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A GIS STUDY FOR THE DESIGN OF THE GSM RELAY NETWORKS IN BIHOR COUNTY

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Abstract: More knowledge about the environment leads to new research methods. This requires an interdisciplinary approach. The perfect example in this direction is the GIS concept (*Geographical Information System*) which embodies the intertwining between two scientific fields: geography and computer science. Spatial Analysis is one of the capabilities offered by the GIS technology and it is it this tool that constitutes the GIS resource used in the hereby paper. An advantage of GIS is that it makes possible the use of spatial operations for gaining new information. Such operations are the basis of spatial modeling. Of all the data types used in spatial modeling the raster data are the most suitable for analysis. The ESRI ArcGIS™ extensions provide a large spectrum of operations at cell level. The hereby article aims at creating a visibility map for a mobile telephone network. In achieving our goals several stages were covered:

- the creation of the Bihor County DEM;
- access to relay data;
- the mapping of the fragmentation depth of the terrain;
- the visibility analysis over the entire county based on the mapping of the fragmentation depth of the terrain;
- a classification of the townships based on their visible surface.

The above stages are presented in detail in the next sections.

Key words: *GSM network, visibility analysis, GIS*

The database

In creating the database we used the ArcGIS 9x and GRASS GIS 6.0. software. The use of the latter was mandatory as the execution of certain operations was not possible in the ESRI platform. As a result two operating systems were required WindowsXP for ArcGIS, and **Kubuntu Linux** 5.04 (Hoary Hedgehog) for GRASS GIS 6.0.

The DEM for the Bihor County was realized by downloading the needed DEM file from *http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp* .

As the DEM must be used in the best projection for Romania (STEREO70), it needed to be re-projected from its actual projection system WGS84. Consequently the downloaded DEM file was re-projected in a line mode using ARC/INFO. The DEM georeferencing was achieved with the use of the following commands:

Arc: w
Current location: d:\arc
Arc: w d:\bihor
WARNING: New location is not a workspace.
Arc: &r srtmgrid
Usage: &r srtmgrid <dat_file> <out_grid>
Example: &r srtmgrid N45W122.hgt srtm1g
Arc: &r srtmgrid N45E024.hgt 4524wgs
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All rights reserved.
GRID 9.0 (Fri Mar 5 16:09:26 PST 2004)
Reading N45E024.hgt as 3-arc-second DEM ...
Copying image file ...
Image parameters:
BYTEORDER M
LAYOUT BIL
NROWS 1201
NCOLS 1201
NBITS 16
ULXMAP 024
ULYMAP 46
XDIM 0.0008333333333
YDIM 0.0008333333333
Converting Image to Grid ...
Running... 100%
Define Projection
Local: ST 0
Local: CH 1

Description of Grid 4524WGS

Cell Size =	*0.000833*	*Data Type:*	*Integer*
Number of Rows =	*1201*	*Number of Values =*	*2298*
Number of Columns =	*1201*	*Attribute Data (bytes) =*	*8*

BOUNDARY		*STATISTICS*	
Xmin =	*23.999583*	*Minimum Value =*	*188.000000*

```
Xmax =          25.000417     Maximum Value =        2510.000000
Ymin =          44.999583     Mean          =         772.145988
Ymax =          46.000417     Standard Deviation =    451.759730

                    COORDINATE SYSTEM DESCRIPTION

Projection      GEOGRAPHIC
Datum             WGS84
Zunits           METERS
Units              DD          Spheroid             WGS84
Parameters:
Killed XX00000G with the ALL option
Processing completed.
```

Once the DEM re-projected (**Map 1**) the townships from the county area were vectorized by digitizing their borders. The input data for this process were the analogic maps of Bihor county which were scanned, georeferenced and digitized. In parallel the point theme containing the relays was created.

The next step was the cutting of the DEM based on the limits of the Bihor County with the ARC/INFO command „gridclip":

```
Grid: gridclip
Usage: GRIDCLIP <in_grid> <out_grid>
       {* | COVER <clip_cover> | BOX <xmin ymin xmax ymax>}
Grid: gridclip  d:\bihor\disert\dembihor
Usage: GRIDCLIP <in_grid> <out_grid>
       {* | COVER <clip_cover> | BOX <xmin ymin xmax ymax>}
Grid: gridclip  d:\bihor\disert\dembihor d:\bihor\disert\dembun cover lim
Clipping grid...
Grid: q
```

In order to calculate the relay visibility the mapping of the fragmentation depth was created. As the association between a geomorphologic parameter like the fragmentation depth and a physical parameter like the visibility might seem awkward several questions may be asked. The first question is: whys such an association? and the second what connection may be inferred between the two elements?

A simple exercise of logic provides the connection between the two apparently unconnected elements.

The mapping of the fragmentation depth (**Map 2**) of the terrain gives us areas with different fragmentation: small fragmentation energy in the field areas and in the fluvial terraces or at the top of flat hills and mountains. From such areas the broadcasting of radio waves can be achieved in optimum conditions as well as the reception of the radio signals by the mobile phones without signal loss.

If we take into account that the antennas are placed vantage points (high block, hill and mountain peaks) the reception of the radio waves is optimum on the exposed slopes or at the level of the tabular surfaces where there are no natural obstacles or other physical impediments (egg. interaction with stronger signals). An analogy between such types of areas is thus very feasible.

The visibility analysis

Based on the DEM, the fragmentation depth map, the vectorized layers of the relays and townships an analysis of visibility can be pursued. This can be done with the Spatial Analyst extension from ArcMap.

ARCGIS 9 (ArcMap) is more "user friendly" and thus there is no need for ARC/INFO. In performing the analysis first the following layers must be loaded in ArcMap: the relay layer, the viewshed and the Bihor DEM.

The visibility analysis is performed with the *„viewshed_sa" command:*

Viewshed_sa demgrass relee vzb # CURVED_EARTH #
Executing (Viewshed_3): Viewshed demgrass relee vzb 1 CURVED_EARTH 0,13
Start Time: Mon Jun 06 21:36:33 2005
Validating...
Executing Viewshed...
Processing...
Completed Viewshed.
Executed (Viewshed_3) successfully.
End Time: Mon Jun 06 22:09:49 2005 (Elapsed Time: 1996,00 secs)

By only taking the relays into account when performing the visibility analysis we can create a simple general map which cannot offer reliable information on the entire areas which can be covered by radio signals. In order to emphasize these areas this more general map must be combined with the slopes map or with the fragmentation depth map.

The first combination does not provide the expected result, as the slopes map only offer information about the terrain tilt, which is not enough for our purpose, as we need other relevant information like the areas with different fragmentation.

Such information allows for the identification of areas with different degrees of fragmentation like the so called tabular areas with values between 0 and 10 m/ha (marked in green in the second map from the first chapter). From the map we can notice that there are vast surfaces with fragmentation below 10m/ha. These areas belong to the river meadows from Câmpia de Vest. Similar fragmentation values are found in higher grounds but rather discontinuously. Other patches of "green" can be found on some tabular peaks of the hilly and mountainous areas from the Eastern part of Bihor County. Why such a situation is a question that can be asked if further analysis is intended. However this is not the intended purpose of the hereby paper and therefore we will only point out that the causes for such a geomorphologic situation are complex.

We also must point out that we marked in green any surface between 0 and 5°; with green – to- yellow the areas with a terrain fragmentation between 10 – 50m/ha, and in deep red those areas with high fragmentation.

From the perspective of radio signal propagation we can asses (only heuristically for the moment) that the areas with a fragmentation between 0 - 10m/ha are the most suitable for the reception of radio waves as they are obstacle free. In order to visualize better the areas with good signal coverage the areas with a fragmentation under 10 m/ha were given a value of 1 while the surrounding areas where given a value of 0 (**Map 3**)..

The newly produced map was then exported in GRASS GIS 6.0 for a comparative analysis.

A better visualization of superior quality was obtained with the aid of *„nviz"* module from GRASS GIS 6.0 – **Map 4** (the map of GSM signal coverage resulted after the intersection between the visibility map and the fragmentation map).

The classification of townships according to their visbility

Considering the above results we further continued in our study by creating a map with the signal coverage at township level. The purpose of this is to outline the townships with the best signal coverage. For this several steps had to be taken:

- township vectorization;
- raster conversion;
- selection of the visible areas from the entire surface;

- the creation of the map containing the visible areas at township level;
- shape file conversion;
- queries;
- the visualization of the result.

As the first operation was already computed in the initial stages of the study we only had to enter the names for each township in the attribute table (no other attributes needed to be edited).

The next step was to convert the "township" layer into a raster format. This was achieved with the Spatial Analyst extension form ArcMap (Convert – Feature to Raster).

A new grid was created in ARC/INFO so that the visible cells could be highlighted. The select function was used for this purpose: SELECT(<grid>, <logical_expression>, {o_value_item})

This function is available in the Grid module:

- *grid* – the input grid

- *logical expression* – a logic INFO selection which operates with the attribute values of the grid → the visible cells are given a value of 1 while the rest of cells get NODATA, and are dismissed

- {o_value_item} – defines the selected values from the attribute table of the input grid or and id class for the values from the attribute table of the output grid.

There are some limitations for the use of this function:

- if the input grid is made of float type points and the values from the attribute table are used as input values for the final grid it will inherit the same point characteristics as well as the input grid.
- if <logical_exptression> is TRUE, the values of the final grid cells will be identical to the values of the input cells.
- if <logical_exptression> is FALSE, the values are given no data.

After the *„select"* function was initiated a new grid was obtained in which two areas are visible: a NODATA area and the area with the most visibility.

For the creation of the GSM coverage at township level the *„zonal sum"* function from ARC/INFO must be initiated.

The syntax of this function is *ZONALSUM(<zone_grid>, <value_grid>, {DATA | NODATA})* The return value is a new grid in which each cell from *<zone_grid>* contains in the attribute table a value equal to the *<value_grid>*.

The syntax also contains the options *{DATA | NODATA}* which play a major part is solving the problem.

By selecting *DATA* all the cells will be considered but the *NODATA* cells will be ignored. The opposite happens if *NODATA* is selected.

The obtained grid is converted into shapefile.

The calculus for the classification of townships according to the GSM coverage takes place in the attribute table of the new shape.

New columns are inserted in order to contain the surface of each township (Fig.1).

Attributes of theme1

FID	Shape*	ID	GRIDCODE	Sup
0	Polygon	1	77938	70154975,83
1	Polygon	2	82079	73885493,43
2	Polygon	4	72325	65630884,65
3	Polygon	5	71148	64126790,25
4	Polygon	6	101612	91561375,58
5	Polygon	7	59641	53743240,03
6	Polygon	8	48461	44016256,03
7	Polygon	9	31440	41677602,1
8	Polygon	10	39066	43284271,54
9	Polygon	11	90115	84370651,13
10	Polygon	12	50390	45595602,86
11	Polygon	13	167620	151798812,61
12	Polygon	14	73510	78923793,68
13	Polygon	15	61512	67183454,62
14	Polygon	16	154526	139130617,43
15	Polygon	17	77976	72222168,56
16	Polygon	18	74981	70062549,63
17	Polygon	19	64002	58732048,31
18	Polygon	20	45443	44970842,37

Record: 1 Show: All Selected Records (0 out of 95 Selected.)

Figure 1. *The insertion of the column containing the surface of each township.*

Attributes of theme1

FID	Shape*	ID	GRIDCODE	Sup	Viz
0	Polygon	1	77938	70154975,83	70144200
1	Polygon	2	82079	73885493,43	73871100
2	Polygon	4	72325	65630884,65	65092500
3	Polygon	5	71148	64126790,25	64033200
4	Polygon	6	101612	91561375,58	91450800
5	Polygon	7	59641	53743240,03	53676900
6	Polygon	8	48461	44016256,03	43614900
7	Polygon	9	31440	41677602,1	28296000
8	Polygon	10	39066	43284271,54	35159400
9	Polygon	11	90115	84370651,13	81103500
10	Polygon	12	50390	45595602,86	45351000
11	Polygon	13	167620	151798812,61	150858000
12	Polygon	14	73510	78923793,68	66159000
13	Polygon	15	61512	67183454,62	55360800
14	Polygon	16	154526	139130617,43	139073400
15	Polygon	17	77976	72222168,56	70178400
16	Polygon	18	74981	70062549,63	67482900
17	Polygon	19	64002	58732048,31	57601800
18	Polygon	20	45443	44970842,37	40898700

Record: 1 Show: All Selected Records (0 out of 95 Selected.) Options

Figure 2. *The insertion of the column containing the visibility attributes.*

Attributes of theme1

FID	Shape*	ID	GRIDCODE	Sup	Viz	Neviz
0	Polygon	1	77938	70154975,83	70144200	10775,83
1	Polygon	2	82079	73885493,43	73871100	14393,43
2	Polygon	4	72325	65630884,65	65092500	538384,65
3	Polygon	5	71148	64126790,25	64033200	93590,25
4	Polygon	6	101612	91561375,58	91450800	110575,58
5	Polygon	7	59641	53743240,03	53676900	66340,03
6	Polygon	8	48461	44016256,03	43614900	401356,03
7	Polygon	9	31440	41677602,1	28296000	13381602,1
8	Polygon	10	39066	43284271,54	35159400	8124871,54
9	Polygon	11	90115	84370651,13	81103500	3267151,13
10	Polygon	12	50390	45595602,86	45351000	244602,86
11	Polygon	13	167620	151798812,61	150858000	940812,61
12	Polygon	14	73510	78923793,68	66159000	12764793,68
13	Polygon	15	61512	67183454,62	55360800	11822654,62
14	Polygon	16	154526	139130617,43	139073400	57217,43
15	Polygon	17	77976	72222168,56	70178400	2043768,56
16	Polygon	18	74981	70062549,63	67482900	2579649,63
17	Polygon	19	64002	58732048,31	57601800	1130248,31
18	Polygon	20	45443	44970842,37	40898700	4072142,37
19	Polygon	21	80270	72407412,26	72243000	164412,26

Record: 1 Show: All Selected Records (0 out of 95 Selected.) Options

Figure 3. *The insertion of the column containing the attributes of the no-visibility points*

Then, a new column is inserted containing the visibility attributes from each column (Fig.2).

The last insert is a column containing the attributes of the surfaces without visibility (Fig.3).

After creating this classification, the visibility values must be weighted based on the surfaces in order to obtain percentage values.

Two questions are connected to this operation:

- what does weighting mean?
- why introducing such an index?

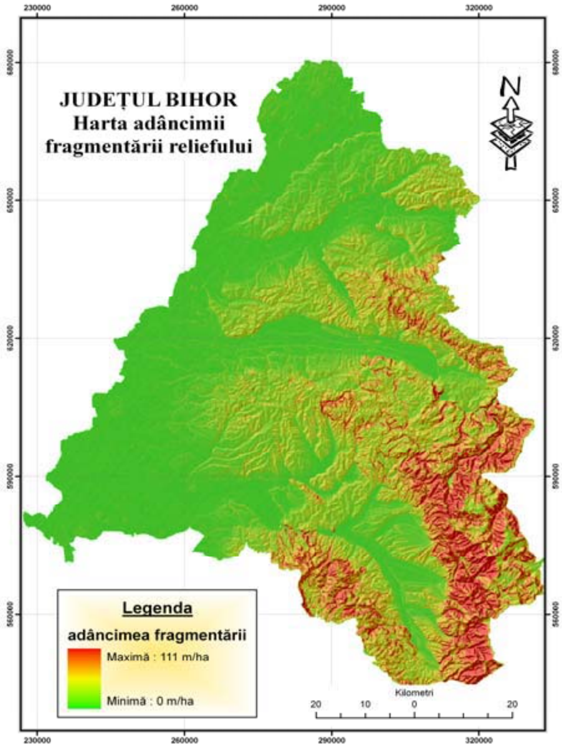
Weighting of a parameter is the separation of a numerical attribute from another one in order to reduce the differences between the areas of the same layer or between the number of layers from the same surface or between the layers from the same surface (polygon).By applying weighting based on surfaces each composing polygon gets 100% from which further percentages needed will be computed.

In our case we obtained the right percentages of surfaces with GSM coverage in each township (**Map 5**).

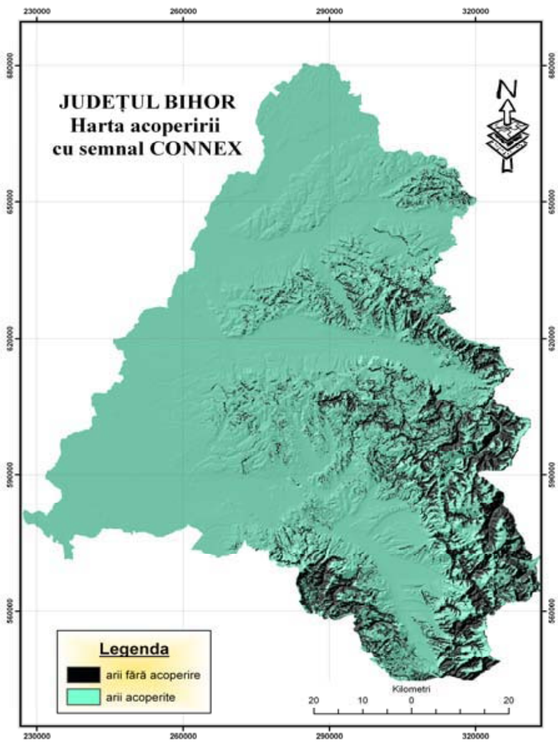
Conclusions

Visibility analysis is very important for those who request it as well as for those who can use the benefits of such an analysis.

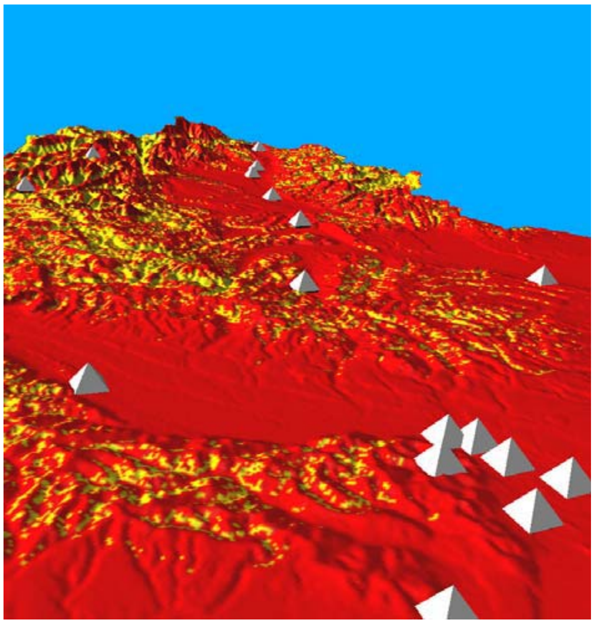
Map 1. *Digital Elevation Model – Bihor County*



Map 2. *The fragmentation depth of terrain*



Map 3. *The GSM coverage map*

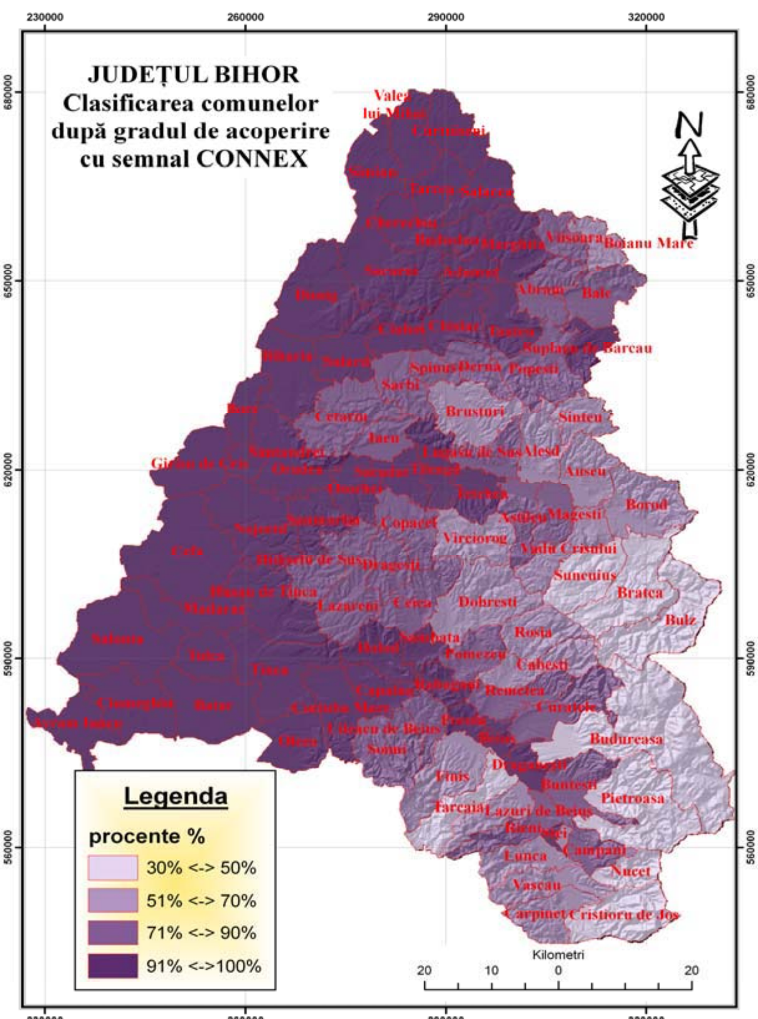


Map 4 . *The GSM coverage map(GRASS GIS)*

The hereby study is not based on precise data about the relay properties (the type, the relay height, the broadcasting frequency etc.) but on geographic data or rather on geomorphologic data as the association base was the fragmentation depth map. The reasons for choosing this parameter were dully explained and at the right time.

The computations done are viable only for the hereby model but a generalization can be made should full data be provided by the telephone company. Even so we are firmly convinced that our results are correct as sound geographic principles support our decisions taken in the study.

Moreover the areas without GSM coverage at township level are mostly consistent with the high altitude terrain and with the flat low areas. However as the GSM coverage is missing in areas with highly fragmented terrain a superimposition of the two maps is virtually impossible.



Map 5. *The township classification based on GSM coverage*