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HIDROTECHNICS

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STUDY OF THE DEFORMATIONS IN THE SYSTEMS OF CARTOGRAPHIC PROJECTIONS BY THE TECHNOLOGY OF THE GEOGRAPHICAL INFORMATIONAL SYSTEMS

BY

C. CHIRILĂ, C. BOFU and *BOGDAN MOROŞANU

Abstract. One of the fundamental criteria for adopting a countrywide cartographical projection, in order that our country should be represented in large scales, is represented by the deformations' character, both by the recorded values and their regional distribution.

For Romania, at the same time with passing to a new geodesic datum and to creation of a new supporting geodesic network, there are discussions about establishing the official cartographic projection for drawing up the great-scaled maps and plans, in the field of cadastre and generally, of the terrestrial measu-rements. Given the recommendation of the European Commission regarding adoption of the UTM. projection, a comparative study of the relative deformations is presented in comparison with the actual, Stereographic – 1970, which, by the suggestive results offered by GIS. technology, represents a fundamental landmark in choosing the most advantageous solution.

Key words: cartographic, GIS, projections, cadastre.

1. Introduction

Official cartographic projection in Romania is usually known as *Stereographic projection* – 1970**,** being effectively applied in geodesy since 1973. The features of the projection define it as an azimuthal, perspective, oblique, consonant projection, on a unique secant plane, relying on the geometrical parameters of the *Krasovski* – 1940 reference ellipsoid. Adoption of this projection took into consideration the clear advantages offered from the point of view of the deformations, for the Romania's approximately circular territory, so that there is a compensation of the relative linear deformations inside the circle of the null deformations with the ones outside it. On the secant plane of the stereographic projection – 1970, the *linear deformations* take negative or positive values depending on the position of the considered point towards "*circle of the null deformations for lengths and surfaces*" and is calculated considering the projection's central point. So, inside the null deformation's circle, linear deformation grows in negative value up to –0,25 m/km *into the central point*, and outside the circle, linear deformation grows positively, up to values of +0,65 m/km (Fig. 1). *Areolar deformations* have the same sign with linear ones, being negative inside the secant circle and positive outside it. Values of the areolar deformations vary depending on the distance from the central point of Stereo-70 projection, between –5 mp/ha in the center of the projection and up to +13 mp/ha towards the extremity of the Romania's eastern border.

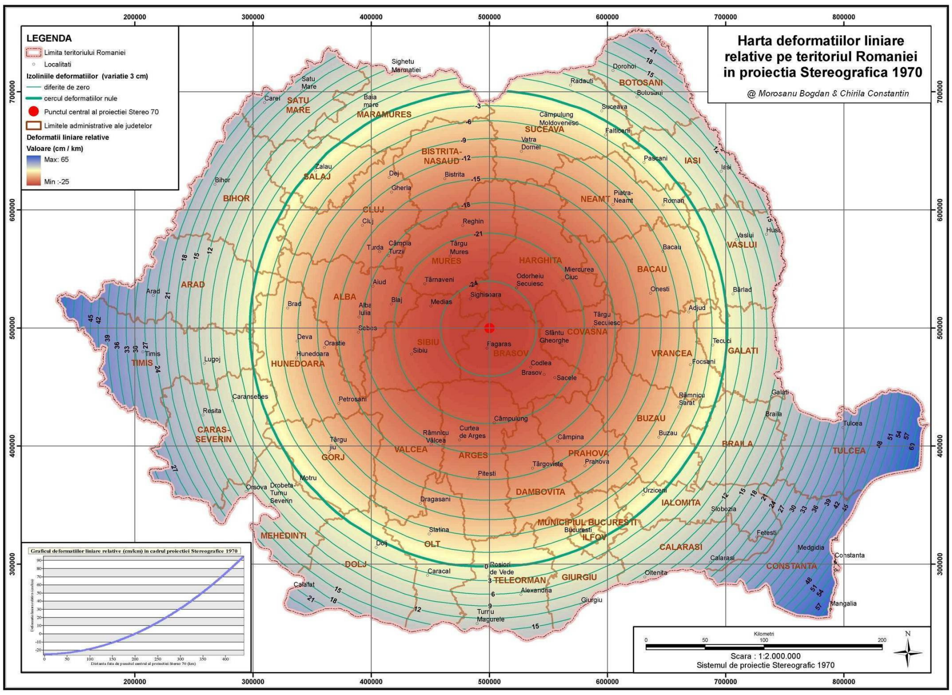

Fig. 1 – Map of the relative linear deformations in the Stereographic – 1970 projection.

The second projection, used also in Romania lately due to accession of our country into the new political and military structures, is UTM projection (Universal Transversal Mercator), a variant of Gauss – Krüger projection which is based on the parameters of WGS–84 international reference ellipsoid.

Romanian territory is mainly included into 34–T, 35–T areas and the part of the northern extremity into 34-U, 35-U areas, with systems of distinct coordinates.

UTM projection is conforming, that is it preserves not distorted the angles, instead, it distorts the distances and, implicitly, the surfaces. The scale of representation on the axial meridian, drawn by a line segment, is not any longer unitary as in Gauss projection, but it has the value of k_0 = 0.9996, expressing the constant ratio between the distances in the plane of UTM projection and Gauss projection. On the *map of the linear deformations* (Fig. 2), two lines of null deformation are to be individuated, symmetric to the axial meridian and approximately parallel to them, at an approximate distance of 180 km. this fact eliminates the necessity of adopting the 3° belt for reducing the deformations in the 6° longitude belt, as it is the case of Gauss projection. The deformations recorded in the 6° longitude belt in UTM projection, are both

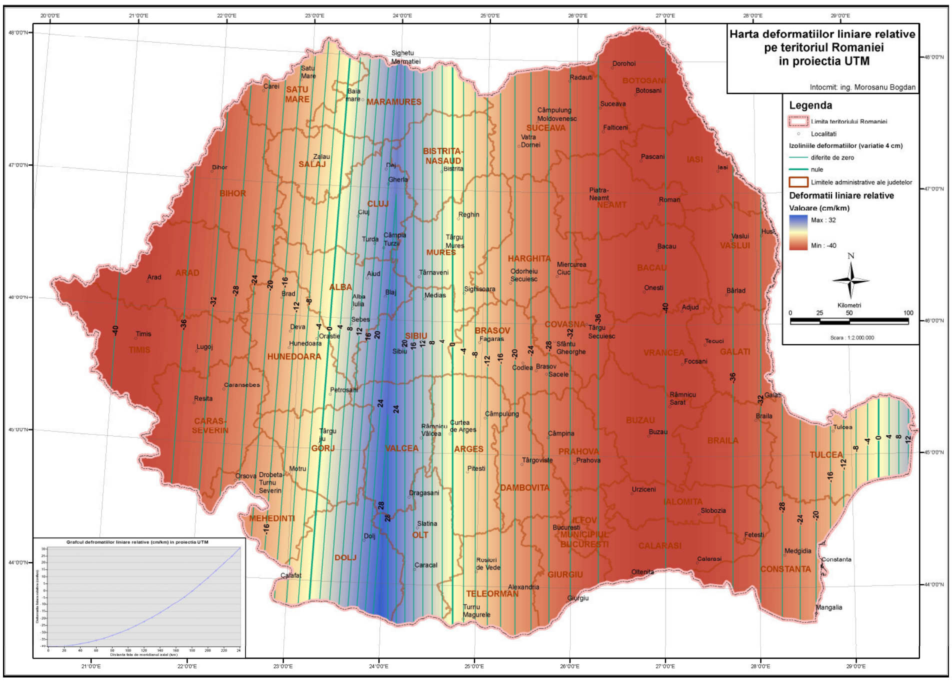

Fig. 2 – Map of the relative linear defor mation in the UTM. projection.

positive and negative. Therefore, on the axial meridian relative linear deformation of –40 cm / km was calculated, in order that it should decrease as we draw near the null deformations lines, where the value of zero is recorded. Going further to the edge of the belt, the deformations grow in positive value, reaching +32 cm/km on the marginal meridian, in the south area. *Areolar deformations* vary in the same sense as the linear ones, having values between –8 mp/ha and +7 mp/ha [1].

2. Comparative Study of the Deformations in the Cartographic Projections, Stereo–70 and UTM, by GIS Technology

In order that the comparative study of the deformations in the two cartographic projections of present interest in Romania, STEREO–70 and UTM, maps of the relative linear deformations were drawn out by means of the technology offered by ArcGIS medium, using color codes reflecting numeric values, calculated on basis of the formulas specific to each projection system (Figs. 1 and 2). Then these maps were used to the comparative analysis of the regional deformations of our entire country's territory and to extracting by reports some real values for certain localities or interest areas [3].

2.1. Statistic Diagrams with Distribution of the Relative Linear Deformations in the Stereo–70 and UTM Projections

For a comparative analysis of the distribution of the relative linear deformations in the two cartographic projections, three values intervals (0...±15 cm/km; ±15...±30 cm/km; ±30 cm/km ...) were set up in order that the maps and their afferent statistic diagrams are drawn up. Consequently, it resulted that in the case of the Stereo–70 projection (Fig. 3), there is a percentage of 60.4 % out

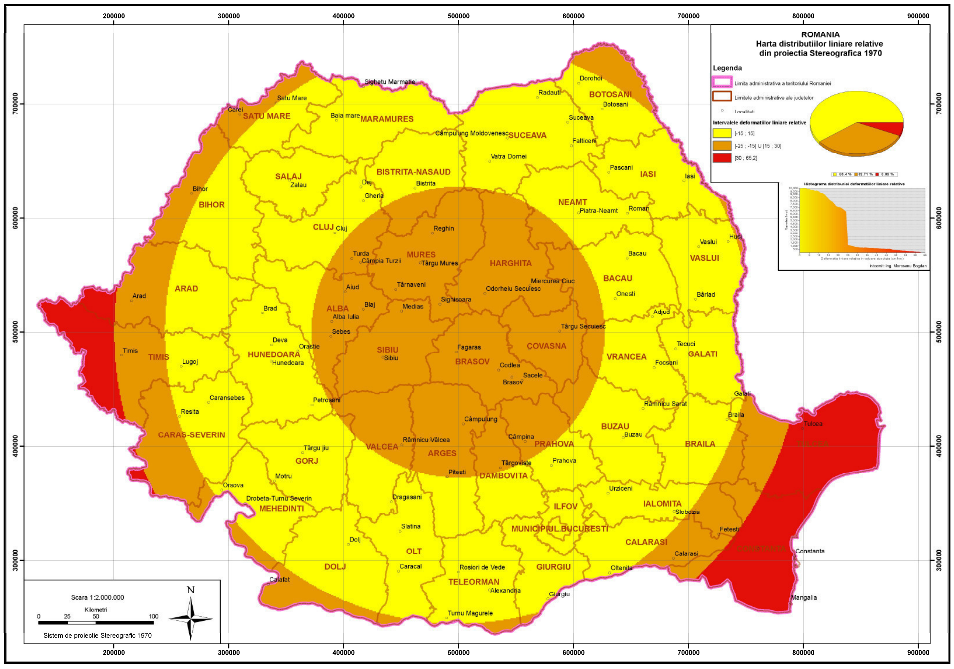

Fig. 3 – Map and statistic diagrams of the relative linear deformations' repartition in the Stereographic – 1970 projection.

of our country's territory where the deformations are in the admissible limit for the geodesic and cadastre works (±15 cm/km), whereas for the UTM. projection (Fig. 4), this percent rises only up to 30.7 % (Table 1).

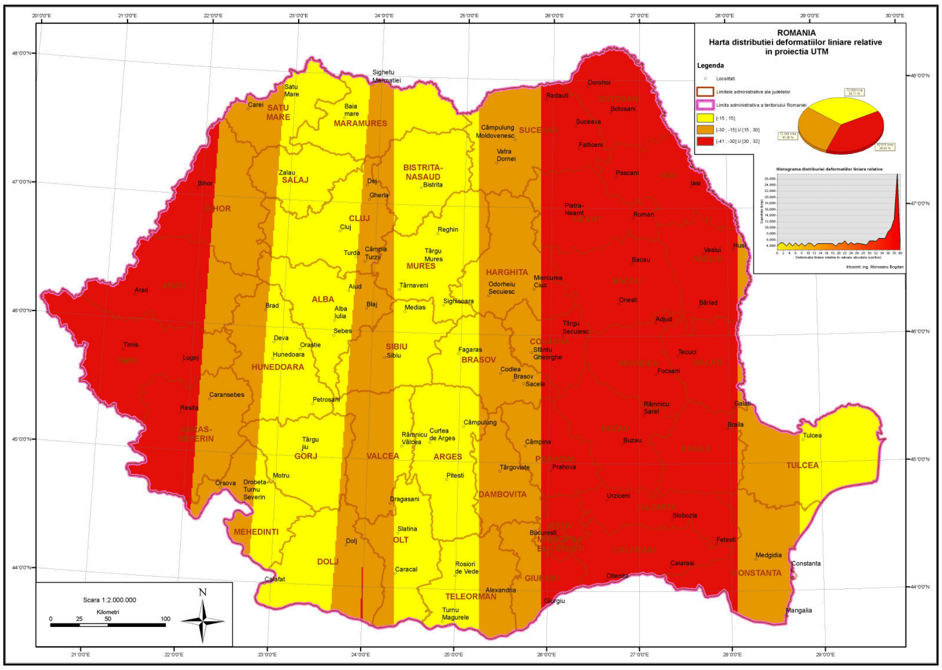

Fig. 4 – Map and statistic diagrams of the relative linear deformations' repartition in the UTM projection.

Table 1

Cartographic projections	0...±15 cm/km	±15...±30 cm/km	±30 cm/km ...
STEREO–70, [%]	60.4	32.7	6.9
U.T.M, [%].	30.7	30.4	38.9

2.2. Comparative Analysis of the Relative Linear Deformations in the Stereo–70 and UTM Projections, by Superposing the Initial Maps

The comparative study of the relative linear deformations of the two cartographic projections points out the areas favored by representing the territory in one of the two systems of cartographic projection. That is why, as comparative etalon, we first chose the differences of the absolute values of the relative linear deformations between the Stereo–70 and UTM projections (Fig. 5) and then, for a more stressed differentiation we chose for the ratio of these deformations' values (Fig. 6).

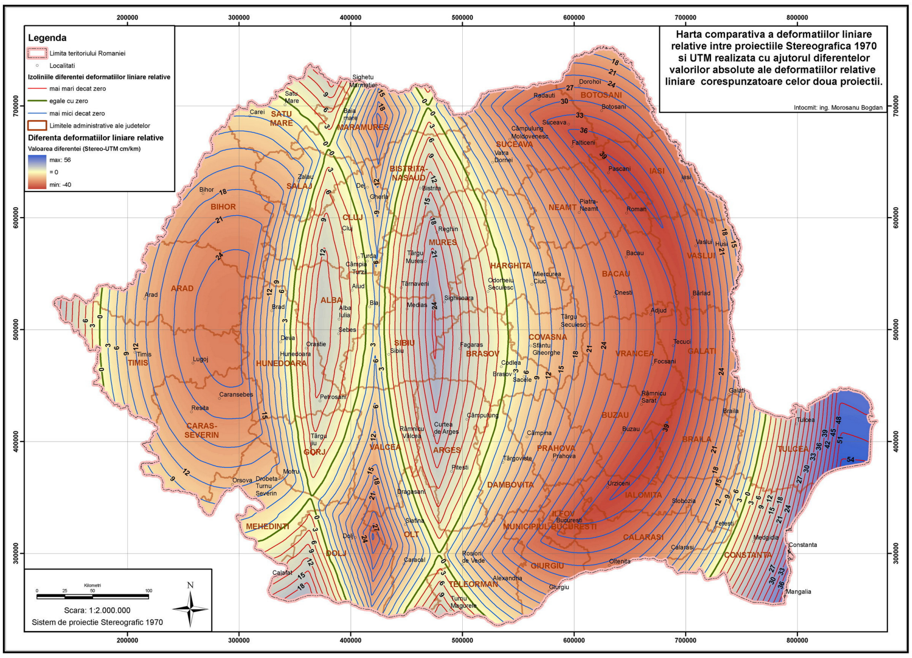

Fig. 5 – Comparative map of the relative linear deformations between Stereo–70 and UTM. projections, drawn up on basis of the differences in absolute value

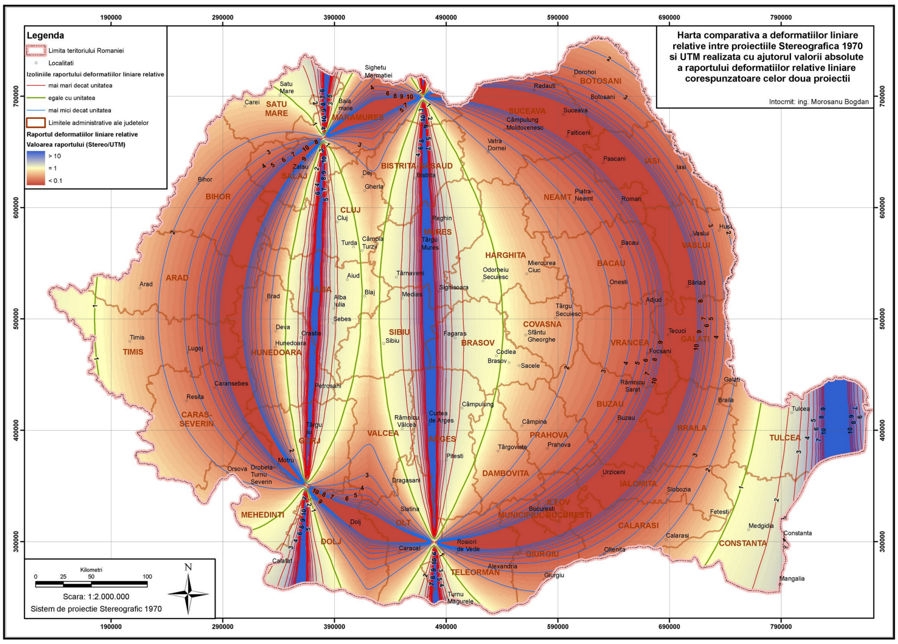

Fig. 6 – Comparative map of the relative linear deformations between Stereo–70 and UTM projections, drawn up on basis of the ratio of absolute value.

2.3. Extracting Reports Containing the Values of the Relative Linear Deformations for the Main Romanian Localities, in the Stereo–70 and UTM Projections

Considering the importance of the topographic–cadastral measurements in our country's localities and towns, where the relative linear deformations must not exceed ±5 cm/km, we extracted their values for 91 localities, both for the Stereo–70 and UTM projections (Table 2).

Table 2

Localities and towns	Values of the relative linear deformation, [cm/km]			
	Stereo–70	UTM	Differences	Ratio
Alexandria	–7.1	–39.8	–32.7	0.2
Aiud	–18.3	13.2	5.1	1.4
Alba Iulia	–17.4	8.2	9.2	2.1
Alexandria	6.3	–17.9	–11.6	0.4
Arad	25.1	–39.4	–14.3	0.6
Bacău	–9.0	–39.9	–31.0	0.2
Baia Mare	3.2	5.3	–2.1	0.6
Bihor	17.2	–34.0	–16.7	0.5
Bistrița	–14.3	4.4	9.9	3.3
Blaj	–20.6	21.7	–1.1	1.0
Botoşani	8.5	–39.2	–30.7	0.2
Brad	–7.1	–16.9	–9.9	0.4
Brăila	12.2	–32.9	–20.7	0.4
Braşov	–22.8	–25.1	–2.3	0.9
Bucureşti	–1.9	–33.6	–31.8	0.1
Buzău	–7.2	–39.8	–32.5	0.2
Bârlad	1.9	–36.8	–34.9	0.1
Călăraşi	20.3	–39.1	–18.8	0.5
Caracal	3.2	15.8	–12.6	0.2
Caransebeş	6.5	–29.1	–22.7	0.2
Carei	19.9	–25.7	–5.8	0.8
Cluj–Napoca	–13.5	7.2	6.2	1.9
Codlea	–23.6	–22.0	1.6	1.1
Constanța	50.8	–18.9	31.9	2.7
Curtea de Argeş	–19.2	1.2	18.1	16.7
Câmpia Turzii	–18.2	19.5	–1.2	0.9
Câmpina	–17.4	–27.7	–10.3	0.6
Câmpulung	–21.1	–11.2	9.8	1.9
Câmpulung Moldovenesc	–5.7	–25.4	–19.7	0.2
Dej	–10.4	17.3	–6.9	0.6
Deva	–8.8	–13.8	–5.0	0.6
Dolj	1.7	20.0	–18.3	0.1

Table 2
(*Continuations*)

Localities and towns	Values of the relative linear deformation, [cm/km]			
	Stereo–70	UTM	Differences	Ratio
Dorohoi	11.7	–37.5	–25.9	0.3
Drăgăşani	–9.5	17.9	–8.3	0.5
Drobeta–Turnu Severin	9.5	–19.2	–9.7	0.5
Făgăraş	–24.8	–9.3	15.5	2.7
Fălticeni	–2.6	–36.5	–34.0	0.1
Feteşti	26.2	–34.5	–8.3	0.8
Focşani	–6.7	–39.8	–33.1	0.2
Galați	12.4	–31.7	–19.3	0.4
Gherla	–12.6	18.9	–6.3	0.7
Giurgiu	12.2	–31.5	–19.3	0.4
Hunedoara	–8.5	–13.8	–5.3	0.6
Huşi	12.7	–31.9	–19.3	0.4
Iaşi	9.7	–37.6	–27.9	0.3
Lugoj	11.2	–34.2	–23.0	0.3
Medgidia	38.8	–27.5	11.4	1.4
Mediaş	–23.3	11.1	12.2	2.1
Miercurea–Ciuc	–21.5	–29.6	–8.1	0.7
Motru	1.0	–10.9	–9.9	0.1
Odorheiu–Secuiesc	–23.9	–18.9	4.9	1.3
Oltenița	13.0	–39.0	–26.0	0.3
Oneşti	–12.9	–39.6	–26.7	0.3
Orăştie	–13.0	–4.5	8.5	2.9
Orşova	12.8	–25.4	–12.6	0.5
Paşcani	–2.2	–39.5	–37.2	0.1
Petroşani	–12.7	1.6	11.0	7.9
Piatra–Neamț	–11.5	–37.2	–25.7	0.3
Piteşti	–15.4	–5.3	10.0	2.9
Prahova	–12.8	–32.7	–19.9	0.4
Rădăuți	4.3	–31.9	–27.7	0.1
Reghin	–20.1	–1.9	18.1	10.4
Reşița	14.7	–34.2	–19.5	0.4
Roman	–4.8	–40.0	–35.1	0.1
Roşiori de Vede	2.1	–8.1	–0.6	0.3
Râmnicu Sărat	–6.3	–40.0	–33.7	0.2
Râmnicu Vâlcea	–17.6	12.7	5.0	1.4
Săcele	–22.0	–27.5	–5.5	0.8
Satu–Mare	15.2	–16.3	–1.1	0.9
Sebeş	–17.4	8.2	9.2	2.1
Sfântu–Gheorghe	–22.4	–29.1	–6.7	0.8

Table 2
(*Continuations*)

Localities and towns	Values of the relative linear deformation, [cm/km]			
	Stereo–70	UTM	Differences	Ratio
Sibiu	–22.1	20.6	1.5	1.1
Sighetu–Marmației	7.5	16.8	–9.3	0.5
Sighişoara	–24.5	–4.1	20.4	6.0
Slatina	–5.0	14.7	–9.7	0.3
Slobozia	11.9	–39.0	–27.1	0.3
Suceava	1.5	–36.1	–34.7	0.0
Tecuci	–2.9	–38.7	–35.7	0.1
Timiş	27.7	–39.6	–12.0	0.7
Tulcea	34.7	–15.6	19.1	2.2
Turda	–17.2	14.7	2.5	1.2
Turnu–Măgurele	13.2	–3.6	9.5	3.6
Târgovişte	–15.7	–21.7	–6.0	0.7
Târgu–Jiu	–7.0	–1.5	5.5	4.7
Târgu–Mureş	–21.9	3.0	10.0	7.4
Târgu–Secuiesc	–20.0	–34.5	–14.5	0.6
Târnăveni	–22.3	13.7	8.6	1.6
Urziceni	–2.4	–39.0	–36.6	0.1
Vaslui	5.3	–36.1	–30.8	0.2
Vatra–Dornei	–10.5	–21.1	–10.6	0.5
Zalău	–0.7	–10.9	–10.2	01

By comparing the obtained data, we calculated (for the whole localities) a value of 71.4% favorable cases for the Stereo–70 projection in regard to only 28.6% for the UTM projection. On basis of these values of the relative linear deformations in the two presented cartographic projections we were also able to render evident the statistic repartition percents, on the values' intervals of the deformations, adapted to the urban requirements (Table 3).

Table 3

Cartographic projections	0…±5 cm/km	±5…±15 cm/km	±15 cm/km…
Steroe–70, [%]	16.5	42.9	39.6
UTM, [%]	9.9	19.8	70.3

The percentage ratio for the first two values' intervals, with an important significance for the urban cadastre and topological–geodesic measurements, is 62.5% to 37.5% (interval 0...± 5 cm/km), respectively 68.4% to 31.6 % (interval ±5...±15 cm/km), in favor of the official Stereo–70 projection.

3. Conclusions

As a result of the complex analysis with the help of GIS technology and of the deformations appeared in the Stereo–70 and UTM cartographic projections, both on the entire territory of Romania and the main localities of our country, we can conclude that the Stereo–70 projection is superior from the point of view of the deformations' character. Taking also into consideration one of the major disadvantages of the UTM projection, that is representation of our country's territory in different coordinate systems, the idea of the continuity in using the Stereographic – 1970 projection as the official projection for Romania, but redefined on an international geocentric ellipsoid specific to the satellite measurements (WGS–84 or GRS–80) should remain in use.

Although in the military field the applications continue in the UTM projection and, probably, this one will also be valid in other fields of the European interests, operating with these two cartographic projections raise no problems because the fast conversion of the coordinates by the method of the formulas with constant coefficients, determined for the whole Romanian territory is a rapid and efficient means of transferring the geodesic and cartographic information [2].

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"Gheorghe Asachi" Technical University of Iaşi,
Department of Cadastre
e-mail: tynelro@yahoo.com
and
**Search Corporation Bucureşti*
e-mail: morosanubogdan@yahoo.com

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STUDIUL DEFORMAŢIILOR ÎN SISTEMELE DE PROIECŢII CARTOGRAFICE, PRIN TEHNOLOGIA SISTEMELOR INFORMAŢIONALE GEOGRAFICE

(Rezumat)

Unul dintre criteriile de bază pentru adoptarea unei proiecţii cartografice la nivel naţional, în scopul reprezentării teritoriului ţării la scări mari, îl constituie caracterul deformaţiilor, atât prin valorile înregistrate, cât şi prin distribuţia lor regională.

În cazul României, odată cu trecerea la un nou datum geodezic şi la crearea unei noi reţele geodezice de sprijin, se pune problema stabilirii proiecţiei cartografice oficiale pentru întocmirea hărţilor şi planurilor la scări mari, în domeniul cadastrului şi a măsurătorilor terestre, în general. Dată fiind recomandarea Comisiei europene privind adoptarea proiecţiei UTM, se prezintă un studiu comparativ al deformaţiilor relative în raport cu proiecţia actuală, Stereografică – 1970, care prin rezultatele sugestive oferite de tehnologia GIS, să constituie un reper de bază în alegerea celei mai avantajoase soluţii

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SLOPE STABILITY STUDY BASED ON GIS ALGORITHM

BY

ZSOLT MAGYARI-SÁSKA and IONEL HAIDU

Abstract. Based on the SINMAP model our study presents the implementation and development of an ArcGIS macro for determining the most probable trigger points of landslides.

Key words: GIS, slope, landslides. algorithm.

1. Introduction – the SINMAP Model

The study of a phenomenon can be made on quantitative or qualitative manner, using direct or indirect methods. The indirect methods based on GIS are used especially for larger areas [1]. For studying slope stability the data driven or process driven methods are both convenient, but in case of historical data lack the last methodology is suitable. The infinite slope model is used on SHALSTAB [2] and SINMAP submodels. While SHALSTAB neglects the root cohesion [3] SINMAP takes account also this aspect. The SINMAP stability index used to study the phenomenon is determined on the basis of the following formula

(1)
$$\mathrm{SI} = \frac{C + \cos\theta\left(1 - wr\right)\tan\phi}{\sin\theta},$$

where:

$$C = \frac{C_s + C_r}{h\rho_s g}; \qquad w = \frac{h_w}{h}; \qquad r = \frac{\rho_w}{\rho_s};$$

C_s – force of soil cohesion
C_r – roots cohesive force
h – coating soil thick
h_w – water layer thick of the soil
ρ_w – density of water
ρ_s – density of soil
θ – region slope
φ – friction angle

One of the advantages of the method is that the value of index is categorized into the meanings what it defines. Another advantage is that for some parameters is possible to define a value frame, through removing the necessity of time costing exact measurements. Another advantage is that for the analysis is not necessarily to have a historical database of landslides.

Table 1
The Appreciation of the Value Index of Stability

SI value	Stability	Influences
> 1.50	Stable	Instability may occur due to major factors of destabilization
1.50…1.25	Moderately stable	Instability may occur due to medium factors of destabilization
1.25…1.00	Slightly stable	Instability may occur due to minor factors of destabilization
1.00…0.50	Lower threshold of instability	Instability without external factors
0.50…0.00	Higher threshold of instability	The stability is due to the presence of stabilization factors
< 0.00	Instable	Stabilization factors are required

Interpreting the sense of stability factor (Table 1) as the ratio between the forces who oppose to landslide and those favoring sliding, when the value factor is above 1, the area can be considered stable.

2. Case Study – the SINMAP Extension and the Necessary Data

Although there are several possibilities for the study the chosen method was SINMAP for several reasons. Firstly the results provided by this methodology are directly interpretable, and may constitute inputs for a possible further analysis, and secondly the existence of a program (ArcView/ArcGIS extension) allows an easy approach to the analysis.

SINMAP extension is freely available in two variants for ArcGIS and ArcView respectively (Fig. 1). The possibilities offered not differ significantly, and neither the way of calculation.

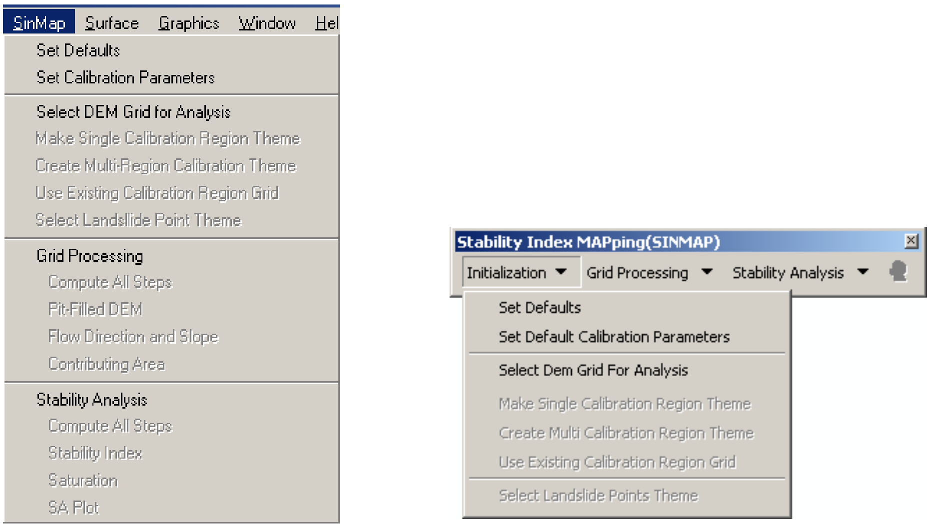

Fig. 1 – Interface of SINMAP extension in ArcView3.2 and ArcGIS9.2.

The performed steps of the analysis using these extensions are:
a) the selection of digital elevation model;
b) the decision on the type of study areas (zone unit or multi-zone);
c) defining the parameters for each area of analysis;
d) the removal of imperfections of elevation model;
e) calculating the slope and drainage maps;
f) determining the drainage areas;
g) calculating the stability map.

It’s not necessary to include the rock type in the study as the SINAMP model doesn’t models rock falls, just landslide [4].

Steps remembered are absolutely necessary to carry out the study regarding the slope stability. However the system offers other possibilities, such as specifying the location recorded landslides.

The SINAMP extension comply with the idea of automatic spatial analysis, since-as after defining the entry parameters with two mouse clicks the whole analysis is carried out automatically, thus allowing the rerun of the full analysis (and possibly reuse partial results which are not amended – ex. slopes map) with different parameters.

Parameters relating to the properties of the soil in the area were approximate with values of similar studies and soil tables [5].

Based on the calculation formula of stability index the cohesion is without measure, since-as they relate to the product of density, gravity acceleration and soil depth. Also the cohesion should contain the root cohesion. For this latter amount initially a range between 0…5 kPa was considered.

Another requested parameter of the SINMAP model is the *T/R* report, where *T* is soil transmissivity and *R* is the rate of ground recharging for a short period, preferably before the landslide. Transmissivity can be calculated based on hydraulic conductivity and soil thickness, as follows

(2) $$T = k_s \cdot H$$

Based on tables the hydraulic conductivity varies between 0.001 and 0.000001 cm/s depending on the composition of the soil.

For an approximation of the ground recharging value there are several options. When we have historical records on landslides a possibility is to use the values of precipitation before the sliding period [6]. Without these records another possibility would be to use the value of the maximum daily precipitation [7]. In the present analysis, having no historical records on landslides, but taking account that the phenomenon occurs due to soil saturation, having direct link with abundant rainfall, has used the following methodology for assessing the recharging value:

a) interpolating the precipitation recorded at meteorological stations in the area based on the study of multiple regression;

b) determining the percent of minimum and maximum daily precipitation over annual rainfall taking account all meteorological stations;

c) for each study zone (determined based on the soil type) the average interpolated precipitation is calculated;

d) based on the percents determined in the previous step to determine the two limits (minimum and maximum) of recharge value (*R*) is calculated .

A relatively recent [8] research makes further analysis seeking those points at which is most likely the launch of landslide can appear. The trigger besides that must have a classification of instability based on SINMAP analysis must be along the drain canal.

To determine these points in a GIS system, Tarolli proposes the following principle:

a) determining the minimum values of stability index along the drainage channels with downstream spreading;

b) determining the minimum values of stability index along the drainage channels with upstream spreading;

c) those cells that have equal stability index under a certain fixed threshold, are the most vulnerable points where they can trigger the landslides.

Tarolli noted that the algorithm was implemented in C programming language, in a recurring way. Given that, recursivity is a programming method that require significant resources of calculation (memory capacity and calculation power) and that any approach to a recursive problem has an iterative solution, the study proposes to develop a not recursive implementation of the basic algorithm, using the statistical system in R and Borland Delphi [9].

The two raster layers containing the propagated stability index in both directions (downstream and upstream) boots with the original stability index.

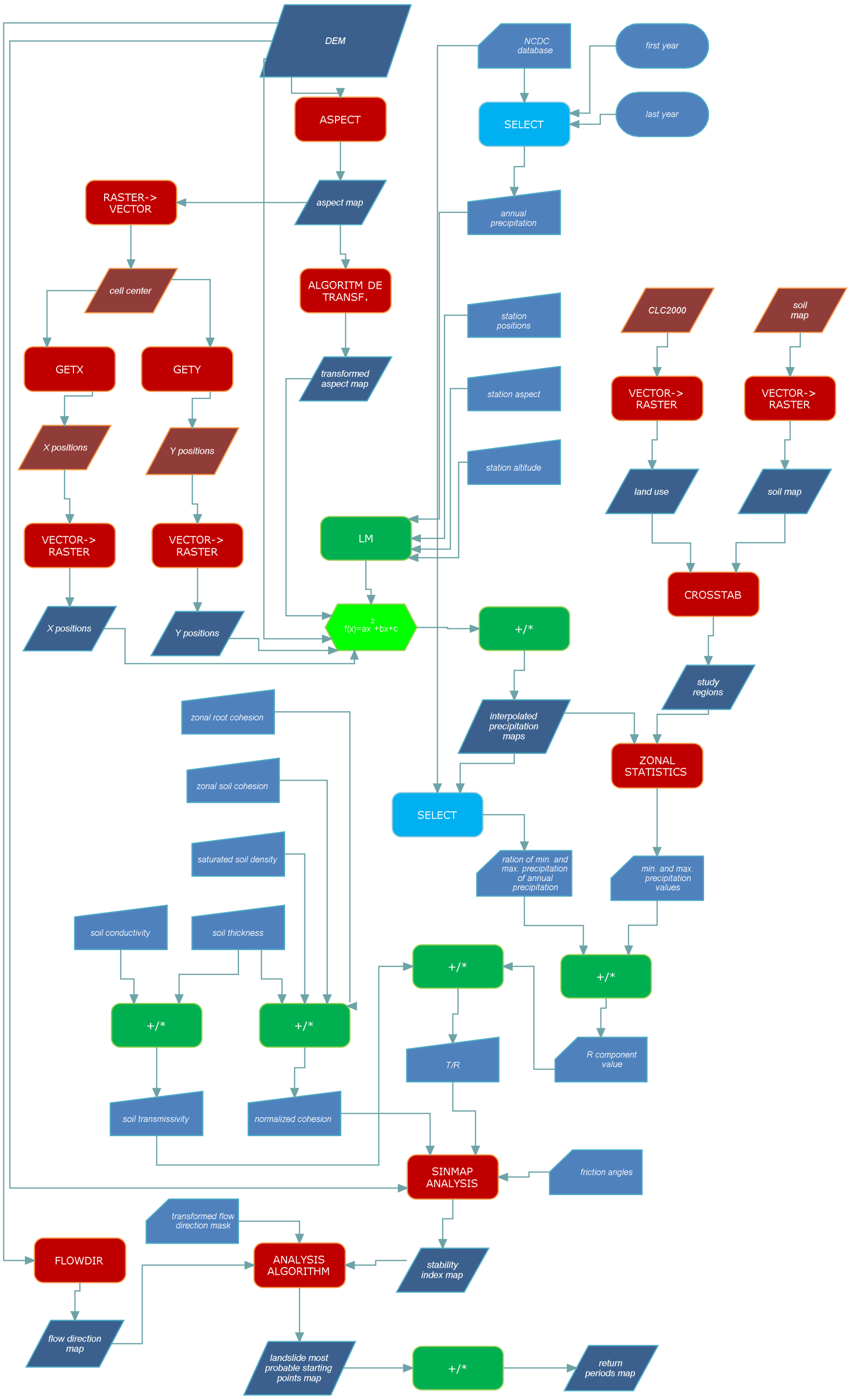

Fig. 2. – The algorithm used in the study of slope stability.

Knowing that the flow directions in ArcGIS are represented by a direction matrix a symmetrical one has been made, so that the direction from which water flows in the middle cell can be identified.

Matrix thus obtained is situated on each cell in the image representing low directions, and the where values of the image coincide with the mask there the minimum value for the index of stability was chosen. This way the downstream spread of stability index value is made.

With the downstream spread the upstream spreading is done, generating the corresponding image using the same mask. In this case, however, if the current cell contains a lower stability index than the center cell this is propagated to those cells whose flow directions coincide with the directions under the mask.

The overlap of the mask is repeated until there is at least one cell value change in any direction, after which another function, for which must be specified the threshold value of instability, marks those cells that are below the threshold values and present equal values to the index of stability.

3. Results and Discussion

The methodology has been applied to the study region. In some areas the obtained results confirms the reality (Gheorgheni Lăzarea, Gălăuţaşi), but there are areas in which the danger of instability seems exaggerated and inconclusive. We also should note the fact that there are no areas with extremely dangerous slide imminent (upper threshold).

Trying to obtain a conclusive result we considered the vegetation on Corine Land Cover 2000, making a crosstabulation of two levels one with the content of clay, with the various coverings of vegetation. Four classes have been defined for vegetation coverage (lack of vegetation, agricultural crops, poor vegetation, forest area), for each giving the values of cohesion due roots.

The result obtained is more eloquent (Fig. 3). On the one hand it is noted a much clearer appreciation of dangerous areas, and the cells with high risk appears, particularly in the area of Sălard and Gălăuţaşi. It is considered as danger zones the lower river of and downstream of the lake Răstoliţa. The most likely trigger points are offered after running the own developed module (Fig. 4).

Taking account the probabilistic interpretation of stability index stability (values over 1 represents stable areas, and values below 1 the probability that in the specified location landslides will not occur), but also the method how to account values below 1 (using cumulative probability functions) the transformation of these probabilities has been made in return periods. This transformation has been achieved for both the stability index map obtained from the SINMAP analysis and for the map containing the most likely trigger locations for landslides.

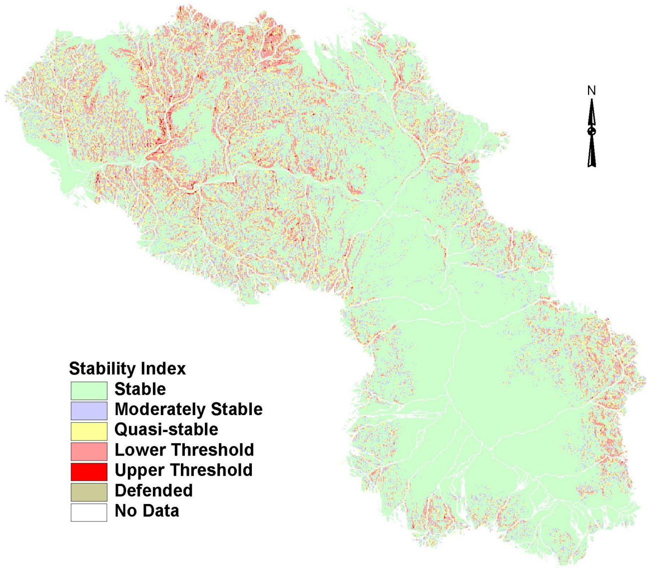

Fig. 3 - Index stability map, taking account the land use.

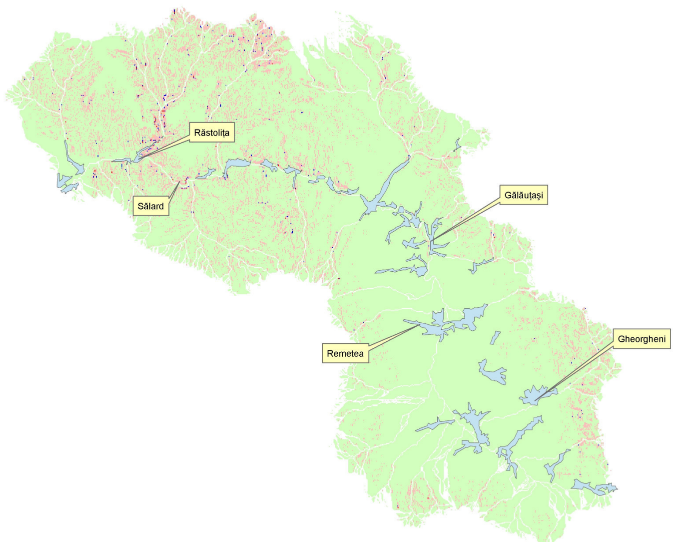

Fig. 4 - The most likely trigger points of landslides.

4. Conclusions

The research includes both methodological and practical aspect. Even if the base methodology for determining the SINMAP stability index is given, the calibration of most of its parameters is difficult. The possibility of SINMAP model to define parameter intervals is a great advantage is such cases. The importance of root cohesion (neglected in SHALSTAB model) is clearly revealed, because without it the stability index map doesn't presents obvious values.

The free R statistical system presents handicap when we want to operate on huge matrix structures, its calculating speed doesn't permit a useful integration in an ArcGIS macro, so we have to implement the Tarolli's algorithm in a general programming language. Even with this remark the possibility to integrate different programming environments in ArcGIS permits that special operations which are strongly related to a GIS algorithm (ex. statistical work), but are not implemented in such systems could be performed by specialized applications.

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Babes-Bolyai University,Cluj-Napoca,
Faculty of Geography
e-mails: zsmagyari@gmail.com
ionel_haidu@yahoo.com

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STUDIU STABILITĂŢII VERSANŢILOR BAZAT PE ALGORITM GIS

(Rezumat)

Pentru studiu stabilităţii versanţilor există mai multe posibilităţi, unele se bazează pe abordare statistică, altele pe modelarea fenomenului. Modelul pantei infinite stă la baza modelelor SHALSTAB şi SINMAP, care utilizează cea de a doua abordare. Modelul SINMAP este implementat ca şi extensii pentru sistemele ArcView şi ArcGIS, având avantajul dea utiliza calcul probabilistic pentru aprecierea stabilităţii. Studiul prezentat realizează o calibrare a parametrilor modelului SINMAP pentru Bazinul Superior al Mureşului, ţinând cont şi de coeziune solului datorată vegetaţiei, după care – pe baza unei extensii ArcGIS de dezvoltare proprie – determină cele mai probabile puncte de declanşare a alunecărilor, folosind atât harta indicelui de stabilitate cât şi harta direcţiilor de scurgere, conform algoritmului lui Tarolli. Pe baza rezultatelor se observă că locaţiile cu cel mai mare grad de periculozitate se află în special în zona localităţii Sălard şi Gălăuţaşi. Este considerată zonă periculoasă şi cursul inferior a râului Răstoliţa în aval de lacul Răstoliţa.

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USE GIS FOR LANDSCAPE ANALYSIS OF CIULUCURILOR HILLS

BY

NICHOLAE BOBOC

Abstract. The research shows that the structure of parental rock is an important factor in formation and distribution of forest and steppe landscape in the Ciulucurilor Hills along with climate conditions and landscape, represent and nature of parent rock.

Key words: GIS, landscape, spatial, type soil.

1. Introduction

Sustainable environmental management entails work on the improvement of spatial landscape structure through various activities, including the completion of the afforestation. The process of creating new forest plantations requires addressing specific types of forest landscapes depending on geoecologic conditions [1]. The purpose of the research is to assess environmental conditions, which determine the spatial distribution of our common forest landscapes using geographical information systems.

2. The Object of Study and Methods

The study focused on the specifics of landscape allocation in Ciulucurilor Hills, a region located in north-central part of Moldova, in river basins of Soloneț, Ciulucul Mare, Ciulucul de Mijloc and Ciulucul Mic the left tributaries of the Răut river. In the East and South the Ciulucurilor Hills are limited by the Dniester and Codri plateau units, while in the North and West –

by the Middle Prut River Plain and the Balti Plain or Cubolta Plain. As for the relief's morphological and morphometric specificity, modeling processes, the annual amount of precipitation, etc. Ciulucurilor Hills have much in common with Codri Plateau. Most pronounced differences pertain to the specificity of landscape of Codri Plateaui, as shown in its name (Codri means Forest) is the most forested region of Bessarabia, while Ciulucurilor Hills is characterized by the predominance of steppe landscapes. The research was based on maps published in the late nineteenth century (1880), scale 1 : 126 000, a 1 : 200 000 Austrian-Hungarian map from the early twentieth century (1910), large-scale topographic maps of the second half of the twentieth century, Landsat satellite images in 2000. Relief and geological composition specificity was assessed based on field research, cartographic materials, while peculiarity of the soil was evaluated on the basis of bibliographic sources [4], [7],…,[9], field research, a 1 : 200 000 scale soil map and laboratory tests.

The purpose of research is to evaluate the main geoecologic factors with possible influence on how the spatial distribution of forest and steppe landscapes.

3. Results and Discussion

In 1940s Natalia Dascalescu [2], in addition to the steppes plains and flooding area, singles out Codrii or Hills Forest in Bessarabia. Forests, in turn, by geographical location and floral composition are divided into Tour Codrii or Codrii Hotinului and Central Codrii with the following components: Codrii Nistrului, which is also called Codrii Orheiului or Codrii Mici, Codrii Bacului and Codrii Tigheciului.

With the above-mentioned in mid, we can conclude that the differentiation of the two major categories of natural units (forest and steppe) was carried out, proceeding from the relief characteristics. The hills and plateaus fit forest landscapes while plains are appropriate for steppes. Most of the authors explain the location of forest landscapes mainly in higher land areas by a higher annual average precipitation rate, which exceeds the annual average rainfall in the plain regions [2], [3], [7],…,[9]. The role of rainfall in the distribution of forests is not limited solely to providing optimum quantity of moisture to arborescent vegetation. Bigger rainfall also contributes to providing physico-chemical and structural changes in soils, especially in high porosity soils in which water has a greater penetration rate. Thus, water dissolves soluble salts (chlorides, sulphides, sodium salts, etc.), pushing them down sometimes to phreatic horizon. But penetration rate depends on size and porosity of the soil composition, characteristics largely determined by specific maternal rock. In most of the territory of the Republic of Moldova maternal rocks are represented by Neogene (clay, sand, gravel, limestone, etc.) and quaternary formations (loessoide deposits and loessuri, aleurite etc.). Sandy formations alternating with clay and covered in some places with gravel with thicknesses up to 40-50 m are present mainly on the higher peaks of Codrii Bacului and Tigheci Hills (Prut - Ialpug interfluves). Sands with gravel can occasionally be found in regions further north, including the Dniester-Prut interfluve, and in the Raut-Prut interfluves, the boundary between Middle Prut Plain and Cubolta Plain. Highest peaks of the Dniester River Plateau (Băxani Hill , Vadeni Hill etc.), where until now natural forests have been preserved also consist of sandy deposits of basarabiană age, which, in some places, are covered by sand with gravel of younger age and thin strata of loessoide (Fig. 1).

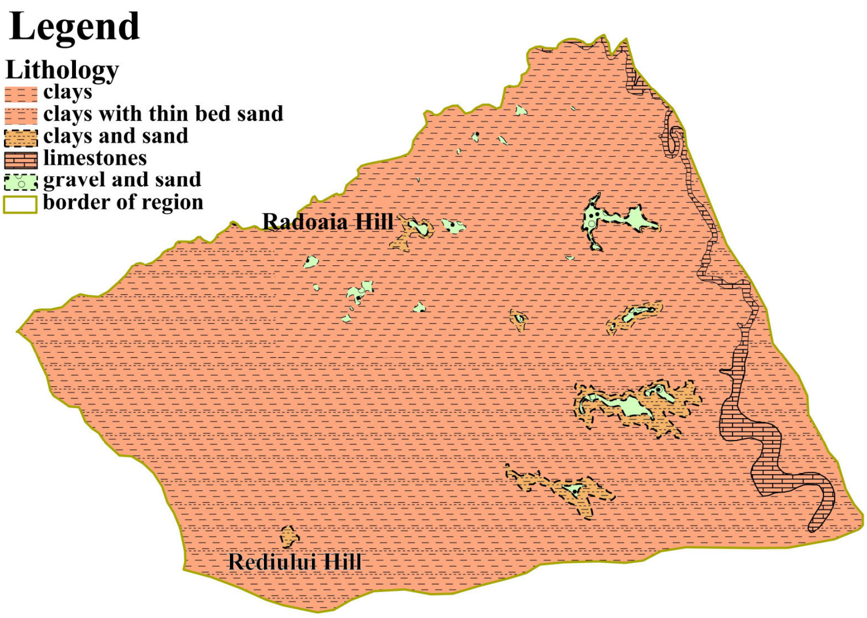

Fig. 1 – Hills Ciulucurilor. Geologic Map.

It is known that the Neogene rocks in the subsoil of Moldova as a whole are rich in salts. According to [2] "... forest vegetation could not spread into neither the steppe nor the lower Bugeac of Balti region because orographic situation and rainfull shortage prevented the release of soluble salts, especially NaCl, Na_2CO_3, Na_2SO_4 so hazardous to forest "(p. 16) from soil and subsoil. But Ciulucurilor Hills does not fit this concept. Some hills in the region exceed the height of 320…340 m (Rădoaia Hill – 339 m, Rediul Hill – 349 m, etc.). According to most of the authors, the landscape of the Ciulucurilor Hills can be described as steppe, but this contradicts the higher land nature of its relief, and the relatively greater amount of precipitation, compared with regions of flat terrain in the north. According to digital cartographic models developed on the basis of multiple correlations, the average annual amount of precipitation on the highest peaks of the Ciulucurilor Hills exceeds 600…630 mm, sufficient for the development of forest landscapes. It is necessary to note that there are some small areas of forests, such as hills Rădoaia, Rediul, etc. on the highest peaks of the Ciulucurilor Hills (Fig. 1). Most oak forest areas are currently found in the Soloneț river basin. A comparative analysis of digital models, geological maps, soil and ways of natural forests distribution shows that some pockets of natural forests are still present on the clay-sand deposits of basarabiană age, sometimes covered with alluvial deposits, which formed typical gray and soft soils, clay - iluviale black soils [4], [7]. As for Ciulucurilor Hills in many cases when the relief altitude exceeds 300 m and annual precipitation amount surpasses 600 mm forest landscapes are missing today and, judging from the specificity of soil, they didn't exist in the past. These ridges are covered by steppe landscape that is developing on chernoziom.

Steppe landscape dominance in the Ciulucurilor hills can be explained, in our concept, through specific geological composition, primarily that of maternal rock lithology.

Topography and contemporary landscape of the majority of Ciulucurilor hills ridges was formed on relatively homogeneous substratum of basarabiană age clays (Middle Sarmatian) with an noticeable content of salts, including gypsum. On some hills, at altitudes of 310…320 m, clays are covered with sand, which alternate with thin layers of clay of the same age as the underlying clays. Sands with clay, in turn, have the roof with sand gravel deposits of medium Pliocene age (Figs. 2 and 3). In case of Rădoaia Hill (elevation 335 m), maternal rock consists of basarabiene limestone. Under oak, hornbeam, maple and other vegetation, leachate clay Greyzems formed on the limestone.

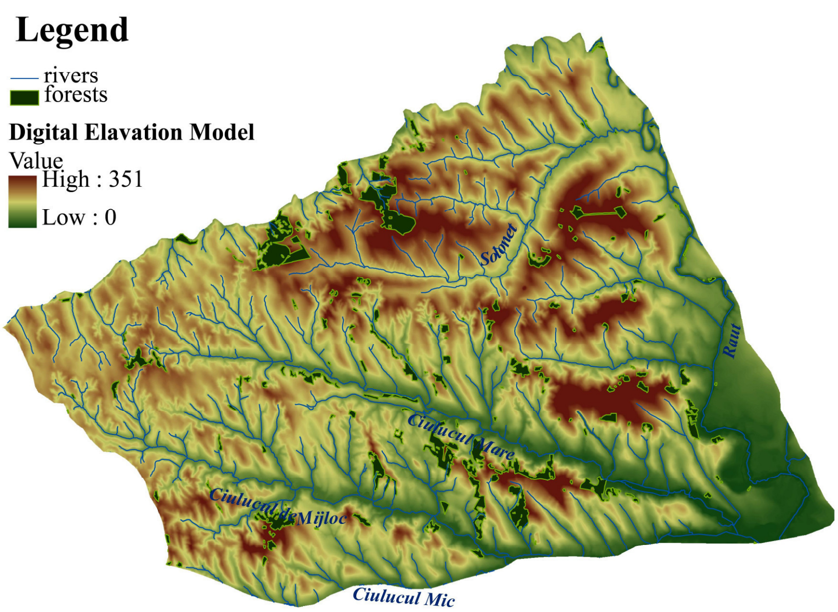

Fig. 2 – Hills Ciulucurilor. Distribution of Forests.

Thus, the availability of limestone (Rădoaia Hill), sands with sandstone

(Rediul Hill etc.) and relatively sufficient moisture (up to 630 mm) of annual average precipitation have created the optimal conditions for forest vegetation development.

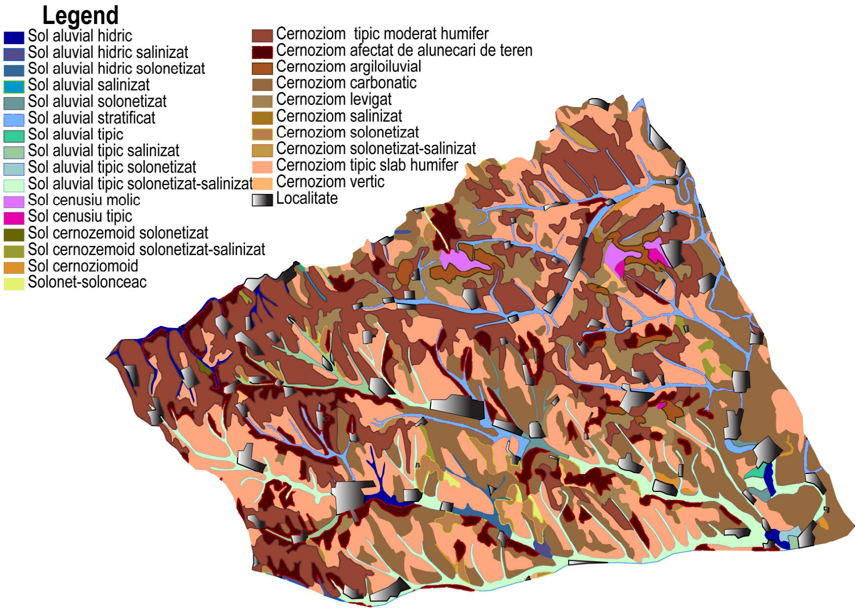

Fig. 3 – Hills Ciulucurilor. Map of Soils.

4. Conclusions

The presence of maternal sandy rock, the limestone and other permeable sediments, and a landscape of plateaus, contributes to the downward free flow of water, which causes salt dissolution and its washing out of the soil and underlying rock. Under the conditions when soil is formed on clay, impermeable rock, with a high content of salts, such as, for example, if most of the territory of Ciulucurilor Hills and Cubolta plain, steppe vegetation is being developed under which typical Chernozems, Solonetz, Chernozems Solonetzic, Saline Chernozems (Fig. 3).

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Institute of Ecology and Geography,
Academy of Sciences, Republic of Moldova,
e-mail: nicboboc@yahoo.com

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UTILIZAREA SIG IN ANALIZA PEISAJELOR DIN DEALURILE CIULUCURILOR

(Rezumat)

În baza materialelor cartografice, imaginilor satelitare şi sistemelor informaţionale geografice se analizează specificul repartiţiei spaţiale a peisajelor silvice şi a celor de stepă în Dealurile Ciulucurilor din Republica Moldova. Cercetările demonstrează că specificul litologic al rocii materne reprezintă un factor important în formarea şi distribuirea peisajelor de pădure şi a celor de stepă. Prezenţa calcarelor (pe Dealul Rădoaia) nisipurilor cu gresii (Dealul Rediului ş.a.) şi umezeala relativ suficientă (până la 630 mm media anuală de precipitaţii) au determinat apariţia condiţiilor optime pentru dezvoltarea vegetaţiei silvice. Pe rocile materne argiloase, bogate în săruri, se dezvoltă de padure de stepă.

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OPPORTUNITIES FOR DEVELOPING WINTER TOURISM IN CEAHLAU MOUNTAIN IDENTIFIED BY USING GIS

BY

ALEXANDRU–ROMEO CHELARU and ADRIAN URSU

Abstract. The study identifies the most suitable areas for developing winter tourism in Ceahlau mountain using GIS techniques by taking under consideration parameters like altitude, slope, exposure, land use and distance from human settlements.

After researching for the ideal conditions for winter tourism in the mountain area, were created the next maps that need to be overlapped in order to identify most opportune zones in our case study: the hypsometric map, slope map, slope's exposure map, the land use map and the distance buffer from human settlements. The conclusions are to be reached after applying the operations of addition and multiplication of grades for each parameter.

Key words: GIS, development, tourism, maps.

1. Introduction

The global average percent of tourists that visit mountain resorts for practicing ski or other winter sports is approximately 70%, the rest of them being purely “contemplative” ones. In Romania, the situation is totally different: the touristic infrastructure in general (and the one destined to winter sports in particular) is a rare concept. For example, Ceahlau Mountain – the well-known and impressive mountain from Eastern Carpathians – has only 3 touristic chalets and just a single ski slope in Durau mountain resort.

In the last period of time the number of tourists going to Ceahlau has increased and the touristic potential imposes immediate adaptation to present demands. It arises the question: *is Ceahlau Mountain suitable for winter tourism? And if it is, what are the most opportune areas for creating the infrastructure for winter sports?*

The objective of this study is to find the answer to these questions by using the references, the materials and the methods, and also GIS analysis based on topographic maps at 1 : 25000 scale. The expected result of research will be identified through map interpretation.

2. Background

Ceahlău Mountain is located in Romania, in the Central part of Eastern Carpathians, more precise at the intersection of 47 degrees North latitude parallel and the 26 degrees East longitude meridian.

Next valleys represent the limits with the neighbours: to North – valley of Bistricioara, to South – valley of Bicaz, to East – valley of Bistrita and valleys of Bistra, Pintic and Jidan's to the West. The mountain is made of a system of radial disposed peaks that vary between 1,000 and 1,300 metres and that converge towards the two highest points: Ocolasul Mare (1,907 m) and Toaca (1,904 m).

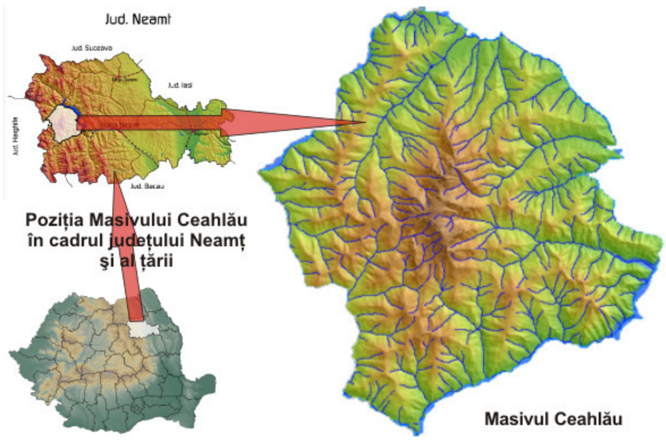


Fig. 1 – Localization of area of study.

Ceahlău Mountain (also known as Kogaion or Pion), considered the holly mountain of Antiquity, can be seen in conditions of clear weather from a distance of almost 350 km – from Danube Delta. It is one of the pillars of Romanian spirituality, being a holy mountain, a true Olimp for Romanians, that drives man towards nature.

Actual touristic activity consists in the specific *attraction*, *accessibility* and the *infrastructure* of Ceahlău Mountain.

The attraction can be translated into touristic potential of a dual origin: natural and anthropic – it is one of most appreciated mountain in Romania receiving the name of "touristic massive". It is not the highest mountain in Moldova and not even the largest, but it is delimited by deep valleys that give it greatness.

Larix deciduas ssp. carpatica is quite common in Ceahlau, and so are other vegetal or animal species. In 1955 was created Ceahlău National Park that covers 7742.5 ha of the mountain, with the purpose of protecting ecosystems and for relaxing.

As for *the accessibility*, Ceahlău Mountain is accessible from 4 main directions: Piatra Neamț and Bacău on National Road 15 and County Road 155F, Transilvania through Gheorghieni, Lacu Roşu and Cheile Bicazului on National Road 15C and County Road 155F, Vatra Dornei on County Road 17B, then National Road 15 and County Road 155F, from Târgu Neamț on Național Road 15B and County Road 155F. The accessibility of the 7 touristic paths in Ceahlau is average.

The touristic infrastructure is poor and quite old. It consists of 3 touristic chalets: Izvorul Muntelui (at 797 m), Fantanele (1,220 m), Dochia (at 1,750 metres of altitude), and 7 authorized tourisctic tracks. The types of tourism identified for Ceahlău Mountain are: for visiting Durău mountain resort and surroundings plus ascending the mountain, climatical tourism (Durău is known to be an area with a pleasant microclimate fit for neurological affections), transit tourism from Transilvania (through Toplița) and from Moldova (through Borsec) and the agrotourism that is developing in adjacent localities . Most of the flux of tourists that come to visit Ceahlău are concentrated to Durau mountain resort and their safety is assured by Salvamont Service Neamț.

3. Determinant Conditions for Winter Tourism

The factors that influence the development of winter tourism can be percept from two views: geographical and economical; generally, the natural factors belong traditionally to geography and the anthropic ones belong to economy (or human geography).

From the natural factors: *climate conditions* and *the relief* are most important and they condition each other, so the absence of either one of them excludes the possibility of winter tourism.

The anthropic factors that can influence winter tourism are: *human settlements* and *ways of communication*. Their favorability is inverse/counter proportionate to the distance towards them, so a bigger distance means a small favorability.

The determinant climatic parameters for the development of winter tourism are solid precipitations, the number of days with snowpack, the thickness of the snowpack and so on. In the next table we find the specific parameters of the Ceahlău Mountain's topoclimate (source: Ceahlău National Park's Management Plan).

Table1
Climatic Parameters for Ceahlău Mountain Area

No. crt.	Parameter	Value	
		Ceahlău Toaca	Ceahlău Sat
1	Air temperature, [°C]:		
	1. annual mean	0.7	7.2
	2. january's mean	–12.4	–8.3
	3. july's mean	13.2	23.4
	4. absolute maximum/registration date	25.0/04.07.1998	24.5/10.01.1968
	5. absolute minimum/restration date	28.2/06.02.1965	24.5/10.01.1968
2	Annual number of days:		
	6. with frost (temp. minimum ≤ –10°C)	66.6	27.0
	7. of winter (temp. maximum ≥ 0°C)	127.4	40.4
	8. of freezing (temp. minimum ≤ 0°C)	193.0	133.2
	9. of summer (temp. maximum ≥ 25°C)	1	39.4
	10. tropical (temp. maximum ≥ 30°C)	0	2.6
3	Air's relative humidity, [%]	83	77
4	Wind speed frequency, [%]:		
	11. 0…2 m/s	12.7	59.0
	12. 3…5 m/s	24.9	36.4
	13. 6…10 m/s	25.3	4.6
	14. 11…15 m/s	17.0	0.3
	15. 16…20 m/s	17.3	0.0
	16. > 20m/s	8.2	0.0
5	Total nebulosity, annual mean (in tenths from 0…10)	7.0	6.2
6	Amount of precipitation, [mm]:		
	17. annual mean	738.4	617.8
	18. rainiest month's mean/month	107.5/06	104.3/07
	19. driest month's mean/month	33.5/11	26.6/01
	20. maximum in 24 h/registration date	54.5/17.08.2002	55.9/08.06.1969
	21. rain	100	112.2
	22. snow	108.8	50.6
7	Thickness of the snowpack, annual mean, [cm]	11.3	4.7

After analyzing the data results that the climate conditions from Ceahlau Mountain are suitable for winter tourism. With an average air temperature of 0.7°C at the peak (7.2°C in the village) and with an absolute average temperature of 28.2°C, the winter season (days with a maximum air temperature below or equal to 0°C) reaches 127.4 days in the high mountain area and only 40.4 days in the village. Another important indicator is the number of days with freezing (days with a minimum air temperature below or equal to 0°C): at the peak 193 days and in the village 133.2. The thickness of snowpack as a multiannual mean value measures 11.3 cm at the peak and 4.7 cm in the village.

As for the climate, the opportune areas for winter tourism are the medium heights going up towards the peak, but not the high altitudes where the blizzards take place and sylvan vegetation is missing.

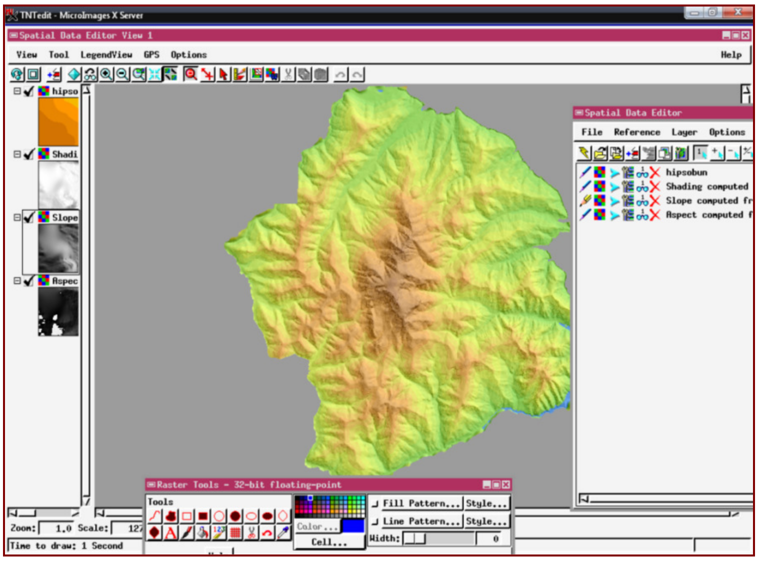


Fig. 2 – The MNT of Ceahlău Mountain.

The relief: Ceahlău Mountain appears as a unique presence in the scenery of Eastern Carpathians, standing out through altitude and massiveness. The actual aspect owes to the massive pack of 500 m high Cretacic conglomerates with increased resistance. The slopes have in Ceahlău values from very small to great abruptness, which's base is made of structural glacis of periglacial age.

The relief is very fragmented and slopes have approximately equal proportions between cardinal points, but identifying the opportune areas for winter tourism is quite hard using old-fashion techniques.

As for the anthropic factors, human settlements from Ceahlău Mountain area have a decisive role in tourist activity because they have the potential of becoming winter sport resorts. Any previous infrastructure that might exist can be modernized. These last two parameters will be will be later analyzed using the GIS techniques.

4. Materials and Methods

The laboratory research stage of research coincides with the GIS analysis, that has the advantage of applying the criteria analyzed to the hole area of study, at the end giving the possibility of the interpretation of data and the comparison of found results with the expected one.

The main materials used are the topographic maps at scale of $1:25{,}000$

which, after working with the professional software Micro Images TNT Mips 6.9 led to obtaining the digital terrain model (MNT) and the other maps needed.

First of all, the 8 topographic maps were imported to GIS software and then they were georeferenced into the coordinate system Gauss-Kruger with a Krassovsky 1938/1940 reference ellipsoid. Using the georeference points all 8 maps were joined automatically.

Over the digital topographic representation of Ceahlau Mountain has been made a vector layer of level curves through “stretch” method of drawing lines and polygons, which were assigned the Z value; afterwards, by applying the operation of “Surface Modelling” and some filters over the vector layer was generated the digital terrain model (MNT). Based on MNT were realized three thematic layers that will be used forward in analysis: *shading, slope, aspect.*

By combining the three layers with the MNT and different other vector layers (like human settlements, hydrography, roads, land use) it will result next maps:

a) *Hypsometric map* (the higher the altitude, the higher the values of climatic parameters till 1,400m, where there is the abrupt of Ceahlău);

b) *Slope map* (is rather a classification criteria because the only slopes not favorable for winter tourism are considered the ones with an angle of less than 3 degrees and more of 50 degrees – suitable for professional ski only);

c) Slope’s exposure map (influences directly the temperature or duration of snowpack);

d) Land use map (was made using the data of Corine Land Cover 2000 program; the most opportune areas are the ones with coniferous forest, the mixt forests and the deforestated ones);

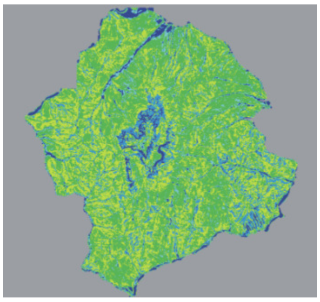
e) Distance buffer from human settlements map (using the GIS software were automatically generated some buffers at distances of 500, 1000, 1500, 2000 and more than 2000 m from human settlements).

5. Research Results

Once made, these five maps are to be classified and given grades according to the favorability they have for winter tourism. The last class is considered to be most favorable, and receives the biggest grade.

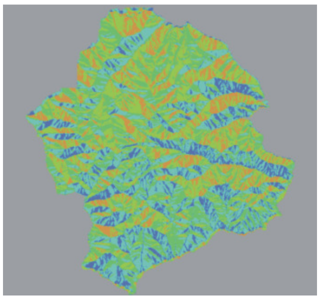
The *hypsometric map* is classified in:
Class 1/grade 0: <800 m
Class 2/ grade 1: 800…1000 m
Class 3/ grade 2: 1000…1200 m
Class 4/ grade 3: 1200...1400 m
Class 5/ grade 4: > 1400 m

The areas under 800 m altitude and the upper plateau of Ceahlau Mountain received 0 grade because they are totally not favorable.



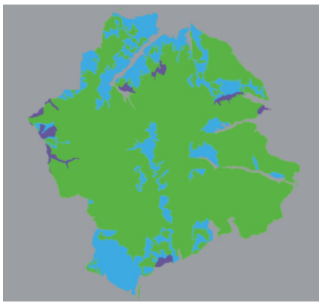
The ***slope map*** is classified in 5 classes:
Class 1/grade 0: <5 and >50 degrees
Class 2/grade 1: 5 - 10 degrees
Class 3/grade 2: 10 - 20 degrees
Class 4/grade 3: 20 - 30 degrees
Class 5/grade 4: 30 - 40 degrees

Slopes under 5 degrees (river valleys) and those over 50 degrees are not favorable!

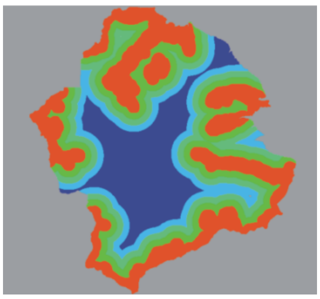


The ***slope's exposure map*** is classified in next 5 classes:
Class 1/grade 1: S
Class 2/grade 2: S-E şi S-W
Class 3/grade 3: E, W
Class 4/grade 4: N-E şi N-W
Class 5/grade 5: N

North is the most favorable cardinal point and the grades decrease towards South.



The *land use map* is classified in:
Class 1/grade 0: areas covered with water, stones and human settlements;
Class 2/grade 1: agro-industrial areas, complex agriculture;
Class 3/grade 2: pastures, natural meadows, savine and broad-leaved forests;
Class 4/grade 3: coniferous and mix forests.



The ***distance buffer from human settlements*** is classified in 5 classes:
Class 1/grade 1: > 2000 m
Class 2/grade 2: 1500…2000m
Class 3/grade 3: 1000…1500 m
Class 4/grade 4: 500…1000 m
Class 5/grade 5: < 500 m

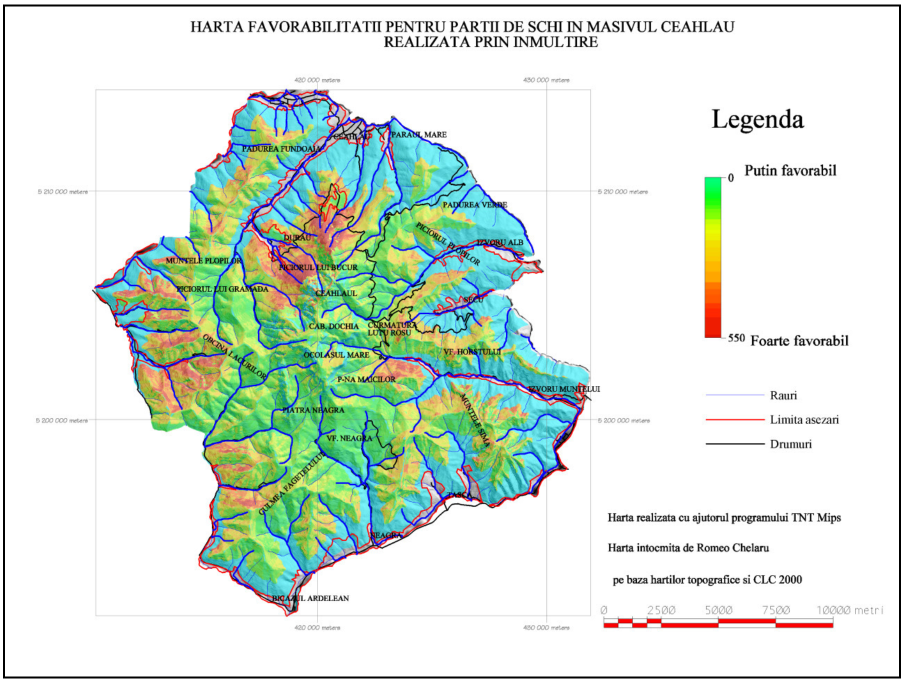


Fig. 3 – Map of favorability obtained by multiplication of grades.

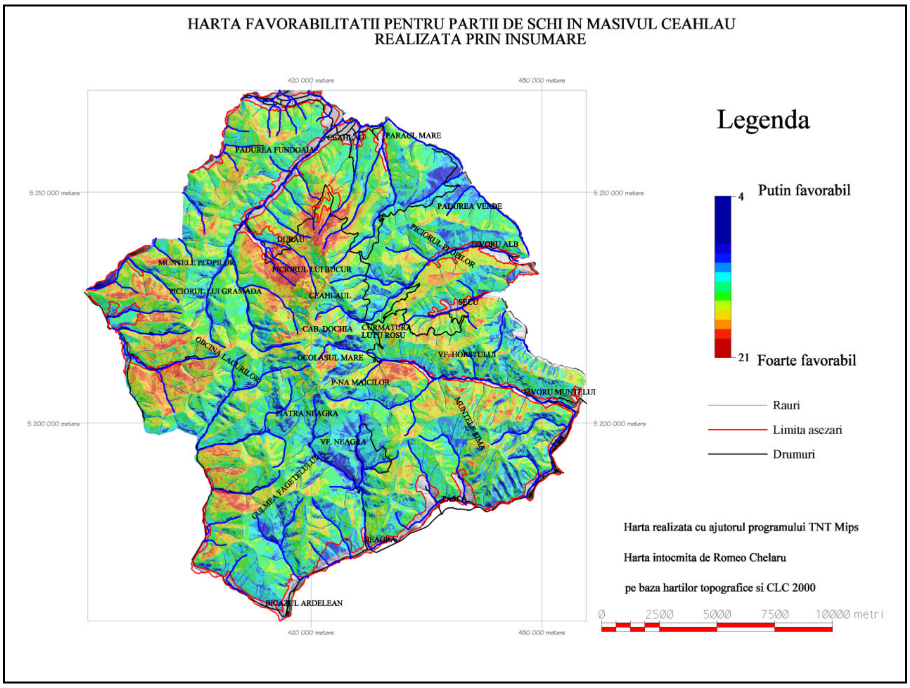


Fig. 4 – Map of favorability obtained by addition of grades.

By applying simple operations of ADDITION and MULTIPLICATION to the grades corresponding to same class from all 5 maps will result the main maps for GIS analysis.

The two maps are quite similar: the general fragmented aspect of Ceahlau Mountain apparently does not recommend it for winter tourism, but there are hole areas that comply to the ideal conditions: *the most opportune area seems to be the one near Durău resort* (Durău as forest, Fântânele chalet, and "Picioarele" his Ghironte, Odăii, his Bucur, or Şchiopului going to the base of mountain abrupt); also a favorable area is the one at the East of Ocolaşul Mare peak. In the west side, the settlements of Poiana, Bradul, Pintic or Teleac have a great potential of becoming a mountain resort and being able to sustain the winter tourism activity for the neighbor areas (Plopilor Mountain, Piciorul Arsitei, Piciorul Suricului, Piciorul Tarsoase, Piciorul Păltinişului, on the valley of Bista Mică, Pâraul Caprei, Pâraul Frânturilor and so on). On the east side good values has the mountain in the south of Izvorul Muntelui chalet.

4. Conclusions

The closest conditions to the ideal model for the favorability of winter tourism in Ceahlău Mountain have the next values for the analyzed parameters:

a) Altitude between 1000 and 1400 meters;

b) Average slopes without abruptness;

c) Slope's exposure predominantly to the North;

d) Forest vegetation (that acts like a barrier for strong winds):

e) As for the distance to human settlements, it is clear that the most favorable area is the one right near them (the example of Durau mountain resort – Fântânele chalet)

Ceahlău Mountain's winter touristic potential is represented by two types of tourism: the one specific to average altitude areas (slopes for alpine ski), and the high plateau area, suitable for extreme skiing.

In conclusion, Ceahlău Mountain has an important potential for developing the winter tourism and one of the explanations for it's poor development can be the immense value of investments that have to be made in order to get the project going. On another side, another restraining factor can be the problem of owner's right for the area.

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"Al.I. Cuza" University, Jassi
Department of Geography,
e-mail: ursu_v_adrain @yahoo.com

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OPORTUNITĂŢI DE DEZVOLTARE A TURISMULUI HIVERNAL ÎN MASIVUL CEAHLĂU IDENTIFICATE PRIN TEHNICI SIG

(Rezumat)

Studiul de faţă îşi propune să identifice cele mai oportune zone pentru dezvoltarea turismului hivernal din Masivul Ceahlău utilizând tehnicile SIG şi luând în considerare parametri precum altitudinea, panta, expoziţia, utilizarea terenului şi distanţa faţă de aşezările umane.

În urma cercetării condiţiilor ideale pentru dezvoltarea turismului hivernal în aria montană au fost create următoarele hărţi care vor fi suprapuse cu scopul de a identifica cele mai oportune zone din aria studiată: harta hipsometrică, a pantelor, a expoziţiei versanţilor, a utilizării terenului şi bufferul distanţei faţă de aşezările umane. Concluziile studiului sunt obţinute în urma aplicării operaţiunilor de însumare sau înmulţire a notelor acordate fiecărui parametru.

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OXTENDING THE ARCGIS PLATFORM THROUGH OBJECT ORIENTED PROGRAMMING

BY

DOMNIŢA MATEI

Abstract. This work presents the possibilities of extending the ArcMap application and the other applications in the ArcGIS platform through Object Oriented Programming (OOP). Using OOP a developer can create new features or functions based on the existing ones. The main objective of the work is creating a command for ArcMap that adds a new function to ArcMap version 9.2. The new function offers the possibility of exporting a set of vector or raster layers in KML format for data viewing in open source and free software. ArcGIS version 9.2 and lower does not offer the possibility of exporting geographic data in KML format (or in other open formats), so users that need to view the data must use software provided by ESRI or oe of the open source GIS alternatives. But exporting data in the KML format allows the user that only needs to view the data to be able to do this in free applications like Google Earth or directly on the internet in Google Maps.

Key words: GIS, programming, applications, software.

1. Introduction

A Geographic Information System (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information, analyzing spatial relationships, and modelling spatial processes. A GIS allows users to view, understand, question, interpret, and visualize data in many ways in the form of maps, globes, reports, and charts [1].

A GIS helps users answer questions and solve problems by looking at data in a way that is quickly understood and easily shared (the digital map). The GIS can offer the information needed to solve certain problems, allows viewing the relations and connections between data and modelling the geographic space and events that happen within it. For example, a GIS can be used by a transportation company to estimate transport costs and timings between two locations, can choose and create a map of the best route. Also, a GIS can perform other types of operations like estimating avalanche risk on a mountain slope, creating an evolution model for a forest fire and any other problems that can be related to geographic location of elements.

ArcGIS is an integrated collection of software products, providing a standards-based platform for spatial analysis, data management, and mapping. ArcGIS can be used via the Web, mobile devices, and desktop applications and can also be integrated with other enterprise systems such as work order management, business intelligence, and executive dashboards [3].

The ArcGIS desktop applications can be accessed using three software products, each providing a higher level of functionality. All the three software products share the main applications (ArcMap and ArcCatalog), just the functionality is different:

a) ArcView® provides comprehensive mapping and analysis tools, along with simple editing and geoprocessing tools.

b) ArcEditor includes the full functionality of ArcView, with the addition of advanced editing capabilities.

c) ArcInfo extends the functionality of both to include advanced geoprocessing [3].

The main application for working with maps in the ArcGIS Desktop products is ArcMap. ArcMap lets users create and interact with maps. In ArcMap, users can view, edit, and analyze the geographic data. Users can query the spatial data to find and understand relationships among geographic features. Users can symbolize the data in a wide variety of ways [2].

Different users use the applications from the ArcGIS platform in different ways, so the platform offers different levels of customization. From creating shortcuts or toolbar buttons for widely used commands to creating new complex tools that offer functions different from the existing ones, the possibilities of customizing the platform are presented in chapter **2**.

2. Customizing the ArcInfo Platform

The first and simplest level of ArcInfo customization involves no programming knowledge. All users can easily change the look and feel of the ArcInfo applications using standard user interface capabilities. For example, toolbars can be turned on and off using the customize dialog or buttons can be added to a toolbar and many application properties can be changed using simple actions like this.

The second level involves using the in-built Visual Basic® for Applications (VBA) application scripting capabilities to add new menus, tools, and work flows to the ArcInfo applications. The ArcMap and ArcCatalog applications include a VBA development environment. With VBA, it is possible to create applications using existing functions and data that run within the ArcMap and ArcCatalog application frameworks. It is not, however, possible to create new custom feature classes or build applications that run outside ArcMap and ArcCatalog. VBA is a very good choice for small-to-medium-size applications that use or extend the existing ArcInfo applications or functions.

Serious software developers who want to create reusable software building blocks, new applications, or custom feature additions to the geodatabase object model will prefer to work with ArcObjects directly using Visual Basic, or, especially in the latter case, Microsoft® Visual C++® or Delphi® [5]. This level of customization involves knowledge of Object Oriented Programming and ArcObjects, which will be presented later.

The application presented here will use the third method of customizing the ArcGIS Platform to create an extension to the ArcMap application. To understand the way this extension is created, the concepts of Object Oriented Programming and details about ArcObjects are presented first.

3. Object Oriented Programming

Object-oriented programming (OOP) can trace its roots to the 1960s. Researchers studied ways to maintain software quality and developed OOP to address common problems and improve reusability of program parts. The methodology focuses on data rather than processes, with programs composed of self-sufficient modules (objects) each containing all the information needed to manipulate its own data structure.

OOP may be seen as a collection of cooperating *objects*, as opposed to the conventional model, in which a program is seen as a list of tasks (subroutines) to perform. Each object is capable of receiving messages, processing data, and sending messages to other objects. Each object can be viewed as an entity with a distinct role. The actions (or "operators") on the objects are closely associated with the object.

We will use a simple example to present the basic concepts of OOP. As OOP uses objects to create a programming model, we will consider a car as the main object on which the examples are based.

The basic concepts are the following:

Class. The root word of classification is *class*. Forming classes is an act of classification, and it is something that all human beings (not just programmers) do. For example, all cars share common behavior (they can be steered, stopped, and so on). Different behaviors appear as different *methods* in a program. A method is a series of instructions that describe a behavior of an object. Also, cars share common *attributes* (they have four wheels, an engine, and so on). You use the word *car* to refer to all of these common behaviors and properties [4].

Object. The word *car* means different things in different contexts. Sometimes we use the word car to refer to the general concept of a car: we speak of car as a *class*, meaning the set of all cars, and do not have a specific car in mind. At other times we use the word car to mean a specific car. The term *object* or *instance* is used to refer to a specific car.

The three characteristics of identity, behavior, and state form a useful way to think about and understand objects.

Identity is the characteristic that distinguishes one object from all other objects of the same class. For example, two cars created in the same factory in the same year with the same parts appear identical. The thing that makes them different is the serial number on the chassis.

Behavior is the characteristic that makes objects useful. Objects exist in order to provide behavior. Most of the time you ignore the workings of the car and think about its high-level behavior. Cars are useful because you can drive them. The workings exist but are mostly inaccessible. It is the behavior of an object that needs to be accessible.

State refers to the inner workings of an object that enable it to provide its defining behavior. A well-designed object keeps its state inaccessible. For example, the driver should not have access to the inner workings of the engine.

Inheritance. Inheritance is a relationship that is specified at class level. A new class can be derived from an existing one. For example, a car looks and acts the same whether it's an AllRoad vehicle, a town car or a limousine. Each of these have four wheels, a steering wheel, brakes and other known characteristics. But each of these types of cars have new features added to the standard features of a car. Instead of rewriting every method or attribute that already exists at a car, the programmer can inherit all the characteristics of the car and only add new properties or behavior.

Interfaces. In a typical class hierarchy, the operation (the name of a method) is declared in the base class, and the method is implemented in different ways in the different derived classes. The base class exists solely to introduce the name of the method into the hierarchy. In particular, the base class operation does not require an implementation. An interface contains no implementation of any kind; An interface contains only operations (the names of methods). Interfaces are important constructs in object-oriented programs. When you derive from an interface, it is said that you *implement* that interface. When you derive from a non-interface (an abstract class or a concrete class) it is said that you *extend* that class.

4. The ArcObjects Library

***ArcObjects*™** is a collection of components that form the foundation of ArcInfo™ software (Fig. 1). Developers can use the ArcObjects framework to enhance and extend ArcInfo programmatically. With ArcObjects, developers can, for example, add new tools or work flows to the ArcInfo, ArcMap™, and ArcCatalog™ applications, or extend the ArcInfo data model by adding new custom feature types. These are only two examples of the many ways in which developers can build on, embed, or extend ArcInfo [5]. This set of components includes more than 1,200 objects that may be used to customize, extend, or construct GIS applications.

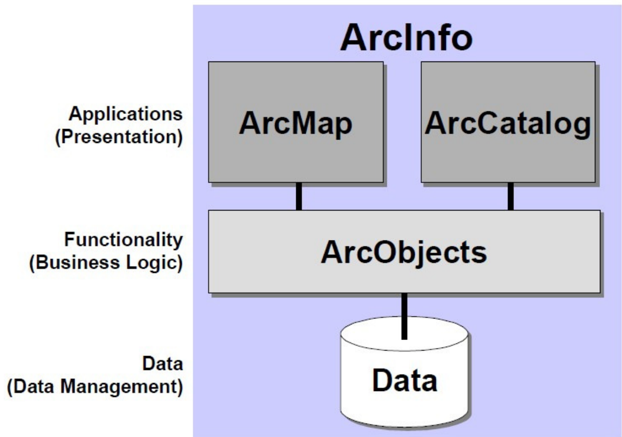

Fig. 1 – The place of ArcObjects in the ArcGIS platform.

ArcObjects is not sold separately; it is included with ArcInfo software like Avenue™ is an integral part of ArcView® 3 software. To build applications using ArcObjects, users must obtain a copy of ArcInfo and any derivative applications require a fully licensed ArcInfo seat [5].

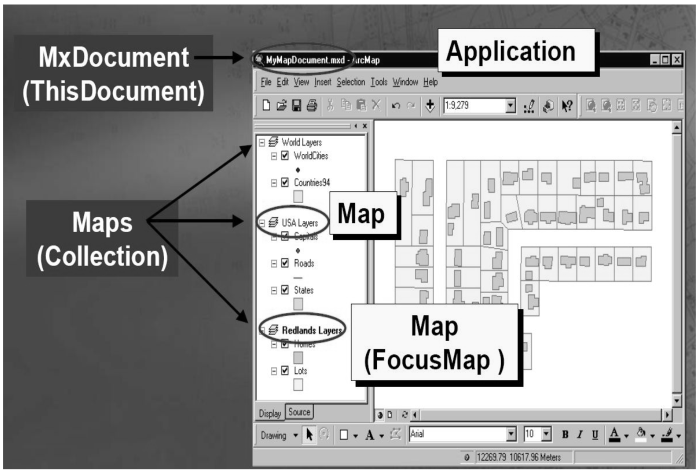

Fig. 2 – The ArcMap application and the main objects within it.

The main objects in ArcObjects built for the ArcGIS Desktop applications are structured similar to the applications in ArcGIS Desktop, so programming using ArcObjects is only harder until the programmer understands the structure and the relationships between these objects. The usual ArcMap window has a lot of objects that a programmer can use from it. Some of these objects are presented in Fig.2, and their classes are also presented.

The object that references all the other objects that a programmer can use is the Application object. This application can have a map document opened (a .mxd file) which is an instance of the MxDocument class and can be accessed using the Document property of the application object. The main part with the active layers named ActiveView is an object from one of the classes that implement the IActiveView interface. When ArcMap is in geographic view, the ActiveView is a Map and in layout view, it is a PageLayout.

The Table of Contents(ToC) at the left is an IContentsView object. The ToC contains a list of layers that are called Maps, each of these maps being a Map object. Each of these maps contain a list of Layers , which are instances of classes that implement the ILayer interface. Each Layer can be a RasterLayer, a FeatureLayer, a TinLayer or other types of Layers depending on what the user needs.

Each of these classes have methods or properties that offer access to the corresponding objects. The structure presented can be illustrated using the hierarchy in Fig. 3.

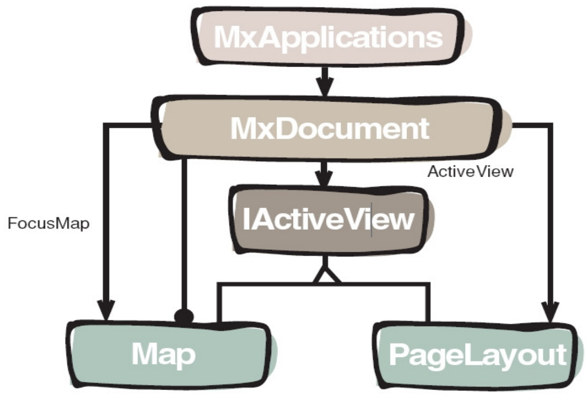

Fig. 3 – Structure of ArcObjects for a Layout View with a Map.

For a more practical example, a real-life situation corresponding to Figs. 2 and 3 is presented below.

If ArcMap displays a document with three data frames in layout view, there will be three Maps attached to the MxDocument, the ActiveView property will return the PageLayout, and the FocusMap will return the Map corresponding to the data frame that is highlighted [6].

Programming with ArcObjects is not limited to applications that work on top of the ArcGIS Desktop product family. Although the application presented here will only work with an existing ArcMap application and an ArcInfo license, any product created using ArcObjects will fall into one of the ArcGIS product families:

ArcGIS Server – The object is used within the server framework, where clients of the object are most often remote. The remoteness of the client can vary from local, possibly on the same machine or network, to distant, where clients can be on the Internet.

ArcGIS Engine – Use of the object is within a custom application. Objects within the Engine must support a variety of uses; simple map dialog boxes, multithreaded servers, and complex Windows desktop applications are all possible uses of Engine objects.

ArcGIS Desktop – Use of the object is within one of the ArcGIS Desktop applications. ArcGIS Desktop applications have a rich user experience, with applications containing many dialog boxes and property pages that allow end users to work effectively with the functionality of the object.

5. The Shape2KML Command

Shape2KML is an ArcMap command that was created using ArcObjects desktop development and can be used to export geographic data from ArcMap Layers to a KML document. This command has a user interface and a complex function, so it will be referred to as the Shape2KML application from now on.

KML is a open standard file format used to display geographic data in an Earth browser such as Google Earth, Google Maps, and Google Maps for mobile. KML uses a tag-based structure with nested elements and attributes and is based on the XML standard. This is why KML files are actually formatted text that can be interpreted by different applications but can also be inspected using a simple text editor, unlike the shapefile that is a binary format and can only be viewed in a limited list of applications.

The Open Geospatial Consortium, Inc. (OGC) announced the approval of the OpenGIS® KML Encoding Standard (OGC KML), marking KML's transition into an open standard which will be maintained by the OGC. Developers will now have a standard approach for using KML to code and share visual geographic content in web-based online maps and 3D geospatial browsers like Google Earth®. This makes KML the first broadly accepted standard for the visualization of geographic information [7].

The Shape2KML application can be used to export a set of raster layers of type jpg and png or vector layers that contain 2d features to a single KML document. This KML document can be viewed in any of the applications that support the KML format and can be shared as a single file with all the data. The application interface is presented in Fig. 4 and it’s very straightforward.

The left of the form has the list of Layers visible in the ToC, from which the user can select the ones that are exported to the KML file. The chosen layers appear in the Selected Layers dropdown list. For a vector layer, the user can choose where the altitude attributes can be extracted from. The altitude can be relative to ground or absolute, according to the KML specifications.

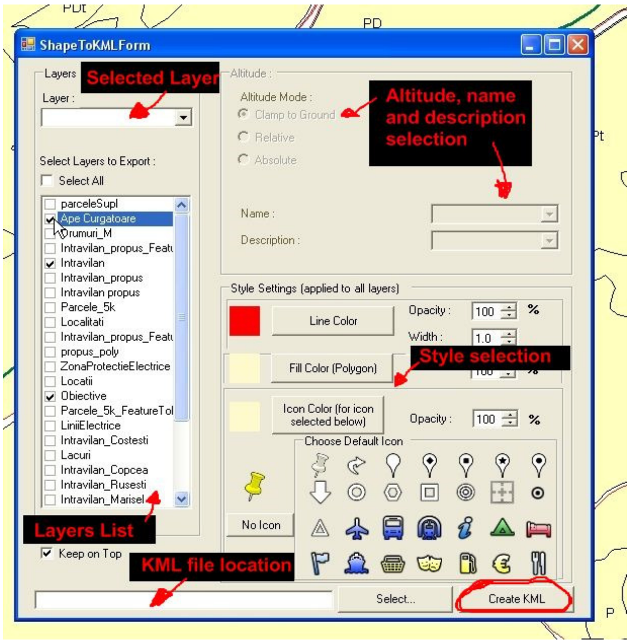

Fig. 4 – The Shape2KML user interface.

The lower right part of the form allows users to choose a style for the exported features. The style is composed of a color and other characteristics like width for a line or a specific icon for the point. The user chooses a location for the file and exports it. The application shows the progress in exporting the file.

6. Conclusions

The The exported file can be viewed in Google Earth ,viewed on the web in Google Maps or opened using any of the programs that support the KML format. Fig. 5 presents one of the files exported to KML representing contour lines for a terrain with the altitude extracted from the attribute table of the shapefile. As the example shows, the lines are exported correctly and they fit well on the elevation model generated by Google Earth from SRTM data.

The application also allows exporting raster layers at their correct location on the Earth surface for studying data from these layers related to data from Google Earth.

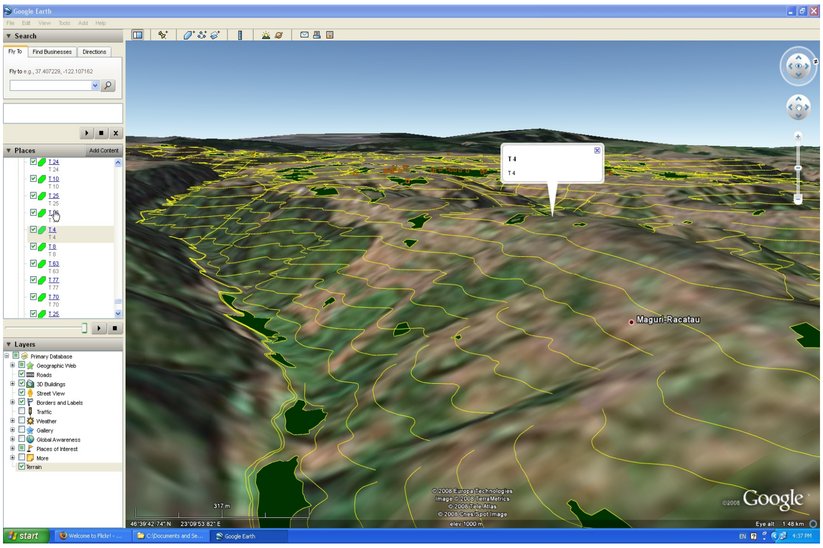

Fig. 5 – Conversion results.

Building this application allowed me to understand the ArcGIS object model and the way a developer can use ArcObjects to extend the ArcGIS desktop applications. Using ArcObjects more complex applications can be built on top of the ArcGIS applications or even independent from these.

The application and the source code were published on the ESRI developer network website to allow potential users to use it or study the source code and extend it or modify it by their needs.

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Babes-Bolyai University,Cluj-Napoca,
Faculty of Geography,
e-mail: mdomnita@gmail.com

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EXTINDEREA FUNCȚIONALITĂȚII PLATFORMEI ARCGIS PRIN PROGRAMARE

(Rezumat)

Sunt prezentate posibilitățile de extindere a aplicației ArcMap din platforma ArcGIS prin Programare Orientată pe Obiecte pentru a obține o funcționalitate nouă.

Obiectivul lucrării este crearea unei extensii ArcMap care să ofere posibilitatea exportării unui set întreg de Layere din documentul curent în format KML pentru vizualizarea acestor date în Google Earth. Google Earth oferă o bază de imagini complexă formată din imagini satelitare obținute din diverse surse, precum şi o bază de date complexă pentru unele zone formată din rețeaua de drumuri, limite administrative, date despre vreme, date despre trafic. Pe lângă acestea Google Earth mai oferă şi o experiență 3d unică prin afişarea de modele tridimensionale la clădirile mai importante şi prin afişarea terenului ca un model tridimensional, dacă se doreşte acest lucru, în majoritatea zonelor.

În data de 14 aprilie 2008 formatul KML a fost acceptat de OGC (Open GeoSpatial Consortium) ca fiind un format "open" de descriere a datelor geografice, care poate fi folosit de către oricine fără a fi necesară plata unei taxe sau alte demersuri. De asemenea, acceptarea KML ca un standard în industria geospațială pentru descrierea datelor geografice măreşte popularitatea acestui format, permițând utilizarea lui în foarte multe aplicații Desktop sau Web care lucrează cu date geografice.

ArcMap nu oferă posibilitatea de a exporta datele în format KML, iar exportarea în acest format ar permite vizualizarea datelor folosind o mulțime de aplicații gratuite, precum şi vizualizarea lor pe internet fără a fi necesară instalarea vreunei aplicații. De asemenea, suprapunerea fişierelor KML peste datele existente deja în Google Earth poate oferi vizual diverse informații importante fără a fi necesară cumpărarea vreunui produs.

Extensia creată extinde funcționalitatea aplicației ArcMap prin adăugarea acestei operații de exportare care permite trimiterea informațiilor geografice pentru vizualizare în format KML către orice utilizator de calculator. Informațiile pot fi vizualizate folosind aplicații gratuite uşor de instalat sau interfața web Google Maps care nu necesită nici o instalare pe calculator. Astfel, datele pot fi transmise unor utilizatori care nu au o pregătire în domeniul GIS sau care nu au programele necesare pentru a deschide formatele proprietare care aparțin ESRI.