category	Favorability coefficients for different crops					
		%	Wheat	Potato	Beet	Vegetables	Apple	Vineyard
01	Horizontally	< 2	1	1	1	1	1	1
03	Very slightly inclined	2.1 – 5.0	1	0.9	0.9	0.9	1	1
07	Slightly inclined	5.1 – 10.0	0.8	0.7	0.8	0.7	0.9	0.9
18	Moderately inclined	10.1 – 25.0	0.5	0.5	0.6	0.5	0.8	0.7
37	Strongly inclined	25.1 – 50.0	0.3	0.2	0.3	0.2	0.7	0.6
75	Very strongly inclined	50.1 – 100.0	0.2	0.1	0.1	0.1	0.4	0.5
99	Steep	> 100.0	0.1	0.1	0.1	0.1	0.1	0.1

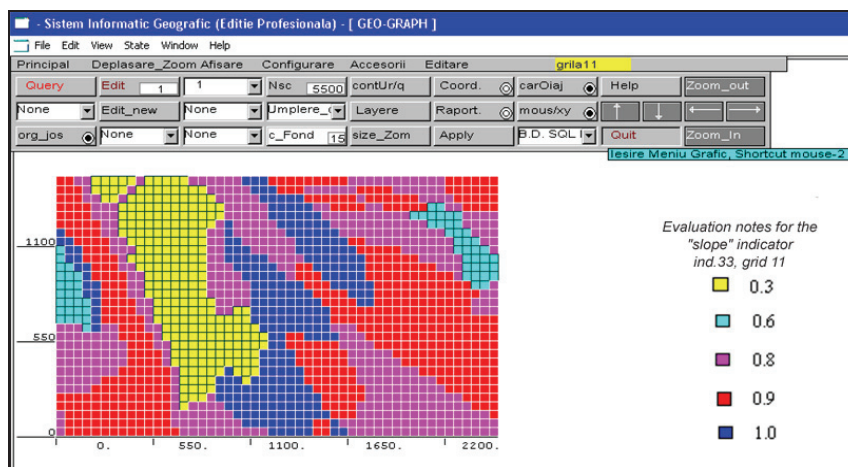


Fig. 7. Information system „Layer 11” for the slope indicator, Ind. 33

Table 3. Indicator 39 (Code assignment for - Groundwater depth and favorability coefficients) (Teaci D., 1980)

CODE	Name	Limits (m) in texture soils		Favorability coefficients for different cultures					
		fine- medium	coarse	Wheat	Potato	Beet	Vegetables	Apple	Vineyard
00.2	Superficial	< 0.50		0.2	0.2	0.2	0.2	0.1	0.1
00.7	Extremely low	0.51 – 1.00	0.51 – 0.75	0.5	0.5	0.6	0.7	0.1	0.1
01.4	Very low	1.01 – 2.00	0.76 – 1.40	0.7	0.7	0.8	0.8	0.4	0.6
02.0	Low	2.01 – 3.00	1.41 – 2.00	1.0	1.0	1.0	1.0	1.0	1.0
03.5	Medium	3.01 – 5.00	2.01 – 4.00	0.9	0.9	0.9	0.9	0.9	0.9
15.0	High	5.01 – 10.0	4.01 – 10.0	0.8	0.8	0.8	0.8	0.8	0.8
99.0	Very high	> 10.1		0.6	0.7	0.7	0.7	0.6	0.7

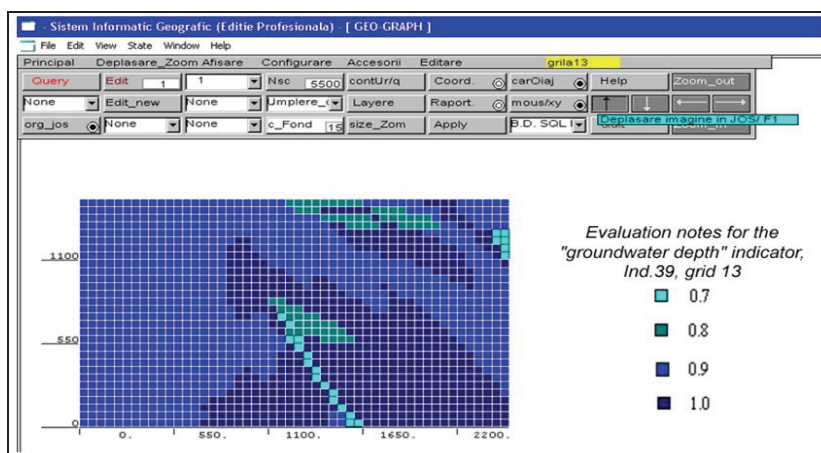


Fig. 8. Informational layer „Layer 13” for the groundwater depth indicator, Ind. 39

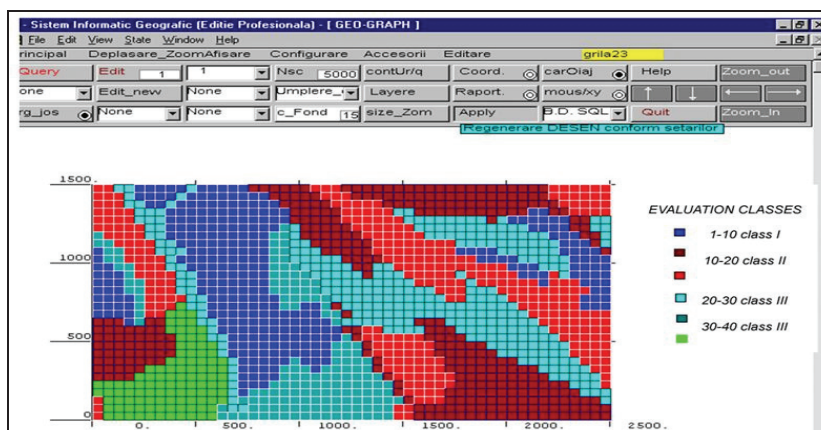


Fig. 9. Informational „Layer 23” of favorability categories

2. Using GIS to establish and develop land quality progress and detect possible degradation processes is possible for relatively small parcels of land owners, more or less evenly spread in a territory and also for larger areas, cadastral administrative territories.

3. Increased accuracy for the studies undertaken on land quality can be achieved through the development and updating of databases and the use of complex mathematical models to forecast its evolution. Such models can integrate into the system a large variety of data acquired from various sources, sometimes extended by automated statistical processing, and thus obtaining information including overviews on specific time periods, graphs, maps presenting thematic degradation risk or intervention needs by agricultural - pedologic - improvement works etc.

4. Increased performance of land quality research activities can be achieved by diversifying data acquisition methods (including Photogrammetry and Remote Sensing), development and continuous update of databases, and by using complex mathematical simulation models as WEPP, EPIC, GRASS, AGPNS etc. It is worth mentioning also the significant advantages of spatial remote sensing.

5. Using Geographic Information Systems (GIS) in land quality evaluation enables the acquisition, storage, update and fast computer-based processing of a large amount of spatial and descriptive data from different sources, typical for a given territory. Based on such valuable data, complex monitoring of soil fertility can be achieved at low cost, and the most appropriate protection and preservation measures can be implemented.

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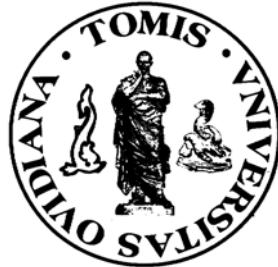
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The evaluation of the quantities of mineral aggregates extracted from ballast-pits by using the GIS technique: Case study.

Biali Gabriela, Pavel Dan

Abstract: The evaluation of mineral aggregates quantities from the watercourses beds, and the monitoring of activities from ballast-pits represents actions of great importance, since the exploitation of alluviums sources from the river beds, much over the power of natural regeneration, has determined high decalibrations of beds and of the transit regime of alluviums. They estimated that in our country, at the end of this century, only 65% of the reserves of bed alluviums would be available for explorations.

As regards the things presented, the current paper exposes an own methodology, based on a SIG/GIS technique, for the quantification of the extraction rate of mineral aggregates from a quarry/gravel pit for the duration of 4 years, making also some references regarding the impact of this exploitation on the bed morphology.

Keywords: ballast-pit, river bed, GIS technique

1. INTRODUCTION

It is generally a known fact that the ballast exploitations from the river beds can sometimes determine significant modifications of their morphology and of the liquid and solid courses dynamics, representing “aggressive” actions.

In the current conditions, in which we discover in Romania a significant increase of the number of ballast-pits and quantities of extracted mineral aggregates, the modifications that are produced in the beds obviously affect a series of riparian economic-social objectives, both regarding their safety and the possibilities of exploiting the water resources [3].

The Informational Spatial /Geoinformational systems were created with the purpose of computed acquisition and processing of data and of analyzing the information concerning the terrestrial space (Geo suggesting the ides of Earth and georeferential data).

The geographic Informational Systems (SIG) were created from the necessity of knowledge, monitoring and arrangement of the territory based on the digital maps.

They are capable to ensure the automatic map plotting, the inventory of resources, management of human activities etc., being the only which have the capacity to accomplish complex functions, carry out spatial analyses and data modelling/georeferential information [2].

In the present paper, for emphasizing the placement taken in the study, we used the AutoCad Map software and for the GIS modelling and the evaluation of the extracted mineral aggregates volumes, we used the Surfer software.

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2. THE LOCALIZATION OF RESEARCHES: THE BALLAST-PIT TIMIȘEȘTI – CRISTEȘTI

The ballast-pit Timișești – Cristești is situated in the middle sector in the minor bed of Moldova river, on the territory of Cristești commune, Iași county, downstream at about 700 m from the concrete road bridge from DN 15 B (km 60 + 800), figure 1. Hydrographically, in this area, the Moldova river (right affluent of Siret) is characterized through the elements presented in table no. 1.

In the sector studied, the Moldova river has a very unstable minor bed, divided in 2-3 main branches whose positions and depths change during the out rushes and the major bed has a large opening, reaching up to 1 ... 2 km.

Table 1 – Morphometric data of Moldova river at Timișești (outrush confluence Neamț ,Ozana), [8])

Length (m)	Data regarding the watercourse				Data regarding the hydrographical basin		
	Amplitude (m)		Average descent (‰)	Sinuosity coefficient	Surface b.h. (km ²)	Average altitude (m)	Wooded surface (%)
	Upstream	Downhill					
156	1116	276	5	1,31	3057	762	59,8

Under the hydrological aspect, the river Moldova is characterized through a permanent flow regime, but with high variations of the debits during a year of longer periods. For the section Timișești we can notice a few more important data [9]:

- multi-annual average debit: 30.4 m³/s;
- monthly average debits: 57.9 m³/s (June); 58.3 m³/s (July); 46.2 m³/s (August); 38.2 m³/s (September) 22.4 m³/s (October);
- maximum debit with the probability 1%: 1530 m³/s; maximum debit with the probability 5%: 1310 m³/s;
- average debit of alluviums in suspension: R=18 kg/s;
- minimum daily average debit with the probability of 95 %: 1.35 m³/s.

In Moldova Valley, the accumulation of alluvium deposits along the lowland, under the form of successions of dejection cones, interrupted by the expansion of outfall fans of the right affluents (Râșca, Ozana, Topolița) and even of the left ones, is characteristic (Moțca, Boureni etc.),[1].

Through the extremely close granulometry through sorts of the mineral aggregates requested by the constructors, the alluvial of Moldova bent, represents the largest exploitable perimeter from Moldova, a permanently renewable richness because of the lack of hydrotechnical barrier arrangement.

In the analyzed area, Moldova river flows in a large bed formed of its own alluviums producing erosions on the right bank. The most important transformations are produced during the large waters, when the flow in the major bed has a normal direction of the meanders direction, some branches disappearing by sand-up while other branches may appear further on with a completely different route.

The relatively accentuated descent of the river makes the volume of solid harsh alluviums transported through traction become significant.

The exploration method used in the ballast-pit is imposed by the Company Romanian Water, through the annual exploitation authorization, outlining the directions and the sense of exploitation, the width of the exploited layer, the quantities and restrictions applied in view of protecting the river bed against the erosion and abatement, corrosion of banks in the periods. Starting from these issues, the extraction method used is the following: the mechanized exploitation with DRAGLINĂ, IFRON, VOLA on parallel, successive lines, longitudinally oriented from the downstream to the upstream and from the water course to the bank, on a width of 1.0 m, according to the characteristics of the alluvium deposit, the positions and the prognosis of the solid and liquid debits dynamics of the river.

3. THE WORK MANNER AND THE RESULTS OBTAINED

In order to determine the influence of the ballast exploitation on the surface flow and the river bed (thalweg) dynamics, we delimited an extended polygonal area, mainly represented by the major river bed in the analyzed area, delimited by the points P1, P2, P3, P4 (table 2). These points delimit an area of : $S = 706841 \text{ mp} \sim 70,7 \text{ ha}$, on a length of watercourse of 1400 m. On this distance, the altitude (Z) varies between: $270 \div 280 \text{ m}$.

Table 2 – The coordinates of the points in the system STEREO '70 (to limit of studies perimeter)

Point	X - NORTH (m)	Y - EAST (m)
P1	639471	616961
P2	639823	617213
P3	639119	618480
P4	638707	618011

In order to establish the modifications occurred on the major bed during time, especially in the years 2001 ÷ 2004 we used the calculation of the volume of the body delimited by the horizontal plan, passing through the Z area = 269 k and the surface generated by the topographic measurements.

At the same time, we established 5 routes for the transversal profiles delimited by the point's 1A-1B ÷ 5A-5B. It is recommended that these points be marked in the land for the subsequent monitoring of the bed modification, the river bed (thalweg) and for the control of exploitation works.

Their report of Z axis (altitude) was carried out having as reference the road bridge near the position whose quota, in the south corner, towards the ballast-pit, was considered : $Z_{\text{bridge}} = 280,00 \text{ m}$

In order to monitor in time the modifications that occurred in the area delimited by P1÷P4 we used the land surveys achieved for the documentations of existent authorization.

Thus, we used surveys achieved in the years 2001 (T1), 2002 (T3), 2003 (T5) and for 2004 (T7) we achieved our own measurements with the total station GEODIMETER 444, with a precision of 1 sec. ($\pm 2 \text{ mm/km}$).

The old plans were digitized and processed in software applications of CAD type in order to achieve the profiles through the points established and their superposition. At the same time, we used a GPS system, model GARMIN eMAP in order to place as correctly as possible in the coordinates STEREO '70 the analyzed area. Thus, we can claim that the

placement precision was determined with an error of $0,5 \div 1,0$ m. At the same time, because of the presence of the bridge on DN 15B we could achieve a correlation of these plans with the cadastral ones.

The work stages have been:

3.1. Processing and centralizing data:

- We used previous topographic plans (2001, 2002)
- We achieved topographic measurements
- Z was correlated based on the common elements (fix points) existent in the available plans
- The analyzed perimeter was established (figure 1)

3.2. Creating the database based on the topographic measurements

- The introduction of data in a table containing the coordinates of the points from the measurements (figure 2)
- Data processing; obtaining the files *.grd (figure 3)
- Choosing the interpolation method (figure 4)
- Generating the M.N.T. (figure 5)

3.3. Calculating the volume

- Generating the surfaces
- Establishing the secant plan (apron) (fig 6)
- Calculating the volumes (fig. 7)

3.4. Achieving MNT through the RTN combined method (triangular irregular network) with interpolation in RD (rectangular network)

- Representing the perimeter in the 4 years taken in the study (figs 8,9,10,11)

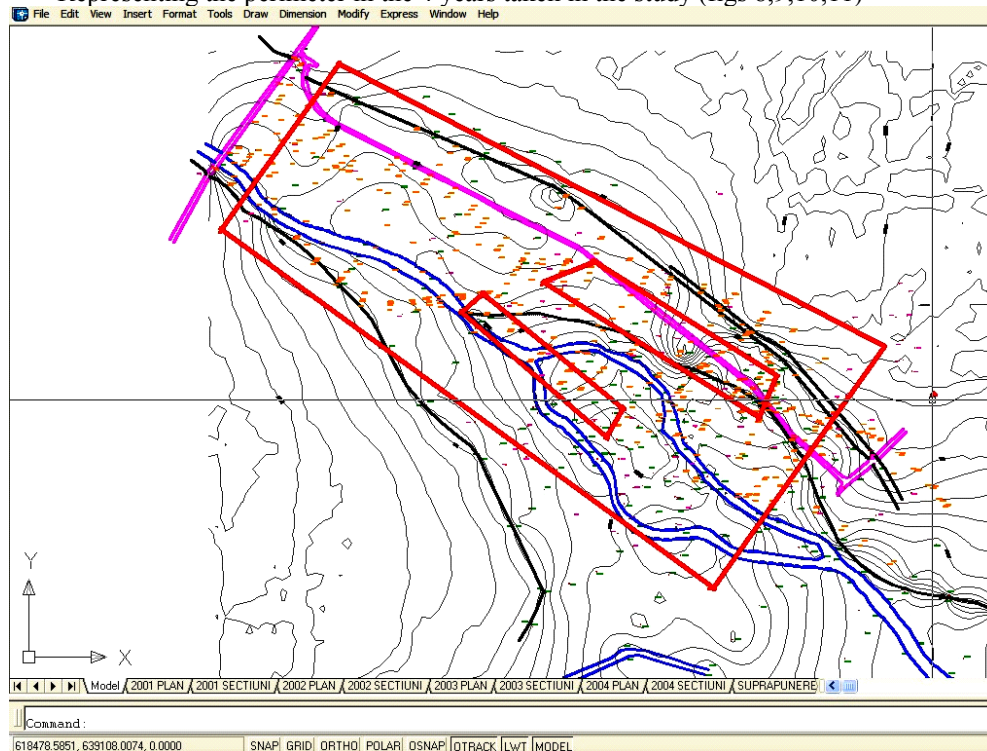


Fig 1. The placement of the perimeter studied within the ballast pit Timișești – Cristești

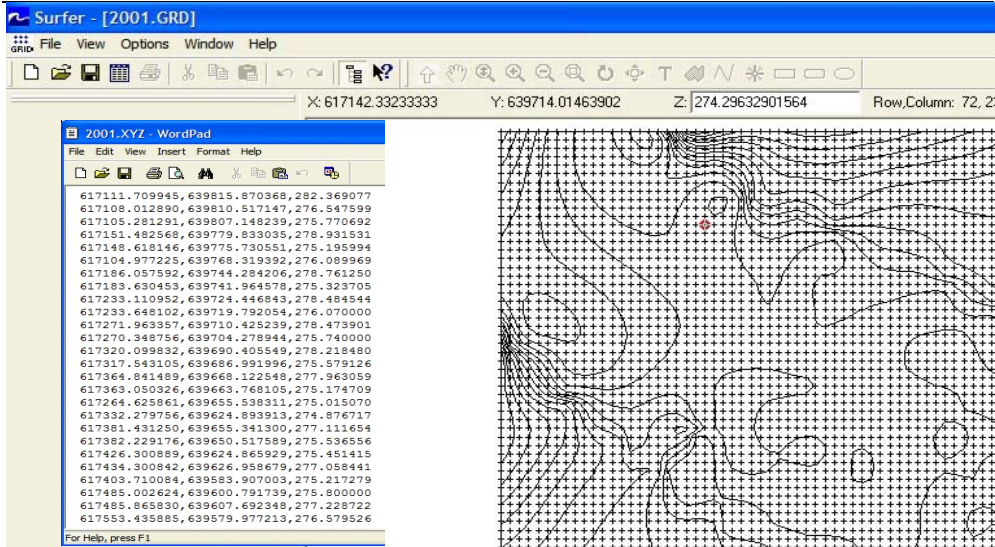


Fig. 2 Data introduction (coordinates from the measurements)

Fig. 3 Data processing obtaining the files *.grd

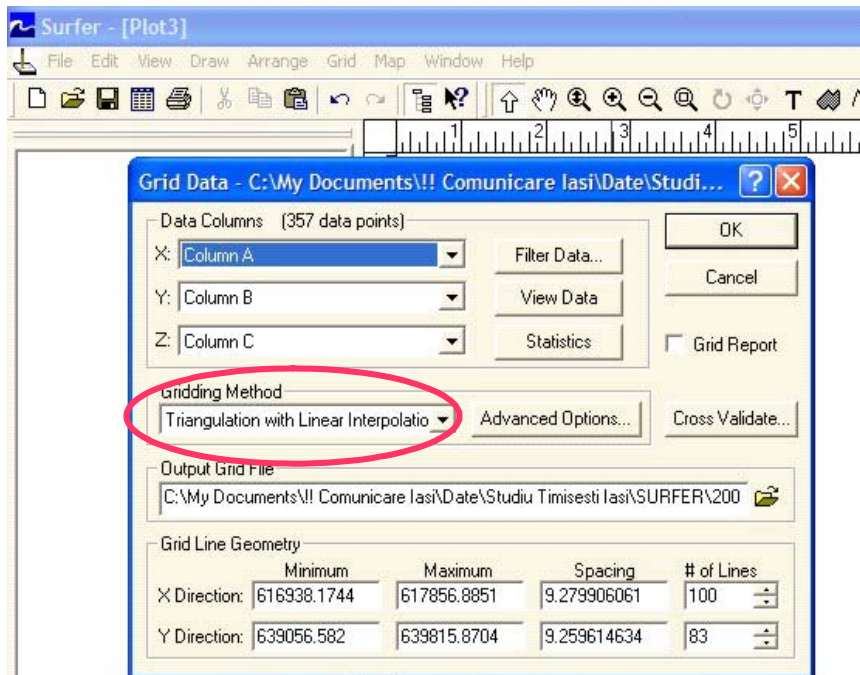


Fig. 4 Data interpolation through TIN method (with Surfer Software)

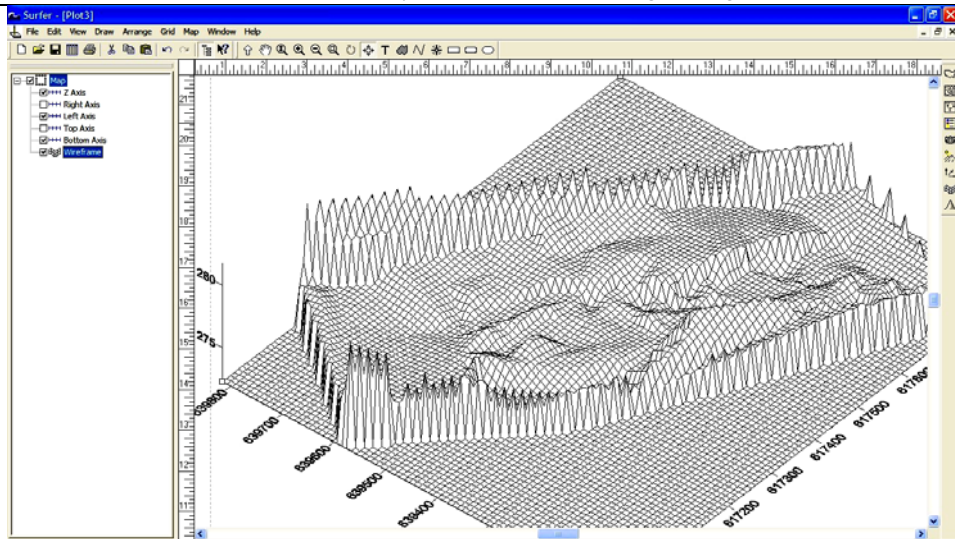


Fig. 5 – 3D representation in wire - frame of the Land Numerical Model (MNT) of the studied perimeter

3.3. Calculating the volumes of the ballast

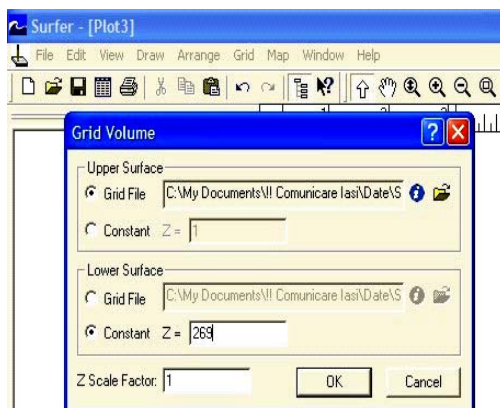


Fig. 6 Establishing the secant plan (apron) for calculating volumes

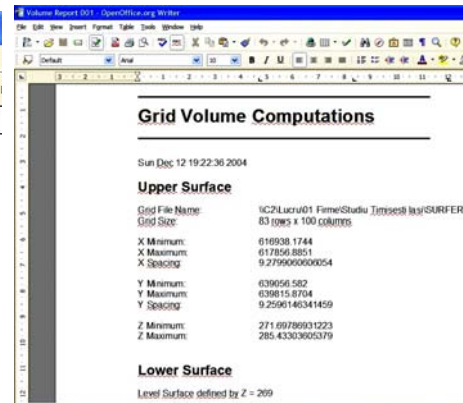


Fig. 7 The sequence for the automatic calculation of volumes with Surfer software

After establishing the limits of the ballast-pit and the secant plan, we continued with the calculation of the evaluated volumes (through extraction and alluvium transport) in each year and for which the topographic plans were available.

**Without Ballast
Exploitation**

Volume Input
 V_{IN}

**With Ballast
Exploitation**

Volume Input
 V_{IN}

Area / perimeter analyzed

$$V_{ANALYZED} = V_{OUTPUT} - V_{INPUT}$$

$V_{ANALYZED} > 0 \rightarrow$ Regeneration

Area / perimeter analyzed

$$V_{ANALYZED} = V_{OUTPUT} - V_{INPUT} - V_{EXPL.}$$

$V_{ANALYZED} < 0 \rightarrow$ Erosion

3.3. Making MNT combined method (RTN with interpolation DR) software Surfer

Year analysis: **2001**
 Share the plan: Z = 269 m
 Volume calculated: **5.511.299 mc**

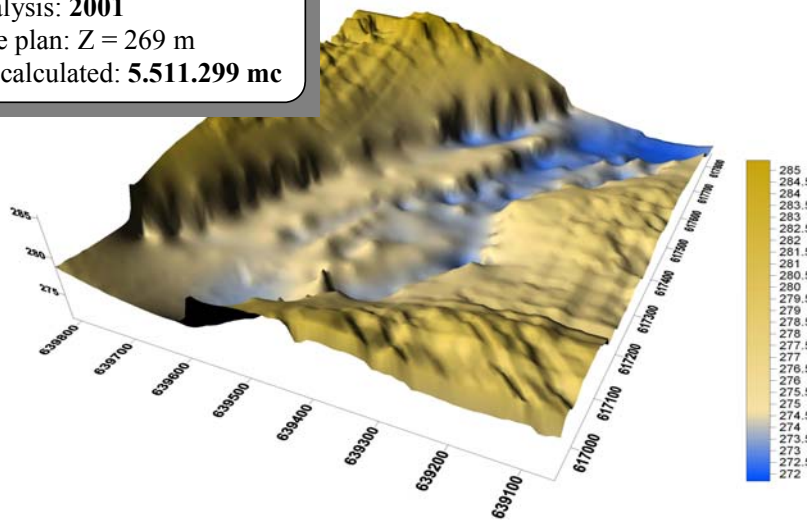


Fig. 8 Digital Model of Terrain (MNT) of the studies perimeter – Year 2001

Year analysis: **2002**
 Share the plan: Z = 269 m
 Volume calculated: **8.689.231 mc**

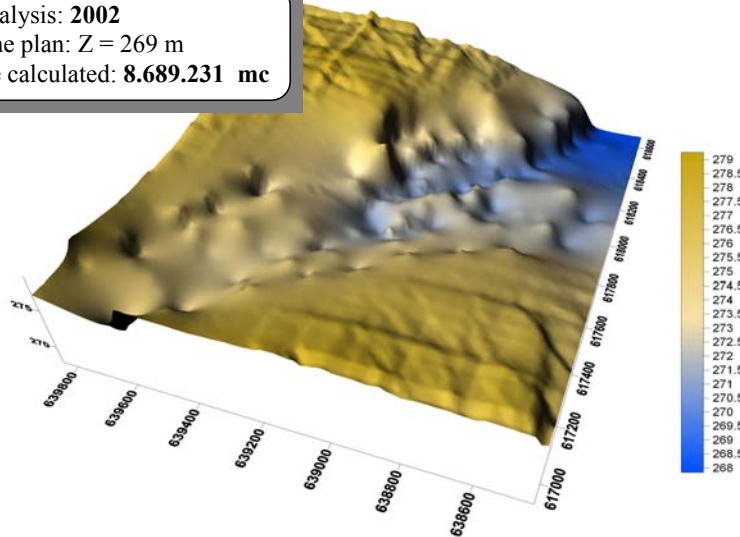


Fig. 9 Digital Model of Terrain (MNT) of studies perimeter – Year 2002

Year analysis: **2003**
 Share the plan: Z = 269 m
 Volume calculated: **8.642.977 mc**

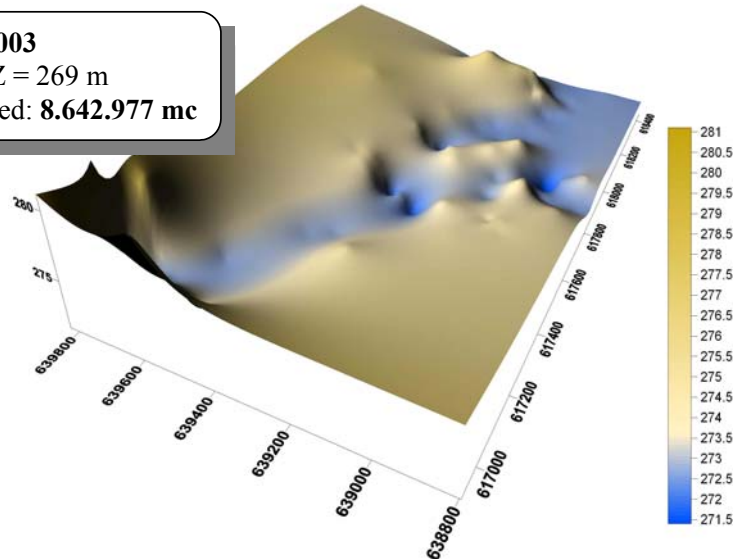


Fig. 10 Digital Model of Terrain (MNT) of studies perimeter – Year 2003

Year analysis: **2004**
 Share the plan: Z = 269 m
 Volume calculated: **8.599.111 mc**

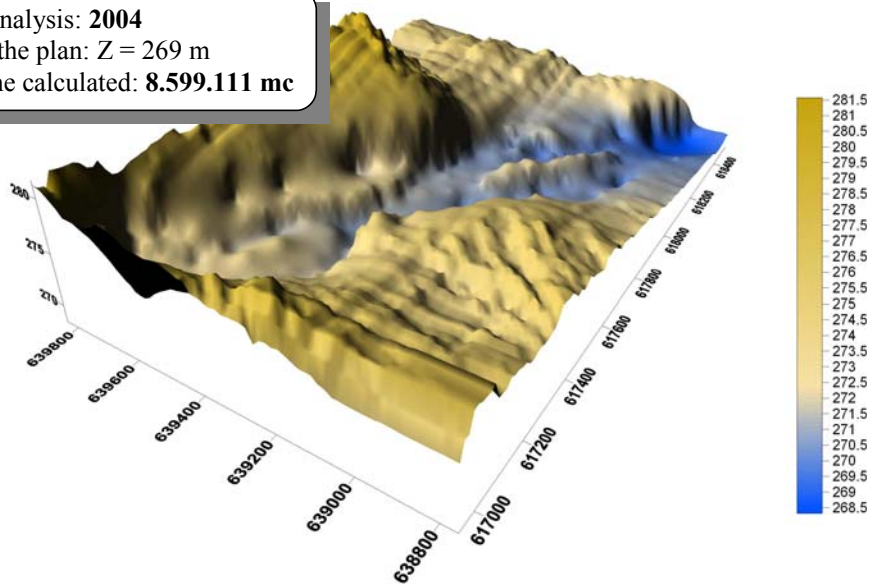


Fig. 11 Digital Model of Terrain (MNT) of studies perimeter – Year 2004

4. INTERPRETING THE RESULTS FROM THE CALCULATION OF VOLUMES

Since the topographic measurements from 2001 did not comprise the entire analyzed area, this year will not be taken into the calculation of regenerations.

Analyzing the things presented in the paper, we ascertain in general a decrease of the thalweg quota, more emphasised in the years 2002, 2003 and more reduced in 2004.

We notice that in general, the thalweg quota decreased to values between 0,2 and 1,3 m. This fact is confirmed also by the previous calculation of volumes.

Table 7. Results obtained and interpretation

Year	Calculated volume (m ³)	Difference from the previous year (m ³)	Quantity exploited in the area according to the authorization (m ³)	Quantity resulted from regeneration (m ³)
2001	-	-	-	-
2002	8.689.231	-	-	-
2003	8.642.977	-46.254	75.000	28.746
2004	8.599.111	-43.866	75.000	31.134

We ascertained that there are also areas in which the thalweg increased with 0,2 ÷ 1,1 m, especially in the area in the downstream.

Table 8. Changes in thalweg of the years studied

Year	Maximum value	Minimum value	Average
2001			
2002	-1,000	0,600	-0,397
2003	-1,320	-0,065	-0,416
2004	-1,86	-0,017	-0,899

5. CONCLUSIONS

a.) By using a MNT / MNA we can determine with high precision the ballast exploitation rate in an exploitation perimeter of the ballast in an exploitation perimeter, in comparison with the currently used topographic methods.

b.) Having at the disposal a MNT / MNA in the exploitation perimeter (ballast-pit) we can achieve profiles on any direction, which facilitates the detailed knowledge of the bed processes in the area, including the evolutions of quotas on the river bed (thalweg).

c.) The exploitation depth must not be equal with the depth of the thalweg and the exploitation must focus on the holms that appear in the area and decrease the transversal section through which the water passes, increasing the speed. Through the exploitation of holms, the surface for the water passage is increased in transversal section, which implicitly leads to the speed reduction and the increase of deposits in the affected area.

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The assessment of deformations in the decantation pool Valea Tărnicioara, through the signal analysis method

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Abstract: The appropriate design and execution of the decantation pools ensure the increase of the stability reserve of this type of construction.

In the present paper, we partially approach the study of deformations, decisional element in the analysis of taluses and versants.

Thus, in the following paper we will present the evolution of the deformations in Valea Tărnicioara decantation pool from Suceava county, deformations that were measured topographically, on scale marks situated on the berms of the decantation pools. There are horizontal and settlement deformations, towards the downstream, of the decantation pool body, measured in 2004 and 2005.

Keywords – decantation pools, stability, horizontal and settlement deformations

1. INTRODUCTION

The deformations that appear in the interior of earth rocks, on taluses or in versants, having a very varied range of forms, from hardly visible cracks, to morphological forms specific to the relief affected by landslides, represents the best indication regarding the incipient landslide process or in course of occurrence. Therefore, the study of deformations represents the main source of information for the practical prognosis of the landslides.

The decantation pools are special hydrotechnical retention constructions, of permeable type having as objective the safety depositing of the sump mine and the evacuation of all the water debits from the sites.

The stability of decantation pools, barrages and dams for their formation, of banks and bordering areas is analyzed under the aspect of the general stability of the dump talus, of the initial barrage (dam) and foundation land.

The factors that can cause the instability of a dump deposit are:

- exceeding due to the bending of the talus or its height of the limits that ensure the stability in the real conditions of the geomechanical characteristics of the deposited dump, dam or initial barrage and foundation land;
- the action of water flowing in the dump mass.

The analysis of stability is achieved for certain breakage hypotheses (in the mass of the foundation land, through the body of the initial dam or only in the dump mass). The study of deformations must be considered as a main process for the prognosis of the landslides and taluses. For the practical efficacy increase of this work process, it is necessary that the deformations measurement have a preventive character, for the discovery of the sliding process in its incipient stage. That is why it is necessary to extend the

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geodesic measurements for all the taluses, without exception, on all the versants susceptible of landslides.

The discovery of a landslide, in its incipient stage, means a great economy of money and technical means for stabilizing or reducing the intensity of the sliding process. It is unanimously recognized that the technical measures taken for the prevention of landslides are much more economic and practically easier to achieve than those necessary for stabilizing the landslides when the sliding process is already in course of evolution.

2. LOCALIZATION OF RESEARCHES

Valea Tărnicioara decantation pool is situated in the hydrographic basin of Brăteasa course, affluent of Moldova river.



Fig. 1 – The localization of the decantation pool Valea Tărnicioara

Leșu Ursului mine exploitation, the Preparation factory Tarnița and Servicing Base Frasin are positioned on a very large territory, in Stănișoarei Mountains. The distance on the road between the extreme points exceeds 60 km, and as altitude, from 555 m (Baza Frasin), at over 1000 m. The road Frasin – Holda, crosses Stănișoarei peak through Puzdra clough, at the altitude of 1160 m.

From the upstream of Ostra begins the area with the highest density of improvements and installations, with the two decantation pools no longer functioning, overgrown with grass and almost completely remade. Then come the two affluents of Brăteasa, Tărnicioara and Străjii river, from the left and respectively right of Brăteasa valley.

In the area of brooks, two active decantation pools were created, *Tărnicioara* and *Straja*. Then follows the complex of buildings and installations of Tarnița preparation Factory with the two sections, nonferrous and barite, continued at around 500 m upstream from a group of buildings with administrative purposes of E,M, Leșu Ursului, near them being the mine Aluniș, the Ostra quarry and Ostra dump.

The density of the hydrographic network grows from 0.53 kg/km² in Moldova basin and the inferior and middle basin of Suhăi, at 0.68 kg/km² in the hydrographic basins Brăteasa and Bistrița.

The pool Valea Tărnicioara was destined to exploitation in 1975. The decantation pool reached presently a height of over 80 m (the main closing barrage) and the average slope of the general talus being under 18° (1:3).

As “valley pool” it has the priming dam situated on Valea Tărnicioara. The dam is founded on old, Cretaceous deposits, known under the name of “Sinaia layers”, made up of marl chalks and sandstone, resistant rocks that ensure both the stabilization of foundation land, and of the pool bed. The rocks are bended towards the upstream, at around 40 – 50°, which represents an important condition in favour of stability.

The pool has two ramifications, one on Valea Tărnicioara and the other on Scăldători brook- left affluent of Valea Tărnicioara. The watercourse of Valea Tărnicioara was deviated and moved into a gallery dug in the right versant of the valley, and the watercourse of Scăldători brook goes under the pool in a visitable under-crossing gallery (with a diameter of 1.8 m) and is continued to Valea Tărnicioara existing the pool in the downstream from the primer dam.

The decantation pool Valea Tărnicioara is a valley pool that is founded on a priming dam and was built through the elevation process “towards the upstream”.

The pool has in the upstream two tail barrages, one on Valea Tărnicioara which is barring the watercourse in order to take it to the gallery and another on Scăldători brook.

3. CHECKING THE STABILITY OF VALEA TĂRNICIOARA DECANTATION POOL. THE RESEARCH METHOD

Valea Tărnicioara decantation pool belongs to the importance category “special importance barrage” from: “The Emergency Ordinance regarding the safety of barrages from November 28th 2000”.

In this context, through “barrage” we understand “any hydrotechnical work with an existent structure or proposed which is capable to ensure the accumulation, permanent or non-permanent of water, liquid industrial waste deposited under the water (from the chemical industry, energetic industry, and the decantation pools from the mine industry) whose breakage could produce the uncontrolled loss of the accumulated contents, with extremely important negative effects on the social, economic and/or natural environment (Emergency ordinance regarding the barrages’ safety from November 28th 2000).

The two serious events occurred in the decantation pools in our country in the last three decades integrally motivate the fact that the pools belong to the II importance class.

The two events are:

The breakdown, in 1971, of the decantation pool Certej – Săcărâmb – Deva mining area, where about 100 people lost their life;

The accident from the decantation pool “Aurul” (The Gold) – Baia Mare mining area, from January 2000.

For estimating the stability of the decantation pool, the settlement deformations and the horizontal deformations, topographically measured, were analyzed.

In the first stage we analyzed the information registered until March 2004 and in the second stage, the results obtained until March 2005.

For evacuating the purified water, presently, only one inverted probe is functioning, positioned near the last dam from Valea Tărnicioara, which ensures the normal functioning of the pool. By lifting up the pool, the rest of the inverted probes were abandoned, respectively deteriorated and taken out of service.



Figure 2 – The water screen from the beach of the decantation pool Valea Tărnicioara



Figure 3 – The inverted probe from the beach of the decantation pool Valea Tărnicioara

The purified water was initially evacuated through two systems; one on Scăldători brook formed from inverted probe which discharged the water in the undercrossing gallery and another one on Valea Tărnicioara formed of inverted probes which discharged the water in the undercrossing gallery and another one on Valea Tărnicioara formed of inverted probes as well connected to a pipe posted on the pool bed. As a result of the elevation of the pool some inverted probes were taken out of service. In the inverted probe, the smallest width possible of the water screen is maintained, of about 0.5 m.

The natural stability of the versants of the decantation pool, both on Valea Tărnicioara and on Scăldători brook is very good. In the future, the versants of these valleys will not endanger the pool stability either.

The decantation pool stability is monitored with topographic guiding marks for measuring the taluses deformations, and with piezometric forages for measuring the depth of the underground water from the pool bed.

The estimation of the taluses stability starts from the deformations measured in the interval of the last 5 years (2002-2007) processed through the method of signal analysis, the only method for evaluating stability based on real deformations, measured "in situ".

Taking into account the time intervals between the measurements, for the signal of the horizontal movement we used the formula:

$$\eta_d = \left(\frac{d_0}{\alpha \cdot d} - 1 \right) \cdot 100$$

In which:

d_0 – is the non-cumulated "current deformation" corresponding to the last time interval measured t_0 (current time) – expressed in millimetres;

d – "previous deformation" non cumulated, corresponding to the previous time interval t – expressed in millimeters;

α – deformation proportioning coefficient depending on the time interval in which it was made – dimensionless

η_d – horizontal displacement signal – expressed in percentage (%).

Recording periods:

22.07.2002 – 16.07.2003 $t = 359$ days

16.07.2003 – 03.07.2004 $t_0 = 352$ days

In this case the previous time interval being greater than the current time interval ($t > t_0$), the proportioning coefficient is expressed like this:

$$\alpha = \frac{t_0}{t} = \frac{352}{359} = 0,98$$



Fig. 5 – Topographic marks on the bank of Valea Tărnicioara decantation pool

Considering the size of time intervals t_0 and t we calculated the correction coefficient for which we obtained the correction value $\alpha = 0.98$, which gives the displacement signal a high degree of confidence in the calculation results.

4. RESULTS OBTAINED AND THEIR INTERPRETATION

4.1. Assessment of Horizontal Displacements: Expertise of 2004

Concerning the calculation results, the negative values of the horizontal displacement signal, they point out a normal evolution of the pool stability, a tendency of attenuation of the deformations. The positive values and the null values show, on the contrary, an increase of the deformations, which requires a very careful supervision of stability, by reducing the time interval between measurements and even of application of some measures for increasing stability.

Using the deformations measured on the profiles 1 and 2 at the basis of the pool there were calculated the signal analyses 1 and 2, Analysis 1 including the topographic marks no. 11, 12, and 13, and Analysis 2 the topographic marks no. 15 – 28. Both analyses are calculated in table 1 and illustrated in the charts of figures 6 and 7.

Table 1 – Signal Analyses 1 and 2 – marks of the profiles at the basis of the pool

No. topographic marks	$\eta_d = \left(\frac{d_0}{\alpha \cdot d} - 1 \right) \cdot 100$		
	d_0 (mm)	d (mm)	η_d (%)
11	5,4	11,2	-51
12	22,3	8,6	165
13	8,9	15,5	-42
15	9,8	25,5	-61
17	3	12,5	-75
18	14	25	-43
19	2	25	-92
20	20,2	18,8	7
21	31	31,5	0
22	13,6	11,3	23
24	29,1	19	57
25	8	10,4	-22
26	12,1	34,4	-64
27	6,7	26	-74
28	13,6	31,8	-56

Profile no. 1

Profile no. 2

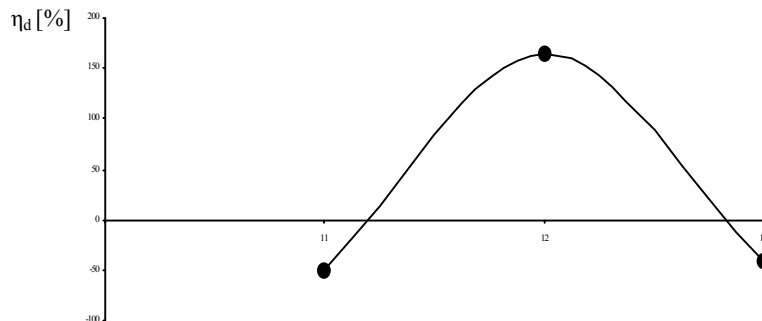


Fig 6 – Signal Analysis 1 – Tărnicioara Decantation Pool

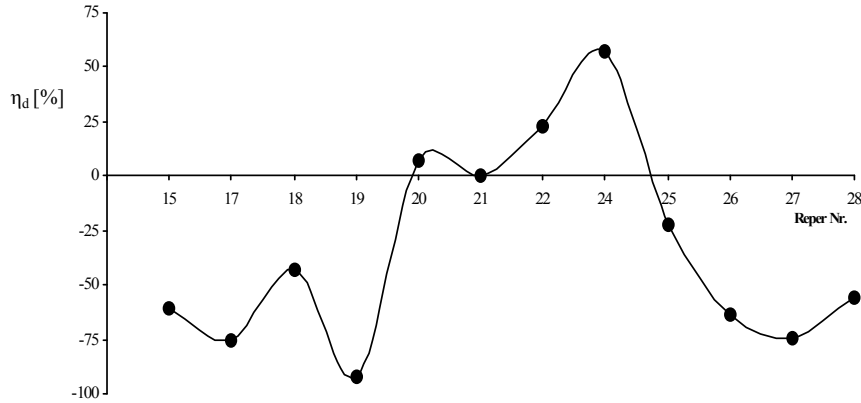


Fig. 7 – Signal Analysis 2 – Tărnicioara Decantation Pool

Studying the results of table 1, of the 15 values of the displacement signal, 10 of them are negative, which indicates a tendency of attenuation of the deformations, whereas 4 values are positive and one value is null, they emphasizing, locally, deformations still active within the lake body.

4.2. Assessment of Horizontal Displacements: Expertise of 2005

Expertise periods: 25.07.2002 – 15.07.2003 $t = 300$ days and 15.07.2003 – 22.03.2005 $t_0 = 614$ days. In this case the previous time interval being smaller than the current time interval ($t < t_0$), the proportioning coefficient is expressed like this:

$$\alpha = \frac{t}{t_0} = \frac{300}{614} = 0,5$$

Table 2 – Signal Analyses 4 and 5 – marks of the profiles at the basis of the pool

No. topographic marks	$\eta_d = \left(\frac{d_0}{\alpha \cdot d} - 1 \right) \cdot 100$		
	d_0 (cm)	d (cm)	η_d (%)
11	10,8	1,58	240
12	14,5	1,5	380
13	39,4	1,27	1450
15	5,8	1,2	140
17	8,8	1,1	300
18	9	1,3	250
19	6,7	1,22	170
20	5,6	0,86	220
21	4,5	0,9	150
26	2,3	1,48	- 22
27	4,7	1,03	130
28	5,7	1,42	100

Profile no. 1

Profile no. 2

Considering the size of time intervals t_0 and t we calculated the correction coefficient for which we obtained the value $\alpha = 0.5$, which gives the displacement signal a high degree of confidence in the calculation results.

Concerning the calculation results, the negative values point out active deformations within the body of the decantation pool. As physical sizes, there are a few centimeters per year, values that are within the admissible deformations for the stability of the decantation pools.

The Tărnicioara pool being at rest from the end of 2004, the underground water descended, in most piezometres, at over 10 m deep, which represents an important factor in favour of stability.

Using the information measured on the profiles 1 and 2 at the basis of the pool there were calculated the signal analyses 4 and 5, Analysis 4 including the topographic marks no. 11, 12, and 13, and Analysis 5 the topographic marks no. 15 – 28. Both analyses are calculated in table no. 2 and illustrated in charts in figures 8 and 9.

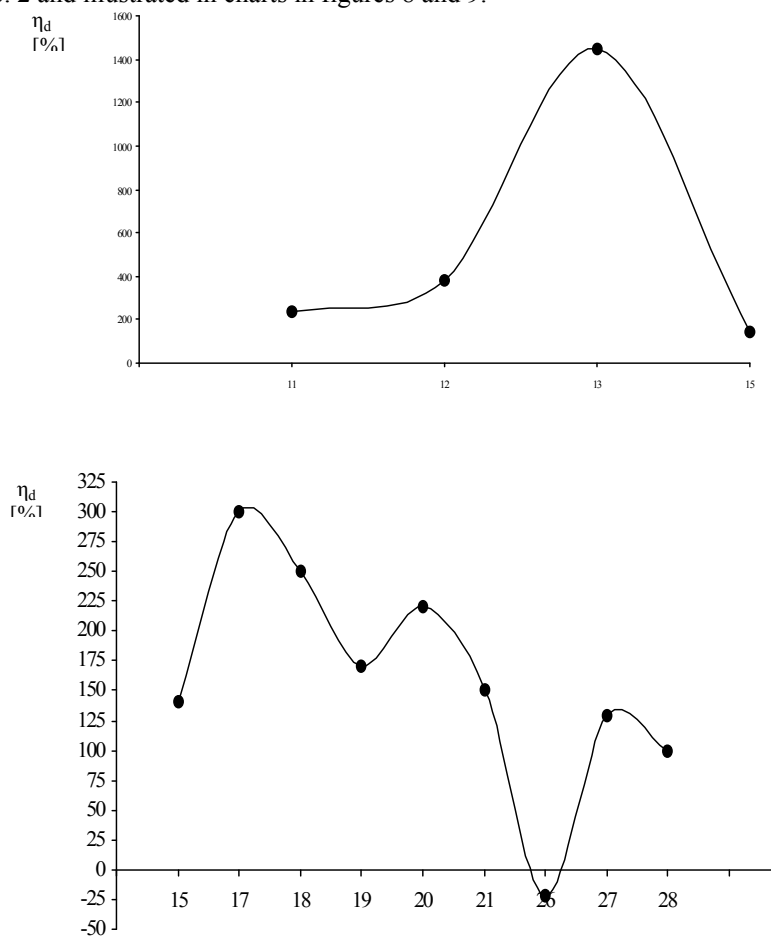


Fig. 8 and Fig. 9 – Signal Analysis 4 Horizontal Displacements – Profile 2 and Signal Analysis 5, Horizontal Displacements – Profile 2 –Tărnicioara Decantation Pool

3. RESULTS AND SIGNIFICANCES

4.3. Assessment of Vertical Displacements (settlements): Expertise of 2004

For the vertical information we used the vertical displacement signal expressed as follows:

$$\eta_s = \left(\frac{s_0}{\alpha \cdot s} - 1 \right) \cdot 100$$

where:

s_0 – is the “current deformation” related to the last time interval measured t_0 (current time) – expressed in millimeters;

s – “previous deformation” related to the previous time interval t - expressed in millimeters;

α – proportioning coefficient of the deformation depending on the time interval in which it was made - dimensionless;

η_s – vertical displacement signal – expressed in percentage.

Expertise periods:

22.07.2002 – 16.07.2003 $t = 359$ days; 16.07.2003 – 03.07.2004 $t_0 = 352$ days

In this case the previous time interval being smaller than the current time interval ($t > t_0$), the proportioning coefficient is expressed like this:

$$\alpha = \frac{t_0}{t} = \frac{352}{359} = 0,98$$

Concerning the significance of the calculation results, the negative values of the vertical displacement signal point out a normal evolution of the pool stability, a tendency of attenuation of the deformations. The positive or null values, on the contrary, show an increase of the deformations, which requires a very careful supervision of stability, by reducing the time interval between measurements and even by applying some measures for increasing stability.

The vertical displacement signal is showed in table no. 3 and represented in the charts of figure 10.

Table 3 – Signal Analyses 6 – marks of the profiles at the basis of the pool

No. topographic marks	$\eta_s = \left(\frac{s_0}{\alpha \cdot s} - 1 \right) \cdot 100$		
	s_0 (mm)	s (mm)	η_s (%)
13	7	8	-10
22	7	2	250

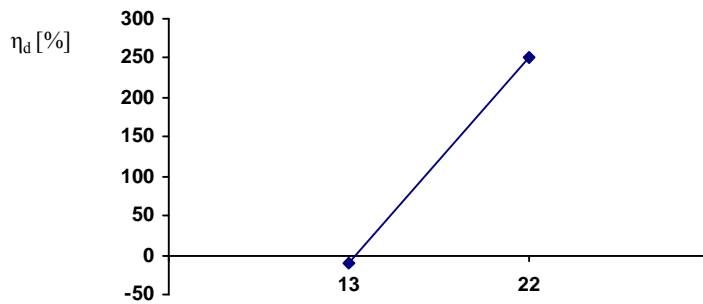


Figure 10 – Signal Analysis 6, Vertical Displacements – Tărnicioara Decantation Pool

This signal also confirms, by its results, both the tendency of attenuation of the deformations, and the existence of active deformations.

4.4. Assessment of Vertical Displacements (Settlements): Expertise of 2005

For the vertical deformations we used the vertical displacement signal which is calculated with the same formula.

Expertise periods: 15.07.2003 – 30.10.2004 $t = 472$ days and 30.10.2004 – 22.03.2005 $t_0 = 149$ days

In this case the previous time interval being greater than the current time interval ($t > t_0$), the proportioning coefficient is expressed like this:

$$\alpha = \frac{t_0}{t} = \frac{149}{472} = 0,31$$

Concerning the significance of the calculation results, the negative values of the vertical displacement signal point out a normal evolution of the pool stability, a tendency of attenuation of the deformations. The positive or null values, on the contrary, show an increase of the deformations, which obliges to a very careful supervision of stability, by reducing the time interval between measurements and even by applying some measures for increasing stability.

The vertical displacement signal is showed in table no. 4 and represented in the charts of figure 11.

Table 4 – Signal Analyses 7 – marks of the profiles at the basis of the pool

No. topographic marks	$\eta_s = \left(\frac{s_0}{\alpha \cdot s} - 1 \right) \cdot 100$		
	s_0 (cm)	s (cm)	η_s (%)
13	10	3	900
15	11	1	3400
20	3	6	60
28	5	7	130

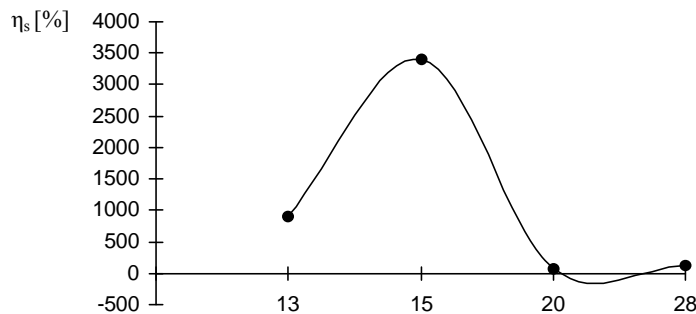


Fig. 11 – Signal Analysis 7, Vertical Displacements – Tărnicioara Decantation Pool

This signal also confirms the existence of active deformations.

5. CONCLUSIONS

a.) Following the results of tables 1-4, we may notice a tendency of attenuation of the deformations, but locally, there are deformations still active within the pool body.

We notice that the bank deformations are within the admissible limits for the stability of the decantation pool. According to the provisions of the joint Order of the Ministry of Waters, Forests and Environmental Protection of May 7th 1996 and Ministry of Public Works and Territory Management of May 13th 1996 concerning the “Methodology Approval and Contents of Expertise of Safety Status of Related Dams and Accumulation Lakes” and its adaptation to decantation pools.

b.) Concerning the second pool monitoring system, represented by the variations of the level of the underground water and its effects on stability, the situation is under control. At present there are activated 7 piezometric drillings, the level measurements being systematically made. Valea Tărnicioara pool being at rest from the end of 2004, the underground water descended, in most piezometres, which represents an important factor in favour of stability.

The underground water remaining at 8 – 10 m deep, in all piezometres, it doesn't produce negative effects on pool stability, this depth representing even a factor in favour of pool stability.

We mention that along the Târnicioara Valley there are created strong air currents which blow the sand from the beach but especially from the main bank of the pool, which leads to the reduction of steps height and covering the berms, forming in the lower part of the pool, a bank with a continuous slope. Sand removal by the wind reduces the cap dyke height, by several centimeters every year, leaving without support the transport line pipe of dirty water, which requires the periodical restoration of the cap dyke.

c.) Tarnicioara decantation pool is a valley pool, built on two valleys: one of the Tarnicioara creek which is deviated through a gallery that turns round the deposit and one of the Scaldatori creek which is directed, under the deposit, through an undercrossing gallery.

This leads to the need to make more ample works to increase pool stability. Of which we mention the most important ones: deformations measurement, during the operation period only, twice a year, in spring and in autumn; weekly measurement, of the piezometric level in the observation drillings; maintaining a low water level, from 0.5 m thick, at the inverted probe, to attenuate the suffusion in the pool body; maintaining the valve of the damaged water discharge pipe from the right slope in the "on" position, as long as there are not entrainments of sand in the water stream; periodic examination of concrete condition from the undercrossing ditch and elimination of water infiltrations appearing in the ditch; accelerated consolidation of dump by eliminating the water through the pores by installing vertical drains, following a pre-established distribution network; executing enrolements with gross stone to protect the banks and the hydraulic structures in case there are large water inrushes on the streams of the Scaldatori and Tarnicioara creeks; preventing the entrainment by the water inrush of the dump from the pool and the banks erosion; controlled collection and direction outside the pool perimeter of rain waters by making drains at the basis of the slopes, impermeabilization of the ditches foundation plate with geomembrane;

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