TRACKING A VOLCANIC ERUPTION WITH BET_EF SOFTWARE: APPLICATION TO THE AUCKLAND VOLCANIC FIELD, NEW ZEALAND

Robert CONSTANTINESCU[1], Jan Marie LINDSAY[2]

ABSTRACT:
Bayesian Event Tree for Eruption Forecasting (BET_EF) is a model that allows you to compute and visualize near real time probabilities of different events during a period of volcanic unrest until the moment of eruption. After being tested at different volcanoes, on both past eruptions and a simulated exercise, it was used in March 2008 during Exercise Ruaumoko which simulated a volcanic eruption in the Auckland Volcanic Field (AVF), New Zealand. In this paper we provide a description of the data and parameters that we used to customize the software code for the AVF, and compare the results obtained with those of the advising scientists. We thus emphasize the inputs and the outputs of the BET_EF code, and illustrate how it can be used as an eruption forecasting tool.

Keywords: *volcanic hazard, Auckland Volcanic Field, software, eruption forecasting, e-tools.*

1. INTRODUCTION

Around the world there are many cities built near active volcanoes exposing population and infrastructure to various volcanic events that may cause serious damage. One of the major goals of the modern volcanologist is to be able to provide an accurate eruption forecast in order to decrease the volcanic risk. There have been different approaches, but in the past decade, probabilistic methods have started to be developed (*e.g. Newhall and Hoblitt, 2002; Marzocchi et al., 2004, 2006; Jaquet et al., 2006, 2008*). One method, introduced by *Newhall and Hoblitt* (*2002*) proposed the use of event trees for determining the volcanic risks during an eruption. An event tree is essentially a representation of events in which branches are logical steps from a general prior event through increasingly specific subsequent events to final outcomes (*Newhall and Hoblitt, 2002*). These event trees can give us a better understanding of the likelihood of possible outcomes, one step at a time from unrest till the end of an eruption.

This represented a major advance in methods of eruption forecasting, and the next logical step was to consider the necessity of having clear results in real time. Bayesian Event Tree for Eruption Forecasting (BET_EF) *(Marzocchi et al., 2004, 2008*) is an eruption forecasting tool that was developed to provide such near real time probabilities. It permits the user to compute long–term and short–term probabilities for eruption outcomes by using past data and monitoring data for a specific volcano (*Marzocchi et al., 2008*). BET_EF was used during MESIMEX (Major Emergency SiMulation Exercise) at Vesuvius (Italy) in 2006, and has also been applied retrospectively to two real volcanic crises: the 1982 – 1984 unrest episode at Campi Flegrei (Italy), and the 1631 eruption of Vesuvius (*Sandri et al., 2009*). Given the high risk associated with a possible future eruption in

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Auckland, in March 2008 the New Zealand government ran "Exercise Ruaumoko", a test of New Zealand's all-of-nation preparedness for the major disaster a volcanic eruption in the Auckland Volcanic Field (AVF) would represent. The exercise itself was a simulation of an eruption in the AVF, and the scenario, developed in secret, covered the period of precursory activity up until the eruption. This provided an excellent opportunity to further test the BET_EF methodology.

The role of scientists during the Ruaumoko Exercise was to provide advice to the authorities on matters such as timing, location and size of the impending eruption. In parallel, but totally separated, we ran the BET_EF software to track the unrest evolution and to forecast the most likely onset time, location, and style of the initial phase of the simulated eruption.

The goal of this paper is to present a summarized step-by-step guide to the process of creating a BET_EF code for the Auckland Volcanic Field, using volcanological data available at the time of the exercise. We also highlight related challenges, and compare the final results (probabilities) with those of the advising scientists. For a detailed description of the AVF and Exercise Ruaumoko please consult *Lindsay et al.* (*2010*).

2. BET_EF AND INPUT DATA USED FOR AVF

BET is a probabilistic model that merges all kinds of volcanological information— from theoretical/empirical models, geological and historical data, and monitoring observations - to obtain probability of any relevant volcanic event (*Marzocchi et al. 2007*). The key concept of BET_EF is based on the event tree (**Fig. 1**), which is a branching graph representation of events in which individual branches are alternative steps from a general prior event, state, or condition, and which evolve into increasingly specific subsequent events (*Marzocchi et al., 2007*). The points on the graph where new branches are created are referred to as nodes *(Newhall and Hoblitt, 2002; Marzocchi et al., 2004, 2008).*

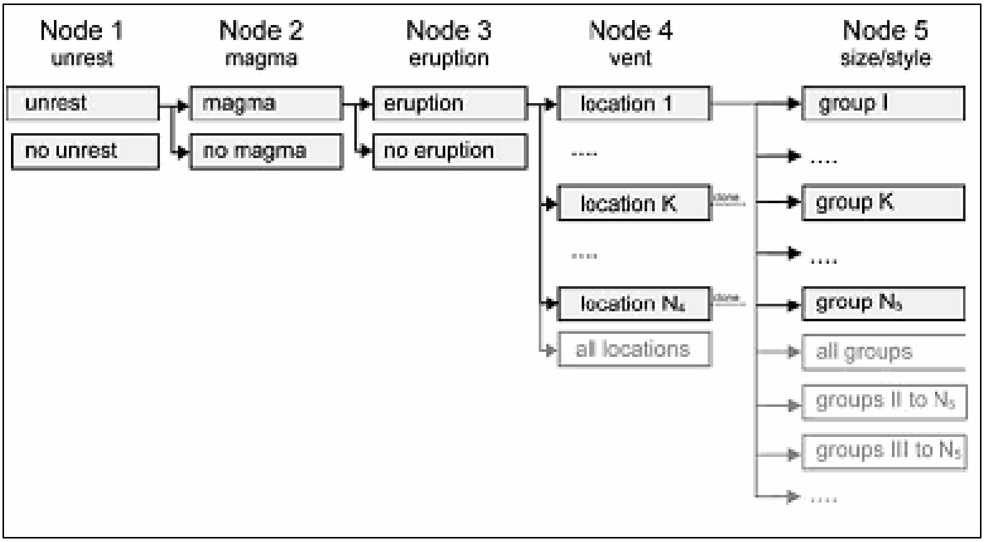

Fig. 1 Schematic representation of the Bayesian Event Tree used here

The BET_EF code comprises a non-monitoring and a monitoring component and merges all this data in order to provide probabilities at the node of interest. Setting up the code for the AVF in a Bayesian Event Tree scheme required some changes to the software. This was mainly related to the fact that the AVF is a monogenetic field, which contrasts with the stratovolcanoes and calderas to which the code has been applied in the past. Following the basic rules of BET_EF, we used past data, mostly based on the interpretation of deposits rather than observations of historical activity, as well as monitoring parameters, which had to be chosen carefully to be representative for the event expected at each node. Relevant parameters and thresholds were established before Exercise Ruaumoko during discussions with the scientists responsible for monitoring activity in the AVF (*Lindsay et al., 2010*). Here we try to give a description of the volcanological information that we used to develop the BET code for AVF, with an explanation of the parameters used at each node. Notably, the BET_EF is open-access software that allows the user to adapt and update the code as new information about the volcano appears. More detail can be found in *Lindsay et al. (2010)*.

Node 1 – *unrest / no unrest*

At Node 1 we tried to determine the long–term probability of having an unrest state in the AVF. In BET_EF we can do that by merging past data and monitoring data. To determine the prior distribution of eruptions in the AVF, we start with the basic well-known facts. There are 49 known volcanic centers that have been created during the past ~ 250,000 years (**Fig. 2**). The last eruption occurred only 600 years ago. This information can be used to compute the frequency of eruptions per month (B = 49/250000*12). However, we also have to take into account that between these eruptions there might have been episodes of volcanic unrest. In general, volcanic unrest is a state of the volcano that is abnormal with regards to its background activity, and as an average it is accepted that 1 in 5 episodes of unrest leads to an eruption (A). Using the past frequency of eruption and the estimated unrest ratio in a volcanic field, we can compute a BETA distribution average = B/A; This ratio represents a lower limit of the frequency of eruption relative to unrest episodes observed in volcanic fields, and accounts for the fact that not all episodes of unrest end with an eruption. The number of equivalent data (Λ) for this distribution is 1 (indicating a rough estimate with large uncertainty) (*Lindsay et al., 2010*). As past data we can use information from the monitoring of AVF starting in 1960; no unrest has been recorded during this time period. As we used BET_EF as a forecasting tool for the Ruaumoko Exercise, we also take into account (as an unrest episode) the simulated seismic swarm in November 2007. This unrest episode should not be taken into account in a real unrest in the AVF, but for the Ruaumoko exercise we used it as past data, with the result that in the past 47 years we have one episode of unrest.

For the monitoring component we choose 6 parameters as follows:

1. *Number of Long Period (LP) earthquakes*: - Given the low level of seismicity in the AVF, in particular the complete lack of historical low-frequency events, it is considered that just one long period (LP) event (or more) would represent an anomaly and be indicative of unrest.

2. *Number of Volcano-Tectonic (VT) earthquakes:* - Given the geological setting and history of AVF we consider that, in the time period we are looking into (one month), a

single VT event could be considered normal, but 3 or more VT would be clearly abnormal and may involve activity related to magma movement.

3. *"Significant" ground deformation*: - In the past years, slow motions of the ground were observed beneath Auckland, and are believed to be related to groundwater. The term "significant" in the definition of this parameter tries to emphasize that we do not consider small variation of the ground level but different and sudden movements considered to be outside the background activity.

4. *Presence of SO_2 gas* / 5. *Presence of CO_2 gas*: - Gases are not usually monitored in the AVF. We used these gases as indicators of volcanic activity due to the fact that they have not been detected in the past, and they are likely to appear only when magma is involved. In a city with a large population we consider that people will alert the authorities if gases are noticed somewhere in the AVF.

6. *Changes in ground water reservoirs:* - Underground water may move as a result of ground movements; any anomaly detected in water wells or aquifers is considered to be indicative of unrest. For parameters 3 to 6, the threshold is set to=1, indicating that any changes in these parameters would be considered anomalous and an indicator of unrest.

Node 2 – *magma / no magma*

At node 2 we try to determine whether or not the confirmed episode of unrest is related to magma. For this, we chose parameters that can provide evidence of magma involvement, and we have to base our analysis on the means at hand, given the fact that the monitoring networks at different volcanoes may differ (e.g. Vesuvius vs. AVF).

For past data we cannot use any information, as during the past period of monitoring there have been no magmatic unrest episodes. We therefore rely on monitoring parameters that may identify and track the magma.

1. *Number of LP earthquakes:* - We use here the same parameter as in node one because it is considered anomalous for the AVF to have any LP events (see Node 1).

2. *Max. Magnitude of VT earthquakes:* - Based on the limited seismic activity recorded in the Auckland region, an anomalously large magnitude earthquake in the AVF would be M=4.5. We make the gradual transition from normal (M<3.5) to anomalous (M≥4.5) using thresholds similar to those suggested by Sherburn et al. (2007) for seismicity during magmatic unrest in the AVF based on analogous eruptions (e.g. Parícutin)

3. *Dispersion in depth of hypocenters*: - Because in the AVF at the time of our study the error in hypocentral location was considered to be ~ 5km, we consider that dispersion in the depths of hypocenters of >5km (and especially >10km) could indicate dyke intrusion and will therefore be a strong indicator of magma moving upward. For this parameter we assign a weight of 2 because we consider it to be much better evidence of magma movement than number of LP events (the first two parameters have a weight of 1).

4. *Acceleration of seismicity (LP or VT)*: - We consider this parameter to have a weight of 1. It is not a general rule that such acceleration may reflect magma migration, however in some cases it may be a reliable indicator (see *Kilburn, 2003*).

5. "*Significant" ground deformation*: - Ground deformation is a strong indicator of magma rising to the surface so any kind of localized uplift or subsidence is considered here. We assign a weight of 2 for this parameter.

6. *Presence of SO_2 gas* / 7. *Presence of CO_2 gas:* - SO_2 gas is typically magmatic in origin and is therefore a strong indicator of magma driving the unrest (weight 2). CO_2

release can also occur during unrest where there is no direct involvement of magma, through, for example, interaction of hydrothermal fluids with calcareous sediments (e.g. *Chiodini and Frondini, 2001; Carapezza and Tarchini, 2007*) and for this reason it is considered here with a weight of 1.

Node 3 – *eruption / no eruption*

If an unrest episode was detected and it was proved to be magmatic, we then try to determine the probability that this magma will erupt. Research has shown that globally, about half of the magmatic unrest episodes in a given time period will lead to an eruption, and we use this information at this node as a prior distribution. For the monitoring component we used:

1. *Seismic tremors:* - There are known cases where, before eruptions, seismic tremors were recorded; we assign a weight of 2 to this parameter.
2. *Depth of earthquakes if dispersion is >5 km*: - as in Node 2, > 5 km dispersion in hypocentral depth is an indicator of magma movement. For this node we also consider that the shallower the hypocentral distribution, the more indicative it is of eruption. For that we assign a weight of 2.
3. *Acceleration of seismicity*: - This phenomenon has been recorded at different volcanoes as a precursor to eruption. *Kilburn (2003)* stated that it has a physical explanation and it was recorded in timeframes between days to hours before the eruption.
4. *Acceleration of deformation*: - Deformation of the ground at an accelerated rate is a strong indicator of near surface magmatic intrusion, and we assign a weight of 2 to this parameter.
5. *Sudden reversals of ground deformation and/or seismicity pattern and/or gas concentrations:* - Based on known cases of eruptions where sudden changes in the volcano behavior occur just before the eruption, we consider a period of volcanic silence as well as a sudden reversal in any parameter indicative of an imminent explosion.
6. *Significant increase in gas concentrations:* - Associated with magma decompression, released gases may significantly increase in concentration once the magma rises close to the surface. For other New Zealand volcanoes, a sudden order-of-magnitude increase in airborne gas emissions to ca. >2000 tones/day for CO_2 and ca. >1000 tones/day for SO_2 would be significant (*Lindsay et al., 2010*).

Node 4 – *vent location*

Determining the future vent location in a volcanic field can be much more challenging than at dominant-vent volcanoes. The dispersed volcanic field of Auckland is composed of 49 different vents that cover a large area (**Fig. 2**). Its monogenetic nature led us to consider for our calculations an area bigger than the actual field, to include the possibility of the next eruption occurring outside the current borders. The limited data regarding the ages and activity of the volcanic field cannot offer us a clear spatial – temporal distribution of the vents. Recent work by *Cassidy (2006*) and *Cassata et al. (2008*) suggest that some past eruptions may have occurred simultaneously in different parts of the field. In order not to be biased in determining the future vent location, we used a uniform prior probability distribution over the entire area, and consider that the most probable vent will occur where monitoring parameters show anomalies.

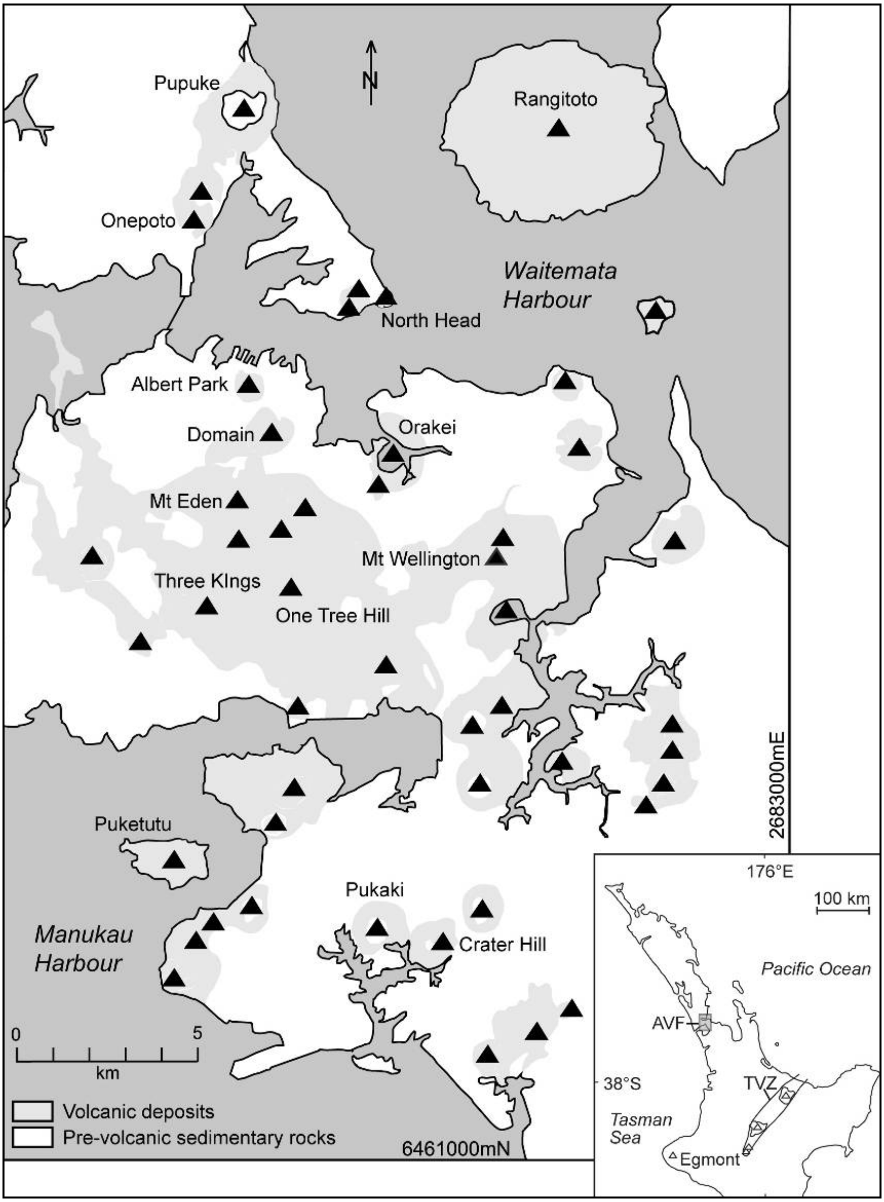

Fig. 2 Map of AVF with volcanic centers and deposits (after *Kermode 1992*). Inset shows the location of the AVF in the North Island as well as Mt Egmont volcano and the Taupo Volcanic Zone (TVZ).

The map we used at this node (as shown here) is extended outside the actual field in accordance with the geological structure of the region. Monitoring data are not used at this node as the information recorded from the ongoing activity will indicate a location with anomalies during computation of the first 3 nodes.

Node 5 - *size / style of the first eruption*

For this node, we only use non monitoring information as monitoring parameters do not provide useful insight into the size and style of the impending eruption (e.g. *Sandri et al., 2004*). We considered only the first stages of the eruption as they are most relevant in risk mitigation. The geology of the AVF, as well as its coastal geographical setting, leads to different styles of eruptions. *Allen (1992)* and *Allen and Smith (1994)* showed that 71% of AVF eruptions had phreatomagmatic components, 77% had typical Hawaiian and Strombolian components, and 66% of eruptions produced lava flows. Given the AVF position on an isthmus surrounded by shallow waters, the phreatomagmatic phase of eruptions is considered to last until the water source is depleted. Together with underground aquifers, the high amount of water is likely to result in an early phretomagmatic phase in a future eruption. If the eruption occurs underwater, the water column above the sea floor is unlikely to be great enough to suppress an explosion. Considering geographical and geological information about the AVF, we consider that a future eruption of AVF may begin with either of the following three styles: 1 – *typical phreatomagmatic* – similar to past eruptions in the AVF; 2 – *large phreatomagmatic* – if a large volume of magma is involved and magma : water ratios for explosion are optimal; 3 – *typical effusive activity.*

For node 5 we divided the AVF into WET and DRY cells, according to whether or not surface water was present. We assumed that an effusive eruption onset is only possible in DRY cells (see *Lindsay et al., 2010* for more details). Taking this into consideration, as well as the exceptions in size represented by the relatively large eruptions of Pupuke, Three Kings, Motukorea and Rangitoto (see *Allen and Smith, 1994*) we assumed as past data the following probabilities regarding WET and DRY areas: *typical phreatomagmatic/large phreatomagmatic/typical effusive*: 0.7/0.1/0.2 for DRY cells and 0.0/1.0/0.0 for WET cells.

3. RESULTS: OUTPUTS OF BET_EF

BET is a tool to calculate and visualize probabilities related to eruption forecasting (*Marzocchi et al., 2007*). It allows you to compute probabilities at each node and offers results as a probability density function (PDF) and cumulative distribution function (CDF) (*Marzocchi et al., 2007*).

During Exercise Ruaumoko, based on the information described above, we were able to track the activity from unrest to the location of vent opening. Notably, given the simulated activity in November 2007, on 1 March 2008 (the beginning of the main phase of the exercise) the probability of unrest was already 100%. The probability that magma was driving the unrest (Pm) was calculated at 83%, and the probability of eruption (Pe) 25% (*Lindsay et al., 2010*). Volcanic unrest was indicated by LP earthquakes with decreasing depths of hypocenters, VT events, gas emissions and ground deformation, which increased 2 days before and lasted until the 'eruption' on March 14. During this entire period the BET_EF probability of unrest was 100%. Pm and Pe stayed around 87% and 24%, respectively, from 1 March to 11 March, when there was a jump in Pe to 54% as the depth of dispersed earthquake hypocenters decreased (**Fig. 3**) On 12 March, Pm and Pe increased to 92% and 77%, respectively. On 13 March, an increase in CO_2 soil gas flux and a M=4.5 earthquake resulted in an increase in Pe to 82%. The sudden drop in VT seismicity and onset of tremor on 13 March and the accelerating ground uplift on 14 March led to a probability of eruption of 90% on 14 March, the morning of the eruption.

BET was run during the exercise but it had no involvement in the decision making process. In **Fig. 3** we present the evolution of the probabilities in comparison with advising scientist's opinions. Despite the similarity between these results, it is important to stress that BET_EF is not a piece of software to rely on exclusively, but rather is a tool that can be used to help scientists visualize the evolution of probabilities in near real time.

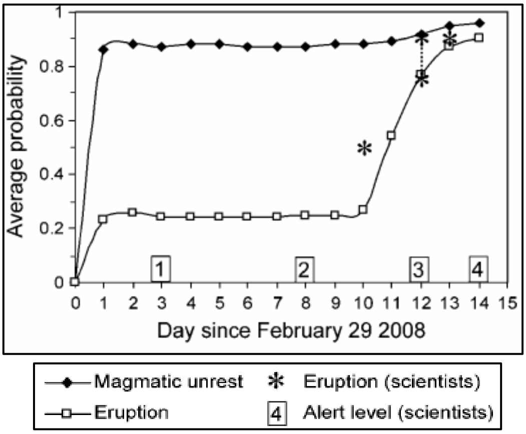

Fig. 3 Time evolution of BET probabilities of magmatic unrest (Pm) and eruption (Pe) compared with probabilities provided by advising scientists during Ruaumoko

Regarding the location of the new vent opening, the BET output is a map of probabilities at each cell, in a color scheme from intense brown to black (highest probability), to pale yellow (lowest probability). The probability maps during exercise Ruaumoko are presented in **Fig. 4** for the last two days before the eruption on March 14.

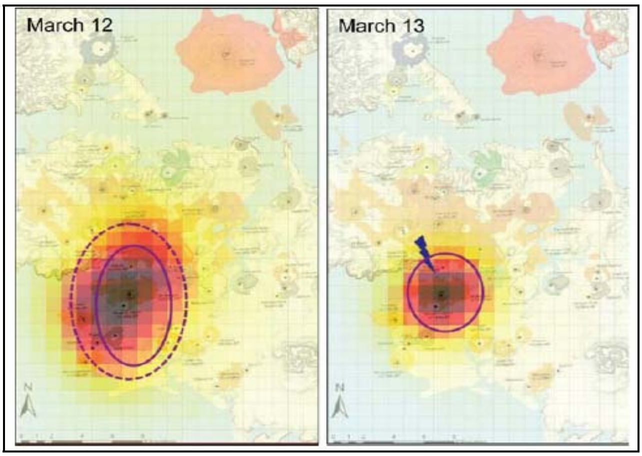

Fig. 4 BET maps showing probability of vent opening. The purple circles represent the advising scientist's opinion and the eventual simulated vent opening is pointed by the arrow.

4. CONCLUSIONS

In this paper we have described setting up the BET_EF code for the Auckland Volcanic Field, and the results produced by the code during the simulated exercise Ruaumoko eruption held in New Zealand in March 2008. We put particular empasis on the nature of the input and output data for BET_EF. The data used for eruption forecasting in this case were presented for each node, and reasons were provided for each parameter. It should be noted that this study is specific to the Auckland Volcanic Field; using the same parameters and thresholds for other volcanoes may lead to misleading outputs. We used data available for the AVF at the time of the exercise, and parameters that were monitored or could have been immediately monitored during a crisis. The eruption forecasting code for the AVF is subject to change as new information becomes available and the monitoring network is developed. The probabilities of eruption and location of the vent computed using BET_EF during this exercise had a very close resemblance to those independently provided by the advising scientists. A subject of ongoing debate is the fact that the time window over which BET provides probabilities is one month. This contrasts with the scientists probabilities, which were typically covering the next 24-48 hours. However, in an escalating volcanic crisis reflected by increasing BET probabilities, the one month BET window can be considered to approximate a 24 - 48 hour period. We also point out that in an ideal situation, when the BET_EF code is established before a given volcanic crisis, it could be used as a tool to assist the decision making process. Of course, the quality of the outputs is closely related to the quality of the input data.

Remarks: This paper is a synthesis of the author's master thesis, and tries to cover the aspects related to the data used in the Ruaumoko Exercise, a disaster exercise simulating an eruption in the AVF. This contribution stresses the nature of the inputs and outputs of BET_EF. For more detail on the Auckland Volcanic Field and the justification behind the use of the specific parameters, please refer to *Lindsay et al. (2010)* and *Constantinescu (2008)*. For more general details on the BET_EF code please consult *Marzocchi et al. (2007)*.

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R E F E R E N C E S

Allen S., (1992), *Volcanic hazards in the Auckland Volcanic Field. MSc thesis*, The University of Auckland.

Allen S.R., Smith I.E.M., (1994), *Eruption styles and volcanic hazard in the Auckland Volcanic Field*, New Zealand. Geosci Rep Shizuoka Univ 20:5–14.

Carapezza M.L., Tarchini L., (2007), *Accidental gas emission from shallow pressurized aquifers at Alban Hills volcano* (*Rome,Italy*): Geochemical evidence of magmatic degassing, J Volcanol Geotherm Res 165:5–16.

Cassata W.S., Singer B.S., Cassidy J., (2008), *Laschamp and Mono Lake geomagnetic excursions recorded in New Zealand,* Earth Planet Sci Lett 268:76–88. doi:10.1016/j.epsl.2008.01.009.

Cassidy J., (2006), *Geomagnetic excursion captured by multiple volcanoes in a monogenetic field,* Geophys Res Lett 33: L21310. doi:10.1029/2006GL027284.

Chiodini G., Frondini F., (2001), *Carbon dioxide degassing from the Alban Hills volcanic region*, Central Italy. Chem Geol 177:67–83.

Constantinescu R., (2008), *New probabilistic tools for eruption forecasting and assessment,* BET_EF (Bayesian Event Tree for Eruption Forecasting) and its application during Exercise Ruaumoko, Auckland, New Zealand, MSc thesis, Babeş Bolyai University, Cluj Napoca, Romania.

Jaquet O., Carniel R., Sparks S., Thompson G., Namar R., Di Cecca M., (2006), *DEVIN: A forecasting approach using stochastic methods applied to the Soufriere Hills Volcano,* J Volcanol Geotherm Res153:97–111.

Jaquet O., Connor C., Connor L., (2008). *Probabilistic modeling for long-term assessment of volcanic hazards*, Nucl Technol 163:180–189.

Kermode L.O., (1992), *Geology of the Auckland urban area. Scale 1:50000,* Institute of Geological & Nuclear Sciences Geological Map 2.

Kilburn C.R.J., (2003), *Multiscale fracturing as a key to forecasting volcanic eruptions*, J Volcanol Geotherm Res 125:271–289.

Lindsay J. M., Marzocchi W., Jolly G., Constantinescu R., Selva J., Sandri L., (2010), *Towards real-time eruption forecasting in the Auckland Volcanic Field: application of BET_EF during the New Zealand National Disaster Exercise 'Ruaumoko',* Bull. Volc. 72: 185 – 204.

Marzocchi W., Sandri L., Gasparini P., Newhall C., Boschi E., (2004), *Quantifying probabilities of volcanic events: the example of volcanic hazard at Mt. Vesuvius,* J Geophys Res 109:B11201. doi:10.1029/2004JB003155.

Marzocchi W., Zaccarelli L., (2006), *A quantitative model for the timesize distribution of eruptions*, J Geophys Res 111:B04204. doi:10.1029/2005JB003709.

Marzocchi W., Woo G., (2007), *Probabilistic eruption forecasting and the call for an evacuation,* Geophys Res Lett 34:L22310.doi:10.1029/2007GL031922.

Marzocchi W., Sandri L., Selva J., (2008), *BET_EF: a probabilistic tool for long- and short-term eruption forecasting,* Bull Volcanol 70:623–632. doi:10.1007/s00445-007-0157-y.

Newhall C.G., Hoblitt R.P., (2002), *Constructing event trees for volcanic crises,* Bull Volcanol 64:3–20. doi:10.1007/s004450100173.

Sandri L., Marzocchi W., Zaccarelli L., (2004), *A new perspective in identifying the precursory patterns of volcanic eruptions,* Bull Volcanol 66:263–275. doi:10.1007/s00445-003-0309-7.

Sandri L., Guidoboni E., Marzocchi W., Selva J., (2009), *Bayesian Event Tree (BET) for eruption forecasting at Vesuvius, Italy: a retrospective forward application to 1631 eruption,* Bull Volcanol. doi:10.1007/s00445-008-0261-7.

Sherburn S., Scott B., Olsen J., Miller C., (2007), *Monitoring seismic precursors to an eruption from the Auckland Volcanic Field*, New Zealand. NZ J Geol Geophys 50:1–11.

DETECTION OF RECENT SPATIAL CHANGES REGARDING LANDUSE IN SMALL BASINS FROM THE APUSENI NATURAL PARK

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ABSTRACT:

Detection of Spatial change in landuse in the small basins from the Apuseni Natural Park is a very delicate problem because of both the importance the tourism in the area and karst topography of the area that require special attention. This matter was researched in the present study using some of the newest methods of monitoring and analysis of the geographical space. Thus, using remote sensing techniques the landuse data was obtained. Through Landsat satellite imagery an analysis was made on the level of afforestation in two different periods: 1988, 2000 respectively. Based on the results of classification thematic maps were made on the level of afforestation of small basins for two periods of time. Detection of spatial changes in the level of afforestation can help in the estimation of the runoff coefficients on the slopes, and the danger of flood occurrence.

Keywords: *landuse, remote sensing, GIS, thematic maps, river basins.*

1. INTRODUCTION

Activities such as agriculture, forestry, transport and housing change the state of nature and the usage of the land. Many environmental problems arise from land use changes, causing climate change, biodiversity loss and pollution of the water, soil and air. Impacts can be direct such as deterioration of natural habitats and landscapes or indirect, for example deforestation is increasing flood risks (*Bejan, 2009*). Detection of changes in land use within a period of time, especially those covered by forests, is an important step. Thus, making maps that highlight the processes of deforestation and reforestation, with data obtained from satellite images, will be a step that contributes to sustainable development in landuse management and forecasting of possible changes that may occur over time (*Podeh et al., 2009*).

This study aims to highlight the changes in landuse in the Apuseni Natural Park, changes that can have repercussions in the flood events (*Domnița et al., 2010*).

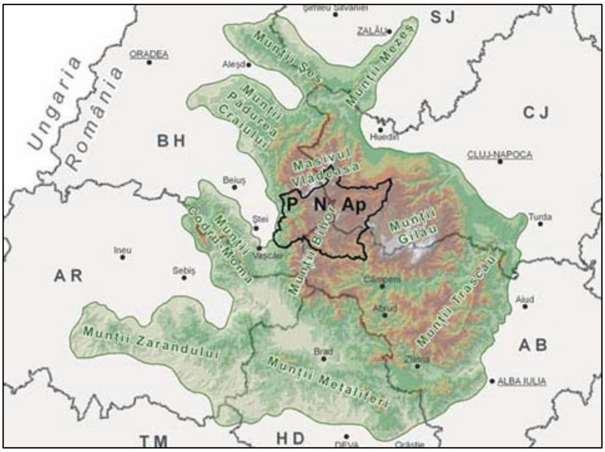

Fig. 1 Location of Apuseni Natural Park (*http://www.parcapuseni.ro/*)

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Apuseni Natural Park is located in western Romania, in the central-north-west of the Apuseni Mountains, stretching a massive part of Bihor mountains in the south and Vladeasa mountains in the north, on the territory of three counties (Cluj 40%, Bihor 32% Alba, 28%) (**Fig. 1**) (*http://www.parcapuseni.ro*).

2. APPLIED METHODS

The study is based on remote sensing and the use of GIS techniques to find the main categories of landuse on the surface of the Apuseni Natural Park, and to calculate afforestation degree in the catchment areas for each zone from the obtained data.

2.1. Applied remote sensing for finding the main landuse categories

Remote sensing is currently the most advanced technique for monitoring the earth's surface. It is defined as a complex of activities that involve obtaining, using the interaction of objects on Earth's surface and electromagnetic radiation sensors, information in the form of photographic conventional image (analog format) or raster images (in any type of digital imagery) (*Imbroane et al., 1999*).

Landsat is the longest continuous remote sensing data collection mission in the world. Nearly four decades of images provide a unique resource for those working in agriculture, geology, forestry, regional planning, education, mapping and global change research (*http://landsat.usgs.gov*).

In this study we have used images taken in two periods of time, namely: 1988 and 2000, all images are captured at approximately the same period of the year during the months of July-August, when a maximum regarding the period of plants vegetation is recorded. For 1988, we used Landsat TM images (Thematic Mapper) and Landsat ETM + for 2000 (Enhanced Thematic Mapper Plus).

Landsat TM images are images captured during the Landsat 5 mission, a mission launched in 1984. These are images captured by „Thematic Mapper” (TM) sensor. Images captured with this sensor have seven spectral bands and a spatial resolution of 30m.

Landsat ETM + images were captured during the Landsat 7 mission, a mission launched in 1999. Sensor „Enhnaced Thematic Mapper Plus” (ETM +) used in the mission, can provide images with a spatial resolution of 15 m.

Fig. 2 "True color" image

Fig. 3 "False color" image - 432 band combination

These satellite images enable the combination of spectral bands. The results of these images color combinations are in "natural" colors (**Fig. 2**) and "false" colors (**Fig. 3**). "False" color images provide a better way to deliver results from the classifications (*Ursu, 2006*).

To make the best out of how the Apuseni Natural Park area is used, we used the 4-3-2 (NIR - Red - Green) bands combination (**Fig. 3**). The resulting images were processed to allow a better observation of the main categories of landuse. This combination makes the band frequencies for vegetation appear as shades of red, because vegetation reflects more light in the NIR. The color red indicates healthy vegetation. Soils with little or no vegetation will vary from white (sand) to green and brown, depending on moisture and organic matter content. Water will change color from blue to black. Clear water is deep dark. Urban areas are in shades of blue-gray colors. Clouds and snow are both white (*http://landsat.usgs.gov*).

In terms of land classification, supervised classification was conducted to highlight the main categories of landuse of the Apuseni Natural Park area and in particular to highlight the desired forest land for afforestation subsequent analysis of small basins from the park.

The end product of classification provides an overview of the main categories of Apuseni Natural Park landuse. In **Fig. 4** and **5** are the results obtained in the two study periods.

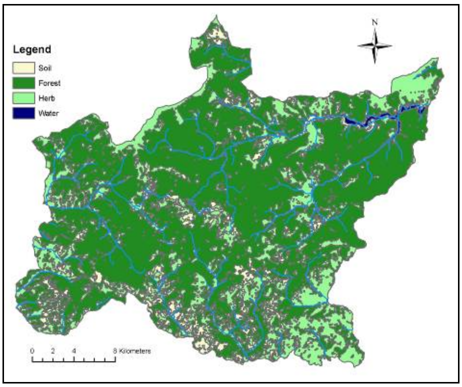

Fig. 4 Classification results for 1988

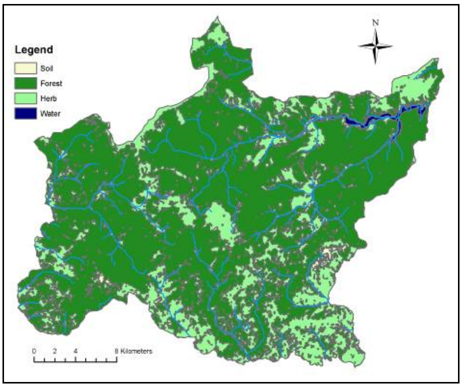

Fig. 5 Classification results for 2000

2.2. Spatial Analysis regarding afforestation degree for small basins using GIS

The extensions of the ArcGIS software, were used to apply the functions needed for obtaining the results. We used the "Spatial Analyst" tool. It allows you to combine the two types of vector and raster data and various calculations and statistics (*Haidu, 1998*).

Thus, from the results of classification values were extracted for forested areas for the year 1988 and 2000, resulting two raster files with information about the forest area of the park for two studied periods (**Fig. 6** and **7**).

The analysis of small basins within the park boundaries was necessary to obtain the watersheds. This was achieved using the an Digital Elevation Model (DEM) obtained from the ASTER database and using ArcHydro extension from the GIS software. The result is a vector file, polygon type, which is representing the small basins (**Fig. 8**).

Note that in achieving these limits we take into account that the area presents sharp horizontal fragmentation which is leading to a large number of small basins. The sub-division was made taking into account all sub-basins with an area greater than 3 km^2.

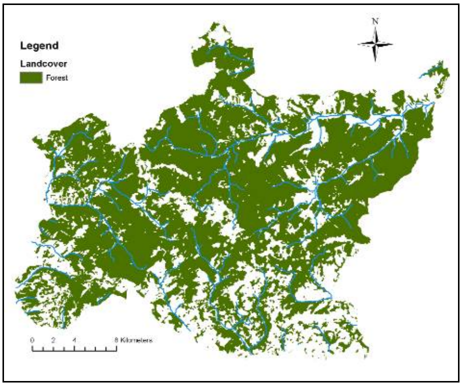

Fig. 6 Forest Landcover for 1988

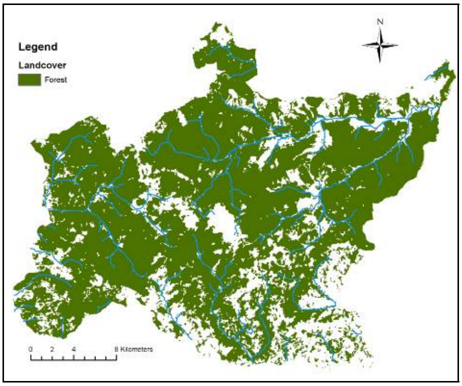

Fig. 7 Forest Landcover for 2000

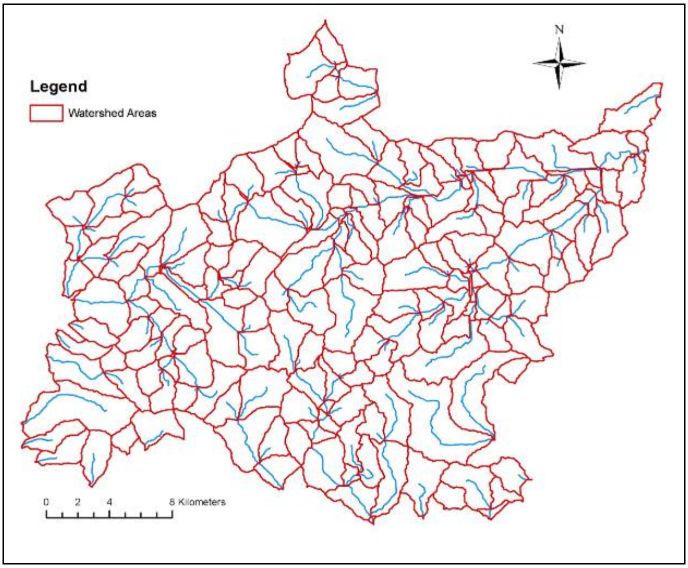

Fig. 8 Watershed areas from Ap.N.P.

These results formed the basis of the spatial analysis that we have undertaken using the Spatial Analyst extension (Zonal Statistics).

Using data's obtained from the analysis of spatial and integrating them into the watershed layer the calculation was possible for the percentage by afforestation for each small basin (**Fig. 9**).

Attributes of Forest_1990

FID	Shape	HydroID	Perimetre	Area_mp	AREA	Afforestation
25	Polygon	1394	3140.613739	48586.696948	0	0
68	Polygon	1439	172.064264	925.19097	0	0
176	Polygon	1549	86.045806	462.742541	0	0
189	Polygon	1562	430.160733	4163.357455	0	0
28	Polygon	1397	3871.952923	254956.78234	5400	2.12
106	Polygon	1478	4947.544484	366014.835173	9900	2.7
35	Polygon	1404	3527.780192	447910.244625	20700	4.62
13	Polygon	1382	9207.199034	1548434.94251	210600	13.6
96	Polygon	1468	1204.512122	38861.955846	5400	13.9
186	Polygon	1559	7313.937928	808883.55134	123300	15.24
34	Polygon	1403	3140.735747	33319.035397	5400	16.21
7	Polygon	1376	17252.63066	6911884.22428	1122300	16.24
184	Polygon	1557	8647.521782	2589919.17953	459900	17.76
166	Polygon	1539	9937.874907	2977965.76773	544500	18.28
105	Polygon	1477	6582.360533	1437678.55715	309600	21.53

Record: 5 Show: All Selected Records (0 out of 193 Selected)

Fig. 9 Attribute table of Afforestation degree in 1990

3. RESULTS

Detection of spatial changes that took place in the small basins of the Apuseni Natural Park has highlighted the fact that the forest vegetation in the park is constantly changing.

The results obtained could be represented as thematic maps for classifying basins after afforestation degree (**Fig. 10** and **11**).

From the change analysis we found that the residents from the basin of Albac river (especially those from rural village: Dărleşti, Trifesti, Petreasa) are most exposed to negative effects caused by deforestation (**Fig. 12**). In year 2000 deforestation was detected over 15% of the forested area that existed in 1988. It should be noted that the deforestation that took place occurred at an average rate of about 4%.

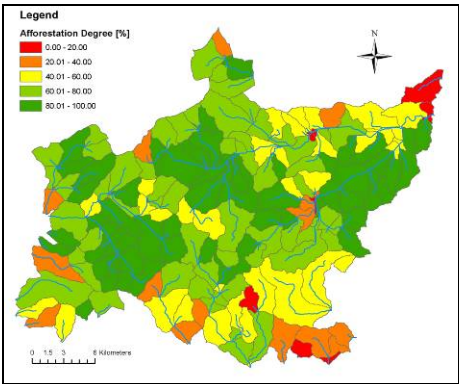

Fig. 10 Afforestation degree for 1988

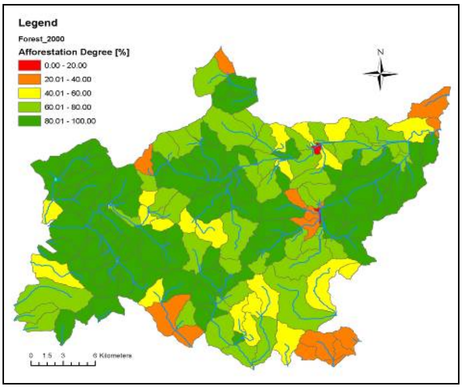

Fig. 11 Afforestation degree for 2000

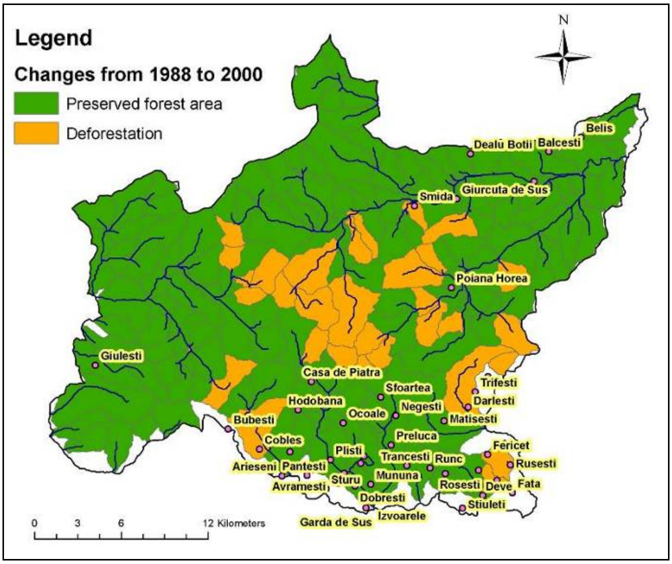

Fig. 12 Forest changes between 1988 and 2000 in the small basins of the Apuseni Natural Park

4. CONCLUSIONS

Determination of the afforestation degree is a starting point in studying the role of landuse in the rainfall-runoff relation and its hydrological impact at the level of the small basins from Apuseni Natural Park. It is known that different landuse types show their influence on the runoff coefficient, flow velocity on the slopes, time of concentration and maximum discharge.

Thus, for a large afforestation degree we have a small runoff coefficient that suggests that the occurrence of floods is more reduced, but the land with a small afforestation degree has an increased runoff coefficient and the risk of floods caused by hillslope runoff grows.

Through analysis of spatial changes in the Apuseni National Park for the 1988-2000 period significant deforestation is shown in the upper basin of the Somesul Cald upstream from Smida and in upper basin of Belis upstream from Poiana Horea (deforestation rate approx. 4%) and in the upper basin of Albac nearby Horea village (deforestation rate reaching 15%).

Using these methods on more recent data could help in making decisions easier and taking measures that can be applied in the Apuseni Natural Park, to prevent its degradation.

Aknowledgements

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REFERENCES

Bejan I., (2009), *Studiu spaţial privind utilizarea terenurilor în Republica Moldova*, Academia De Studii Economice Din Moldova, Chişinău.

Domniţa M., Crăciun A.I, Haidu I., Magyari-Sáska Zs., (2010), *Geographical Information System module for deriving the flash flood hydrograph in mountainous areas*. Proceedings of the 4th European Computing Conference. Published by WSEAS Press. ISSN: 1790-5117, ISBN: 978-960-474-178-6. pp. 260-265.

Haidu I., Haidu C. (1998), *S.I.G. - Analiză spaţială*, Editura *H*G*A*, Bucureşti.

Imbroane A.M., Moore D., (1999), *Iniţiere în GIS şi Teledetecţie*, Presa Universitară Clujană, Cluj-Napoca.

Johnson, A.B. et al., (2002), ***"****Remote Sensing, GIS, and Land Use and Land Cover Mapping Along the I-10 Corridor****,"*** Proceedings of the 15th William T. Pecora Memorial Remote Sensing Symposium/Landsatellite Information IV Conference (CD), Denver Colorado.

Pant D.N. et al., (2000), *Forest Vegetation/Landuse Change Detection and Impact Assessment in Part of Western Himalaya*, International Achieves of Photogrammetry and Remote Sensing, Vol. XXXIII Part B7, pp 1111-1118.

Podeh, S.S., J. Oladi, M.R. Pormajidian and M.M. Zadeh, (2009), *Forest change detection in the north of iran using TM/ETM+Imagery*, Asian J. Applied Sci., 2: pp. 464-474.

RNP, (2004), *Aspecte Generale Privind Fondul Forestier Al României, La Data De 31.12.2004*, http://www.rosilva.ro/categorie.php?id=4.

Ursu A., Stoleriu C., Sfîca L., Rosca B., (2006), *Adapting the corine land cover nomenclature to the land use specify in Romania*, Geographia Technica, ISSN 1842-5135, No.1, pp. 193-198.

http://landsat.usgs.gov

http://www.ittvis.com/ProductServices/ENVI.aspx

http://www.mmediu.ro/vechi/departament_ape/biodiversitate/rezervatii_parcuri_nationale.htm

http://www.parcapuseni.ro/

GIS APPROACH IN TOURISM MANAGEMENT IN NATIONAL PARK BERCHTESGADEN (BAYERN, GERMANY)

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ABSTRACT:
This paper examines and reflects on GIS approach in management of environmental impacts of tourism. We stress that the focus is on National park Berchtesgaden as a case study for this research, and accept at the outset that the approaches discussed are necessarily partial and would only form part of a wider sustainability assessment. However, we argue that the selected approaches are useful in assisting with the different organizational challenges and questions facing nature protected area managers who wish to understand the environmental consequences of tourism. Environmental impacts are analyzed through their indicators. The paper shows how GIS has been used to assess the environmental impacts of tourism in the National park Berchtesgaden, and then examines overlapping of layers and input of environmental indicators to provide useful insights into understanding the environmental effects of tourism within the nature protected area.

Keywords: *GIS, National Park Berchtesgaden, sustainability, tourism management, environmental impacts.*

1. INTRODUCTION

In early phases of tourism development it was believed that tourism itself is a "green industry". Growing number of tourists affected in higher pollution of the environment, so in the seventies the global awareness of pollution hazard grew as well as knowledge of negative impacts of tourism on the environment. Tourism and leisure activities are followed by a number of complementary activities that are indirectly related to tourism industry. Leisure activities and satisfaction of tourists is directly related to quality of the natural resources. Therefore, tourism and environment compose a unique symbiosis. Man's impact on the natural systems has made very many plant and animal species lose their habitat and living conditions, becoming extinct long before their genetic potential and usefulness could be assessed.

2. THE DEVELOPMENT OF INDICATORS FOR SUSTAINABLE TOURISM

In 2008 there have been 924,1 million of registered tourist visits (World Tourism Organisation). Even though a global activity of this scale can be assumed to have a substantial impact on the environment, its consequences have never been assessed and quantified (*Gössling, 2002*). Many environmental indicators have been accepted within the tourism industry. However while purporting to represent the environment, indicator research fails to evaluate the environmental impact of tourism (*Hughes, 2002*). There are many indicators that reflect economic growth and welfare, but they do not show the

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sustainability and the environmental impact of economic growth. Unlike socio-economic indicators that are acknowledged as précised, environmental indicators are facing difficulties to be quantified. Another challenge is to bring the theory into practice. Their uncertainty of managing the environmental impact of tourism makes them hard to be delivered. Therefore, indicators of environmental impact of tourism are necessary to accurately and precisely determine them, whether they are positive or negative. The attempt to measure sustainability has to face some conceptual challenges:

1. The concept of sustainability is not univocally defined and efforts to measure it are difficult to implement;
2. Sustainability is not a universal concept, it may be influenced by local environmental, social and economic contexts which may require more attention to be paid to specific aspects over others;
3. Legal compliance is not enough to define a sustainable model of development and, in many cases, is difficult to achieve (*Castellani and Sala, 2009*).

Carrying capacity is the most complex concept in both theory and practice of tourism. It represents the maximum number of tourists visiting a destination without a negative impact on the environment on one hand and satisfaction of tourists on other. For World Tourism Organisation, carrying capacity is fundamental for environmental protection and sustainable development. It represents the sum of ecological, social, psychological and economical aspects. Limiting factor of wider implementation of carrying capacity is the difficulty of its determination (*Stojanović, 2006*).

Table 1. *Carrying capacity of destinations and leisure activities in the EU*
(Source: *Jovičić, 2006*)

Destination/ Leisure activity		Carrying capacity
Seaside destination	Mediterranean	3 m^2/person
	North Sea	1,7 m^2/person
	Sailing	5-30 tourists/ha
	Fishing	5-30 tourists /ha
	Water skiing	5-15 tourists /ha
Mountain destination	Ski sports	100 tourists/ha
Nature protected area	Forest	15 tourists/ha
	Park in an urban area	15- 17 tourists/ha
	Hiking	40 tourists/ km of trail
	Horseback riding	20- 80 tourists/ km of trail
	Large picnic	300-600 tourists/ ha
	Small picnic	60- 200 tourists/ ha

The Carrying Capacity indicator is closely related to Limit of Acceptable Change. This model informs the management whether the conditions are in the limit of acceptable standards, meaning that the current number of tourists and nature of their activities are in frame of the capacity of the host destination. Once the limits of acceptable change have been reached, it means that the capacity of the destination under current management model has also been reached. Limit of Acceptable Change includes a set of indicators reflecting the environment, that are consisted of natural resources, economic criteria, attitude of local population and tourists. This model faces technical difficulties in compatibility with the quality assessment of tourism development. Also, this model requires structural system planning and large quantity of skilled labor and capital in order to implement, monitor and evaluate it through all phases. Ecological impact assessment method should also be mentioned. It provides the management assessment of possible ecological impact of their actions. The problems connected to this indicator are variable methodologies, unprecised timetable of long-term effects and question of objectivity (*Stojanović, 2006*).

One of the most widespread indicators is the ecological footprint. The ecological footprint is specifically designed to express aggregate environmental impact in terms of pressure on the global biosphere, and can account for travel-related impact components (*Collin et al., 2009*). The ecological footprint provides an aggregate estimate of demands upon the biophysical productivity and waste assimilation capacity of nature imposed by human lifestyles. A much used benchmark for comparison in ecological footprint studies is the so-called "fair earth share" value; i.e. the global average area of productive land/sea space available annually on a per capita basis (*Hunte and Shaw, 2007*). This indicator was created to measure the impacts on a global scale, and not on specific tourism related components. Very little attempt has been made to examine ecological footprint in this context.

Hughes (*2002*) defines three categories of indicators to reflect differing policy needs. These are termed "corporate indices", "national level indicators", and "site or destination specific indicators". This three- category division forms the top level of the hierarchy of indicators.

Since nature protected areas are of special interest and significance for tourists, Europarc Federation has presented European Principles for Sustainable Tourism in Protected Areas. The Charter is consisted of ten principles:

Working in partnership

1. To involve all those implicated by tourism in and around the protected area in its development and management

Preparing and implementing a strategy

2. To prepare and implement a sustainable tourism strategy and action plan for the protected area

Addressing key issues

3. To protect and enhance the area's natural and cultural heritage, for and through tourism, and to protect it from excessive tourism development
4. To provide all visitors with a high quality experience in all aspects of their visit
5. To communicate effectively to visitors about the special qualities of the area
6. To encourage specific tourism products which enable discovery and understanding of the area
7. To increase knowledge of the protected area and sustainability issues amongst all those involved in tourism
8. To ensure that tourism supports and does not reduce the quality of life of local residents
9. To increase benefits from tourism to the local economy
10. To monitor and influence visitor flows to reduce negative impacts (*Europarc, 1995*).

Based on the Charter Principles, *Castellani and Sala* (*2009*) have defined Sustainable Performance Index (SPI), which is an integrated index composed of 20 indicators concerned with: demographic dynamics; economic and social conditions of local communities; environmental factors and tourism characteristics of the region under investigation. These indicators are:

1. Net migration
2. Old-age index
3. Level of education
4. Rate of houses not owned from resident people
5. Number of local unit in services sector
6. Voluntary work
7. Number of daily routes of public transport
8. Employment rate
9. Number of enterprises with ISO 14001 or EMAS certificate.
10. Rate of new enterprises survived after 18 months from birth
11. Female entrepreneurship
12. Rate of commuting population
13. Per-capita value added
14. Urbanisation
15. Production of energy from renewable sources
16. Ecological state of fresh water
17. % of separate waste collection
18. % of farming area occupied by organic farming
19. Overnights
20. Number of bed& breakfast and agritourism/ total number of hospitality structures

Gössling (2002) has defined changes in land cover and land use by calculating the area required for tourism using land use per bed as an indicator. Land use per bed is a measure of the area required for a hotel at ground level, including gardens, parking sites, swimming pools, etc. divided by the total number of beds. However, this indicator only shows the changes of land use under that was directly changed by a construction of accommodation facility, neglecting the indirect changes.

3. STUDY AREA

National Park Berchtesgaden is located in southeast Germany, in Bavaria, on the border with Austria (**Fig. 1**). It covers an area of 20808 ha and it is with whole of its surface in the Berchtesgaden Alps region. Berchtesgaden is a nature protected area since 1910 and as such it is the oldest nature protected area in Germany. It was proclaimed a national park in 1978. Berchtesgaden is also the oldest tourism destination in the Alps. Since the 19th century tourism as we know it today started its development here.

Tourism was especially promoted by the Bavarian royal family, which had a villa and a hunting lodge here. Today's equivalent of a destination management organisation- Verschönerungsverein, was founded in 1871. Alpine club Berchtesgaden (German Alpine Association- Berchtesgaden entity) was founded in 1875. They are responsible for the development of alpinism and construction of first accommodation facilities. Alp tourism was booming, so Berchtesgaden became one of the most popular destinations of that period. Along with the tourism development, there have been structural changes in the economy of Berchtesgaden. Tourism sector became more significant to traditional salt mining, forestry and even agriculture (*Nationalparkplan, 2001*).

Fig. 1 Position of National Park Berchtesgaden
(Source: *www.wikipwedia.com*)

4. CREATION OF GIS DATABASES

Three maps were available for digitization at scales 1:50.000. The maps which represent different phenomenon's, produced in 2001 by Bavarian State Ministry for Environment and Development country was used as the data source for digitizing the various data layers required. Most of the data sets were obtained from the National Park documents. The authors used ArcGIS 9.3 software. A first step in creation of GIS database was to input borders of different protection zones (core zone, temporary protection zone, buffer zone). Second step was to input various data sets of physical features and park amenities (ski area, hiking area, sanitary hunting area, zone of tourism events and zones of wildlife protections. Representing all layers in one map (collected from three different maps) which shows different phenomenon's, by layers overlapping some conclusions are obtained.

5. RESULTS AND CONCLUSION

Management of National Park Berchtesgaden has developed maps in *Nationalparkplan* (*2001*) that define zones of certain leisure and other activities. GIS are instruments that helps the specialists to analyse and identify natural protected areas from the environment point of view (*Herisanu and Zavoianu, 2006*). Using GIS in management is also an advantage because it creates a complex database that is easy to manipulate, that allows for the organization and update of the information (*Haidu et al., 2009*).

On several separate maps zones of nature protection, skiing, hunting, events, land and water recover and, flora and fauna protection are defined. Using zoning methodology together with carrying capacity prevents negative changes in land cover and land use. This means that areas with a nature protection priority should be excluded from tourism development, whereas other zones should have limited tourism development, preventing negative changes of mass tourism. By using zoning methodology, most popular locations are relieved from pressure of mass tourism by promoting other less known locations with same or similar tourism value. This way, tourists are equally distributed in the national park area which minimizes the risk of negative impacts. Apart from this, zoning allows to physically separate incompatible zones (e.g. when development in one leads to degradation in other zone). However, if all these zones are presented together, certain overlapping is noticeable that point out oversights in national park management. So, on **Fig. 2** there is overlapping of layers representing zone of rest and peace for the deer and the zone of tourist events.

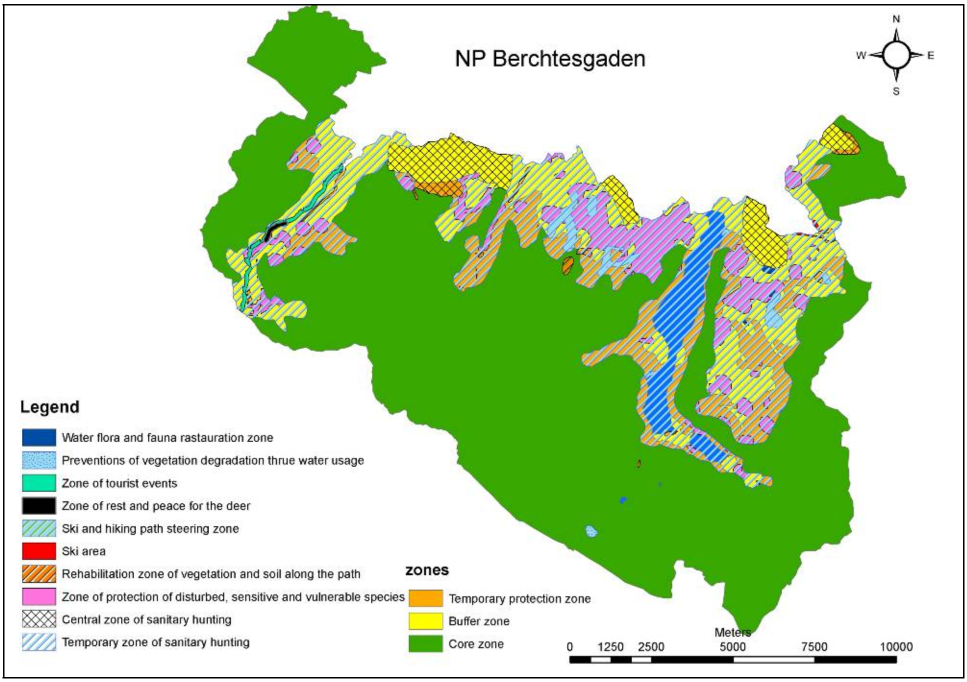

Fig. 2 Overlapping of layers in National Park Berthesgaden

Deer game is due to breeding and mating most sensitive in the summer period or from May to October to be more précised. This is also a tourism high season, so it is necessary to avoid this overlapping. In this particular case it would mean relocation of the event zone to provide peace and rest so needed for deer game. In the same manner, protection zone of disturbed, sensitive and vulnerable species overlaps the ski and hiking path steering zone. It is virtually impossible to have both of these activities in the same area due to their incompatibility. Since ski and hiking path already exist, protection zone of disturbed, sensitive and vulnerable species should be relocated to some area far away from leisure activities. Some oversights can also be noticed in zone of rehabilitation of vegetation and soil along the ski and hiking paths and the steering zone. Most of these zones are in the buffer area, but some parts of these zones enter the core area, where any human activity is not recommended. Therefore the authors suggest shrinking these zones and giving up the surface entering core area. Overlapping the layers also revealed overlaps of sanitary hunting zone, event zone and skiing zone. For safety reasons it is necessary to surround hunting area with a buffer zone of at least 500m width from tourist gathering locations.

REFERENCES

Bayerisches Staatministerium für Landesentwicklung und Umweltfragen, (2001), *Nationalpark Berchtesgaden Nationalparkplan,* Freistaat Bayern, München.

Castellani V., Sala S., (2009), *Sustainable performance index for tourism policy development*, Tourism Management, pp. 1-10 (Article in press).

Collins A., Jones C., Munday M. (2009), *Assessing the environmental impacts of mega sporting events: Two options?,* Tourism Management 30, pp. 828–837.

Europarc Federation, (1995), *European charter for sustainable tourism in protected areas*, Grafenau, Germany.

Gössling S., (2002), *Global environmental consequences of tourism*, Global Environmental Change, Vol. 12, pp. 283–302.

Haidu I., Crăciun A. I., Lupău C., Şerban C., (2009), *Using GIS in order to detect the optimal areas for dedicated advertising – The Oradea city case*, Geographia Technica No. 1/2009, pp. 40-49.

Herişanu Gh., Zăvoianu I., (2006), *Using Geographical Information Systems in the management of protected natural areas*, Geographia Technica, No. 2/2006, pp. 43-48.

Hughes G., (2002), *Environmental Indicators,* Annals of Tourism Research, Vol. 29, No. 2, pp. 457–477.

Hunter C., Shaw J., (2007), *The ecological footprint as a key indicator of sustainable tourism*, Tourism Management Nr. 28, pp. 46-57.

Jovičić D., (2000), *Tourism and environment-sustainable development concept*, Zadužbina Andrejević, Beograd (in Serbian).

Stojanović V., (2006), *Sustainable development of tourism and environment,* University of Novi Sad, Faculty of Science, Department of Geography, Tourism and Hotel Management. Novi Sad, pp.178.

www.unwto.com

www.wikipedia.org

THE GEOGRAPHICAL INFORMATION SYSTEM FOR THE STUDY AND THE EVALUATION OF THE QUALITY SURFACE WATER IN TAFNA RIVER'S CATCHMENT IN THE WEST OF ALGERIA

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ABSTRACT:
The present study fits with an important step into the country development and its hydrous capacity valorization. For that purpose, an evaluation study of surface water quality of Tafna catchment's basin was accomplished. Within the framework of this study, we propose to elaborate a water surface quality maps based on the physic-chemical quality calculation Global Quality Index (GQI). Considering the various indexes and the important amount of data to be handled, we think that it is more judicious to elaborate a computerized program in order to perform an automatic and rapid calculation of different indexes in the time. With the help of the Geographical Information System (GIS) we created a quality maps in accordance with Quality Indexes. The studied has revealed a bad water quality in the whole basin. The registered pollution is of organic type. The main source of water pollution comes from the industrial plants located in the basin.

Keywords: *Tafna catchment, surface water quality, GQI, GIS, maps.*

1. INTRODUCTION

The management of the superficial aquatic quality of the circles requires a good knowledge of their state and their evolution. Thus it's agrees to select among the most successful methods of study towards problems posed and nevertheless compatible with the available means (*Descy, 1992*). The evaluation of the quality of waters of surface answers a double preoccupation: the first one is the protection of the ecosystem and the biological potentialities; the second is the conservation of the resource in waters in quantity and quality with the aim of the satisfaction of certain manners (human food, irrigation, and industrial custom).

- The methods used in the studies of pollution recover typically from two different approaches:

The physic-chemical approach, which consists in the presence of pollutants parameters.

The biological approach which aims at characterizing the pollution by its effects and toxicity on the bodies (*Fawzi et al., 2001*). From an ecological point of view, the quality of a water of surface can be defined on the basis of an appreciation of the distance existing between the current and natural physic-chemical properties.

In this study, it was necessary to check the quality of waters of surface by a method of calculation containing several physic-chemical parameters. The adopted physic-chemical approach is going to lead to actions of cleanup and the application of the regulation in the zone of study.

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The system of evaluation applied in this article was finalized and inspired by the program (PEGASE) planning and Management of the Purification of Waters financed by the Walloon region and on various surrounding areas of researchers.

This system is based on the following principles:

- The evaluation, is made in reference to the natural properties of the water defined by the parametric variables ranges met in stations (resorts) not altered by the studied network.
- The parameters are distributed in various families' correspondents each to a type of pollution determined thanks to value system thresholds.

The types of pollution are integrated into a system of penalties which ends in a global quality indication (GQI) accumulating the various changes.

The procedure of determination of the GQI is established in the form of a program of calculation the result is a global note varying of 1 (excellent quality) in 5 (bad quality).

This system at first was applied to the Walloon's catchment and then was calibrated and validated by an application in the Rhône's catchment (*Descy and Coste, 1988*).

The application of the system on an Algerian's catchment will be the first one in the studies of evaluation of the quality of waters of surface. The degradation of the water quality in the basin will be illustrated in the discussion of the results.

The choice of the catchment of Tafna is justified by its importance in water resource in the Algerian West; the presence of more than 06 dams in exploitation brings us to a rigorous evaluation of the quality of waters of surface, the presence of an industrial plant which participated in the degradation.

2. GENERAL ASPECT OF THE TAFNA BASIN

The Tafna's river catchment, situated in the northwest of Algeria, extends over a surface of 2660 km^2. Tafna River is 170 km in length, takes it source near Sebdou. It feeds the dam of Béni Bahdel, then continuous towards Maghnia to result finally in the beach of Rachgoun near Béni-Saf. It receives the following tributaries: Wade Khemis, Isser, Mouillah, Waderfou, Abbas and Sikkak. We can subdivide the Tafna River into three parts:

- high Tafna, average Tafna and low Tafna (*Achachi, 1997*), from Ouled Ouriach or high Tafna, the Wade is outlined after the junction of several ramifications dug in the Jurassic grounds which come down from crests of 1.500 m in the neighborhood of Sebdou until Sidi Medjahed (*Baba Hamed et al., 2001*).
- Average Tafna, begins to Sidi Medjahed, this part of the catchment is crossed by numerous tributaries among which some are important. On the right bank, Tafna receives Wade Boumessaoud, Zitoun and finally Isser, tributary the most mattering as well by its long course as by its strong flow. On the left bank, tributaries are less important than on the right bank; only Wade Mouillah which originates in Morocco is remarkable by its course and its important flow.
- Low Tafna extends since the gorges of Tahouret up to the sea, on a distance of 20 km; it receives the little important tributaries of east-west direction Wade Lemba and Fed El Ateuch on the right bank and Wade Bendjelloul on the left bank (*Terfous et al., 2001*).

The catchment the Tafna River is characterized by a dry semi climate. The annual average temperature is about 15, 5°C; the warmest two months, in July and August, have an average temperature of 26°C.

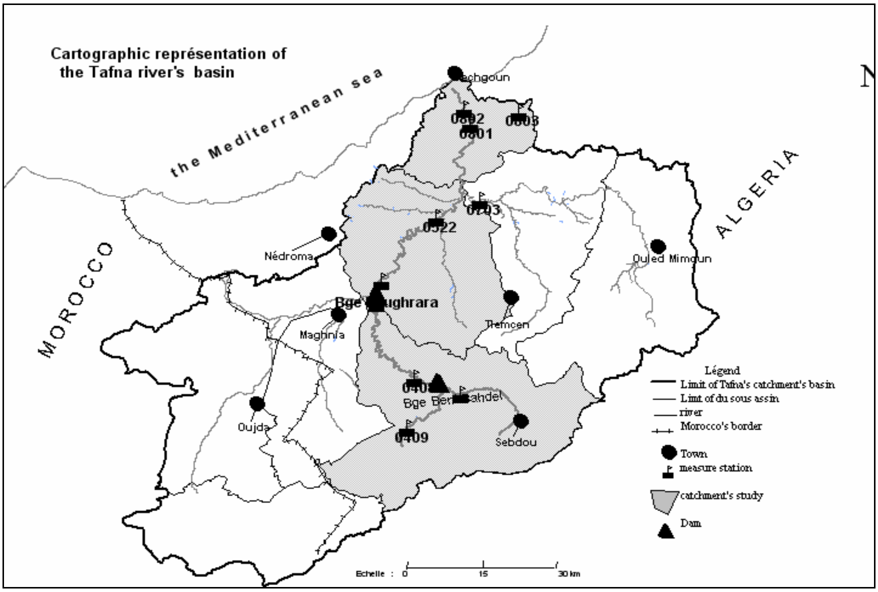

Fig. 1 Cartographic representation of the Tafna's river basin

The pond directed in front of the sudden North the influence of the complex disturbances of the Mediterranean diet. The precipitation is there irregular with relative maxima October and November exceeding easily 100 mm, the minimum being situated in July with a pluviometer appreciably no 1,5 mm) (*Baba Hamed, 2001*).

3. MATERIALS AND METHODS

Our study was essentially based on the physic-chemical analyses made at the level of the Regional laboratory the West of the ANRH. Measures will be made on several stations of the network of surveillance of the quality of superficial waters of the ANRH, implanted along the Tafna River since the source up to the mouth with a frequency of a taking a month over a period going from 2006 till 2008.

The taken samples were placed in flasks in polyethylene and preserved at low temperature in refrigerator, the organoletic parameters, the temperature and the pH are measured on-site, for the determination of the parameters of pollution, and we use generally the sulphuric acid for a better preservation.

The taking is made in glass flasks with injection of Nitric acid. To analyse the heavy metals and the Total Organic Carbon (COT), the chemical parameters were measured in the laboratory according to standardized methods of analysis according to the techniques of analyses of the water (*Rodier, 1996*). The methodology of evaluation of the quality is based on the following principles (*Halen, 1992*):

1. Establish a quality grid of surface water grid.
2. Distribute the various parameters physic chemical in several families corresponding each to a type of pollution **Table 1**.
3. Attribute a note in various changes given by a quality indication, the accumulation of the notes of the various types of pollution is managed by a system of penalties, certain number of points is deducted from an initial total of 100 points.

Table 1. ***Pollution type and physic-chemical parameters used in Global Quality Indic calculation method***

Types of pollution	Index	Parameters
Organic Alteration	Iorg	O_2 dissolved NH_4^+, DBO_5, TOC, DCO
Metals Alteration	Itxm	Cd, Cu, Cr, Hg, Ni, Pb, Zn
Organic compound Altération Toxic Detergents	Itxo	Phénols, Poly Aromatics Hydrocarbon (PAH) Anionics Détergents (MBAS)
Salinity	Isal	SO_4^{2-}, Cl^-, Conductivity

3.1. Determination of the values thresholds

The procedure of determination of the values thresholds in every brought in parameter several factors to know the statistical distribution of the values exposed by (*Halen 1992*). The Algerian standards values are also used the values of SEQ-Eau (*Oudin and Maupas, 1999, Babut et al., 2003*). The chemical parameters were grouped together in several families according to the type of pollution. We know that the following parameters (O_2 dissolved - DCO-DBO5-TOC) are representative of an organic pollution.

Table 2. ***Parameters class limit defining organic change Index (Iorg)***

Class	O_2 (% saturation)	DBO_5 (mg/l O_2)	DCO (mg/l O_2)	TOC (mg/l C)	NH_4 (mg/l N)
1	> 90	< 3	< 20	< 4	< 0,5
2	90 - 70	3– 6	20 - 30	4 – 6,5	0,5 – 1,5
3	70 - 50	6 – 10	30 – 40	6,5 - 9	1,5 – 4
4	50 - 30	10 – 25	40 – 80	9 - 14	4 - 8
5	30	25	80	14	8

We indicated in **Table 2** and **5**, the thresholds values of class for the various parameters determining a type of alteration.

Table 3. ***Heavy metallic concentration class limit in µg/l defining toxic heavy metals (Itxm)***

Class	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1 2 3 4 5	0.009 0.009 – 0.09 0.09 – 0.85 >3	0.36 0.36-3.6 3.6 - 36 > 700	0.27 27 – 2.7 2.7 - 27 > 40	0,007 0,007 – 0,07 0,07 – 3 > 3	1.2 1.2- 12 12-120 > 720	1 1-10 10-100 > 40	1.4 1.4 – 14 14 – 140 >330

3.2. Method of determination of the global quality index (gqi)

For every point of measure and each of the moderate parameters we realize the following stages:

1. We transform every value measured in a value of class referred in the established thresholds presented in **Tables 2** to **5**.
2. We establish the value of class for every parameter by basing itself the average of the value-class "measure" is on the maximum in certain case.
3. We determine the quotation for every type of pollution by referring at most of the values-class obtained for the parameters characterizing the type of pollution.
4. On the basis of the quotation, we establish a penalty see the correspondences quotation penalty for every family **Table 6**.
5. At the end we calculate the value in point (VPO) by deducting the penalties from a total of 100 points given in **Table 7**.

Table 4. ***Other toxic inorganic component class limits in mg/l defining (Itxi)***

Class	F^-	NO_3^{--}	NO_2^-	NH_3	CN
1	0,15	6	0,03	0,005	0,01
3	0,15 – 0,25	6 - 9	0,03 – 0,1	0,005 – 0,025	0,01 – 0,05
4	0,25 - 1	9 - 13	0,1 – 0,5		-
5	>1	>13	0,5 – 1	> 0.025	> 0,05
			1		

3.3. Determination of the quotations and the penalties of the various changes

The organic index of pollution is based on some parameters resulting from organic pollution: Oxygen dissolved (O2), Oxygen Chemical Demand (DCO), ammonia (NH4+), Total Organic Carbon (COT) and the DBO5.

The quotation attributed to the organic index (Iorg) represents the maximum of the values class determined for every parameter where VC is the value of class for each parameter.

$$Iorg = Max\ (VCO2,\ VCDBO5,\ VCOCD,\ VC\ COT,\ VC\ NH4) \qquad (1)$$

Table 5. ***Salinity Class limits (Isal, in mg / l)***

Classe	SO_4^{2-}	Cl^-	Conductivité
1	200	150	400
3	200 - 300	150 - 300	400 - 750
4	300 - 400	300- 500	750 - 1500
5	> 400	> 500	> 3000

The class values for Itxi and Itxo indexes (**Table 1**) will be defined according to the same procedure described for Itxm.

The indexes for toxic substance Itx will be defined by the three toxic substances overall quotation.

Itxm, Itx, Itxo. These indexes are classified according to decreasing quotation:

$$Itx\ 1 > Itx\ 2 \quad > Itx\ 3 \qquad (2)$$

Toxic substances penalty is then defined by the relation:

$$ptx = p«Itx»\ 1 + p«Itx»2 + «Itx»3 \qquad (3)$$

Table 6. ***Penalties for overall quotation calculation with each of the five quality classes***

Classes Indices	1	2	3	4	5
Iorg	0	5	15	30	50
Iepe	0	5	15	25	35
Idet	0	0	0	5	10
Isal	0	0	5	15	30
Itx1	0	0	5	15	30
Itx2 Itx	0	0	5	10	10
Itx3	0	0	5	10	10

3.4. Global quality index (gqi) calculation

GQI index is defined according to the overall quotation value obtained after subtracting from 100 the penalty sum resulting from pollution evaluation.

$$GQI\ (valeur\ points) = 100 - (pIorg + pIepe + pIdet + pIsal) \qquad (4)$$

Table 7. ***Global Quality Index (IQG) points value classification***

QI (Valeur en points)	QI (Classe)
> 80	1
60 - 80	2
40 - 60	3
20 - 40	4
20	5

Once GQI value (1 to 100) is calculated the result must be more simplified it classified in a descriptive category. According to the elaborated classification proposed by (*Descy, 1992*) categories or classes in this study are as follows:

- Class I (Blue colour): Excellent (QI>90): water quality is practically not degraded; conditions are similar to natural water.
- Class II (green colour): Good quality (60<QI<89), low pollution water quality is slightly degraded.
- Class III (Yellow –Green colour): medium quality (40<QI<59), quality water is occasionally degraded, important pollution.

- Class IV (Yellow colour) : poor quality (20<QI<39) , quality water is often degraded , important pollution.
- Class V (Orange colour): bad quality (-20 <QI<19), quality water is almost always degraded, high pollution and cannot be used unless treated at high price.
- Unclassified (Red colour): (QI<-20), water quality is unclassified, pollution is very high and water is extremely degraded **Table 4**.

4. RESULTS AND DISCUSSION

Quality indexes were elaborated on a computerized program basis that allowed studying an important amount of data in according with the method described ahead in order to give an evaluation study of surface water quality.

More the index is higher; more the water point is contaminated, consequently quality of water is affected and a high pollution is present.

We have presented in this **Fig. 2** the Global Quality Index calculation result GQI in accordance to the water quality evaluation method explained underneath, the overall Global Quality Index allows to translate the physical chemical data in one clear and simple appreciation.

The water quality outcome represented by the geographical information system (**Fig. 2**) allows as to the following results:

1. No stations presents quality index 1.
2. Only 12 % of measured stations presents index 2, especially the measure points situated in the Tafna sea basin. This water is considered as good with a very low pollution percentage.
3. Only 4 % of stations present medium quality water with o moderated pollution.
4. 20 % of stations present index 4, this water is of a poor quality with important percentage pollution.
5. 20 % of the stations show index 5, the water quality degradation is important, the pollution is high.
6. 16 % of the stations measured are out of range. The degradation is very high in the Mouillah and Hammam Boughrara basins. These waters are of a very bad quality. We registered very high organic type pollution.
7. The remaining 28 % measured points do not present an index, due to an absence of recent data on these stations, which are difficult to reach.
8. It is a map representation of the Global Quality Index (GQI). We see that most (40 %) of the measured points present a quality index between 4 and 5.

The abundance of the organic pollution could be related to the human activity (factory, spreading of fertilizers), we can see **Fig. 3** map representation of organic pollution (Iorg). The great measured points (44 to 55 %) present a quality index between 4 and 5, showing organic pollution domination on the overall basin and particularly the station close to the living areas as Tlemcen, Maghnia, and Sebdou.

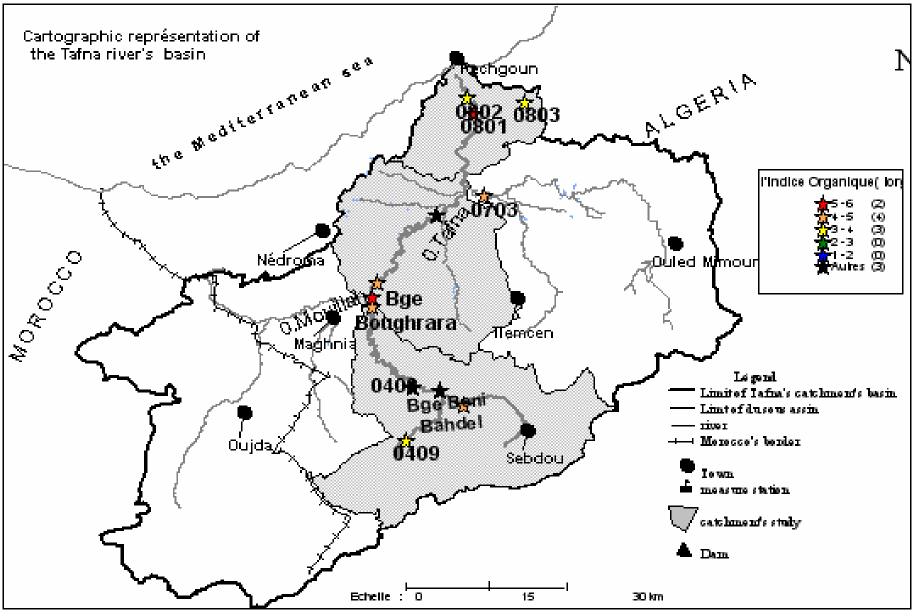

Fig. 2 Overall Organic Index (Iorg) Cartographic Performance

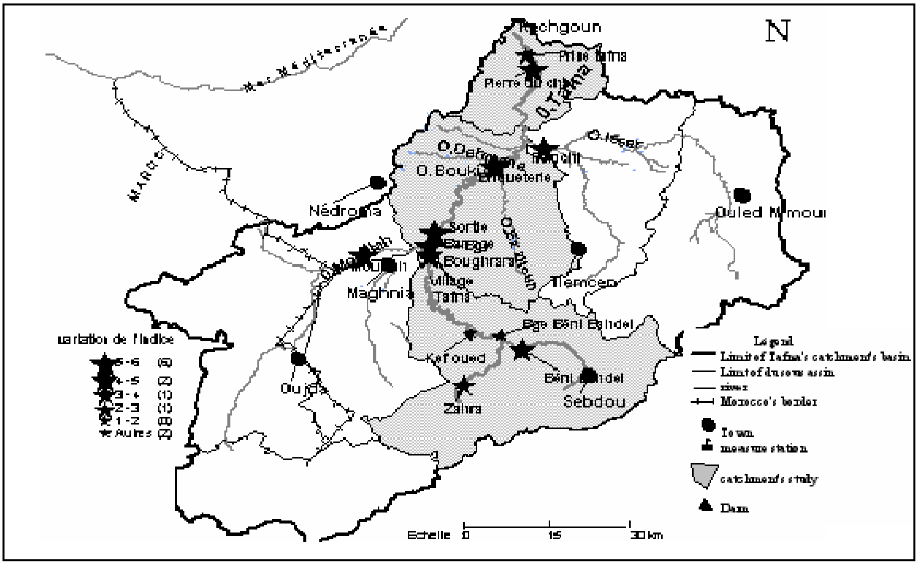

Fig. 3 Representation of organic pollution (Iorg)

This organic pollution is attribute at the first to the industrial and urban waters poured directly in the river without any treatment almost an Insufficient treatment, the second the geographical position of Wade Mouillah which is an common river with Algeria and morocco, this river bring all waste water from the neighbours agglomerations, then the pollution is very high in this river.

5. CONCLUSION

The study of surface water quality of Tafna catchment's basin allowed us to evaluate the surface water pollution range in the region based on the quality index calculation methodology which has revealed:

- The treatment of a various data based on a computerized program in order to give a practical and simple results which is the Global Quality Index GQI.
- Water quality map representation makes easier the use of the Quality Index.
- The quality map created through the GIS revealed a degradation of surface water quality on the whole basin.
- Finally, the water quality study has allowed us to bring out important points to such study:
- Water quality is revealed by the various parameters values taken or various chemical substances where the difficulty to gather all these parameters at the same time.
- Water quality is defined according to the final use.

The study of the quality of surface water of the Tafna's catchment allowed us to estimate the degree of water pollution superficial of the region based on a methodology of calculation of the Global Quality Index which revealed that the treatment of a mass of data very varied with a computer program gave a simple and practical result [3,10], thus the cartographic representation of the quality of water is facilitated by the use of these quality index ,beforehand to know the Organic Quality Index , the salinity Index, the toxic elements Index.

The elaborated quality maps showed a degradation of the quality of waters of surface on the totality of the catchment only 12 % of no measure present IQG = 2 - 3 where from a rather good quality of waters which could be intended for the consumption without expensive treatment, more than 40 % of the points of measure presents good quality of waters which could be intended for the consumption without expensive treatment, more than 40 % of the points of measure presents a GQI varying between 4 and 5 what shows the degradation of the quality of waters on the totality of the catchment and particularly the stations close to towns Maghnia, Tlemcen, Sebdou where are poured the urban and industrial waste water, without forgetting the contributions of the oued Mouillah loaded (charged) in organic pollution coming from morocco.

The realization of such a synthesis on the quality of waters allowed us to rerelease the indispensable points and the difficulties met in such a study, to note that the quality of waters is appreciated by the values taken by multiple parameters or chemical elements highly varied where from the difficulty bringing in all these parameters at the same time.

The classification makes intervene also the manners of the water, what allows to minimize the cost of the treatment and to limit the wasting of good quality waters and to prevent the pollution risk (*Babut et al., 2006*).

The diagnosis is then rapidly, this method can be generalized to several parameters by calculating indexes for different type of pollution, which requires a chemicals analyses data base which can be treated by our program then we can have different view of water quality.

REFERENCES

Achachi A., (1997), *Etude Hydrogéologique des Monts de Tlemcen*, Agence Nationale des Ressources.

Baba Hamed K., et al, (2001), *Analyse des crues de l'Oued Isser (Tafna.NW Algeria),* National Meeting on Water, Univ. Tlemcen, Algérie, pp. 49-55.

Baba Hamed K., (2001), *Contribution à l'étude hydrographique de trois sous bassins de la Tafna (Sebdou, Mouillah, Isser)*, Magister, Univ. Tlemcen, Algérie, pp. 7, 27-40.

Babut M., Bonnet C., Bray M., Flammarion P., Garric J., Golaszewski G., (2003), *Elaboration of Environmental Quality Standards for various pesticides and priority pollutants for French freshwaters,* Journal of Environmental Management, 69, pp. 139-147.

Babut M. P., Hélène Delmas, Bray M., Durrieu C., Yves Perrodin, Jeanne Garric, (2006), *Characterizing the risks to aquatic ecosystems: a tentative approach in the context of freshwater dredged materials disposal*, Integrated Environmental Assessment & Management, 2, 4, pp. 330-343.

Descy J.P., Coste L., (1988), *Application d'un nouvel indice diatomique (indice CEE 88) au réseau national de bassin Rhône-Méditerrannée–Corse,* A.E Report. Rhône-Méditerrannée-Corse, 86, pp. 83.

Descy J.P., (1992), *Qualité des eaux de surface en Wallonie. Compte rendu coll,* A.U.E. Nov. 1991, Tribune de l'Eau n°555, 1992, pp. 53- 57.

Fawzi B. and al., (2001), *Application de certains indices diatomiques à un cours d'eau marocain Oued Hassa,* Rev. Sci. Eau, 14/1, pp. 73-89.

Halen H., (1992), *Méthodologie pour l'appréciation de la qualité physico-chimique des eaux de surface,* Tribune de l'eau N°555/1, pp. 61-71.

Oudin, L.C., Maupas, D., (1999), *Système d'évaluation de la qualité´ de l'eau des cours d'eau*, Rapport de présentation SEQ-Eau (version1), Agences de l'eau Orle´ans, pp. 59.

Rodier J., (1996), *L'analyse de l'eau,* 8ème édition; DUNOD, PARIS.

Terfous A., Megnounif A., Bouanani A., (2001), *Etude du transport solide en suspension dans l'oued Mouillah (Nord-Ouest algérien),* Rev. Sci. Eau 14/2, pp. 173-85.

EXTREME RAINFALL EVENTS AND THE FLOODING PHENOMENON IN BANGUI CITY

Cyr Gervais ETÉNÉ[1], Michel BOKO[1]

ABSTRACT :
This study aims to analyse the environment vulnerability of Bangui, when faced to extreme rainy events. It analyzes the frequency and the magnitude of the rainfall extremes that are likely to represent climatic risks for the town of Bangui. The determining process as well as the analysis of the extreme rainfalls was done by employing the Extreme Value Theory (EVT). The series of maximum annual depth of rain in 24 hours show a frequency increase of 3% for the extreme rainy events over the period spanning from 1990 to 2005. Some of the suggested strategies are the improvement of the drain systems and the use of techniques leading to better infiltration.

Keywords: *Bangui, rainfall, events extreme, flood, impacts.*

1. INTRODUCTION

At a planetary level, the climatic and meteorological extremes are ceaselessly breaking the record values. Their unexpected violence leads to material loss, damages caused to the environment and above all, to the loss of human lives.

If the damage caused by extreme rainfall events hasn't yet reached to an alarming degree in the Central African Republic, it doesn't mean that the country registers no destructive rainfall events. As proof stand the rainfall events in August 1990 (115,6 mm) and July 2000 (108 mm) as well as the research studies on the Central African Republic, studies conducted by *Kokamy-Yambere* (*1994*), *Nguimalet* (*2004*) and *Eténé* (*2007*), showing the vulnerability of the country when faced with these events. Even more vulnerable is the city of Bangui, due to its geographical location and its morphostructural and geomorphological characteristics.

Recent study regarding variability of spatio-temporal precipitations influence over the floods in Benin was realised by Amoussou et al. (2009).

Having as geographical coordonates 4°22'00'' North and 18°35'00'' East (**Fig. 1**), the city of Bangui has been registering an important number of extreme rainfall events. According to the IPPC (2001) cited by *Houndakinnou (2005)*, the number of extreme rainfall events will probably increase in the following decades. In addition, Bubois (2004) stated that, in all likelihood, the frequency of extreme rainfall increased during the second half of the XXth century. Actually, the city of Bangui is already vulnerable to the normal quantities of rainfall (*Bomba, 1999 et Eténé, 2007*), therefore, even more so to the extreme rainfall events and their problematic consequences (flooding, runoff, erosion, etc).

Having taken into account the people's difficulties when dealing with the extreme quantities of rain, the presents study focuses on the impact the phenomenon has on the physical and human environment of the city.

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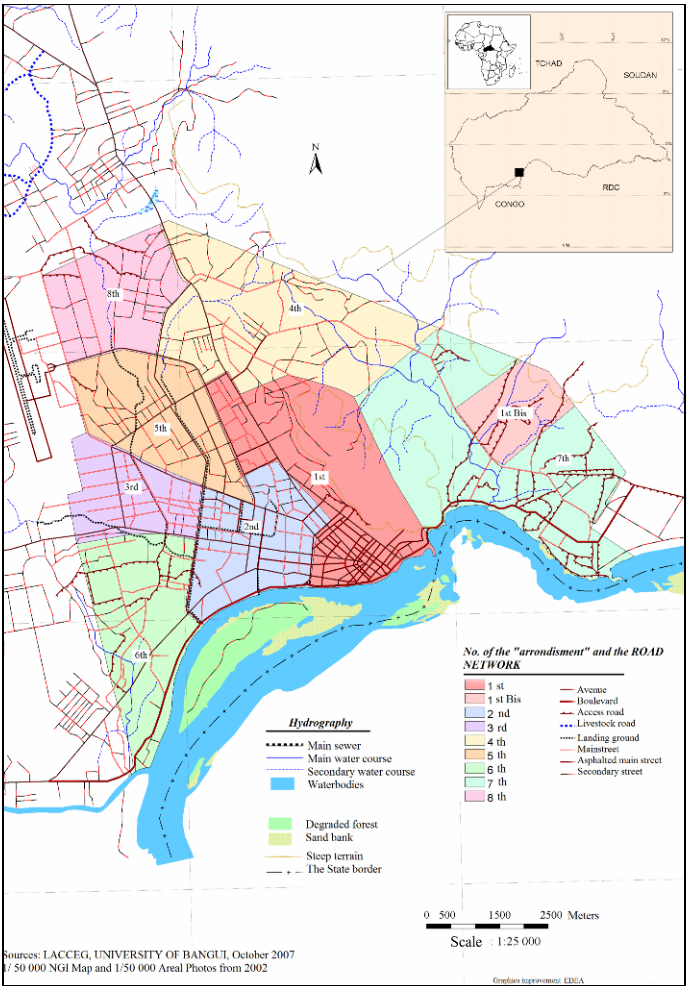

Fig. 1 Localization of Bangui City

2. DATA AND METHODOLOGY

The analyzed data consists of the vertical depth of water and the number of rainy days from the year 1990 to 2005. The data was supplied by the Agency for Air Navigation Safety in Africa and Madagascar, in Bangui (ASECNA-Bangui) and by the Central African Institute for Agronomic Research. The information on environmental damage was gathered either directly from the field or was supplied by the Central African Red Cross.

Field observations focused on the settlements most vulnerable to floods. There had been several criteria according to which the sites to conduct the interviews had been chosen, namely: areas with high densities, the slums, and areas with drain systems. Therefore 07 city neighborhoods were chosen: Miskine, Combattant, Gbakodja, Yangato, Kokoro, Bruxelles and Yapélé.

The interviewees were 90 people, older than 20 and who had a perfect knowledge of their city (wise men, neighborhood chiefs, sanitation technicians, etc.). The investigations were related to the storm water runoff, floods and their impact on the physical and human environment.

The study of the extreme values distribution was done according to the Extreme Value Theory (EVT). The distribution of extreme values expressed as percentiles has led to identifying the maximum and minimum values of the maximum annual depth (*Fallot and Hertig*, *2009*). Therefore the Extreme Value Theory is expressed under the form shown below:

Be it $X_1, \ldots, X_n$ the series of maximum annual precipitation depth in 24h. If these values are independent and have an even distribution and if F_x (.) is the distribution function for the X_t values, then $Pr(M_n < x) = Pr(Max(X1, \ldots, X_n) < x) = Pr(X_1 < x, \ldots, X_n < x) = (F_x(x))^n$. And $M_n = Max(X_1, \ldots, X_n) = - Min(-X_1, \ldots, - X_n)$.

The process of compiling a series of extreme values supposes, on one hand, the gathering of annual maximum vertical depth of water data series and on the other, the gathering of the annual exceeding values. This second operation consists in choosing all the values above a precise threshold (40 mm), namely the highest "n" measured values in "N" years.

So as to evaluate the impacts on the environment components affected by extreme rainfall events, Kates' incidence approach (1985) was employed. It uses the direct "cause-and-effect" link (**Fig. 2**).

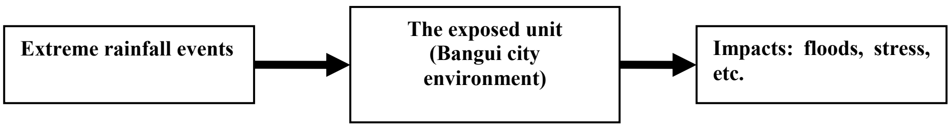

Fig. 2 The incidence approach adapted by Kates (1985) in CARTER, 1995.

These research methods regarding the consequences that the extreme rainfall quantities have on the physical and human environment of Bangui has led to several results.

3. RESULTS

3.1. The frequency of extreme rainfall events in Bangui

The frequency analysis for the extreme values and the critical threshold established for the city of Bangui are presented in **Fig. 3** and **4**.

Fig. 3 represents the frequency of maximum annual depth of water in 24 hours in Bangui for the period 1990-2005. An analysis of the figure shows that the minimum values (40 mm) have an occurrence frequency of 2% at this station. The maximum of the extreme values (values higher than 150 mm) have an occurrence frequency between 2% to 4 %. As the extreme maximum values for the city of Bangui have an occurrence frequency superior or equal to 2, there is evidence for the significant increase of 3% in frequency.

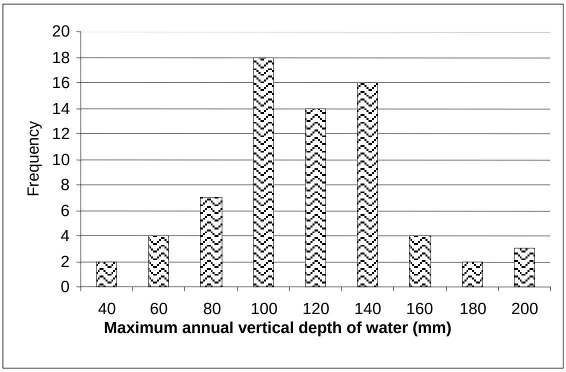

Fig. 3 Frequency of extreme rainfall events in Bangui (1990-2005)

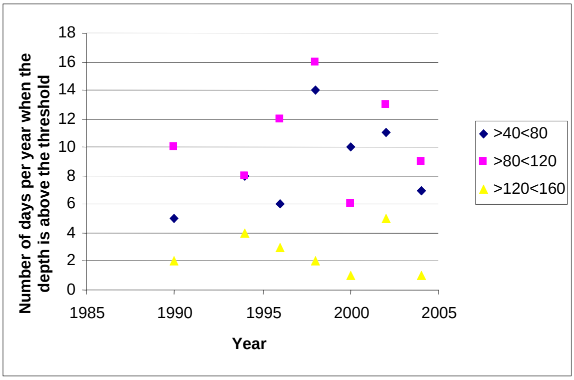

Fig. 4 The number of daily rains per year above the established threshold for Bangui

The frequency analysis shows that most of the rain events in Bangui City register in between 100 mm to 150 mm vertical depth of water. Exceptional rain events register more than 150 mm. Generally, the extreme rainfall events are on the increase.

The limit value that can be considered as critical for Bangui city is indicated in **Fig. 4**. This critical value has been determined by taking into consideration the morphostructural and topographic conditions. **Fig. 4** shows the number of days in a year during which the maximum annual depth of water has passed 40 mm (representing the critical value for the city of Bangui). It is obvious that a 40 mm rainfall occurring at the end of the dry season, or at the beginning of the rainy season, can't lead to severe flooding as at the end of the dry season the ground water levels are low. On the contrary, when these rainfall events occur during the rainy season or at the end of it, they become extreme rainfall events as the soil is already saturated.

In conclusion, the extreme rainfall events produce a higher amount of damage in the Bangui city than the regular rainfall events do. The impacts they have and the protection measures needed have to be pondered on.

3.2. The impact of extreme rainfall events in the city of Bangui

The extreme rainfall events cause important damage to the urban environment of Bangui. The nature and the importance of these damages are different, but the most dramatic impact is the flooding of the city. As there is the cause-effect relationship, there are several other impacts correlated to the flooding of Bangui.

Actually, the threshold analysis has allowed us to determine the critical value (40 mm) starting from which Bangui risks of being inundated.

The flooding in the city, as stated before, is determined especially by the topography, the absence of a drain system and the city's structure. According to *Villien et al*, *1990*, the South-West part of the city (Sango, Yapélé, Kpéténé, etc.) has only an insignificant slope degree (from 0% to 1%). The very rare pieces of land presenting small degrees of slope form depressions that turn into natural reservoirs. Furthermore, the ground water levels are situated at less than one meter underground. All these characteristics determine a small level of runoff and infiltration. Therefore, during the rainfall events, the neighborhoods of the city are rapidly flooded (**Fig. 5a** and **5b**).

Fig. 5 Flooding of the Kpéténé neighbourhood (a) and Flooded house in Yapélé (b)
(By: *Eténé, October 2007*)

Moreover, the urban development resulted in the increase in waterproof surfaces. The absence of urban planning can be clearly seen as the development of the city resulted in the building of roads at higher levels than that of the neighboring houses. In addition, the insufficient network of the drain system and the poor maintenance of it in the areas where it actually exists, leave the city vulnerable to flooding.

According to 65% of the interviewed people, 2/3 of the roads and streets of the city are flooded and at most of the times unusable due to the extreme rainfall events (**Fig. 6a** and **6b** have been taken after a rainfall event with a water depth of 112,6 mm, in October 2007). Logically, this leads to material and even human loss.

Regarding the human and material damages, around 10 000 riverside residents of Oubangui River were victims of the October 1999 flooding as well as of the one in 2005 when 3000 houses collapsed, leaving around 20 000 people without shelter in the Central African capital city (*www.sangonet.com* and *Nguimalet, 2005*). The most affected neighborhoods are Bruxelles, Langbassi, Sango, Kokoro, Yapélé.

Fig. 6 Flooding on street «de France» (a), Flooding of the Martyrs' Boulevard (b)
(By: *Eténé, October 2007*)

3.3. Adaptation strategies

Adaptation measures to extreme rainfall events, can lead to a decrease of incidents, but they need major investments. The capacity to adapt and to face the impacts of the extreme rainfall events is proportional to the existing financial possibilities, scientific and technical knowledge, information and unexpected skills.

The exposed Bangui population has developed reaction adaptation strategies. They have acquired experience related to the construction of their habitat. The people in the flood-exposed neighborhoods like Gbakodja, Kpéténè, Yapélé, Combatant, etc, build the house foundations at a maximum height to avoid, as much as possible, the flooding of their homes. Structural measures such as cleaning the drainage outlets and building drainage ditches are foreseen as well. The state has already built water collectors that drain the runoff towards the Oubangui River.

Nevertheless, all these strategies have only a limited effect. Hence, for effective prevention it is important that the state take measures so that the lodging legislation is respected, the building norms are applied, houses are relocated and to create a schema for water planning and management.

4. CONCLUSION

This research shows that extreme rainfall events associated with the soil type, the topography etc. give a reasonable explanation for the amplified flood phenomenon taking place on a yearly basis in Bangui city.

Rainfall data over the investigated period (1990-2005) shows an increased frequency of the extreme rainfall events (3%). This increase complies with the forecast of the IPPC (2001).

The impacts of the floods in Bangui city consist of house, roads destruction etc. This type of damage is caused, among many other reasons, by the insufficient drain system network, the absence of a planning and development politics. In this context, reaction adaptation strategies have appeared, among which the improved building techniques and the efficient application of legislative texts regarding housing are worth mentioning.

REFERENCES:

Amousssou E., Camberlin P., Boko M., Perard Jocelyne, (2009), *Impact de la variabilite sur les apports liquides dans la basse Vallee du Mono (Benin, Afrique de L'Ouest),* Geographia Techinca, Numéro spécial, *pp. 35-40*

Etene C. G., Vissin W. E. Et Boko M., (2007), *Vulnérabilité des infrastructures urbaines à l'érosion pluviale dans la ville de Bangui (Centrafrique)*, Actes du 1er colloque de l'UAC des Sciences, Cultures et Technologies, Géographie : p. 23-35, 2007.

Fallot J.M., Hertig J.A., (2009), *Determination de precipitations extremes en Suisse a l'aide d'analyses statistiques*, Geographia Techinca, Numéro spécial, pp. 163-168.

GIEC, (2001), *Bilan 2001 des changements climatiques,* rapport de synthèse, Genève, 308 p.

Houndakinnou G.R., (2005), *Fréquence des événements pluvieux extrêmes et leurs impacts environnementaux dans la ville de Cotonou*, Mémoire de DEA en Gestion de l'Environnement, EDP-FLASH-UAC, 60p.

Kokamy-Yambere S., (1994), *Erosion et dégradation de la colline de Bangui: impacts sur le milieu urbain,* Bilan des trois années d'étude (1991, 1992, 1993). Centre ORST

Nguimalet C. R., (2004), *Le cycle et la gestion de l'eau à Bangui (République Centrafricaine)*, Approche hydro géomorphologique du site d'une capitale africaine. Doctorat Thèse unique, Université Lumière Lyon 2, 442 p.

OM, *Laboratoire de Géologie et d'Hydrologie*, Bangui (RCA) 76 p.

Villien F., Soumille P., Vidal P., Pirovano J.P., (1990), *Bangui, capitale d'un pays enclavé d'Afrique centrale*, Etude historique et géographique. CRET, collection «Pays enclavés», 4, 202 p.

www.sangonet.com

IMPLEMENTING THE ARC HYDRO FRAMEWORK ON THE MUREŞ RIVER, THE PETRIŞ-PĂULIŞ SECTOR

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ABSTRACT:
Implementing the Arc Hydro framework on the Mureş River, the Petriş-Păuliş sector. The Arc Hydro Data Model is applied on the Mureş River by populating the geodatabase with data derived from raster and vector analysis. Through the use of several Arc Hydro Tools, the watersheds of the monitored rivers in the study area are automatically delineated. Finally, the flow direction of the rivers is defined by building a Hydro Network.

Keywords: *Arc Hydro framework, raster analysis, vector analysis, watershed delineation, Hydro Network.*

1. INTRODUCTION

Arc Hydro is a geospatial and temporal data model for water resources, which operates within ArcGIS. Among the several simplified versions of the Arc Hydro Data Model, we will apply the "Arc Hydro framework" on the Inferior Corridor of the Mureş River. Arc Hydro framework stores information about the river network, the watersheds, waterbodies and monitoring points. It is based on ideas and concepts that can be adapted and developed to suit individual applications (*Maidment, 2002*).

This article focuses on the implementation of the Arc Hydro Data Model on the Mureş River, the Petriş-Păuliş sector in Arad County, Romania. With the help of the ArcHydro Tools, automated watershed delineation is made possible. A model was built with the help of ArcGIS Model Builder so as to delineate the watershed for the Mureş River in between Petriş and Păuliş and the two belonging to the tributary rivers where monitoring activity exists, namely Petriş and Troaş. In the last part of the article, a geometric network, called Hydro Network, will be built for the rivers as well as the relationships between the Hydro Network features and Arc Hydro features, hence forming the starting point for water flow simulations in further studies.

Several key terms used in this research and essential for its understanding are explained in the following lines.

A *Data Model* is a model showing how tables, data in those tables and relationships between those tables are handled. Sometimes this is purely to have a clear overview of the process but most of the time models are used so that data can be interpreted by software correctly. Models can be enforced by validation tools. *The Framework* is a collection of tables and relationships that define what data will be inserted in those tables and how they are structured, but without any actual data in them.

The Arc Hydro Data Model is the data model used by the Arc Hydro extension to be able to interpret and calculate data. A *class* is a construct used as a blueprint (or template) to create objects of that class. A *geodatabase feature class* is a special ESRI developed

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class which functions in an object-relational database. Classes function as classes but with the functionality and relation possibilities of a database.

The Arc Hydro framework is applied on the Inferior Mureş River Corridor in Arad county. The Inferior Mureş Corridor spreads South of the Apuseni Mountains, between the settlements Vințu de Jos and Păuliş. From the length of 716 km that the Mureş River registers on Romanian territory, the Inferior Mureş Corridor has a length of 255 km (*Rus, 2006*). The study area is the watershed of the Mureş Corridor in Arad County and the two watersheds belonging to the tributary streams where monitoring activity exists, namely Troaş and Petriş. As Northern limit for the watershed are the Zărand Mountains and the the Săvârşin Mountains ridges, the latter representing a subdivision of the Metaliferi Mountains. In the South, the limit is composed by the highest altitude contour line in the Lipova Hills. The Eastern border is Petriş and the Western one is Păuliş.

2. THE APPLICATION

In the present study, the Arc Hydro geodatabase will be built starting from a Digital Elevation Model (DEM). With the help of raster analysis, the streams and the watersheds for the study area will be delineated, than transformed in vector Arc Hydro features which eventually will be linked to the Hydro Network. These operations are possible thanks to the Arc Hydro Data Model Toolset containing four main functions performing watershed analysis. The functions are: **Terrain Processing** which deals with basic processing of Digital Elevation Models; **Watershed Processing**, which allows watershed and sub-watershed delineation; **Attribute Tools** that assign key attributes to feature classes and **Network Tools** which are used to build geometric networks by connecting the existing points and lines and assigning the features their flow direction.

2.1. Raster Processing

The Arc Hydro Data Model Toolset facilitates the automated delineation of drainage areas on the basis of a land-surface terrain model. The model can be a Digital Elevation Model (DEM) or a Triangulated Irregular Network (TIN) *(Maidment, 2002*).

The watershed for the present study is delineated on the basis of a DEM. A DEM is a grid, or raster of cells whose values represent the surface elevation. DEMs are the most used terrain models for drainage delineation, as due to their regular cell structure they allow a correct defining of drainage flow paths.

The data needed for the building of a DEM for this project was gathered by digitizing the 1:100000 topographic map of Romania. The contour lines of these maps were digitized from 10 to 10 meters for the Mureş Corridor in between Petriş and Păuliş and finally, the DEM for the Mureş River was generated and can be seen in **Fig. 2**. DEMs used in hydrologic analysis are called HydroDEM's (*Djokic, 2008*). A HydroDEM has to assure that the water is flowing from one cell to another. In order to do so the *Fill Sink* function was implemented in the Arc Hydro Toolset, a function able to adjust the height of the cells that are surrounded by others with higher elevations. This prevents the occurrence of unexpected pits in the represented areas.

By using raster operations integrated in the Arc Hydro Toolset and the resulted DEM for the Mureş River, a series of grid layers needed for the watershed delineation are determined one after the other. The Flow Direction grid will serve, generally, as input data for generating other layers. A second raster layer is required as input data as well and it is a layer that resulted from processing the Flow Direction Grid.

The *Flow Direction* grid, the first grid derived on the basis of the DEM, is one of the most important grids as all of the subsequent layers of the present study are determined from it. In the Flow Direction Grid, cells have as values the direction in which the water flows through the respective cells. The algorithm at the basis of these calculations is the eight-direction pour point model. It states that there are at most eight cells adjacent to each individual grid cell in a DEM, hence water in a cell can flow to one or more of its eight adjacent cells according to the slopes of the drainage paths. In ArcGIS, the used variant of the eight-direction pour point model allows water to flow only into one cell, namely along the direction of the steepest descent (*Maidment, 2002*).The resulted map has a legend with eight different numerical codes that represent the cardinal points.

The eight-direction pour point algorithm was applied in the present study, on the Corridor sector of the Mureş River. The results show a Western flow direction for the Mureş River and a South, South-Western flow direction for the tributary rivers on the right side of the Mureş, Troaş and Petriş being among them. On the basis of the Flow Direction, the *Flow* Accumulation grid is calculated. It records the number of cells that drain into an individual cell. The Flow Accumulation grid is the layer needed in order to define streams and it has been determined for the Mureş River as well.

In the next grid, *Stream* Definition, the cells receive two values: 1 or NO DATA. The cells with a value of 1 represent the rivers. The cells value are calculated on the basis of a threshold value, usually set at 1% of the maximum value registered in the Flow Accumulation grid. The Stream Definition grid generated for the Mureş River used the threshold value of 1% from the maximum of the Flow Accumulation registered for the study area. This means that all rivers with a watershed surface larger than 21,03 km^2 were delineated. Troaş and Petriş have a larger watershed than the mentioned threshold hence they were correctly delineated. Hydrometric activity in the studied region exists on another river as well, the Monoroştie River. The small size of the watershed led to an unreliable generated stream network so the Monoroştie watershed delineation won't be the focus of the present study.

The resulted stream network will be divided in distinct stream segments and each of their corresponding catchments will be defined with the help of the Arc Hydro Tools. Stream segments are derived on the basis of the *Stream Segmentation* function. All the cells composing a certain segment share the Grid Code specific for the segment.

The *Catchment Grid Delineation* function creates a raster where each cell has a value, namely the Grid Code that indicates to which catchment the cell belongs to. It is the same Grid Code value as the stream segment from that drainage area. This is possible as the Stream Segmentation grid serves as input data for the process of applying the Catchment Grid Delineation function.

2.2. Vector Processing

Vector processing is the second stage in the delineation of the watershed. It involves the transformation of raster data into vector data and the very important derivation of key attributes for the features in the Arc Hydro Data Model.

Basically, the grids are transformed in feature classes: the Catchment grid is transformed in Catchment polygons, the Stream links into line features called *Drainage Lines* and the outlet cells form *Drainage Points* features (*Maidment, 2002*).

The *Catchment Polygon Processing* function is run so as to transform the Catchment Grid in the Catchment feature class. Regarding the attributes, in the attribute table of Catchment, the GridID field stores the grid value of the associated Catchment Grid. The unique identifier for the Arc Hydro geodatabase, the HydroID, is assigned at this level in the watershed delineation process.

A number of 43 catchments has been determined for the Mureş River in the studied section. By taking a glance at the map we can see that in the lower depression areas the catchment boundaries are constituted from what seem to be straight line segments. D. Maidment, 2002 mentions that the eight-direction pour point model might determine unusual drainage patterns in areas of lower altitudes and *Djokic (2008)*, suggests that in such cases the DEM must be reconditioned.

The following step is the transformation of the Stream segments in *Drainage Line* features. The needed input data are the Stream segments grid and the Flow Direction grid. As a result, the GridID attribute contains the GridID of the corresponding Catchment and the NextDownID contains the HydroID of the next downstream Drainage Line feature. (*Djokic, 2008*).

The Drainage Line generated for the Mureş River Corridor in between Petriş and Păuliş presents problems as well. First of all, the Mureş River shows no signs of meandering in the depressions, when compared to a vector layer of the rivers in the area, extracted from the topographic map of Romania.

Nevertheless the Petriş and Troaş rivers are represented accurately since their drainage areas cover zones with higher altitudes than that of the Mureş. However, by using the Measure tool it can be seen that the outlet of the Petriş River is wrongly determined. Compared to its actual location, the Drainage Line function represents it 1.3 km towards North-East. The Troaş outlet has been determined at 0.3 km towards South than its real location.

The *Adjoint Catchment Processing* followed so as generate the "aggregated upstream catchments from the Catchment feature class" (*Djokic, 2008*). The Adjoint Catchment feature class is a polygon representing the upstream drainage area constructed for each catchment that is not a head catchment. It is a feature class derived on the basis of the Drainage Line and Catchment feature classes.

Several attributes have been added in the attribute table of Drainage Line feature class and Catchment feature class. *Djokic* (*2008*), gives explanations on the meaning of the attributes generated. Adjoint catchment processing added for the Catchment feature class the NextDownID field that contains the HydroID of the next downstream catchment. For the Drainage Line feature class the DrainID field containing the HydroID of the catchment corresponding to the drainage line has been added.

As to what the attributes of the Adjoint Catchment feature class are, the HydroID is the unique identifier of the adjoint catchment and the GridID field contains the GridID of the catchment immediately downstream from the adjoint catchment.

The entire work flow process described so far can be seen in the model in **Fig. 2**.

2.3. Correction methodology

Considering that a more accurate representation of the Catchments and Drainage Lines is needed, a correction of the DEM is necessary as the DEM is the raster on the basis of which all the grids and feature layers are derived.

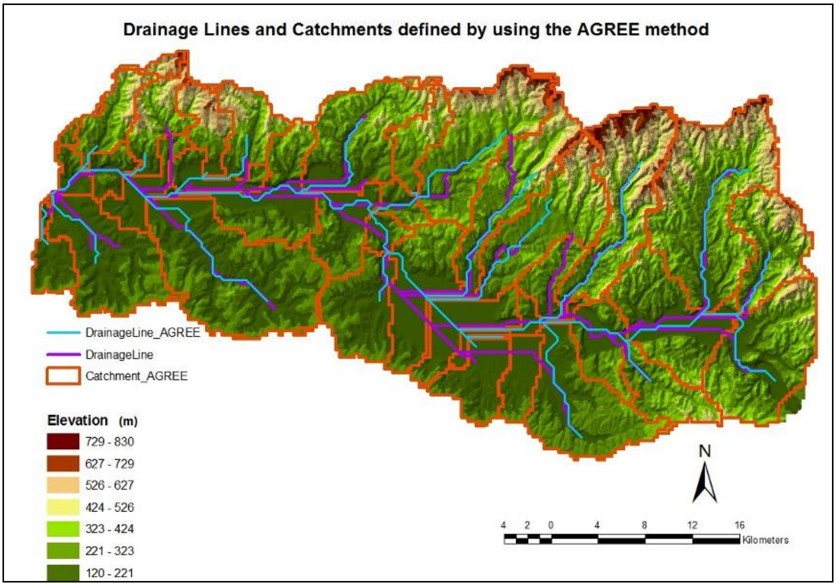

Fig 1. Drainage Lines and Catchments defined by using the AGREE method

Maidment (*2002*), specifies that the eight-direction pour point model might pose problems for calculating the flow direction in flat areas, as the cell being processed might have the same value as its neighbours. Arc Hydro makes use of the AGREE method through its *DEM Reconditioning Burning Streams* function (*Djokic, 2008*). It is a method developed by the University of Texas at Austin in 1997, allowing the user to adjust the elevation of the DEM according to a vector layer, hence using as input data a DEM and a linear feature class. The final result is a more accurate representation of the Flow Direction. In order to define the drainage system all the steps in **Fig. 2** must be repeated.

The AGREE method was applied on the Mureş River Corridor between Petriş and Păuliş. The input data was the DEM and the vector data the river network, digitized from the topographic map of Romania. The result is a visibly more accurate flow path of the Mureş River with some meandering representation problems due to the low altitudes areas (120 m) the river traverses (**Fig. 1**).

2.4. Watershed delineation

The watershed delineation is facilitated by the *Watershed Processing* functions. In order to use them, the aforementioned Terrain Preprocessing functions must be used when buliding a geodatabase starting from a DEM.

So as to delineate a watershed, the *Batch Point Generation* function must be run. It creates the *Batch Point* feature class for which Watersheds will eventually be delineated.

In the present study we started by confirming the name of the Batch Point feature class that we are about to create. For the Mureş River the default name, „BatchPoint" was accepted. The second step was the creation of the four points needed, with several clicks on the map. A dialog box appeared at every click made, box in which the names of the tributary rivers and the Mureş monitoring points were filled in. The points were placed exactly on the location of the monitoring stations.

Once the Batch Points had been established, the watersheds were delineated by running the *Batch Watershed Delineation* function.The input data needed was that derived during the terrain preprocessing, namely the Flow Direction, the Stream Definition, Catchment, Ajoint Catchment. The results were the *Watershed Point* feature class and the *Watershed* feature class.

As four BatchPoints were defined, the same number of Watershed Points and Watersheds were determined: two for the tributary rivers, Troaş and Petriş and two for the sectors of the Mureş where monitoring activity exists, namely at Radna and Săvârşin (**Fig. 3**). These feature classes are related, as by looking in the attribute table of Watershed Point and Watershed they share the same Name field with the BatchPoints. Furthermore, the DrainID in the Watershed Point attribute table is the HydroID of the corresponding Watershed.

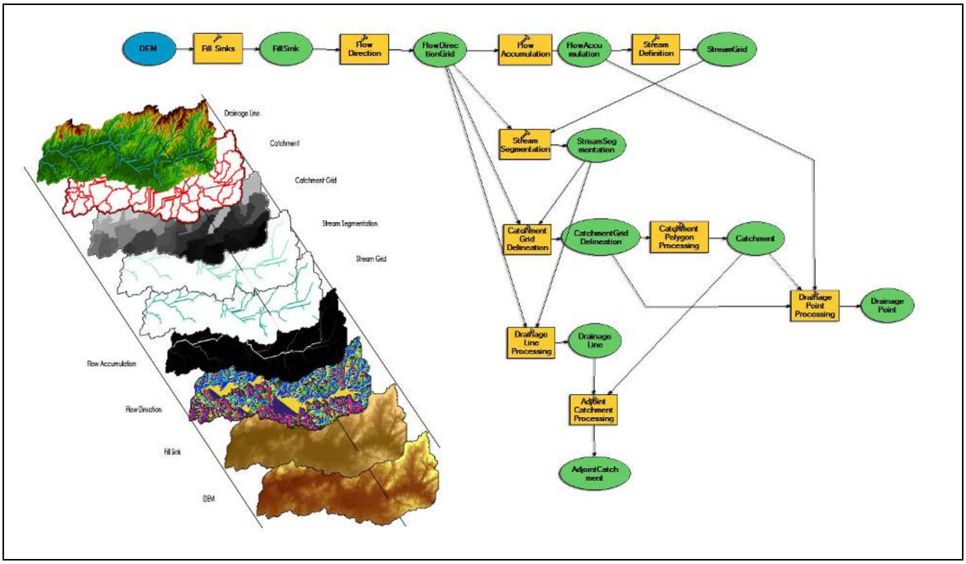

Fig 2. The conceptual model for the Arc Hydro watershed delineation process

2.5. Building the Hydro Network

A hydro network is an ESRI geometric network representing a simplified version of the river and its water movement properties. It is made up from the Hydro Edge, Hydro Junction and HydroNetwork_Junction feature classes. The Hydro Junction feature class establishes relationships with other feature classes in the Arc Hydro Data Model by sharing some common field values.

As all the other feature classes in the Arc Hydro Data Model, the Network features are built atop a generic set of objects and features named ArcObjects. The ArcObjects in the database are arranged in a hierarchy defined through the use of the Unified Modeling Language (UML). In this hierarchy a *Network Feature* object has attributes and spatial coordinates as information, as well as points and lines of interest called *Junctions* and *Edges*.The *NetworkFeature* class is a special sort of class (possibly an abstract class) which can be divided in the *SimpleNetworkFeature* class and the *ComplexNetworkFeature* class. The Hydro Edges are built from the ArcObject *ComplexEdgeFeature* and Hydro Junction from the *SimpleJunctionFeature*.

A Hydro Network is created by using the *Network Tools.* The *Hydro Network Generation* function converts the drainage features into network features. It also creates the relationship class *HydroJunctionHasCatchment* between the HydroJunction feature class and the Catchment feature class. Hence, the catchment is attached to the Hydro Network as the HydroID of the HydroJunction becomes the JunctionID of the Catchment feature class.

The Network feature classes were generated on the basis of the input layeres Drainage Line, Catchment and Drainage Point.

The *Store Flow Direction* is the function that reads the flow direction for a set of lines in the network and sores it in the *FlowDir* field of the Hydro Edge. The flow direction is set through the function from the same Netwok Tools and the use of the Utility Network Analyst extension will ensure that the arrows indicating the water flow direction are displayed on the map.

For the Mureş Corridor between Petriş and Păuliş, after running the above mentioned functions, the Mureş River can be seen flowing in a Westwards direction, surpassing the straits and the depressions. The tributary streams, on the right and the left sides, flow towards their collector, the Mureş River.

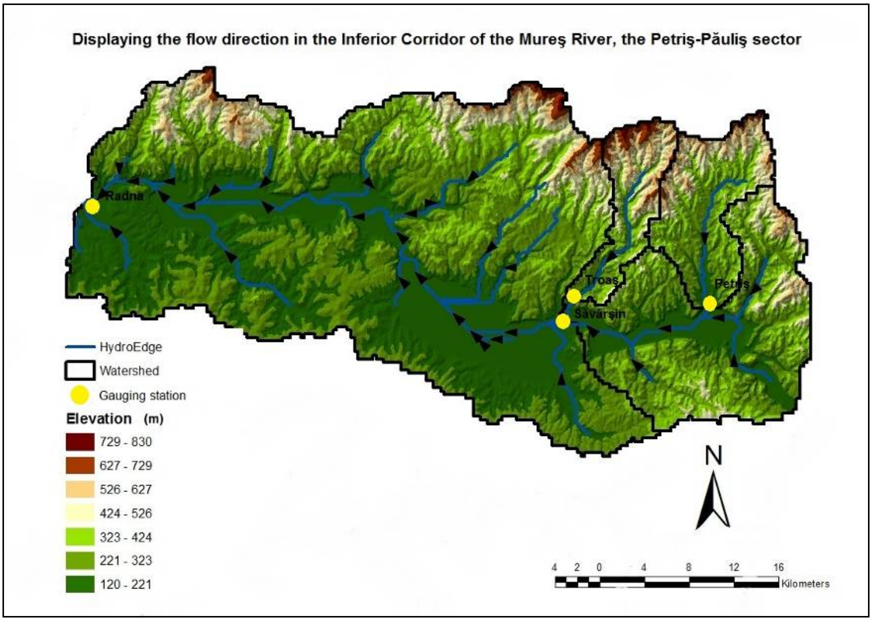

Fig. 3. Displaying the flow direction in the Inferior Corridor of the Mureş River, the Petriş Păuliş sector

3. RESULTS

The Arc Hydro framework was implemented on the Mureş River in between Petriş and Păuliş. Starting from a DEM, the feature classes representing the river system and relationship classes were created.

The streams defined in between Petriş and Păuliş were those that have a watershed larger than 21,03 km^2. This value represents 1% of the maximum value of a precedent raster layer created, *Flow Accumulation*, namely one that records the number of cells draining into one cell. Hence, Petriş and Troaş streams were delineated. They are two of the three tributary streams where hydrometric activity exists. The third is Monoroştie River but its small watershed led to an unreliable generated stream network, therefore the delineation of this tributary river wasn't the focus of the present study. The main course of the Mureş was defined at this stage of the study as well. Regarding the catchments of all the rivers, they have the unusual aspect of straight line segments in the four depression areas in between Petriş and Păuliş.

The unusual drainage patterns in the low areas are even more obvious when the raster Stream segments layer is transformed in the feature class Drainage Line. The main course of the Mureş River shows no meandering in the low areas when compared to a vector layer of the rivers. However, the tributary rivers with monitoring activity are represented more accurately as their drainage areas cover zones at higher altitudes than that of the Mureş. By measuring the distance between the outlets of the tributary streams on vector layers of the rivers in the area and that of the outlets generated with the help of Arc Hydro Tools, we can see that the latter are placed on different sites. They are calculated with and error in between 1.3 km and 0.3 km.

Due to the inaccurate representation of certain drainage aspects, the *DEM Reconditioning Burning Streams* function was employed, as explained thoroughly in the "Correction methodology" section of the present study. As a result, an improved map of the river in the area is obtained. In comparison with the previous Drainage Line feature class, the one derived after reconditioning shows the meandering path of the Mureş River with some exceptions on the same low areas, but not of the same extent as before (**Fig. 1**).

The watersheds of the Petriş and Troaş rivers as well as those for the sectors of the Mureş where monitoring activity exists, at Radna and Săvârşin, were defined on the basis of the raster and the vector layers with the help of the Watershed Processing functions. The Network functions were the ones employed to generate the Hydro Network and the relationship class it implies, *HydroJunctionHasCatchment,* between the the HydroJunction feature class and the Catchment feature class.

4. CONCLUSIONS

The Arc Hydro Data Model is deliberately simplified so as to form the starting point for any water resources application.

By implementing on the Mureş River the Arc Hydro framework, a simplified version of the Arc Hydro Model, the delineation of watersheds was possible: two of the tributary rivers where monitoring gauging stations exist (Troaş and Petriş) and two corresponding to the gauging stations on the Mureş River.

Considering that the geodatabase was constructed starting from a DEM, the raster and the vector analysis led to the creation of a series of feature classes on the basis of which the watersheds were eventually determined. Each Arc Hydro function ran, generated feature classes needed in the next steps of the watershed delineation process. Among the most important layers was nevertheless the Flow Direction grid that served as input data in the creation of a large number of the output layers.

The automatic delineation of watersheds spares the hydrologists time for defining the drainage area boundaries. Even though some inaccuracy exists in the drainage patterns resulted for the low areas, reconditioning techniques of the original DEM are available in ArcGIS, through the use of which more precise results can be obtained. Another solution to the problem could be a source map at a larger scale.

The Terrain Preprocessing tools are essential when building a geodatabase from a DEM as the output layers are used as input data in the generating of Watershed feature classes and Network feature classes. It is by building a geometric network, the Hydro network, that the flow for the Mureş River and the Troaş and Petriş tributary rivers was established.

The application of the Arc Hydro framework on the Mureş River led to the creation of a comprehensive geodatabase where the key attributes and relationships were set among the feature classes. Time series can be further added to the present geodatabase which can also serve as a starting point for water simulation processes.

REFERENCES

Arctur, D., Zeiler M., (1999-2004), *Designing geodatabases: case studies in GIS data modeling*, ESRI.

Djokic, D. (2008) , *Comprehensive Terrain Preprocessing Using Arc Hydro Tools*, ESRI.

Goodall, J., Maidment, D., Sorenson J. (2004), *Representation of Spatial and Temporal Data in GIS.*

Maidment, D.R.(ed), (2002), *Arc Hydro: GIS for Water Resources,* ESRI Press, Redlands, CA.

Rus, D. (2006), *Culoarul Mureşului, sectorul Brănişca – Păuliş - studiu geografico-uman*, Casa Cărții de Știință, Cluj-Napoca.

*** Arc Hydro Tools – Tutorial Version 1.3 (2009), ESRI.

http://forums.esri.com/Forums.asp?c=93.

http://support.esri.com/index.cfm?fa=downloads.datamodels.filteredgateway&dmid=15.

http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=welcome.

http://www.crwr.utexas.edu/gis/archydrobook/DataModelFiles/Tutorial/ArcHydroPart1.htm.

http://www.crwr.utexas.edu/gis/archydrobook/DataModelFiles/Tutorial/ArcHydroPart2.htm.

http://www.crwr.utexas.edu/gis/archydrobook/DataModelFiles/Tutorial/ArcHydroPart3.htm.

http://www.crwr.utexas.edu/gis/gishydro05/Time/RepresentingSpaceAndTime.htm.

http://www.crwr.utexas.edu/giswr/events/091999giswr/.

http://www.crwr.utexas.edu/giswr/hydro/ArcHOSS/model/index.cfm.

DROUGHT AND EXTREME MOISTURE IN SMALL MOUNTAINOUS BASINS

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ABSTRACT:

The evaluation of meteorological drought and/or extreme moisture can be done with SPI index, which needs only the precipitation data for a studied region. Its calculus has a solid mathematical base using the Gamma distribution, a methodology which is auto adaptive in time and space, making possible to achieve meaningful comparisons even for different locations. In this research our objective was the make a characterization of the mentioned two phenomenons at yearly and for summer periods for three hydrographical basins in the Apuseni Mountains (Romania). After the first results we continued to characterize the hazard of drought and extreme moisture by determining the return period for key SPI index limits.

Keywords: *SPI index, Apuseni Mountains, precipitation interpolation, fast calculus, hazard map, return period.*

1. INTRODUCTION

Although drought and extreme moisture are considered two distinct phenomena they have a common factor that is major rainfall. In addition to this factor are others that cannot be neglected, such as land use, slope, pedology of the area, the presence or absence of irrigation, evapotranspiration, etc.

By definition drought/excess moisture is an extended period (months or years) when the region suffers/is excess supply of water from different sources. This can have important effects on the ecosystem and agriculture.

Drought and extreme moisture evaluation has two different approaches: process or data-driven approaches, if the studied phenomenon is modeled taking into consideration the physical reality as much as possible, or based on a smaller or larger dataset, which are processed using statistical formulae (*Craciun, 2008*). The SPI (Standard Precipitation Index) is a well-known and appreciated *Lloyd-Hughes* and *Saunders* (*2002*) index that characterizes drought and moisture severity on different time scales (*Edwards, 2008*). One of its advantages is that the cumulated precipitation value is the only necessary time-variable data to calculate its value, without modeling the water balance of the studied region. Another important element is that the mathematical background of the SPI index calculus makes possible meaningful comparisons even for regions with different pluviometric conditions.

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2. RESEARCH METHODOLOGY

The SPI value calculation is based on Gamma distribution. After distribution fitting of the measured precipitation data, the Gamma probability values are calculated for every initial value. To obtain the normalized (comparable) indices value the formulae (1) and (2), developed by *Abramowitz and Stegun* (*1972*) were used:

$$SPI = -(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}) \quad (1)$$

when the calculated Gamma probability is in (0,0.5] interval and

$$SPI = +(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}) \quad (2)$$

when the calculated Gamma probability is in (0.5-1) interval where:

$t = \sqrt{\ln[\frac{1}{H(x)^2}]}$, for probabilities in (0,0.5] interval,

$t = \sqrt{\ln[\frac{1}{1 - H(x)^2}]}$, for probabilities in (0.5,1) interval and H(x) represents the fitted Gamma probability value for a given *x*.

The *c* and *d* parameters have the following values: c_0=2.515517, c_1=0.802853, c_2=0.010328, d_1=1.432788. d_2=0.189269, d_3=0.001308.

Table 1. ***SPI values meaning***

SPI indices	Meaning
>2	Extreme moisture
1.5 – 2.0	High moisture
1.0 – 1.5	Medium moisture
0.0 – 1.0	Normal moisture
-1.0 – 0.0	Normal drought
-1.5 – -1.0	Medium drought
-2.0 – -1.5	High drought
<-2	Extreme drought

The research was conducted at raster cell level, having 21.5m resolution, for the three river basins (Belis, Capus, Smida). Starting with daily precipitation data from seven meteorological stations (Cluj, Stana de Vale, Huedin, Campeni, Vladeasa, Stei, Baisoara) near the mentioned basins, using the NCDC (National Climatic Data Center), GSOD (Global Summary of Day) data a new suitable database was created with yearly and summer time rainfall.

To determine the best methods of interpolation the following possibilities were tested: IDW, Kriging, Spline, and multiple regressions (*Magyari-Saska, 2007*).

The first three alternatives were studied using ArcGIS, and the latter using the R statistical system for determining the law of regression and ArcGIS for the calculations. We studied the spatial distribution of multi-annual precipitation values, calculating for each method the root mean square error for each station in the studied region. Based on the value of these errors the best method was chosen to be used to actually make the interpolations.

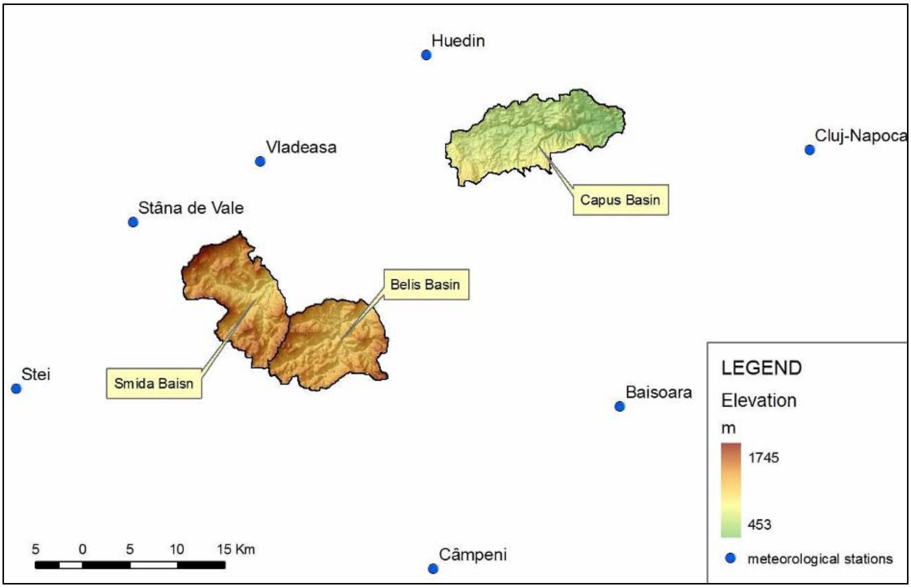

Fig. 1 The studied basins and the surrounding meteorological stations

Due to geographical positioning of the seven meteorological stations, the relatively low density of meteorological stations, the local character of precipitations and the topographic features of this area, makes that the first three interpolation methods cannot be considered acceptable.

Because of this our research has opted for the method of multiple regression, used efficiently also for other regions (*Loukas and Vasiliades, 2004*). For the assessment of the method we started from the assumption that the 3 major factors that can influence the amount of precipitation are: geographical position, altitude.

Due to the relative low station number the general form of the interpolating equation (3) could have no more than six parameters:

$$P = a_1 \cdot px + a_2 \cdot py + a_3 \cdot h + a_4 \cdot px \cdot h + a_5 \cdot py \cdot h + a_6 \qquad (3)$$

- where:

P	– precipitation value
a_1 .. a_6	– coefficients
px	– x coordinate (Stereo70 reference system)
py	– y coordinate (Stereo70 reference system)
h	– altitude

For every precipitation map (one for every year), the above equation was calibrated and optimized in R statistical system.

Starting from the optimized model the calculation of precipitation values were done in R System using the exported ASCII raster files. The situation of calculated negative precipitation values also should be considered. The most simplest way is to assign a zero value in this cases could not represent the differences between this regions, so a new approach was used. All those cells having negative precipitation values got new values which is the reverse on their modulus (4).

$$p = \begin{cases} p, \text{ for } p \geq 0 \\ \dfrac{1}{|p|}, \text{ for } p < 0 \end{cases} \qquad (4)$$

To calculate the SPI index we cancelled the use the R statistic system mentioned in our other researches (*Magyari-Saska, 2007; Magyari-Saska and Haidu, 2009*) because of the extremely long computing time for Gamma distribution fitting for 20 year periods. For current analysis we developed a computing system in Borland Delphi shortening the calculus time by more than 90%. Our system uses TPMath which is a library of scientific programs written in Pascal and continuously maintained.

```
c0:=2.515517;  c1:=0.802853;  c2:=0.010328;
d1:=1.432788;  d2:=0.189269;  d3:=0.001308;

lv:=lnvector(x,n); {logarithm of vector values}
lm:=ln(mean(x,n)); {logarithm of mean}

 pa:=lm-(sum(lv,n)/n);
 p1:=1/(4*pa)*(1+sqrt(1+(4*pa)/3));
 p2:=mean(x,n)/p1;

for i := 1 to n do
 begin
  p[i]:=FGamma(p1,1/p2,x[i]); {used from TPMath}

 t1:=sqrt(ln(1/power(p[i],2)));
 t2:=sqrt(ln(1/power(1-p[i],2)));

 spi1:=-(t1-(c0+c1*t1+c2*power(t1,2))/(1+d1*t1+d2*power(t1,2)+d3*power(t1,3)));
 spi2:=(t2-(c0+c1*t2+c2*power(t2,2))/(1+d1*t2+d2*power(t2,2)+d3*power(t2,3)));

 if p[i]>0.5 then spi[i]:=spi2 else spi[i]:=spi1;
end;
```

Fig. 2 Code segment for calculating SPI index in Borland Pascal fitting the Gamma distribution

3. RESULTS

Based on the visual observation (**Fig. 3**) of the determined annual SPI maps the years of drought and extreme moisture has shown as follows:

- Basin Smida
  - drought: 1998 and 1999 - medium, high and extreme, 2000 – extreme
  - excess of moisture: 1988 - medium and high

- Basin Belis
  - drought: 1998, 1999 - medium, high and extreme, 2000 – extreme
  - excess of moisture: 1988 - medium and high

- Basin Capus
  - drought: 1990 - medium and high
  - excess of moisture: 1994 - high and extreme

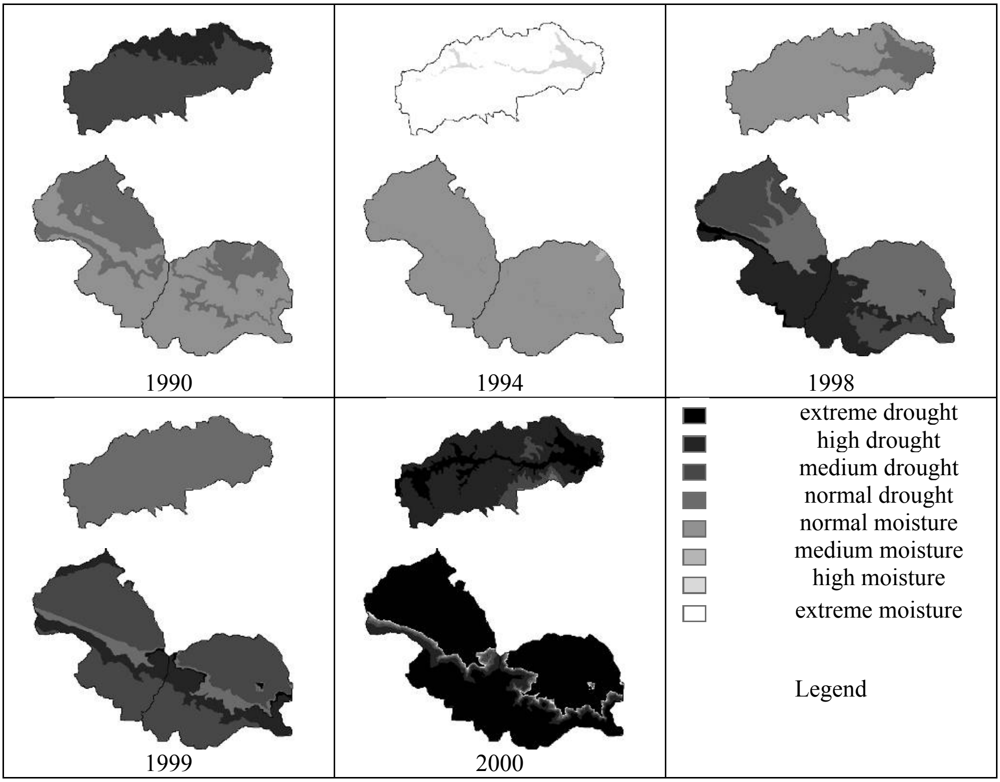

Fig. 3 SPI12 maps for mentioned years

For an assessment of the summer months the analysis was performed for these months, SPI3 for June, July and August. Visual assessment of the results in this case are as follows:

- Basin Smida
    - drought: in 1998 - medium and high, 1999, 2000 - high and extreme
    - excess of moisture: 1994 - medium and high
- Basin Belis
    - drought: 1998 - medium and high, 1999, 2000 - high and extreme
    - excess of moisture: 1994 - medium and high
- Basin Capus
    - drought: 2000 - high and extreme
    - excess of moisture: 1994 - medium and high, 1997 - high and extreme

We can therefore draw the conclusion that both phenomena are present in the three basins, and extreme manifestations occurred in both phenomena. It should be noted that in case of of drought the years for SPI3 for summer and SPI12 coincides, while for excess of moisture the place of 1998 is taken by 1997.

When the emergence of a risk phenomenon depends on the appearing of extreme values, frequency analysis is the method to determine the probability of the occurrence of extreme values. Thus, this step is present in this study, as an important element in the achievement of hazard maps associated with the studied phenomenon (*Ricci, 2005*).

Thus the Gamma distribution was used again over the SPI values in this case for determining the probabilities of exceeding the appropriate threshold ranges from the definition of SPI index, and the obtained values were converted to return periods based on formulae 5.

$$T = \frac{1}{1-p} \qquad (5)$$

- where ***T*** represents the return period corresponding to ***p*** exceeding probabilities. For an easier evaluation we defined 7 return period classes as presented in **Table 2**.

Table 2. ***Classified return periods***

Class code and symbols	1 □	2	3	4	5	6	7 ■
Return periods [year]	1-10	10-25	25-50	50-100	100-250	250-500	>500

Based on the return periods associated with different SPI indices we can appreciate that both drought and excess moisture in their medium forms (-1/1 SPI index) have a return period of less than 10 years. Considering the hazard associated with extreme drought and extreme moisture (-2/2 SPI index) (**Fig. 4**) we can observe that for Belis and Smida basins the return period for extreme drought has less than 10 years for most region, while for Capus basin there is a long range from 10 to 250 years, depending on the location, even if the majority has between 10-25 years.

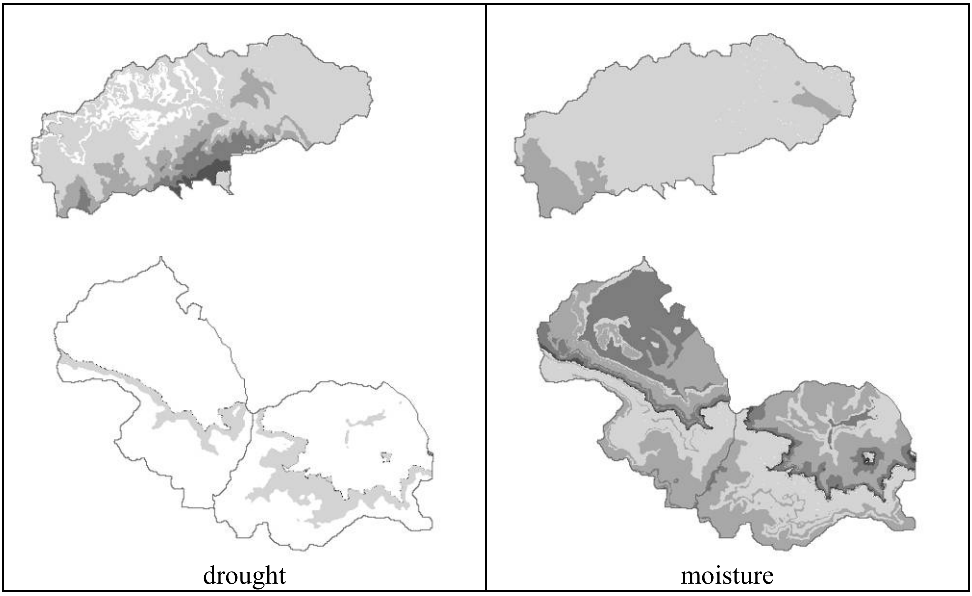

Fig. 4 Return period classes for -2 (extreme drough) and 2 (extreme moisture) SPI indexes

In case of extreme moisture Capus basin has a return period between 10-25 years,while for Belis and Smida basins we could observe a wider range of return periods between 25-100 years.

4. CONCLUSION

SPI index based solely on recorded rainfall quantities, thus usable for the assessment of meteorological drought and excessive moisture, provides us a measure of evaluating the hazard and risk associated with this phenomenon. The possibility to calculate the SPI index for various periods of time represents a temporal portability of the methodology.

From our study results that despite of the relative stability of drought and excessive moisture, during the studied time interval, the danger of both phenomena is emphasized. As SPI index is dependent solely on precipitation, the resulted probability and return period maps can be considered as representative for rainfall hazard.

Concerning the study region we can conclude that the hazard of drought is higher that extreme moisture, but that last cannot be neglected as mentioned in chapter 3. For extreme drought Belis and Smida basins are more vulnerable, while for extreme moisture Capus basin is more exposed.

Aknowledgements

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REFERENCES

Abramowitz M., Stegun I. A. (1972), *Handbook of Mathematical Functions*, New York, Dover Publications.

Craciun A.I. (2008), *Monitoring of Soil Moisture Using the Balance Method and G.I.S.*, Geographia Technica, 2008/2, Cluj University Press; 2008, pp.8-15.

Edwards D. (2008), *S.P.I. Defined*, Master Thesis, http://ccc.atmos.colostate.edu/pub/SPI.pdf [01/11/2009].

Lloyd-Hughes B., Saunders M.A. (2002), *A drought climatology for Europe*, International Journal of Climatology, Volume 22, Issue 13, Wiley InterScience, pp. 1571-1592.

Loukas A., Vasiliades L. (2004), *Probabilistic analysis of drought spatiotemporal characteristics in Thessaly region, Greece*, Natural Hazards and Earth System Sciences Volume 4, pp. 719-731.

Magyari-Saska Zs., Haidu I. (2008), *Precipitation Analysis in the Upper Mures Basin*, In: Car A., Greisenberg G., Strobl J. editors, Proceedings Geospatial Crossroads @ GI_Forum 2008, 2008 July 1-4, University of Salzburg, Wichmann * Heidelberg, pp. 186-189.

Magyari-Saska Zs, (2007), *ArcGIS software module for calculating the S.P.I. value*, Geographia Technica, No. 2, 2007, Presa Universitară Clujeană, pp. 42-48 .

Magyari-Saska Zs., Haidu I., (2009), *Drought and Extreme Moisture Evaluation and Prediction with GIS Software Module*, Proceedings of the ITI 2009, pp. 553-558, IEEE Catalog number CPF09498-PRT.

Ricci V. (2005), *Fitting distributions with R*, cran.r-project.org/doc/contrib/Ricci-distributions-en.pdf [01/11/2009].

THE DROUGHT OF 1956-1957 AND 2001-2002 IN THE NORTH PART OF MADAGASCAR: DETECTION OF SIMILARITY

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ABSTRACT:
Rainfall analysis over an extended period of time in northern part of Madagascar shows that drought is cyclical; it has a frequency of fifty years. Two extremely dry years, those of 1956-1957 and 2001-2002 were considered in this study to identify the similarity of these phenomena. These years are marked by a very large rainfall deficit.

Keywords: *Climate, extreme north of Madagascar, drought, 1956-1957, 2001-2002.*

1. INTRODUCTION

The northern part of Madagascar, located in the Intertropical Convergence Zone (ITCZ) balancing area (**Fig. 1**), has a tropical dry climate. Annual precipitation analysis of this region shows a predominance of dry years despite alternating periods of excessive and deficient rainfall. It is a moderate drought characterized by few precipitations and high temperatures.

The dry periods of low amplitude in this region constitute, nonetheless, a major fact of climate variability to which the rural population adapts itself by organizing its activities and means of production. Drought periods of high intensity can sometimes contrast with the relatively normal climatic trend such as those reported in 1908-1909, 1956-1957 and 2001-2002. These intensive droughts although with long interval mark the climate of the northern part of Madagascar.

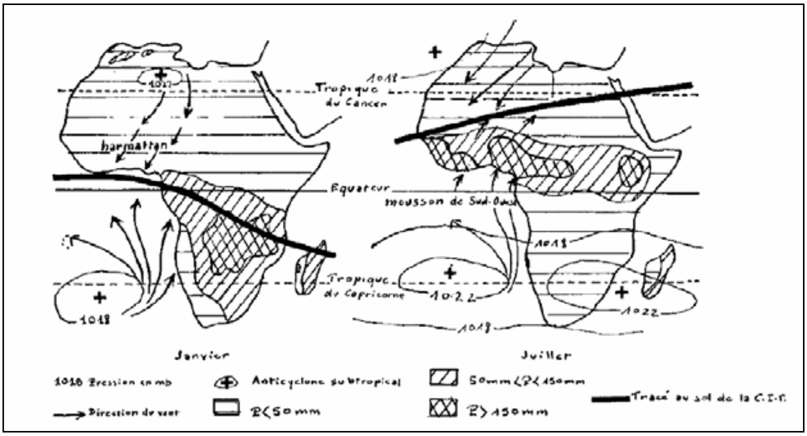

Fig. 1 Location of the Inter-Tropical Convergence Zone in January and July (*Poursin, 1974*)

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Understanding the nature of these droughts can help to identify the risks they may incur to human activities in this region. In this study, it is question of studying the drought years of 1956-1957 and 2001-2002 and to identify the major aspects of these periods by analyzing their characteristics in order to detect the existence of an analogy between the two phenomena.

2. OBEJECTIVES

The aim of the study is to comparatively analyse the drought of 1956-1957 and that of 2001-2002 in the northern part of Madagascar, taking into account their probable causes.

3. THE DATA USED

The data used concern the years of 1956-1957 and 2001-2002 obtained from the department of meteorology and hydrology of Antsiranana. The station located at the airport Antsiranana reliable data over a long period. The second are those of the station located 105 m Arrachart in the northern part-east of the island.

4. DROUGHT CHARACTERIZATION

Drought is defined as a prolonged period where rainfall is below normal (*Pagney,. 1994*). It is first a climatic phenomenon that can later affect several areas requiring the use of water. Its impact is even greater during exceptionally severe time. This climatic abnormality of high intensity was observed in the extreme north of Madagascar in 1956-1957 and 2001-2002; periods in which a very strong rainfall deficit was recorded.

Drought intensity has been estimated using a method based on the expression of the rainfall index in percentage and is classified as follow:

- Very dry year: X <50% of normal rainfall;
- Dry year: 50% <X <70%;
- Year of moderate drought: 70% <X <95%;
- Normal year: 95% <X <110%;
- Wet Year: 110% <X <125%;
- Very wet year: X> 125%;

Where X represents the rainfall of the year studied. The two periods considered in this study are regarded as very dry years compared to the normal 1961-1990. A rainfall analysis for the period of 1950-2007 for this station showed a sequence of very dry and very wet years (*Hong-Wa and Randrianarison, 2009*). These changes in rainfall have no significance because they do not extend over long periods and the interannual variability is very large. The rainfall deficit in this case does not create a situation of drought. We do not therefore speak of drought in this study when the annual precipitation is less than that of the normal thirty-year 1961-1990.

4.1. General features of the drought of 1956-1957 (Arrachart station)

The year of 1956-1957 was marked by a very low rainfall (590.9 mm). The deficit was 606 mm corresponding to 46% of rainfall. Deficits are observed for ten months. This decrease in rainfall is very significant and corresponds to a very dry year in the classification.

Fig. 2 shows the heights of monthly precipitation for 1956-1957 and their relationship to the monthly normal of the thirty-year period. It highlights the persistent deficit in rainfall for certain months of the rainy season. Except for April, where there is a positive anomaly in precipitation, the other months are relatively dry. During the rainy season, from December to April, the calculations showed a decrease of 51%. The rainy months: December, January, February and March are the most affected by the drought. The water levels recorded often did not reach half of the normal for these months except for April.

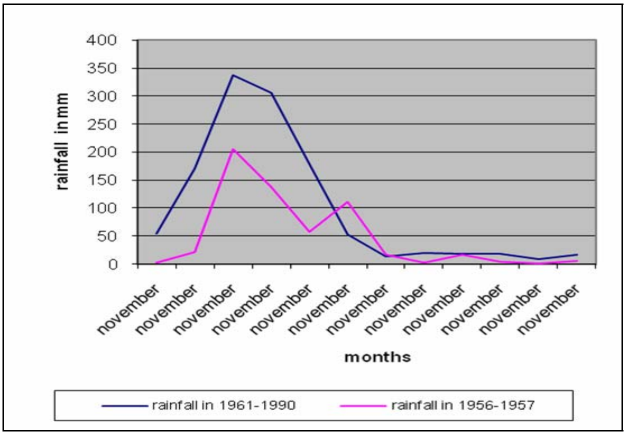

Fig. 2 Monthly precipitation for 1956-1957 and 1961-1990

This situation is aggravated by a consistently high temperature during the year. This high heat favors the phenomenon of evaporation further aggravating the deficit observed. **Fig. 3** shows the temperature trend for the period 1956-1957 compared to the normal thirty-year and indicates an increase for December, February and March. January shows lower temperature than the normal.

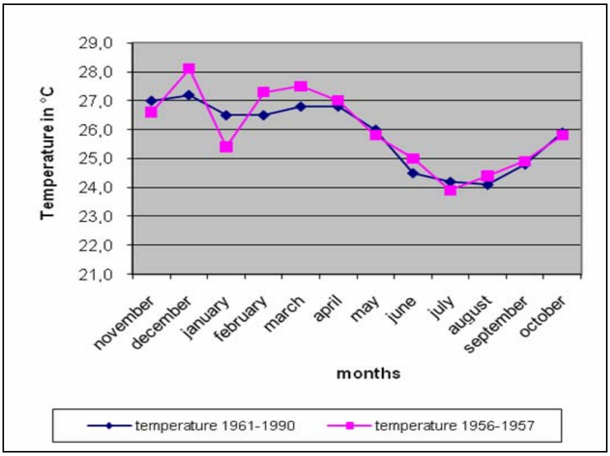

Fig. 3 Monthly temperatures for the periods of 1956-1957 and 1961-1990

Overall, there is an increase in temperature for four months of the rainy season, which can reinforce the drought that plagued the region. However, it should be noted that the annual averages for the periods of 1956-1957 and 1961-1990 are almost identical. But our data showed a slight increase of 0.1°C for 1956-1957.

4.2. Specificity of the drought of 2001-2002 (Arrachart station)

Of an exceptional severity, the drought of 2001-2002 was primarily caused by a very large rainfall deficit corresponding to 56% of the normal rainfall for 1961-1990 and has reached 665 mm. The total rainfall is low (531.8 mm) compared to the average of the thirty-year period (1196.8 mm).

Fig. 4 shows that the monthly precipitation of the dry and cool season is very close to normal. Large differences are observed for the months of the rainy season.

Rainy season normally starts in November but none of the months recorded a normal precipitation. In November, the rainfall recorded at the station is only 4% of the normal. The overall precipitation recorded during the rainy season was 492.8 mm and represented only 44% of the normal of 1961-1990. This explains the extreme drought observed during the period 2001-2002.

In general, the monthly rainfall curve for the period 2001-2002 has the same trend as that of 1961-1990. **Fig. 4** shows that there is no major event such as Cyclone or persisting ITCZ in the northern part of the island that has disrupted the trend in rainfall. However, it appears that all months have had below average rainfall. Therefore, it would seem that an external factor could be the cause of the drought of 2001-2002 in the region of the extreme north of Madagascar.

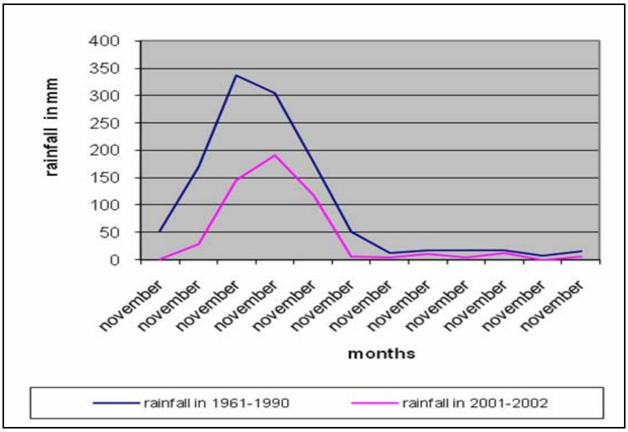

Fig. 4 Monthly rainfall for the periods of 2001-2002 and 1961-1990

Temperature curves for 2001-2002 and 1961-1990 in **Fig. 5**, show that both have the same shape but unlike the monthly precipitation, temperature records for the period 2001-2002 are higher than normal, with the exception of October. The temperature increase is in average 0.5°C. This increase in temperature has an impact on water resources in the region that further accentuates the phenomenon of drought.

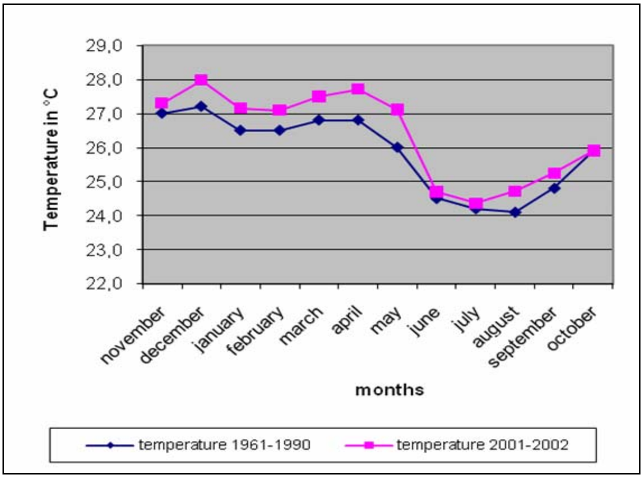

Fig. 5 Monthly temperatures for the periods of 2001-2002 and 1961-1990

5. COMPARATIVE ANALYSIS OF THE DROUGHT OF 1956-1957 AND 2001-2002

The first thing that comes to mind when one looks at the data from these two time periods is to think that these two episodes of drought have similar causes and probably have the same characteristics. The various statistical tests using the software "HYFRAN", of which one followed the "Gumbel distribution is the most probable" with a significance threshold of 95% allowed testing the hypothesis that it is likely that such extreme events can recur after fifty years. To further justify the validity of this result, it is interesting to make a comparative analysis of climatic factors associated with this phenomenon. For this, it is important to see the deviations from the normal monthly rainfall and temperatures to see if there are similarities in the phenomena observed.

5.1. The deviations from the normal monthly rainfall

Observations on the monthly rainfall records of the periods 1956-1957 and 2001-2002 were compared with those from the 1961-1990 normal. Comparing the data month to month helps to define the type of drought. For the deviations from the 1961-1990 normal, we can say that the drought that has affected these two periods is not a seasonal one. It affected every month of 2001-2002 and ten months of 1956-1957; the abnormal negative precipitation being very strong during the rainy season.

From **Table 1**, the abnormal negative precipitations are very important over several months of each period. Rainfall deficit, exceeding 50% of the monthly normal, affected seven and eight months of 1956 and 2001 respectively. These abnormalities affect both the wet and dry seasons but it is clear that it is during the dry season that, the anomalies are significant, particularly in terms of percentage differences. However, in terms of deficit in mm, the differences observed during the rainy season are much higher and generate more impact in climate.

Table 1. ***Monthly rainfall, deviations from the normal 1961-1990***
(*Source: Department of Meteorology and Hydrology Antsiranana*)

	Rainfall in mm						
	1961-1990	**1956-1957**	**Deficit (mm)**	**Variance (%)**	**2001-2002**	**Deficit (mm)**	**Variance (%)**
November	54.6	3.2	-51.4	-94.14	2.4	-52.2	-95.60
December	170.8	22.9	-147.9	-86.59	29.4	-141.4	-82.79
January	337.5	205.2	-132.3	-39.20	145.9	-191.6	-56.77
February	305.8	137.9	-167.9	-54.91	191.1	-114.7	-37.51
March	179.4	58.1	-121.3	-67.61	118.2	-61.2	-34.11
April	52.3	111.7	59.4	113.58	5.8	-46.5	-88.91
May	13.4	17.3	3.9	29.10	4.4	-9	-67.16
June	19.1	3.2	-15.9	-83.25	10.7	-8.4	-43.98
July	19	16.8	-2.2	-11.58	4.2	-14.8	-77.89
August	18.7	5.8	-12.9	-68.98	13.6	-5.1	-27.27
September	8.8	1.9	-6.9	-78.41	0	-8.8	-100.00
October	17.4	6.9	-10.5	-60.34	6.1	-11.3	-64.94
Sum	1196.8	590.9	-605.9	-50.63	531.8	-665	-55.56

5.2. Deviations from the normal monthly temperatures

Like the rainfall data, temperature data provided by the department of meteorology and hydrology of Antsiranana, have also been treated as a monthly table. The deviations from the normal annual averages show that there was an increase in temperature during the two periods considered dry.

This is 0.1°C and 0.5°C between the periods of 1956-1957 and 2001-2002 and the normal 1961-1990 respectively. This temperature variation is even greater if we examine the seasonal differences. **Table 2** shows that for two seasons, hot and rainy (November to April), cool and dry (May-October), there are obvious signs of signs of increasing temperatures.

The seasonal averages reflect this increase in temperature. For the rainy season, temperatures in the period 1956-1957 and 2001-2002 are higher than those of 1961-1990. These differences are respectively 1.1° C for 1956-1957 and 3.9 °C for 2001-2002. This means that rainy seasons are more affected by drought.

Table 2. ***Monthly Temperatures, deviations from the normal 1961-1990***
(*Source: Department of Meteorology and Hydrology Antsiranana*)

	Temperature in °C						
	1961-1990	**1956-1957**	**Deviation (in °C)**	**Deviation (%)**	**2001-2002**	**Deviation (in °C)**	**Deviation (%)**
November	27	26,6	-0,4	-1,5	27,3	0,3	1,1
December	27,2	28,1	0,9	3,4	28,0	0,8	2,9
January	26,5	25,4	-1,1	-4,1	27,2	0,6	2,4
February	26,5	27,3	0,8	3,0	27,1	0,6	2,2
March	26,8	27,5	0,7	2,7	27,5	0,7	2,7
April	26,8	27,0	0,2	0,8	27,7	0,9	3,7
May	26	25,8	-0,2	-0,8	27,1	1,1	4,6
June	24,8	25,0	0,2	0,8	24,7	-0,1	-0,4
July	24,2	23,9	-0,3	-1,2	24,4	0,2	0,7
August	24,1	24,4	0,3	1,2	24,7	0,6	2,4
September	24,8	24,9	0,1	0,4	25,3	0,4	1,7
October	25,9	25,8	-0,1	-0,4	25,9	0,0	0,0
Average	25,9	26,0	0,1	0,4	26,4	0,5	2,0

6. THE CAUSES OF DROUGHT

Droughts of high intensity as those observed during the periods of 1956-1957 and 2001-2002 result from climatic anomalies associated with the swinging of the ITCZ. In January and February, the ITCZ is near 10° south, immediately north of Madagascar, with frequent incursion on the island. Indeed, during the hot and rainy months, the ITCZ moves down to the highlands of Madagascar; the northernmost region being outside its influence does not benefit from the rain it brings.

In addition, the trade winds, which blow during this season, run parallel to the coast thus decreasing the rainfall. This is very similar to the south of the island (*Ravet, 1948*), thus causing a drier climate. The absence of a cyclone increases the deficit in the coastal regions as convective rains affect only the mountainous area of the Montagne d'Ambre.

7. CONCLUSION

The study of the droughts of 1956-1957 and 2001-2002 showed that these phenomena are similar. The rainfall deficits are huge, reaching over 50% of the normal thirty-year 1960-1990. The seasonal differences are more important and it is observed that the differences are most significant during the rainy season.

It is thus assumed that these periods of extreme drought, are influenced by the same phenomenon and recur after a cycle of fifty years. One of the reasons taken into account to explain the recurrent drought is the position of the ITCZ relative to the northern tip of Madagascar and the other, the lack of cyclonic regime during these periods. Furthermore, a correlation of these extreme events with the El Niño phenomenon can also be hypothesized, but that is beyond the scope of this study.

Acknowledgements

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REFERENCES

Hajri J., (2007), *La sècheresse climatique en Tunisie, cas de l'année agricole 1993-1994*, FLM, Variabilité du Climat et Stratégie d'adaptation paysanne en Tunisie, Volume VI, pp.147-201.

Hautbois M., (1976), *La sècheresse de novembre et décembre 1974 à Moroni (Grande-Comores)*, Revue de géographie alpine, Volume 64, Numéro 2, pp. 271 – 280.

Hong-Wa A., Randrianarison J., (2009), *Etude de la variabilité des précipitations dans l'extrême nord de Madagascar et analyse de l'adaptation des pratiques culturales sur le pourtour de la montagne d'Ambre*, Geographia Technica, No. 2, pp. 23 – 30.

Kassav F., (2007), *La sècheresse en Tunisie, cas de l'année agricole 1993-1994*, FSHS, Variabilité du Climat et Stratégie d'adaptation paysanne en Tunisie, Volume VI, pp.203-277.

Pagney P., (1994), *Les climats de la terre*, 2eme édition, éd. Masson, 167 pp.

Pardé M. Sanson J., (1950), *La sècheresse des années 1942-49 en France*, Revue de géographie alpine, Volume 38, Numéro 2, pp. 369 – 404.

Pesneaud F., Hong-Wa A., Ndriandahy Ralinirina F., (2009), *Les effets des changements climatiques sur la vie rurale dans deux régions de Madagascar*, Geographia Technica, Numéro Spécial 2009, pp. 367 – 370.

Poursin G., (1974), *La sècheresse au Sahel,* Annales. Économies, Sociétés, Civilisations, Volume 29, Numéro 3, pp. 640 – 647.

Randriamanaga S. et al, (1995), *La sécheresse de 1990-1991 et de 1991-1992 à Madagascar vue à partir des images infrarouges Météosat et les données conventionnelles*, Cinquièmes journées scientifiques du Réseau Télédétection de I'AUPELF-UREF, Tunis, 21 -24 septembre 1993, pp. 291-304.

Ravet J., (1969), *Atlas climatologique de Madagascar, publication du service Météorologique de Madagascar*, n°10, planche 10.

Ravet J., (1952), *Notice sur la climatologie de Madagascar et des Comores, Mémoires de l'Institut Scientifique de Madagascar*, série D-Tome IV-fascicule 1, pp. 1-37.

POST-INDUSTRIAL LANDSCAPE – ITS IDENTIFICATION AND CLASSIFICATION AS CONTEMPORARY CHALLENGES FACED BY GEOGRAPHIC RESEARCH

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ABSTRACT:
The post-industrial landscape represents a common phenomenon of developed industrial countries. Its dominant definition feature is given by the presence of "fossil" (inactive, off its original destination) industrial and related areas and objects. The identification of relevant "post-industrial" objects and areas on the territory of the representative study area Rosicko-Oslavansko (once heavy industry, Southern Moravian Region) was completed in the course of the works proposed by the project "The fate of the Czech post-industrial landscape". The process of the identification and typology of the post-industrial landscape using knowledge on the secondary landscape structure and GIS technology is demonstrated on example of the Rosicko-Oslavansko area. The procedure developed was used to classification of areas with the different level of the "post-industrialness" in the present landscape. The preliminary results represent starting points for the future planning in the given territory.

Keywords: *industrial heritage, post-industrial landscape, local level, identification, typology.*

1. INTRODUCTION

Industry, or organized concentrated machine-operated production, has been changing the landscape character of developed industrial countries for four centuries. Maximum industrial development had several main stages: a) onset of industrialization at the turn of the 18^{th} and 19^{th} centuries connected with the development of manufactures and introduction of the steam engine into production, later on also into transport focusing on smelting, textile, glass and mining industries b) the peak of industrial revolution in the last quarter of the 19^{th} century which concentrated on smelting, mechanical engineering, food and energy industries c) post-war industrial restoration in the late 1940s and early 1950s focusing on armament, mechanical engineering and petrochemical industries d) industrial restructuralization in the 1970s focusing on the automotive, electrical and chemical industries e) computerization and robotic automation of industrial production characteristic of energy, material and personnel savings, with special focus on ecologization since the 1980s. In each of these stages there were both small and big companies which failed to succeed in industrial production of the following periods. Disused industrial buildings and industry-related premises and zones, if not used for other purposes, began to shape the post-industrial landscape. The collapse of industry as the key employer then triggered a chain reaction of crises in other economic spheres as well as in the public sphere and in settlement and landscape management. The period after 1970 in industrially developed countries saw radical changes in industrial production, both technical and organizational as well as in relation to industry's area distribution and the environment. Defunct and derelict industrial and other premises (military, agricultural, transport, water management, mining

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and others) represent a significant part of an athropogenized landscape. In the Czech Republic alone, derelict zones constitute almost 2 % of the country area (ČR 78 865 km^2), with built-up brownfield area covering approx. 120 km^2 (*Regnerová, 2006*). Digression from heavy industry and labour-intensive production after political changes in the late 1980s was accompanied with painful and not always successful transition to different types of production. However, the tertiary sector (services) usually developed. A postponed and usually not very successful privatization of the less efficient industrial spheres in the state sector further contributed to massive de-industrialization of regions. This in turn led to the collapse of most major mining, smelting and processing companies and lost jobs were only partially retrieved. Only rarely was either massive or small-scale investment directed at services focusing on new (different) land use, as was the case in industrially developed countries. Yet, regardless different and asynchronous development globally, the post-industrial landscape is a reality in all developed countries today.

The post-industrial landscape is the legacy of industrial landscapes. Both industrial and post-industrial landscapes are defined by characteristic physiognomic, structural, dynamic and functional features. While in the industrial landscape these parameters are "recent", the post-industrial landscape is characteristic of a number of features, among them "fossil" ones. As a whole, the landscape may be described by a sum of elements in their synergic and synchronic contexts.

A number of typical attributes characterize the industrial landscape:

1) Natural (primary) structure: changes in the topoclimate (urban heat islands, atmospheric admixtures – gasses and dust), changes in drainage relations (artificial surfaces, drained areas, man-made water reservoirs), soil removal or coverage (by buildings or deposits in their vicinities), terrain changes (due to mining, industrial, water management, transport or other relief shapes), changes in contact with the geological environment (removal of weathering products in the course of foundations construction, isolation and ground levelling embankments, earth dumps, construction and industrial waste dumps), radical changes in the biota (in extreme cases a total removal of vegetation and creation of artificial surfaces, a complete change of fauna).

2) Economic (secondary) structure: land use is characteristic of dominant production facilities with typical buildings (halls, chimneys, heating plants, warehouses), vast communication areas (handling areas, reloading areas, stations, pipelines, container belts, storage tracks, road and railway networks, transport cableways, very high voltage lines), active and passive mining areas (quarries, mine dumps, temporary waste dumps), water management facilities (dams, consumption devices, pumping and compression devices, pools, sewage clarification plant, canals), surrounding dense residential and service built-up areas. Residential areas with service networks tend to be situated in close proximity. These parameters are "recent" in the industrial landscape, while the post-industrial landscape is characteristic of a number of features, among them "fossil" ones.

3) Human (social, tertiary) structure: a change in stakeholder interests is manifested by devastated and later abandoned areas, deterioration and loss of the above mentioned industrial buildings' original function due to neglected maintenance. On the other hand, some buildings are subject to various degrees of protection. A number of residents faced changes in social standing. In some cases this social status change led to emigration or immigration.

4) Spiritual structure: both local residents and visitors perceive the landscape differently. This change is partly due to political as well as economic and social changes, and due to better access to information on the environment, different access to power and power

structures. Buildings and facilities which in the past used to be sources of wealth, as such enabled a better standard of life and thus were perceived positively, may suddenly be perceived negatively (ensuing the loss of their original function even for their former employees and their families). Some places show indisputable genius loci.

Industry has affected both the primary and secondary landscape structures as well as the areas' appearance and perception which it generates. Industry has traditionally been responsible for large-scale pollution of the landscape which damaged the primary (natural) landscape structure and human activities bound to it. Indirect industrial heritage is represented by altered "areas" in the primary landscape structure (devastation caused by industrial air pollution) and changes in stakeholder interests in the tertiary structure, i.e. abandoning certain areas, reassessing of original plans, status changes (e.g. conservation or reserve status), intended conversions of function, changes in the social sphere. Industry usually is/was not responsible for large-scale land use (with the exception of resource mining) as was farming, forest management, water management and urban planning. Direct industrial heritage (apart from currently mined areas) is therefore local, i.e. buildings and areas in the secondary landscape structure representing a mosaic of various economically (un)used areas. The post-industrial landscape is therefore a phenomenon which does not exceed areas of several km^2 or several dozen km^2. Owing to the fact that both experts and laics are aware of its existence but not clear about its future treatment, it has become an attractive focus of expert interest. However, systematic research is still in its infancy.

2. PRESENT STATE-OF-THE-ART

Industrial heritage, i.e. a landscape which has either been created, affected or abandoned by industry, particularly individual landscape objects directly related to past industrial activities, has attracted profound interest of experts coming from a wide range of fields. Traditionally, most attention is paid to the architectural and environmental aspects of individual industrial heritage objects and their sets. Particularly western countries have seen long-term efforts to protect important monuments from demolition and provide them with new functions in the contemporary society. A number of industrial cities opted for revitalization of originally industrial areas and accompanying residential districts with the primary objective of transforming them into modern residential and service areas with high standard facilities. Parallel to restoration and conversion of interesting derelict industrial buildings, an inventory of industrial heritage was taken in a number of countries (England - *http://industrious.icserver26.de/index.php?pageId=1*, Scotland - *http://www.sihs.co.uk/ index.htm*, Ireland - *http://www.industrialheritageireland.info/*, Canada - *http:// www.canadianindustrialheritage.org/index.html*, Latvia - *http://www.i-mantojums.lv/eng /frames/sakumlapa.htm*, Czech Republic – *http://www.brownfieldy.cz*, many regions in the USA, Germany, The Netherlands, Japan and others), with architectural and aesthetic values of the buildings playing a key role in the grading process. A number of professional institutions directly related to industrial heritage and landscape also came to life (at Technical University in Munich - *http://www.lai.ar.tum.de/en/*). Industrial heritage has also attracted tourism (*http://www.erih.net/welcome.html*). The primary objective of all these activities is to draw people's attention to the irreplaceable value of our industrial heritage and the need to conserve it in a sensible degree and form.

A number of institutions focus on research of industrial heritage. A particular attention is paid by architects and historians both in the Czech Republic (e.g. Industrial Heritage Research Center at the Czech Technical University in Prague) and abroad (e.g. Cuffley Industrial Heritage Society – Anglie, The Scottish Industrial Heritage Society, Association for Industrial Archeology, Canadian Industrial Heritage Centre, The Industrial Heritage Archives of Chicago's Calumet Region, etc., some on the international level (The International Committee for the Conservation of the Industrial Heritage, European Route of Industrial Heritage - ERIH). A series of successful solutions, at least from architectural and social perspectives, has been introduced by the redevelopment of industrial, warehouse and dockland areas of Manchester, UK, probably the world's oldest industrial city. Some time later, the redevelopment of formerly industrial parts of Birmingham was launched (*Hillinger et al., 2001*). The redevelopment of east London Docklands is a particularly renowned project. On the continent, an extensive and successful rehabilitation of originally industrial landscape (covering around 800 km^2) of the Ruhr region (*Fragner, 2005*) is taking place in the brown coal mining districts of Niederlausitz and is nearing completion in Oberpfalz. Major projects are being launched in the lower basins of the Czech Ore Mountain. However, only selected industrial heritage buildings tend to be preserved for new purposes, while "new" landscapes devoid of an expressly articulated relation to their industrial past appear in their surroundings.

A significantly less attention is paid to wider areas of industrial heritage. While functional industrial landscapes are part of research portfolios of many academic institutions (e.g. Purkyně University in Ústí nad Labem, Czech Republic – *Vráblíková and Vráblík, 2007*),, the post-industrial landscape has so far failed to secure a firm position in the focus of experts and as such remains in the sphere of popularization. The relations between industrial heritage and the landscape are still subject to less intensive studies but interest in this issue is growing promisingly. Needless to say that even abroad it is initiated primarily by architects (e.g. the newly established Department of Landscape Architecture and Industrial Landscape at the Munich University of Technology in 2009). In the Czech Republic, a certain link can be traced in the work of the Institute of Industrial Landscape Ecology of the Czechoslovak Academy of Sciences which operated in Ostrava in the 1970s and 1980s. Yet, the expert community deals with a number of aspects associated with the post-industrial landscape. Traditionally, architectural (*Cashen, 2006*), economic (*Shahid, Nabeshima, 2005; Dunham-Jones, 2007*) and social aspects (*Kirkwood, 2001; Kirk, 2003; Hansen and Winther, 2006*) of this type of landscape have been the dominant focus of their studies (in the geographic context). Landscape science deals with its ecological aspects, particularly focusing on the occurrence of biotic communities and species (*Kirkwood, 2001; Keil, 2005*), possibly also environmental ones (soil and water remediation). An exception to the existing research practice is the designation of a post-industrial landscape covering 39 km^2 in the vicinity of Blaenavon, southeast Wales, as a World Heritage Site in 2000 (*Rogers, 2006*). With a few exceptions abroad, the issue of post-industrial landscape remains to be elaborated descriptively in cases of individual studied areas. Yet, the descriptive aspect of research is vital, as it turned out necessary in cases of conservation and integration of remaining industrial landscape heritage into territorial planning documents. Projects of future use of selected landscape units have probably been developed relatively best so far, despite the fact that architectural and conservation aspects without deeper elaboration of theoretical approaches probably played a key role in these cases. Needless to say that conservation of such areas was timely and probably came at the eleventh hour.

The methodology aspects of research and assessment, classification and typology outline for this type of landscape are still in their infancy. What is generally lacking is an elementary definition of this landscape type, as well as methodology necessary for its definition, classification and typology. Theorizations on post-industrial landscape assessment according to selected aspects are still in the process of elaboration. The aim of this paper is to present proposals of possible definitions, classification, typology and assessment of post-industrial landscape, as elaborated in 2009 under the grant project "The Fate of the Czech Post-Industrial Landscape" No. IAA 300860903 funded by the Grant Agency of the Academy of Sciences of the Czech Republic (for 2009-2011). The research develops results of earlier papers published on the region (*Hynek et al., 1983; Kolejka, 2006*).

3. GEODATA SUPPORTING THE DEFINITION AND CLASSIFICATION OF POST-INDUSTRIAL LANDSCAPES

A number of data on individual landscape structures, including those which are related to industrial heritage, may be obtained either from the existing records or through field work. There is no doubt that these data have a spatial dimension and thus represent an interesting subject for geographic research, including landscape science research.

The following types of geo-data are used as post-industrial landscape indicators:

- land use in the CORINE Land Cover database (industrial areas - class 121, mining areas – class 131, waste dumps – vlase 132); fossil areas, however, must be extracted with the help of supportive data or in chronological map sequence (CLC1990 and CLC2000, differences in CLC2006),
- topographic maps in analogue or digital form and their chronological sequences used for identification of differences in industrial, mining and other type of areas,
- undermined and mining sites in geological service databases,
- lists of brownfields in public and private databases
- lists of sites with chemical load in public and private databases,
- interpreted aerial photographs and aerial orthophotomaps available on public servers or made upon request,
- land use maps of individual regions available on the internet thanks to regional administrative,
- territorial planning documents in analogue and digital form available for settlements and regions on the internet or intranet.

The existence and availability of data differ when regional and local levels are compared: potentially more data are available on the regional level (usually in the form of national and regional data sets) but their accuracy decreases with decreasing scale and resolution. GPS generated data are an exception to this rule. On the other hand, on the local level one can rely on detailed field research which in model sites can be conducted in the course of field campaigns.

Terrain mapping and identification of post-industrial buildings and sites was carried out in the Rosice-Oslavany model site in the South Moravian Region. Over the last 250 years, this area situated 20 km west of Brno has undergone several industrialization stages as well as local industry decline, particularly of the iron and steel and mining industries (**Fig. 1**). An extensive public questionnaire survey was conducted in the area. This survey focused both on the residents (approx. 500 completed questionnaires of 62 questions each) and the state administration and local governments (one questionnaire of 25 questions per municipality). The obtained data sets are the prerequisite for yielding interesting results.

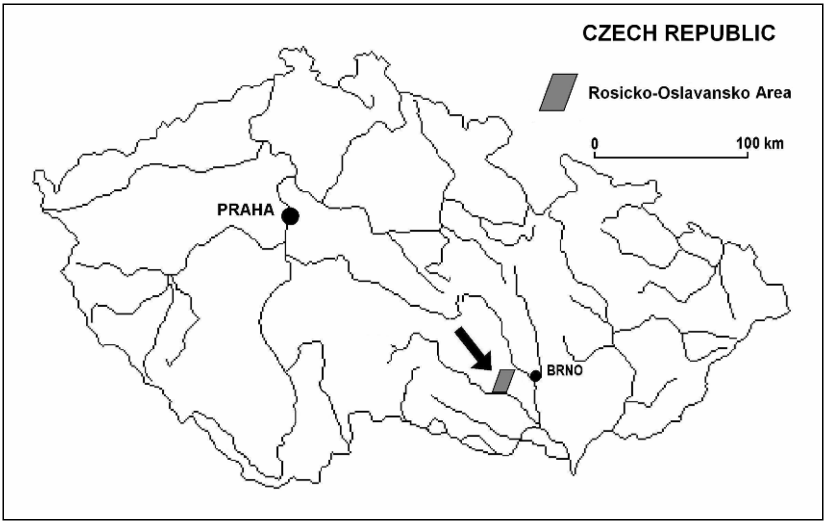

Fig. 1 Location of the Rosice-Oslavany study area within the Czech Republic

4. EXAMPLE OF IDENTIFICATION, CLASSIFICATION AND LANDSCAPE TYPOLOGY OF THE ROSICE-OSLAVANY

The original Rosice-Oslavany Coal Basin was represented by a belt of Perm-Carboniferous coal-bearing layers stretching from the Říčany municipality in the north to Nová Ves in the south and covering approximately 14 km in length and 1 km in width. Three out of a total of seven coal beds were suitable for mining. In the belt of coal-bearing layers, the depression of the Oslavany Furrow was partly overlaid by Pleistocene loess deposits which in the warm climate of the beech-oak altitudinal vegetation zone developed into fertile brown soil. Even before coal mining was launched, the area had been virtually deforested and subject to intensive farming, unlike the neighbouring more elevated region of the Bíteš Uplands with its poorer soils and colder climate. A settlement network surrounded by open landscape with fields and meadows, and several larger stretches of woodland has developed along the furrow's western edge.

In 1760 coal was discovered in the vicinity of Padochov (**Fig. 2**). Mining in the vicinity of Oslavany was launched already in 1783 but did not reach an industrial scale until the early 19th century north of Zbýšov. Between the present towns of Zastávka and Oslavany a total of eight deep mines were dug. Over the course of the 19th century, miner colonies appeared in older settlements, while the town of Zastávka was built from scratch in 1840 as a smelting and iron and steel industry centre. More iron and steel industry developed in Oslavany. At the same time, the area of arable land (at the expense of the last remnants of forests) and orchard farmland (on originally arable land) increased, while the extent of permanent grassland decreased (ploughed up) and fishponds were completely eliminated. As of the mid-19th century the mining area became connected to potential markets in the developing Brno industry via railway. Part of coal was burned in the Oslavany power station built in 1913. After World War 1 coal mining continued to thrive despite economic crisis declines (in 1919-20 and in 1929-32). The towns of Oslavany, Zbýšov and Rosice expanded to include miners' housing estates.

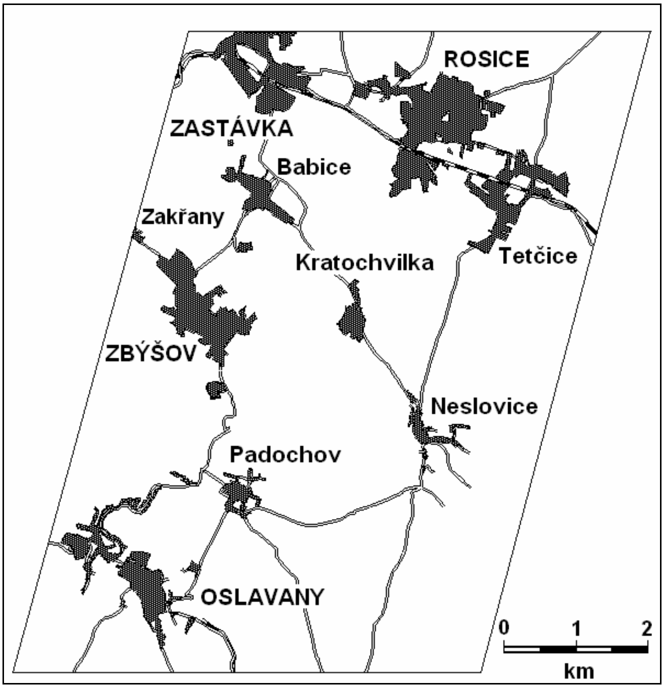

Fig. 2 Settlement structure of the Rosice-Oslavany study area

After World War 2, a five-kilometer-long overhead freight cableway running from the Jindřich Mine across Padochov and past the František Mine to the Oslavany power station was built. In the meantime ironworks in Zastávka had closed down and had partially been replaced by engineering production and the same happened to sugar refineries in Rosice and Oslavany. In the northern part of the coal-mining district some railway sections were dismantled. Starting with the 1960s coal mining was gradually reduced to be completely halted in the late 1980s. The Oslavany power station closed down in 1993 and was dismantled shortly afterwards. Some mining facilities were converted to small production halls or warehouses, particularly after the political and economic changes in 1989. Other facilities were pulled down, shafts were filled up and only some buildings were conserved as technical monuments. In the 1990s a number of buildings were abandoned and became derelict, while the mining, communication and industrial relief shapes became gradually disrupted. Farming production in more demanding conditions (steep slopes, humid valley bottoms) was reduced. Forests expanded to extreme sites (gullies, railway embankments, slag heaps, parts of brownfields). The belt along the Boskovice Furrow's western edge in the so-called Rosice-Oslavany coal mining district constitutes a mosaic of buildings and sites directly or indirectly affected by coal mining and industrial production as well as agricultural production intended for both local and more distant markets. It can be seen as an example of a post-industrial landscape produced by the past coal mining and iron production boom.

In the course of a detailed topical landscape research of scale 1:10 000, mapping the secondary landscape structure, or land use, was conducted in 2009 (**Fig. 3A**). From its onset the mapping was conducted in a way which differentiated sites which had either direct or indirect relation to industrial heritage (**Fig. 3B**). After being removed from a general land use map, these sites established a special “post-industrial areas” layer.

Through comparison with a historical land use map from 1821 (based on indication sketches of the stable cadastre) settlement core zones were separated, which allowed us to differentiate an increase in built-up areas following the onset of industrialization. Areas of fishponds drained in order to prevent water seepage into the mines were also identified, although other buildings have been built in these sites.

Despite the fact that only one of the landscape structures was identified, the obtained data may allow us to determine landscape classification and possibly also landscape typology according to the secondary structure. The reference area was established through a regular square grid (**Fig. 4A**) over the post-industrial site map by using the ESRI Create Vector Grid tool in Hawth's Analysis Tools for ArcGIS extension.

In the course of experiments with 100 m, 500 m and 1000 m square side size, it became apparent that dimensions of 500 x 500 m are ideal for the topical level as they represent a sufficiently large area to encompass the diversity of land use and at the same time the resolution is not too rough (in comparison, squares of 5 x 5 km play the same role on the country level).

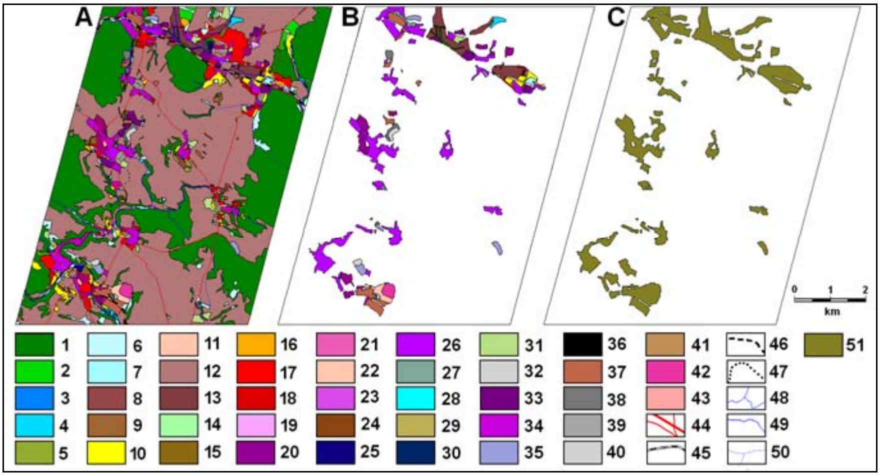

Fig. 3 Land use within the Rosice-Oslavany area in 2009 (Legend: 1 – forest (in traditional location on forest land), 2 – newly established forests on farmland, 3 – water bodies (fishponds), 4 – wetlands, 5 – shrubs, 6 – meadows, 7 – meadows established on bottoms of drained fishponds, 8 – agricultural terraces, 9 – concentration of hedgerows, 10 – orchards, 11 – fallow land, 12 – arable land, 13 – arable land on bottoms of drained fishponds, 14 – cemeteries, 15 – sports facilities, 16 – cottage colonies, 17 – traditional family homes, 18 – individually built family homes, 19 – commercially built standardized family homes, 20 – socialist large-scale development, 21 – commercial housing estate developments, 22 – school, 23 – supermarkets, 24 – chateau, 25 – worker colony, 26 – preserved pre-industrial settlement core zones, 27 – communal water treatment plants, 28 – water tanks, 29 – swimming pools, 30 – farming facilities, 31 – petrol stations, 32 – operating industrial facilities, 33 – modern industrial production facilities, 34 – former mines used for special purposes, 35 – railway stations, 36 – brownfields, 37 – slag heaps with tree cover, 38 – slag heaps with shrub cover, 39 – bare slug heaps, 40 – waste dumps, 41 – waste land, 42 – park lots, 43 – roads and streets, 44 – passenger and freight railroads, 45 – freight railways, 46 – dismantled railroads, 47 – preserved close-to-nature sections of water courses, 48 – canalized sections of water courses, 49 – water course sections in underground pipeline, 50 – combined post-industrial sites)

For each of the squares, whether complete or incomplete with regard to the shape of the study area, the post-industrial land ratio on the surface area of the relevant plane of reference was calculated. The obtained data were then depicted in two versions: 1) in % in values up to 10 plus areas devoid of post-industrial sites, up to 1 % and up to 5 % (**Fig. 4B**) and **2**) according to the contemporary landscape typology (*Kolejka et al., 2000*) where the minimum per cent distribution indicates how many word denomination would be used to describe the contemporary landscape type in a given square (purely on the basis of the secondary landscape structure and regardless other structures) on condition that at least one of the words in the denomination is “post-industrial” (**Fig. 4C**).

A different representation of the data may be obtained through transfer of percentages from the squares and their segments into these areas’ gravity points to create a point network which allows further cartographic experiments (**Fig. 5** and **6** – left). It was necessary to create outer identical value counter points for the every inner peripheral points manually to prevent the following process implemented through the IDW (Inverse Distance Weighted) interpolation method in ArcGIS through Spatial Analyst tool calculate with zero values of the space beyond the study area. Although one can dispute the procedure’s correctness with regard to thematic cartography, the procedure still provides a more accurate (albeit one of disputable credibility) picture of post-industrial landscape typology for the study area on the topical (local) resolution level.

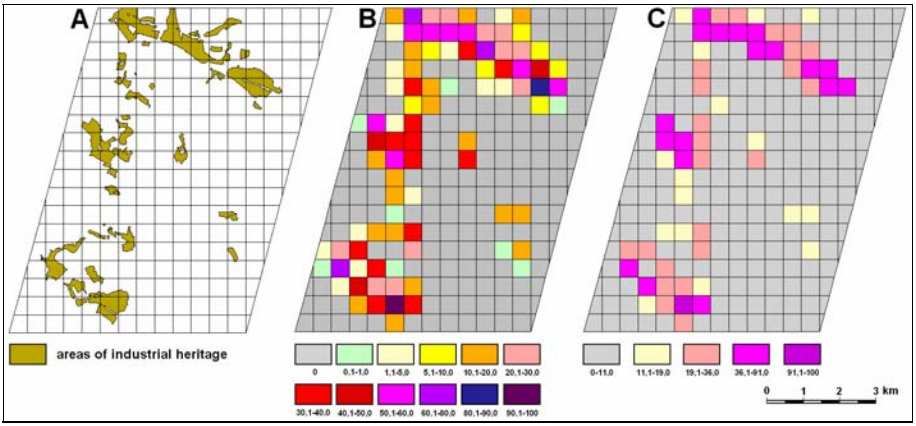

Fig. 4 The Rosice-Oslavany area. Sequence of calculating the distribution classification and typology of post-industrial landscape in 500 m square planes of reference. The percentage in section C provides possible denomination – without post-industrial landscape, four-word denomination, three-word denomination, two-word denomination and one-word denomination where at least one word is “post-industrial” – e.g. forest and meadow post-industrial landscape).

Types of contemporary landscape zones (in referential units):

A. Monofuncional areas where one form of land use constitutes a minimum of 91 % of the referential unit area.
B. Bifunctional areas where two forms of land use jointly constitute a minimum of 91 % of the referential unit area, while the dominant form’s share exceeds 55 % (over a half in total) and the second form’s share constitutes a minimum of 2/3 of the dominant form, i.e. approximately 36 (over 1/3).

C. Trifunctional areas where three forms of land use jointly constitute a minimum of 91 % of the referential unit area, while the dominant form's share is approx. 43 % (less than 1/2), the second form's share constitutes a minimum of 2/3 of the first one, i.e. approximately 29 % (less than 1/3 in total) and the third dominant form's share constitutes a minimum 2/3 of the second dominant form, i.e. a minimum of 19 % (less than 1/4 in total)

D. Polyfunctional areas where four forms of land use jointly constitute a minimum of 91 % of the referential unit area, while the dominant form's share is at least 38 % (over 1/3), the second form's share constitutes 2/3 of the first one, i.e. approximately 25 % (1/4 and more), the third form's share constitutes a minimum 2/3 of the previous form, i.e. approx. 17 % (less than 1/5) and the last (fourth) dominant land use form's share constitutes at least 2/3 of the previous one, i.e. approx. 11 % (1/10 and more).

Interpolation between the points of respective percentage shares of post-industrial areas within squares produced maps of 1) typology based on % of decimal values with the above listed accessories, 2) typology based on standard boundary % values denominating categories of one to more-word descriptions of contemporary landscape types containing post-industrial areas (only based on the secondary landscape structure) or, in other words, types of the post-industrial landscape with respect to the share of post-industrial land use forms within a given square (see **Fig. 5** and **6**).

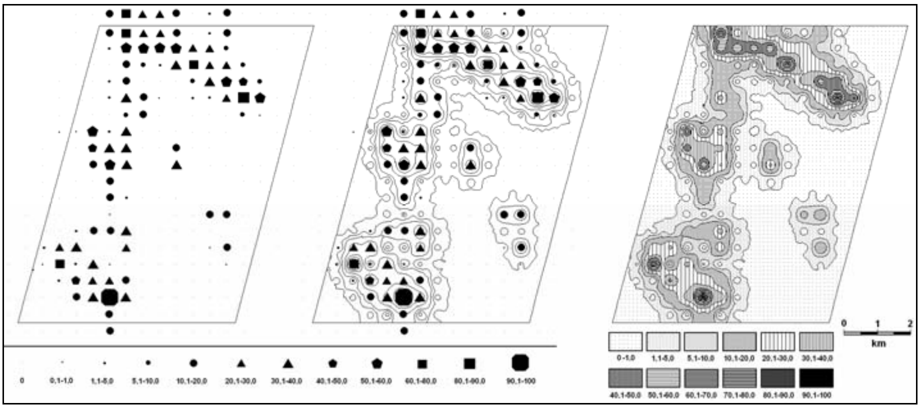

Fig. 5 The Rosice-Oslavany area. Conversion of data on percentage ratio of post-industrial areas in the squares into isoline field (10 % each including additions) and an area map

The procedure, as demonstrated on the example of post-industrial landscape typology, can be used universally to aid landscape typology with regard to a number of other perspectives on the basis of known secondary structure. It provides universal planes of reference which can be related to geo-statistic data and it also abolishes the need to use various verbal descriptions combining secondary structure layers with maps of other structures, mostly natural ones. It therefore rectifies the situation where within referential areas, most often in the form of available geomorphological units, the traditional method often creates funny verbal descriptions combining detailed data on the secondary structure (e.g. cemetery) with a geomorphological unit (e.g. uplands) as entirely different levels of landscape differentiation.

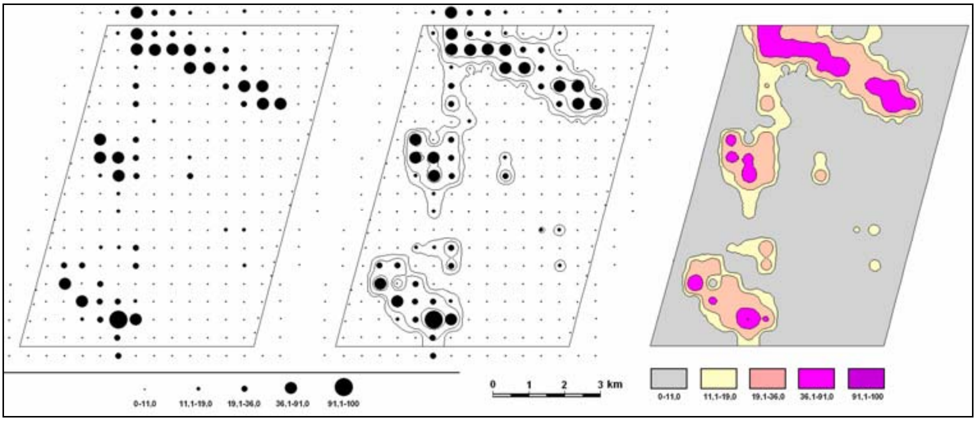

Fig. 6 The Rosice-Oslavany area. Conversion of data on percentage ratio of post-industrial areas in squares into an isoline field (according to boundary % of contemporary landscape types) and area maps. Percentage values in the rightmost part must be interpreted as in fig.4

The above mentioned procedure may be viewed as a possible solution, as theoretically it can be applied on all levels of landscape differentiation, provided that square dimensions are adjusted to the landscape dimensions. Needless to say, the quality of the available data on secondary landscape structure plays a crucial role in this process.

5. CONCLUSION

Typology of the local landscape was conducted with respect to the degree of its post-industrial character and measurements followed the pattern of squares of 500 x 500 m. On the national level this method is not feasible due to the real absence of data on location, size and character of post-industrial buildings and sites. In this case it is necessary to interpret the available data, use the CORINE data, geological surveys, as well as records on waste dumps, chemical burden and brownfields.

Although post-industrial landscape is a generally well-known phenomenon in developed countries, where it originated as a by-product of technological, social and political development, it still remains outside the main focus of physical geography and socio-economic geographic landscape studies.

The presented paper outlines only some possible research approaches and procedures. Individual industrial buildings and sites of indisputable architectural value attract the attention of both conservationist and developer circles. Yet, planning and conservation of wider areas – the post-industrial landscape itself – still lack sufficient sum of results provided by qualified research.

Geography thus faces the challenge of elaborating processes of identification, classification and typology of the post-industrial landscape and needs to identify criteria which might be used in the process of deciding its future.

REFERENCES

Cashen D., (2007), *Redeveloping a North Florida Post-Industrial Landscape,* In: Journal of Undergraduate Research, 8 (3), [cit. 2010-01-18] URL: http://www.clas.ufl.edu/ jur/200701/papers /paper_cashen.html.

Dunham - Jones E., (2007), *Economic Sustainability in the Post-Industrial Landscape*, In: Tanzer, K. & Longoria, R. (eds.): The Green Braid. Towards an Architecture of Ecology, Economy, and Equity, An ACSA Reader, London: Routledge, pp. 44-59.

Fragner B., (2005) *Postindustriální krajina (Porúří-Emscher Park),* Vesmír, Vol. 84, No. 3, pp. 178-180.

Hansen. H., Winter L., (2006), *The Heterogenous (Post-) Industrial Landscape of Copenhagen: Location Dynamics and Divisions of Labour*. In: Proceedings of the Sixth European Urban & Regional Studies Conference, 21st - 24th September 2006, Roskilde, s. 1-26. [cit. 2010-01-19] URL: http://www.byforskning.dk/publikationer/ Siden%20publikationer/artikler/ Hogni20Hansen0LarsWinther.pdf.

Hillinger N., Olaru M., Turnock D., (2001), *The role of industrial archaeology in conservation: The Resita area of the Roman Carpathians,* GeoJournal, Vol. 54, pp. 607-630.

Hynek A. et al., (1983), *Geografická analýza a syntéza Rosicka-Oslavanska,* Folia Fac. Sci. Nat. Univ. Purk. Brunensis, Geographia, Vol. 24, No. 1, pp. 1-101.

Keil A., (2005), *Use and Perception of Post-Industrial Urban Landscapes in the Ruhr,* In: Kowarik, I. & Körner, S. (eds.): Wild Urban Woodlands. Springer, Berlin-Heidelberg, pp. 117-130.

Kirk J., (2003), *Mapping the Remains of the Postindustrial Landscape,* In: Space and Culture, Vol. 6, No. 2, pp. 178-186.

Kirkwood N., (2001), *Manufactured Sites. Rethinking the Post-Industrial Landscape,* Taylor and Francis, London, 272 p.

Kolejka J., (2006), *Rosicko-Oslavansko: Krajina ve spirále,* Životné prostredie, Vol. 40, No. 4, pp. 187-194.

Kolejka J., Lipský Z., Pokorný J., (2000), *Ráz krajiny České republiky. GIS a DPZ pomáhají v jeho identifikaci a hodnocení,* GEOinfo, Vol. 7, No. 2, pp. 24-28.

Regnerová T., (2006), *České brownfieldy,* Development News, Vol. 8, No. 8-9, pp. 6-9.

Rogers S., (2006), *Forgotten Landscapes,* Forgotten Landscapes Partnership, [cit. 2010-02-06] URL: www.forgottenlandscapes.org.uk/FL_ProjectBrief Aug06.doc.

Shahid Y., Nabeshima K., (2005), *Japan's Changing Industrial Landscape*, World Bank Policy Research Working Paper No. 3758. [cit. 2010-01-15] URL: http://ssrn.com/abstract=844847.

Vrábliková J., Vráblík P., (2007), *Využívání území v průmyslové krajině,* In: Střelcová, K., Škvarenina, J. & Blaženec, M. (eds.): "Bioclimatology and Natural Hazards", International Scientific Conference, Poľana nad Detvou, Slovakia, September 17-20, pp. 1-5.

GEOMORPHOMETRIC FEATURES OF THE BUILT AREAS OF THE LOCALITIES ALONG IAŞI CUESTA

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ABSTRACT:
In this paper are analysed two important geomorphometric parameters like relief energy and relief declivity for 42 village built areas located in half western part of Iaşi Cuesta in order to highlight habitation favourability. The strip of villages what were studied, is a result of natural, social and historic factors and records, today, low values for the main social and economic indicators. The analysis of the geomorphometric parameters was done for several distinct historical periods from XIXth and XXth centuries using cartographic sources at very large scale and processed in a GIS environment – TNTMips 6.9. The study reveals that the values of the parameters places the area in a low habitation favourability class.

Keywords: *morphometrical parameters,GIS analysis,built area,territorial evolution, Iaşi Cuesta.*

1. INTRODUCTION

Geomorphological backing was always fundamental for human settlements emergence and development. Parameters that define topography, modelling processess that shaped it, are to be found, at small scale, within settlement location. For present day human society development, land management must observe geomorphological conditions, especially in regions where habitation's favourability is at a low level.

These relatively improper conditions to shape a functional settlements' network also characterize the villages studied in this paper, that is western half of Iaşi Cuesta. Demarcated by Bahlui and Bahluieț valleys at north and Bârlad river divide at south, the studied area encompass 12 village administrative areas (i.e. Strunga, Brăieşti, Tg. Frumos, Ion Neculce, Lungani, Sineşti, Popeşti, Dumeşti, Podu Iloaiei, Lețcani, Horleşti and Voineşti).

Located in center of Iaşi county (north-eastern Romania), this is a southern subregion of Jijia Hilly Plain, which makes transition to Central Moldavian Plateau. Many factors, especially social-historical ones are added to less favourable natural conditions that shaped present settlements' network with a low development level. Most villages record low levels for main social indicators: demographic behaviour, health, educational and communal services accessibility (*Tudora, 2010*), poor infrastructure quality, etc., in spite of Iaşi city proximity and Iaşi-Tg. Frumos-Roman road transport channel. Except villages located in north side, a low economic efficiency is recorded (self-consumption agriculture and over 90% of population belongs to primary sector (*Muntele et al., 2002*). At the same time, present landuse (mostly arable land and pastures at the expense of a possible specialization for fruit trees and vineyards and a low percentage of forestry) is not proper for region's natural and social conditions.

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2. NATURAL FRAMEWORK

Region's average altitude increases from north and east, from Bahlui Valley and Mogoşeşti-Voineşti lowland area (80-100 m) towards south and west where it reaches and passes altitude of 120-140 m in transition areas to neighborhood plateaus. In NE part of the studied area absolute altitudes are encompassed between 50 and 170 m, and in west and south from minimal altitudes of 80-100 m increase to a maximum of over 220-240 m.

Geomorphologically, area is characterised especially by a high topographic fragmentation, of rolling-hilly type, with narrow interfluves (*Mărgărint, 2004*) - **Fig. 1**. Bahlui river tributaries evolved by many side river captions favoured by exceptional activity (especially in Pleistocene period) of mass movement. This was enhanced by petrographic uniformity (basarabian deposits), monoclinal structure and relative topographic youthness estimated to be upper Pleistocene-Pleistocene (*Băcăuanu, 1968, Apetrei, 1994*). Slightly salty pellitic facies is largely dominated by *Clays with Crypromactra*, while on the southern side, at altitudes over 150 m (at least within Voineşti village area) can be found sands with silt and clay intercalations, sometimes with a crossed structure, which is characteristic for a slightly salty facies (*Brânzilă, 1999*). These conditions are summed up with a climate with continental trends, with a sparse location of phreatic waters and, recently, with a lack of modern farm practice, that favoured the expansion of land degradation processess, especially mass movement, gullies and surface erosion (*Patriche et al., 2006*).

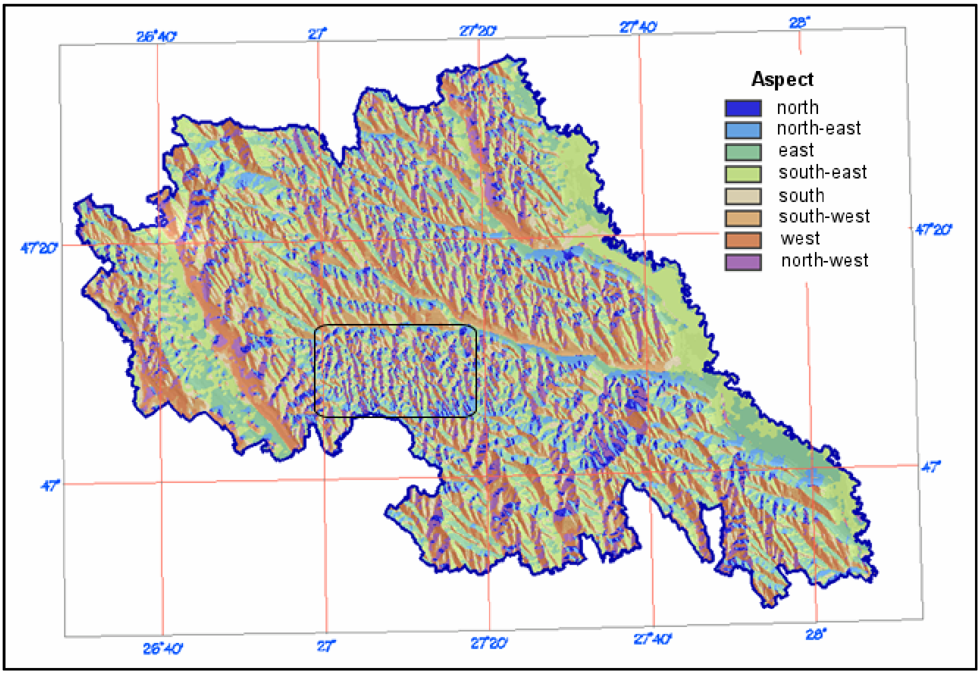

Fig. 1 Relief fragmentation in Iași County evidenced by the slope aspect.
In center – the western half of Iaşi Cuesta

3. SETTLEMENT NETWORK

Within this less favourable geomorphological complex, emerged and developed human settlements' network in several clear periods. Most of them were attested by documents after Romanian medieval states emergence. However, it is possible that they may have had emerged before medieval states creation (XIVth century). They can be found in historic evidence but also by suffix presence *–eşti* (dacic origin) and *–eni/ani* (probably of slavic origin) in the names of the settlements derived from free peasants communities (**Fig. 2**).

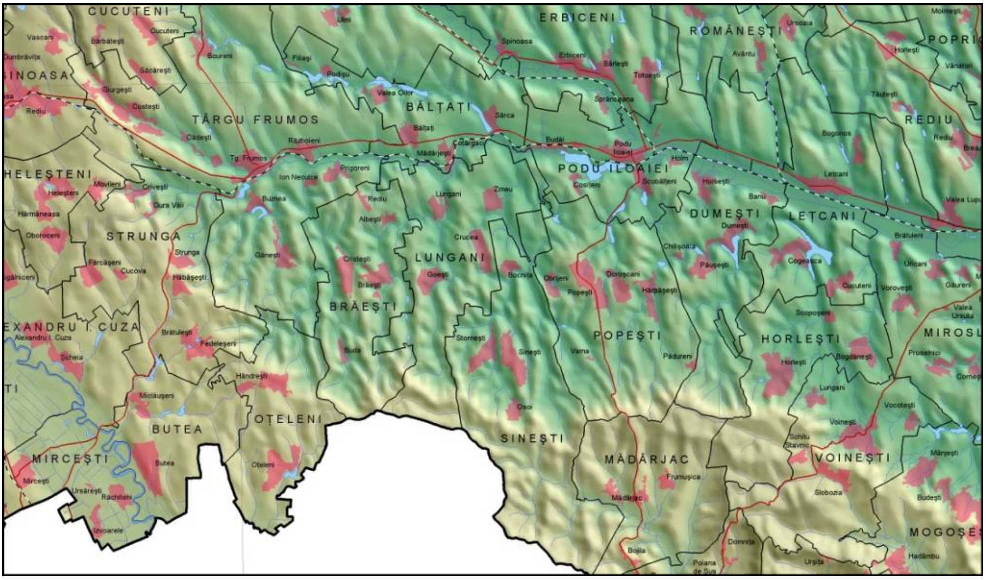

Fig. 2 Central and western part of Iaşi Cuesta. Fragment from the general map of Iaşi County

Sheltered locations prevailed for these settlements especially within larger landslide areas, known as "hârtop": Buznea, Găneşti, Prigoreni, Albeşti, Goeşti, Hărpăşeşti, Dumeşti, Cogeasca, Scopoşeni etc. Without exception it is noticed an irregular road network with various household densities (**Fig. 3**).

Also, it can be noticed that in historic documents were reported many other settlements, whom most inhabitants moved in other locations. In this way, only for present administrative area of Popeşti commune, are reported at least 4 former villages: Rădeni, Mohorâți, Iugani and Cioltani (*Mihalache, 2000*).

Starting with the XIXth century, settlements' network was developed by applying many land reform/allotment laws (*Rotaru and Anculete, 1996*). After Principates' Union this kind of laws, which goal was to modernize Romania, started to have effects even in this area. Moreover, many of these laws did not generated new settlements but triggered the expansion of villages built areas. Were created in this way many sectors with rectangular road network that completes previous irregular road network (Găneşti, Lungani, Popeşti, Hărpăşeşti, Cosiţeni etc).

Fig. 3 Goieşti (left) and Zmeu (right) villages in the 1996 year limits. It easily can be seen the 'hârtop' sit in the first case and the rectangular road network in the second, borned in the second half of the 19th century

Some of these laws and decisions are listed below:

- Royal decree no. 495 from 20th of July 1862;
- Law for establishment of Couny Councils no. 396 from 2nd of April 1864;
- Rural law approved in 14/25 august 1864;
- Law no. 2186 from 13th October 1879 (surnamed as –just married law-), after the Independence war, and had as effect a new generation of allotment villages;
- Law from 17th of July 1921, which had as effect one of the most important agricultural reform;
- Law no. 187 from 23rd of March 1945, with modest effect on agricultural reform, mostly anihilated by colectivization process from 1949-1962;
- Territorial fund law no. 18 from 1991 on which many landowners „forced" built area by building houses within the lots they received outside village built area (Buznea, Prigoreni, Lungani, Goeşti, Crucea, Cogeasca, Cucuteni etc).

As a result, present day settelments' network has emerged, characterized by a spatial distribution from aleatory to uniform (*Groza, 2005*), but marked by constrained functionality due to road quality and configuration. Characteristic is that most villages location didn't observe or ignored topography fragmentation even if it would have been more favourable habitation areas in proximity.

From what was displayed, it results that, qualitatively, there is a high degree of vulnerability of these communities to natural processess like landslides and slope floods. For certain perimeters in the studied area were already done studies that quantitatively assess susceptibility for these processes (*Grozavu et al., 2010*); these studies evidence the parameters that display high correlation coefficients with spatial distribution of these processes. For the selected region, rhw analysis is focused on three main directions: *built areas surface evolution*, *altimetry* characteristics and terrain *declivity*.

4. METHODOLOGY

Morphometrical parameters for the built areas were obtained using DEM (Digital Elevation Model) and its map derivates (*Cracu G. M., Popescu M., 2008*). The model was obtained after digitizing hypsometric curves with 2.5 m interval from topographic maps at scale 1:5,000, in stereographic projection, 1970 coordinate system.

All cartographic products were created and managed by using GIS software TNTMips 6.9. Topographic maps that were scanned and imported in GIS environment were georeferenced by using map corners. All other cartographic sources were registered using corresponding georeference. In this way, village contours from different time periods were extracted in order to make their analysis. For older periods were used topographic maps at scale 1:50,000 printed in 1894 and shooting directory plans at scale 1:20,000 printed in 1940 (*Crăciunescu, 2010*). Residual errors for spatial positioning were between 10 and 30m, which is regarded as acceptable for this kind of study. Better accuracy (0 to 4 m) when registering general urban plans at scale 1:5,000 was obtained, which were used to extract, by on-screen digitization, village limits for year 1996 and present day ones (**Fig. 4**).

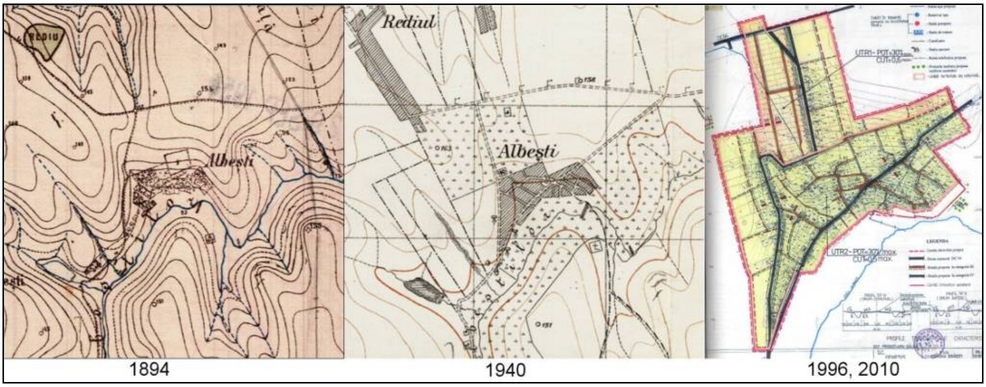

Fig. 4 Albeşti village represented on the topographical maps from 1894, 1940 and in the General Urban Plan (1996)

DEM was generated using Minimum Curvature method with 5m pixel resolution. This was used to extract village DEMs for each period and for each village. Altitude and slope histogram distribution, also statistical parameters values were analysed (minimum and maximum values, mean, median, standard deviation, mode and cell numbers).

5. RESULTS

The 42 present day villages that are comprised in the studied region were analysed regarding spatial evolution, relief altitudes, village extension in altitude and slope values within built areas (will be presented values for 38 villages in 1894 and 40 villages in 1940).

Built areas evolution from 1894 to 2010 display a permanent extension with direct relationship with previously shown allotment process and with the growing number of inhabitants. Total built area of the 42 villages was of 1,621.1 ha in 1894 and 4,530 ha in 2010. Average village surface increased from 42.66 ha in 1894, to 67.51 ha in 1940, 96.09 ha in 1996 and 107.86 ha in 2010.

For each built area, with very few exceptions, the trend was positive. Exceptions were recorded in several time periods:

- 1894-1940: Ion Neculce and Prigoreni, diminution that can be caused by cartographic errors for built area;
- 1940-1996: Lungani, as an effect of arable land extension at the expense of household area (characteristic for communist stage) - **Fig. 5**;
- 1996-2010: Albeşti, Rediu, Buda, Osoi, Obrijeni, Hoişeşti, Horleşti, Bogdăneşti and Cucuteni, as a result of eliminating from within village of those areas used as vineyards and orchards and at some extent of areas that are sensible to landslides and floods.

In 2010, the smallest areas have the villages Holm (18.2 ha) and Vama (19.4 ha) and the largest areas are in Voineşti (309.8 ha), Popeşti (293.1 ha), Horleşti (281.8 ha) and Sineşti (212.0 ha).

Fig. 5 Lungani village built areas in 1940 (orange) and 1996 (red)

As a peculiarity for all the villages within studied area is that they extend themselves especially on hill slopes; even the reason of setting up of these villages was connected to topographic fragmentation that sheltered the inhabitants from migratory waves. This is why most of the villages documentary attested from XIV-XVth centuries within Iaşi county are grouped in central and western part of Iaşi Cuesta (*Lăzărescu, 1948*).

Village altitude extension spans from 31.6 m at Pădureni to 105.8 m at Goeşti (**Fig. 6**). Out of 42 villages, 17 unfolds on over 80 m altitude (i.e. 40.5% from total villages) and 36 unfolds on over 50 m altitude (i.e. 85.7% from total villages). All these in an area that this hilly plain geomorphological unit has average relief energy of about 80 m.

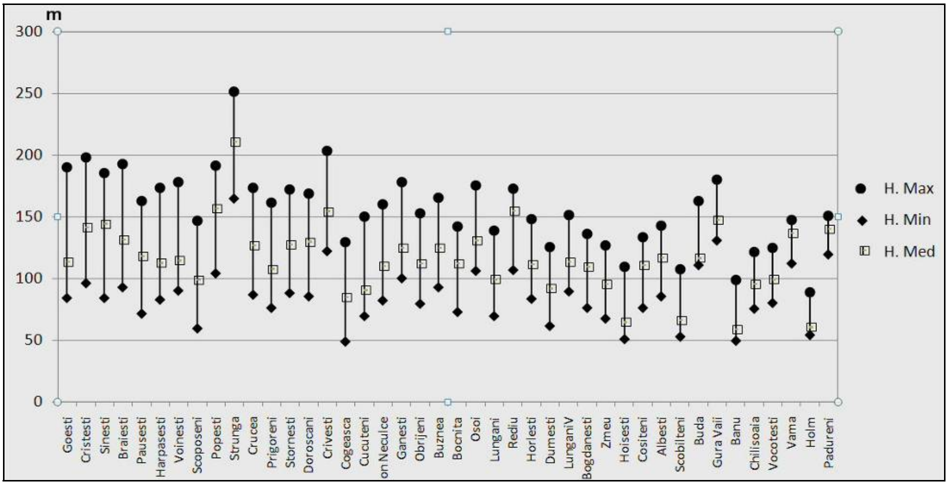

Fig. 6 Minimum, maximum and average altitude for the studied villages

Other characteristic of the villages is that they cover most of the slope areas. To evidence this, a parameter of slope coverage for each village was calculated using the formula: $Io=\Delta hl/\Delta hs \times 100\%$, where: Δhl in altitude difference from the extreme points of the built area and Δhs is the altitude difference from the extreme points of the slope on which is located the village. As expected, very high values were obtained, the average is as high as 70.93%.

Minimal values are specific for the villages located on areas with high altitude differences on the rim of the studied region like the steep slope towards Central Moldavian Plateau (Voineşti, Lungani-Voineşti, Gura Văii, Criveşti, Osoi), or located in the northern part, towards the low area of Bahlui Valley (Buda, Scobâlţeni). Maximum values are specific for the villages located between the two limits, where the spatial extension starts from the floodplain and goes up to the water divides: Storneşti (99,5%), Goeşti (98,0%), Doroşcani (96,1%), Sineşti (95,1%) ş.a.m.d.

Obviously there is a correlation between this parameter and villages areas. Values of over 85% are specific to larger villages of over 130 ha. However, a large percent of the villages display values between 75-85% whom surface is lower than 100 ha Ion Neculce, Chilişoaia, Albeşti, Bocniţa, Cucuteni, Vocoteşti ş.a.). **Fig. 7** displays village distribution according to this parameter and related with built areas. By analysing correlation coefficicients it can be noticed a very low connection among two variable, for polynomial regressions of I^{st}, II^{nd} and III^{rd} order (*Rădoane et al., 1996*).

Regarding terrain favourability for living slope has an even more importance as it is an important factor in triggering mass movement. This fact was proved recently for Lungani commune (Lungani, Goeşti, Crucea and Zmeu villages) for which, by using logistic regression method for slope, was assigned a weight of 0.506 (*Grozavu et al., 2010*).

Average slope values recorded variations for each area in direct connection with the extension or shrinkage of built areas. Above all, specific for all time periods is that all villages extended on the same category of terrain. Also, some regress in surface for villages was largely due to mass movement processess. In **Table 1** are displayed the values of this parameter computed from DEM.

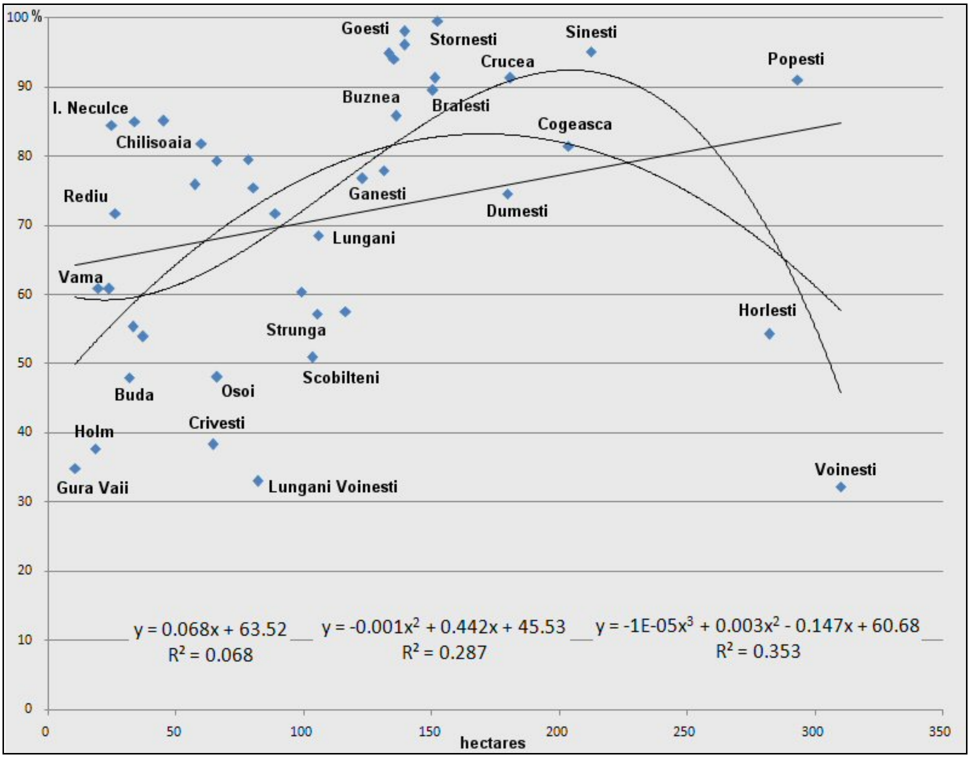

Fig. 7 Relationship between village altitudinal extension and surface. Polynomial regression equations of Ist, IInd and IIIrd order and correlation coefficients (bottom of figure)

Table 1. ***Built areas average slope values for 1894, 1940, 1996 and 2010***

No.	Village	Slope			
		1894	1940	1996	2010
1	Strunga	11°12'	11°12'	14°30'	14°54'
2	G. Văii	25°36'	25°36'	21°30'	22°00'
3	Crivesti	14°54'	11°36'	20°48'	20°54'
4	Buznea	19°54'	20°12'	22°00'	20°18'
5	Găneşti	20°12'	19°42'	22°30'	21°54'
6	I.Neculce	22°00'	21°12'	23°54'	24°06'
7	Prigoreni	22°18'	21°48'	24°12'	22°36'
8	Brăieşti	18°18'	19°12'	19°24'	18°24'
9	Cristeşti	20°24'	21°06'	20°42'	19°54'
10	Albeşti	23°00'	21°42'	16°06'	15°54'
11	Rediu	-	16°06'	17°12'	13°24'
12	Buda	3°24'	8°18'	13°00'	9°30'

No.	Village	Slope			
		1894	1940	1996	2010
13	Lungani	13°18’	11°36’	13°36’	13°24’
14	Goeşti	19°24’	18°30’	18°42’	18°54’
15	Crucea	19°48’	19°24’	19°54’	19°18’
16	Zmeu	-	13°24’	12°54’	13°00’
17	Sineşti	16°42’	17°48’	18°06’	17°42’
18	Storneşti	17°36’	18°06’	18°54’	17°12’
19	Osoi	14°36’	16°06’	16°06’	14°18’
20	Bocniţa	20°12’	17°48’	19°24’	16°06’
21	Cosiţeni	20°36’	19°18’	20°18’	18°06’
22	Scobîlţeni	17°00’	10°54’	14°48’	12°00’
23	Holm	18°00’	16°06’	19°48’	15°42’
24	Popeşti	17°06’	15°00’	15°06’	13°54’
25	Obrijeni	19°24’	18°36’	19°54’	18°54’
26	Doroşcani	17°30’	18°36’	17°30’	16°42’
27	Hărpăşeşti	17°18’	18°06’	17°54’	16°36’
28	Vama	-	-	12°42’	12°24’
29	Pădureni	-	3°06’	8°18’	9°00’
30	Dumeşti	18°12’	17°00’	16°18’	14°48’
31	Păuşeşti	19°42’	18°24’	18°36’	17°06’
32	Chilişoaia	22°00’	22°00’	19°54’	20°18’
33	Hoişeşti	19°48	15°36’	16°24’	14°42’
34	Banu	9°42’	17°24’	17°24’	17°24’
35	Horleşti	14°12’	13°30’	14°06’	11°48’
36	Bogdăneşti	15°42’	16°06’	14°42’	13°54’
37	Scopoşeni	24°36’	25°12’	24°06’	22°24’
38	Cogeasca	18°36’	17°18’	17°24’	16°06’
39	Cucuteni	19°00’	20°36’	21°42’	19°54’
40	Voineşti	10°48’	9°12’	9°48’	9°42’
41	LunganiV	16°36’	14°00’	14°12’	13°24’
42	Vocoteşti	11°12’	12°00’	12°00	12°12’

From the above figures results that, out of few exceptions, all villages are located on high declivity areas. Today, only three villages have a slope value under 10°; Voineşti, which is located in a lowland region and with the largest area, along with two smaller villages, settled recently, in 1864, Pădureni and Buda, respectively. The highest values are specific to the following villages: Ion Neculce – 24°06’ (**Fig. 8**), Prigoreni – 22°36’, Scopoşeni – 22°24’, Gura Văii – 22°00’ etc., that are located on unihabitable areas.

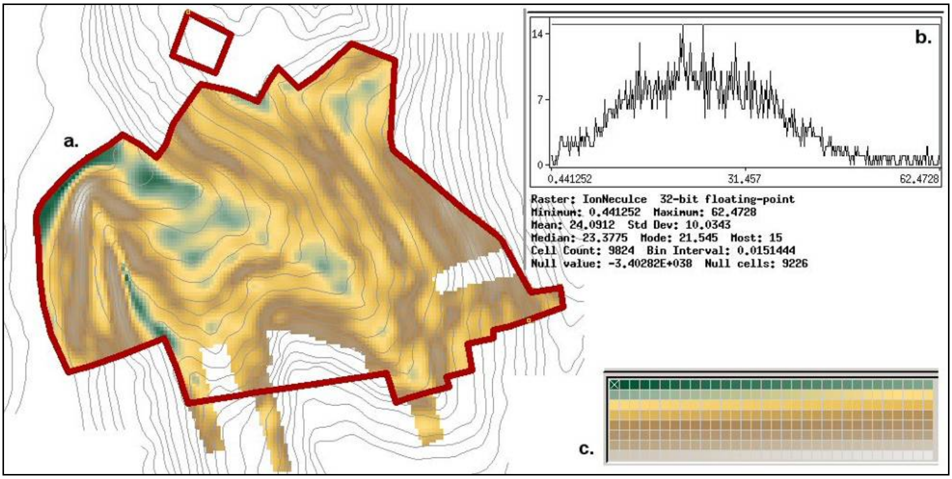

Fig. 8 Declivity map for Ion Neculce village in 1996 (raster) and 2010 (polygon) (a.); slope histogram (b.) and related color palette (c.)

Even today, after general urbanistic plans were finalised, many village areas extended on high declivity areas which, usually, are not included in built areas. These built areas extensions has as a result an increase of declivity values for the period 1996-2010. In this situation are the villages Chilişoaia, Ion Neculce, Gura Văii, Goeşti and Pădureni. But for most of the villages slope value decreased by engulfing in built areas some back of cuestas, colluviums and floodplains.

6. CONCLUSIONS

The villages from central and western part of Iaşi Cuesta emerged and developed in less favourable geomorphologic conditions.

In the Midde Ages dwellers were especially looking for locations of hârtop (small round drainage basins) type, with defensive attributes and was not located on main migratory paths. During time, this preliminary positive asset has transformed, even for newly emerged villages in XIXth and XXth centuries in a restrictive factor for their development. In the last two centuries built areas extended on the same slopy areas, altimetric aspects being totally neglected. Built areas developments considered only planimetric aspects, altimetry being completely neglected. In this respect we recommend the GIS use for land planification, using specific tools, including buffers and overlay in order to identify the best areas for village extension.

REFERENCES

Apetrei, M., (1994), *L'influence de la structure géologique sur la morphométrie des basins hydrographiques. Application au basin du Bahlui*, An. St. Univ. "Al. I. Cuza", tom XXXVIII-XXXIX, sect. IIc (Geogr.), Iaşi, pp.71-80.

Băcăuanu, V., (1968), *Câmpia Moldovei – studiu geomorfologic*, Edit. Academiei, Bucureşti.

Brânzilă, M., (1999), *Geologia părţii sudice a Câmpiei Moldovei*, Edit. Corson, Iaşi.

Crăciunescu, V., (2010), *eHarta: Planurile Directoare de tragere*, http://earth.unibuc.ro/articole/.

Cracu G. M., Popescu M., (2008), *Using GIS techniques to describe morphometrical features within the mountain hydrographical basin of Ialomita river*, Geographia Technica, no. 2, pp. 16-22.

Groza, O., (2005), *Bazele teoretice ale planificării teritoriale*, Univ. „Al. I. Cuza", Iaşi.

Grozavu, A., Mărgărint, M. C., Patriche, C. V., (2010), *GIS applications for landslide susceptibility assessment: a case study in Iaşi County (Moldavian Plateau, Romania)*, Risk Analysis VII & Brownfields V, WIT Press, Southampton, Boston, pp. PI 393-404 (www. witpress.com, WIT Transactions on Information and Communication Technologies, vol 43, doi:10.2495/RISK100341).

Lăzărescu, Laetiția, (1948), *Numărul localităților vechi din Jud. Iaşi constatate documentar între anii 1400 şi 1504*, Rev. Studii, nr. 9, pp. 207-225.

Mărgărint, M. C., (2004), *Utilizarea teledetecției în studiul geografic al teritoriului județului Iaşi*, Teză de Doctorat, Univ. „Al. I. Cuza", Iași.

Mihalache, V., (2000), *Comuna Popeşti – județul Iaşi, schiță monografică*, Edit. Sylvi, Bucureşti.

Muntele, I., Groza, O., Țurcănaşu, G., (2002), *Regionarea spațiilor rurale din Moldova în perioada de tranziție. Fundamentul geografic al strategiilor de dezvoltare, in Moldova – populația, forța de muncă şi aşezările umane în tranziție*, coord. Ungurenu, Al. et al., Edit. Corson, Iași, pp. 148-190.

Patriche C. V., Căpațână V., Stoica D. L., (2006), *Aspects regarding soil erosion spatial modelling using the USLE/RUSLE within GIS*, Geographia Technica, no. 2, pp. 87-98.

Rădoane, Maria, Ichim, I., Rădoane, N., Dumitrescu, Gh., Ursu, C., (1996), *Analiza cantitativă în geografia fizică*, Edit. Univ. "Al. I. Cuza", Iaşi.

Rotaru, M. G., Anculete Gh. C., (1996), *Sistemul cadastral şi regimul funciar din România*, Edit. Tehnică, Bucureşti.

Tudora, D., (2010), *Distribuția geografică a indicilor stării sociale a populației rurale din Moldova Apuseană*, Rez. Tezei de Doct., Univ. "Al. I. Cuza", Iaşi.

* * * (1894), *Harta topografică a Moldovei*, sc. 1:50,000, maps: Tîrgu Frumos, Podul Ilóei and Iași.

* * * (1940), *Planul director de tragere*, sc. 1:20,000, maps: T-gul Frumos, Lungani, Boghicea, Dumeşti, Mădârjac, Iaşi and Ciurea.

* * * (1983), *Topographical map*, sc. 1,5000, IGFCOT, Bucureşti.

* * * (1996-1999), *Planurile Urbanistice Generale* ale comunelor Strunga, Târgu Frumos, Brăieşti, Lungani, Sineşti, Popeşti, Podu Iloaiei, Dumeşti, Lețcani, Horleşti, Voineşti.

* * * (2000), *Reference Manual for the TNT products V6.4*, Lincoln, MicroImages Inc.

ARCGIS MODULE FOR PROPERTY VALUATION IN CITY OF CLUJ-NAPOCA

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ABSTRACT:
This study aims to help us understand the concept of transaction on the property market, the concept of real estate assessment, which determines the market value of properties. From geospatial perspective, the property is characterized by factors that each of them to some extent affects the determination of market value. Currently in Romania, property valuation is applied in practice by the National Association of Evaluators in Romania (ANEVAR). The association's working way has little geospatial influence that is not seen in a geomatic perspective, which is why into the current study, we wish to point out, many factors that are influencing the decision process.

Keywords: *GIS, conceptual model, property valuation, market value, geospatial influence.*

1. INTRODUCTION

Why GIS applied in property valuation? The reasons are multiple, but between the main ones there are the following: this perspective is not being used at this moment in Romania; visualizing the property as a graphical feature containing the appropriate characteristics and its positioning with respect to the environment, no matter the nature of the environment (natural, economic, juridical, etc.); at the same time by creating a conceptual model, facilitating the spatial analysis of property is pursued, applied on its natural factors. The geospatial perspective in property valuation has as a purpose to determine the market value of the properties, a subjective value, with respect not only to real estate prices at the valuation moment, but also involving the geospatial factors in this process.

2. METHODOLOGY

The geospatial perspective of property assessment is intended as described above, determining the market value of property, namely a subjective value, reported not only when assessing the housing market, but also geospatial factors involved in this process. GIS, used as an acronym for Geographical Information Systems, is actually a system that has many types of informational elements spatially referenced, with respect to a coordinate system (*Bălteanu et al., 2001*). The insertion, the storage, the management and the analysis of the components is made by using a computer, the result, firstly, consists of visualizing complex information spatially referenced with respect to a spatial reference system, and secondary, there is the possibility to apply spatial analysis and complex correlations, impossible to be made through classic techniques.

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Representing geographic entities can be done by geometric shapes (feature classes) or cell-based files (raster). The classes of features are typically represented using points, lines and polygons. They are saved by pairs of coordinates that refer to locations on earth. A line or a polygon can be represented by a series of coordinate pairs that are connected to visualize data in a thematic layer. Through this approach, the characteristics are discrete objects on the earth and this representation is called vector representation.

The functionality of the informational society it's based on the capacity to accumulate, to store and to use the information efficiently. The approached subject offers a working tool, respectively the geographic informational systems used for making the information management more efficient, starting from storing the data, moving on to the graphical display and spatial analysis. Real estate market represents the interaction between the offers for properties to be sold and the requests made for this type of products to be bought. The actors in the real estate environment are the vendors, the buyers, the intermediate agencies for transactions and renting places, financial institutions, constructors, developers and others. The real estate market represents an economic category of goods production, in which all the buying/selling contracts find a meaning. It is seen as being an organic unit with respect to the relationships generated by it and connected to the space where those take place. Housing market may be interpreted as the virtual dynamic frame inside which buildings are evaluated, measured, compared, and even auctioned, for trading or renting them.

This type of market dynamics, real estate people maintain a continuous information environment: "What price was established for apartments with two rooms from X area?" "How much is the land?" "What is the price evaluated for this building? " These questions are common in real estate field. The answer to these questions is found by analyzing the real estate market, and not just its current trend, but changes over time too.

A real estate market has the same characteristics as a market for goods and services. In an efficient market:

- goods and services are essentially homogeneous and can be replaced immediately with one another;
- large numbers of buyers and sellers who create the free market;
- prices are relatively uniform, stable and low;
- is self-regulatory;
- buyers and sellers are fully informed;
- the goods are ready for consumption, delivered immediately.

How can we *imagine* the property?

The context that the answer to this question will be explained is one from a spatial point of view, respectively representing the property spatially referenced, containing its characteristics as attributes. *The virtual image* is built using the attributes of the property, from a geospatial perspective. The property has an area, perimeter, dimensions, complex infrastructures, etc. This type of a property image allows us to manipulate its characteristics; as well analytical methods can also be applied on these characteristics

Coming back to the real estate market, seen as a virtual environment for real estate transactions, its primary concern is the "virtual image" of the property, facilitating access to information on any type of real estate object. Market value estimation of a property is made through assessment process and it is composed by a set of coherent and orderly procedures. These procedures are ordered in a logical sense using the principles of assessment. These principles assume that property are fungible goods and therefore there can be applied the economic theory.

Property assessment is done for various purposes, including: financial reporting, to determine the rate of tax, transactions involving the transfer of ownership, mortgages or loans secured by property, litigation, tax matters, consulting or investment decisions. Assessment report for a property held by an individual beneficiary wishing to emigrate, prepared by an authorized assessor, is perfectly valid to the authorities in the recipient country where he wishes to emigrate, to prove financial opportunities. Subject to assessment in these cases is *estimating the market value* of real estate. Property - consisting of free land or land with buildings and improvements - is one of the most important sources of income in the global economy. Because of this, it is extremely important that the "actors" of the property market have access to credible and relevant information on solid analysis, the clear views on property value and the right to receive advice in a wide range of issues relating to both real estate and other property types (enterprise, tangible and intangible goods).

The International Valuation Standards Committee (IVSC) recognizes the complexity of professional evaluation procedures, diversity of types of properties, difficulties arising from the interpretation of assessment by other disciplines, problems in the use and translation of specialized terminology, and overriding public need for professional evaluation, well-founded and developed in accordance with generally accepted standards. IVSC is a non-profit association made up of professional organizations in the assessment, worldwide, which are united by a single act of incorporation. IVSC is an NGO member of the United Nations whose main goals are to develop and publish, for public interest, standards for assessing property, to promote their global adoption, to harmonize the standards of assessment in different countries of the world etc. (*Mihăilescu, 2008*). Currently, these assessment standards are applied in Romania too. The National Association of Evaluators in Romania - ANEVAR - was founded in 1992 as a professional, nonprofit, nongovernmental, independent organization, acting in public interest (in fact supported by its recognition as a public utility by H.G. 1447/09.09.2004) and to promote evaluation methods and techniques through specific means. ANEVAR initiated and developed assessment courses in universities, showing openness to training conducted for the purposes of recognition of these courses organized in property evaluation.

Market value is the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arm's-length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently and without compulsion. (*IVSC, 2007*) All methods, techniques and procedures for measuring the market value, properly implemented, should lead to a common expression of market value. The manner, in which property is traded on the housing market, stands the applicability of various methods and procedures for estimating the market value.

Assessment methods and techniques of real property:

- Comparative Method
- Cost Method
- Income Method
- Nominal Asset Land Valuation Method

2.1. Comparative method

Estimating the market value by analyzing the market is to find similar properties and then comparing these with the properties of assessment. Major premise of this method is that the market value of a property is directly related to prices of comparable and competitive properties. Comparative analysis focuses on similarities and differences between properties and transactions that affect the value. As a limitation of this method, it is rarely applied to special purpose properties, because there are only few properties alike sold on the market. However, this limitation is not applicable to the scope of mortgage and/or real estate, where properties on the market are traded with the destination of residence. (*Yomralioglu et al., 2004*)

2.2. Cost method

Through this method it is tried to estimate the difference the buyer perceives between the property assessed and a new building constructed with optimal utility. An estimated cost its computed to build a replica or a replacement for an existing structure, which to use then to decrease the depreciation of property valuated, estimated on valuation date. The foundation of this method is the substitution principle (no buyer will pay more for a property than the cost of acquiring land and a building immediately with a similar utility and attractiveness). Cost method is important in estimating the market value of new buildings or relatively new, since in such cases the cost and market value are usually close (*Yomralioglu et al., 2004*).

2.3. Income method

The property is considered as an income generating investment. Revenue-generating properties are purchased for investment and from the investor's point of view; the ability to make profits is a key element influencing the property value (*Yomralioglu et al., 2004*).

2.4. Nominal asset land valuation method

Property values reflect the ability to perform a function. With respect to the properties, the functional qualities may include: influence of location (access to points of interest), physical attributes (size, shape, age and circumstances), legal factors, planning factors and economical standards (*Yomralioglu et al., 2004*).

A data model is considered conceptual when it permits direct mapping between real-world perception and its representation through the concept of modeling. The dimension of data modeling is an area of representation of the real world that focuses on specific classes of phenomena, such as data structures, space, time, and multi-representation. The conceptual model assumes to be a way of solving spatial problems. Representation model attempts to describe the objects in the environment, for example buildings, rivers and forests. The creation of these models of representation is executed in a GIS, stored in data sets called layers. The spatial analysis can be applied on raster formats or vector formats. The need to address issues of space determines the individual to seek a logical explanation in any process of cause and effect, then trying to find a viable solution for solving problems. Translating environmental problems, regardless of environment (social, economic, natural, etc.) into a mapping environment, it helps us form a graphic image of all aspects involved in the decision process.

The conceptual model allows us to combine different models in a schematic interpretation, in applicable staged ranges (**Fig. 1**).

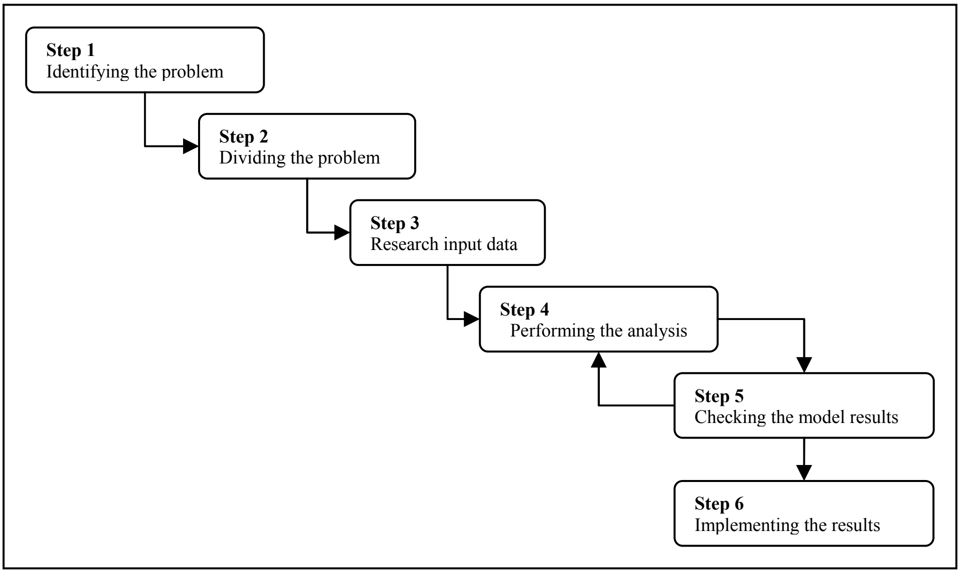

Fig. 1 Conceptual model for solving spatial problems (*ESRI, 2008*)

Step 1 - Identifying the problem

Solving spatial problems as the main goal, first we have to identify the problem that has to be solved and also the purpose we want to achieve.

Step 2 - Dividing the problem

All steps necessary to perform the modeling process are identified and also the data used for processing is established.

Step 3 - Research input data

It is important to understand spatial relations and the relations between attributes of individual objects in the environment, and also the major relationships between these objects. To understand them, we have to examine the input data.

Step 4 - Performing the analysis

All the methods that must be used to complete the model are being identified.

Step 5 - Checking the model results

Depending on the model used, the results are checked to determine whether changes are needed in the parameters, or if there have been created several models, we have to determine which of these is most appropriate.

Step 6 - Implementing the results

We can say that space problem is solved when the results of a model achieves the established purpose in the preliminary stage, at step 1.

Any spatial problem can be interpreted in a GIS perspective. Depending on the complexity of the issues, we must identify the main 'actors' in the modeling process. The conceptual model comes as a help in solving spatial problems.

Spatial analysis or spatial statistics include any formal technique to study entities using topological, geometrical or geographical properties. Using the conceptual model and combining it with spatial analysis, we refer to a variety of techniques, many of them still in development stage, all these using various analytical perspectives, applied in different spheres. Defining spatial entities can be constrained by the analysis that can be applied to those entities and the degree of influence to the final conclusions. The main thing to realize is determining the market value of property. Thus, in order to achieve this purpose there must be identified the factors that influence this value. Property assessment is quite difficult in terms of identifying the participants in the decision-makers.

The market area. The value of a property can be influenced, or even modified, by various social forces, economic, administrative and environmental. Within a zone of influence, there are factors acting in order to determine the property value. The area of influence and, more comprehensive, the market area is the perimeter characterized by certain factors, where the valuated property competes with other properties assessed to attract attention of buyers and sellers in the real estate environment. The market areas are defined by a combination of factors: physical, demographic and socio-economic characteristics of residents or tenants, condition of building (age, degree of maintenance, high vacancy, etc.) and trends regarding the use of properties. As long as the market areas are as people perceive them, build them, organize them and use them, they will have their own dynamic, an evolution on which the property value is depending on. In relation to the assessed property, there have been identified the following factors that influence the value: social factors, economic factors, administrative factors, environmental factors, real estate criteria.

Social factors:

- population density;
- training level, occupational level;
- mean age;
- household dimensions;
- employment and unemployment degree;
- cleanliness;
- existence and quality of educational, medical, social, recreational, cultural, commercial services;
- the crime level;
- public organizations, associations dealing with facilities in the area, clubs, etc.

The economic factors express the financial capacity of the inhabitants of the area and their possibilities to own properties or rent them, keep them in optimal condition, to renovate or rehabilitate them when necessary. The economic characteristics taken into consideration in the analysis and definition of market areas are:

- the average income per household;
- income per capita;
- household income distribution;

- percentage of building occupancy by owners;
- rent levels and trends;
- level and trends of property values;
- the occupancy level in various categories of properties;
- planning and construction volume.

The economic characteristics are analyzed in the last three to five years.

The administrative factors relate to legislation, regulations and taxes on properties, the management and implementation of these measures. There are analyzes the systematic measures in the market areas, construction law, health regulations and fire extinguishing, facilities granted to taxes. The main factors that distinguish administrative market areas are:

- property tax, compared with services provided by local administrative authority, in comparison with other market areas;
- systematic rules, construction, fire and health services;
- quality of public services, police and firemen, security, schools, municipal services, gas, water, electricity, TV cable, telephone, internet etc.;
- environmental regulations;
- restrictions on land and buildings;
- transportation network and its environmental perspective.

Environmental factors represent any natural or man-made features, which are can be found inside the market area or the analyzed area, such as the following:

- land topography;
- vacant areas;
- major sources of pollution: noise, odors, vibration, smoke, fog, mist, etc.;
- quality of municipal services: street lighting, sewerage, electricity;
- maintenance of vacant land;
- display, width and street maintenance;
- attractiveness and safety of entry and exit routes in the area;
- actual age of the properties;
- changes in the type of buildings and land use;
- microclimate characteristics: strong winds, temperature and humidity differences;
- environmental hazards: landslides, floods, frequently earthquakes;
- access to major service providers, industrial platforms, to schools, shops, parks, churches, places of entertainment and jobs.

To create a conceptual model for property assessment were used the following data sets (**Fig. 2, 3, 4, 5**):

- Digital Elevation Model
- Landuse
- Street network
- Railway network
- Property layer
- RATUC bus stations
- Points of interest
- Cluj-Napoca neighborhoods
- Study area

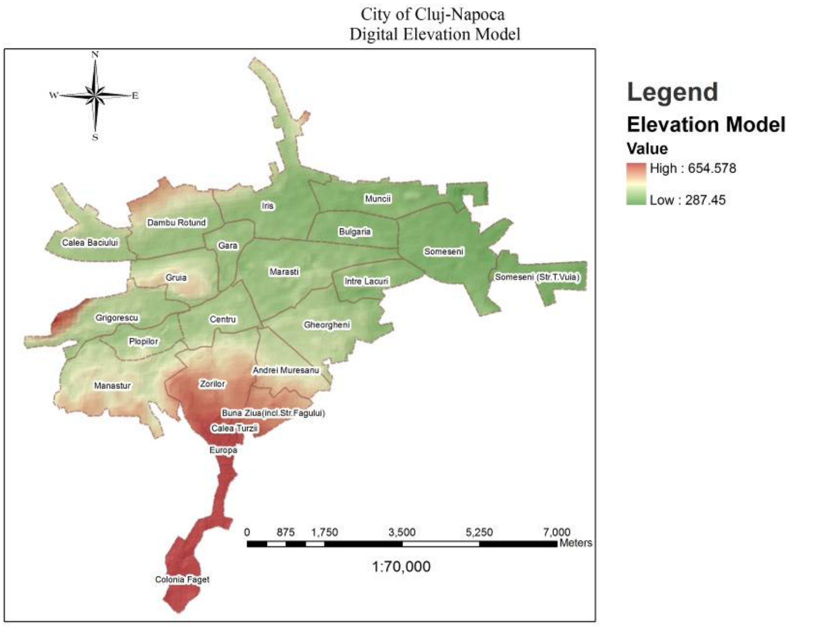

Fig. 2 Digital Elevation Model of the study area

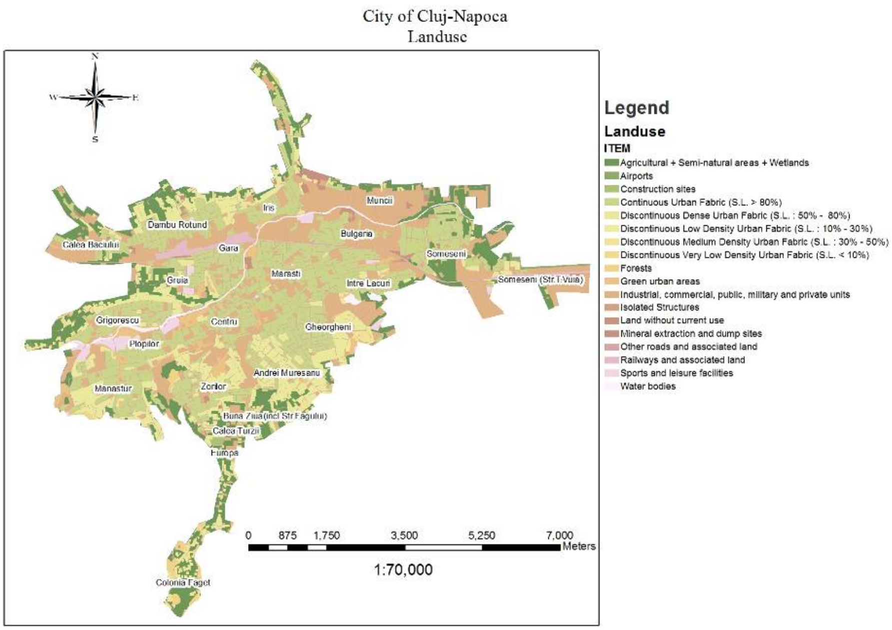

Fig. 3 Landuse layer for the study area

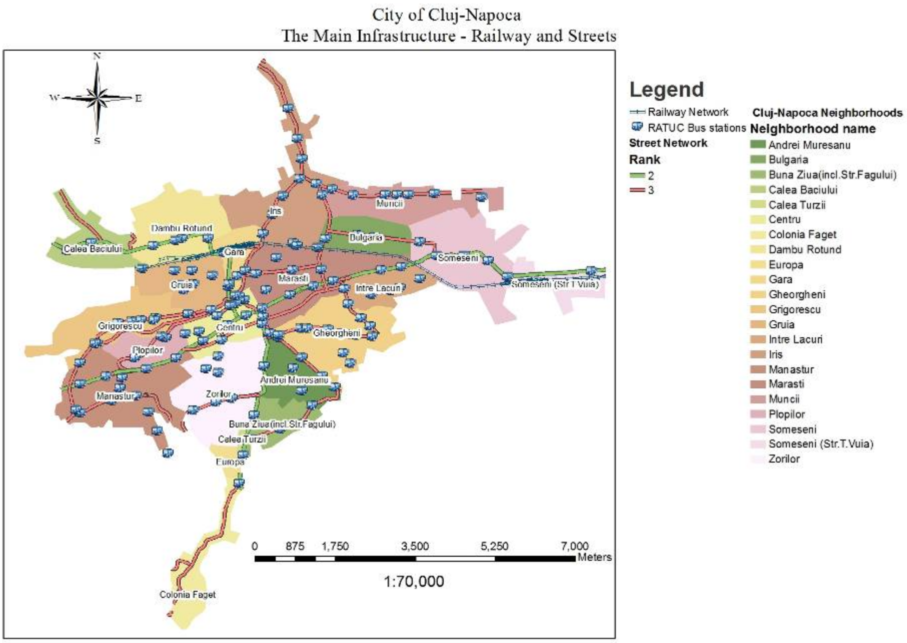

Fig. 4 The main infrastructure and transportation

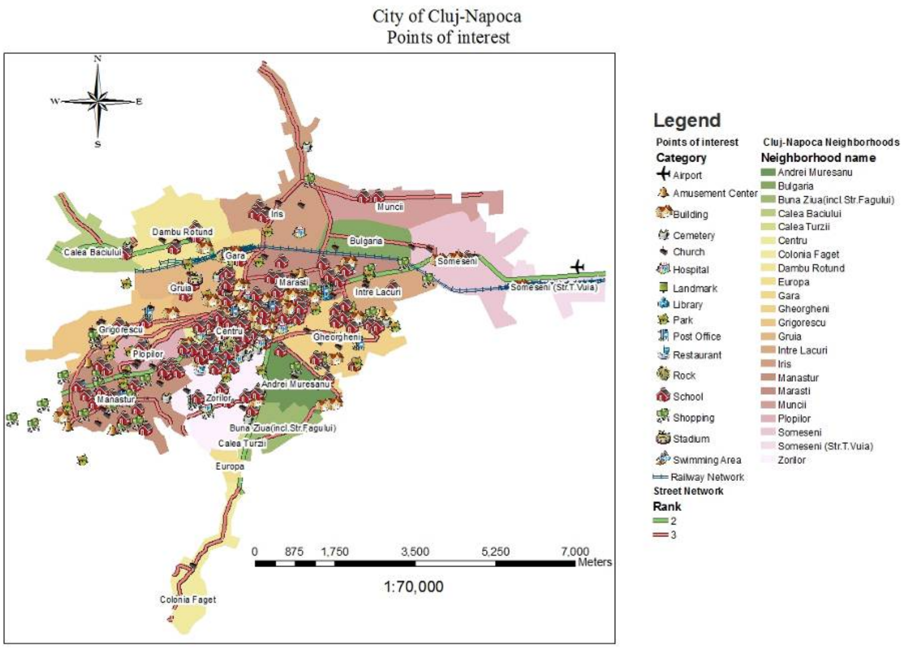

Fig. 5 Points of interest and market areas

The data sets have been limited to a predefined study area. They were created using GIS methods, partly digitized, and the remaining data was collected from free sources. The datasets have been created using the spatial reference Stereographic 1970. Cluj-Napoca is located in the center of Transylvania region, being the connecting point between the Apuseni Mountains, Somes Plateau and Transylvanian Plain. The city is located at the intersection of parallel 46 ° 46 'N and longitude 23 ° 36' E. The reason this study area has been choosen is due to increased land development. The occupied area of the city increases rapidly, in the detriment of areas occupied by natural ecosystems and/or traditional countryside landscapes, also the development of the real estate market and its fluctuations it's taken in consideration. Regarding the factors influencing the assessment of a property, we can not say that we know the exact number of factors involved. In this study I focused on environmental factors and social factors in modeling.

The basic tool used in the current analysis is the application ModelBuilder, part of ArcGIS Desktop package. ModelBuilder is the application used to create, edit and administrate models. By creating a model using ModelBuilder instruments are interconnected, the output of an instrument being interpreted as input for another tool (*ESRI, 2008*). When the model is created, the set of tasks or functions applied to data stored can be accessed several times, this way an automated manner of working being created. The model created is added in ArcToolBox as a *model tool* that can be directly executed by accessing the function, or by Command Line window. In ArcToolBox, this conceptual model created has the following structure (**Fig. 6**):

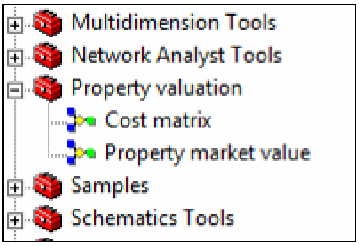

Fig. 6 *Model Tool* added in ArcToolBox

Land evaluation is the process of identifying the factors that affect the estimation of market value, with associated weights. The result is an opinion of market value based on the assessment of these factors and the relevance of this value on a sample of properties. A cost matrix has been created using the using a conceptual model (**Fig. 7**). *Cost matrix* – accesing this function from the structure shown previously, the end result is a cost matrix, the calculation of this matrix involving a number of factors, with associated weights. *Weighted sum* function was used for final calculation of the matrix, but up to this step there were applied a series of functions on the datasets to get data in raster format.

Afterwards running the first set of functions, from which the final result is a cost matrix, in this second part of the evaluation process using a conceptual model, there are involved a number of individual characteristics of properties, features that make the difference between them, and also it is assigned a subjective interpretation for the values resulting after running the second model – *Property market value*.

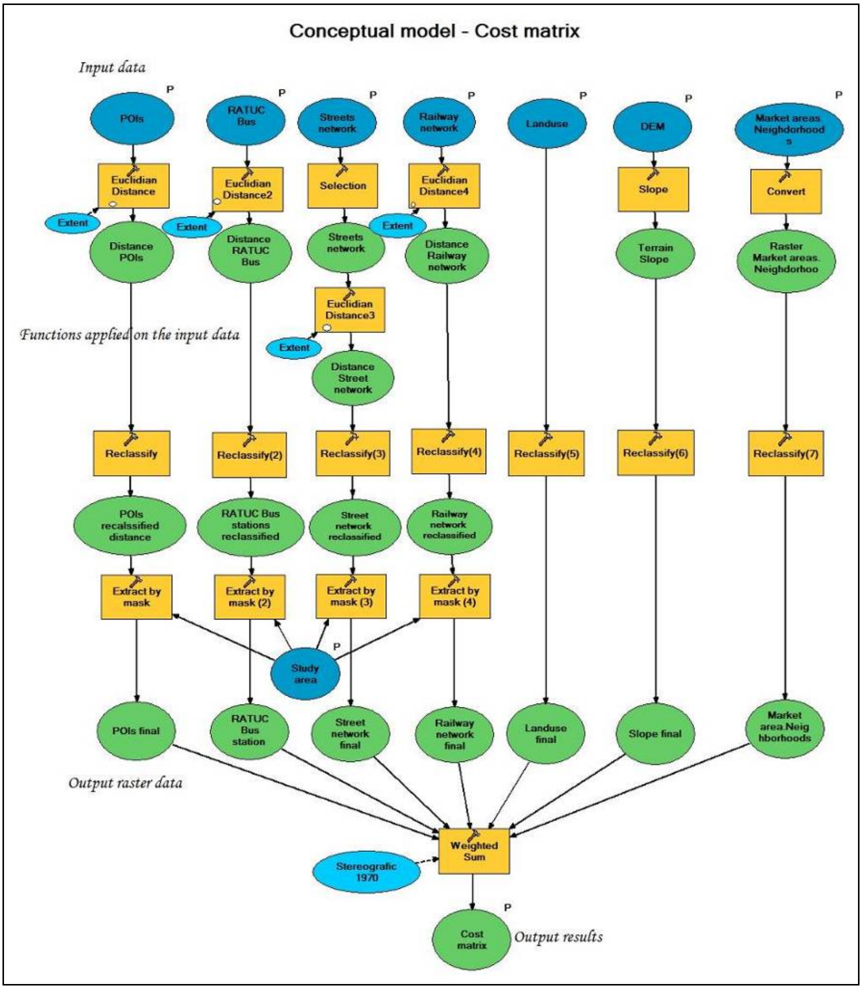

Fig. 7 Conceptual model for the calculation of a cost matrix

The cells from the output raster (**Fig. 8**) files after running the model, in order to determine the market value for properties are defined as a multiplication between the weighted sum of the physical characteristics and the area of the property valuated, according to the following formula:

$$V_i = S_i * \sum_{i=1}^{n} (C_i * p_i) \quad (1)$$

- where:

V_i - is the market value;

S_i - property area;

C_i - physical characteristics of properties;

p_i - the weights (*Yomralioglu et al., 2004*).

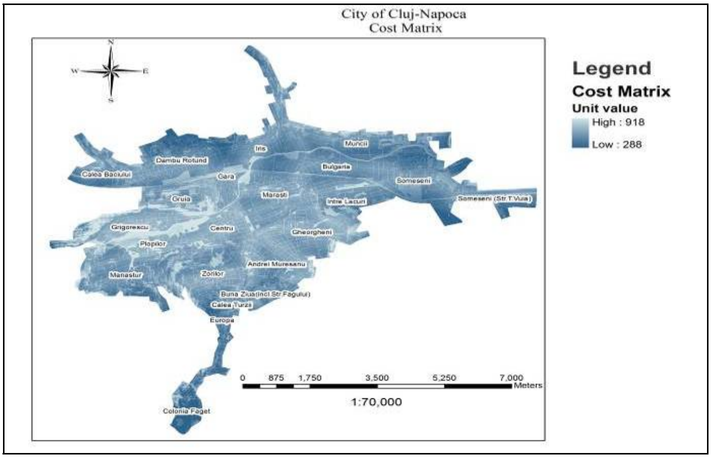

Fig. 8 Cost matrix resulted after running the first conceptual model

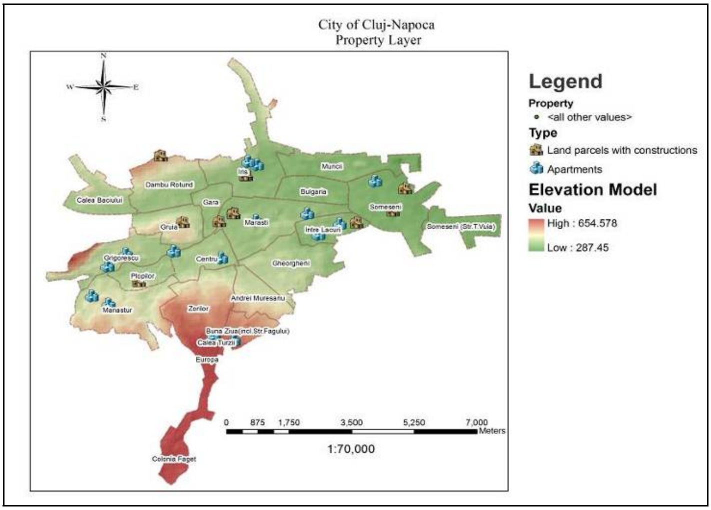

Fig. 9 Distribution of properties used in the valuation preocess
for estimating the market value

The second model (**Fig. 10**) is related to the result of the first model, the cost matrix having a great impact on the result of this model. As input data it has been used a property layer (**Fig. 9**), where it has been stored data about properties, dimensions, characteristics, obtained through land surveying methods, fieldwork, property valuation requirements and ownership analysis, for the current study to be relevant.

A set of 26 properties has been used, parcels with constructions and apartments too, located in different areas of Cluj-Napoca.

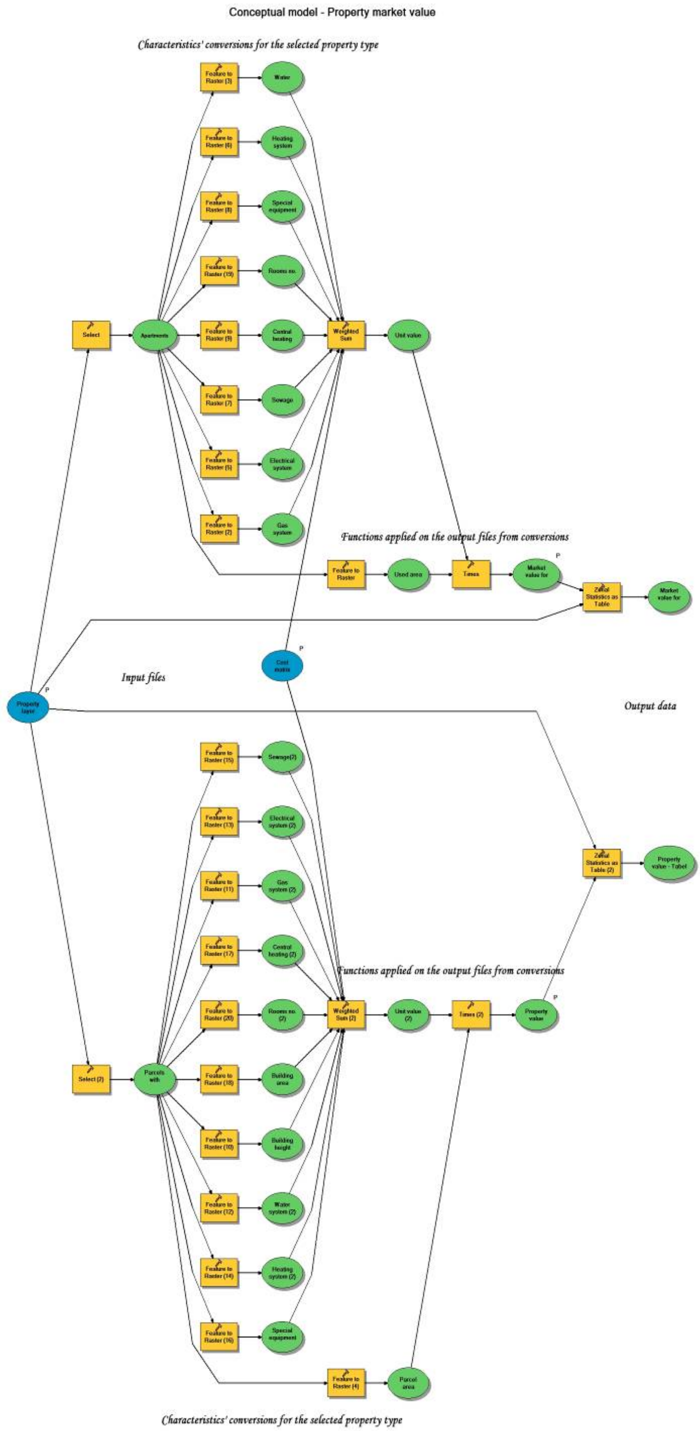

Fig. 10 Conceptual model for the calculation of a property maket value

3. RESULTS

The total number of factors involved in the assessment of property is quite uncertain. Because of this, the precise value of property can not be determined easily. Real value of buildings is almost impossible to determine, for which the estimated value is accepted. Due to complexity of assessing property, in order to provide a comprehensible explanation to the owners, of how their property was assessed, it is a challenge for even for evaluators.

Run results of the second model is represented by two raster files and two tabular files, depending on the type of property (apartment or parcel with construction), interpreted as two real estate units, each defined by the data stored in the attribute relevant for each o them.

Table 1. ***Property market value for apartments resulted after running the second conceptual model***

ID	2	6	7	12	13	14	15	16	18	19	21	24	25	26	27
Property market value (LEI)	57730.4	69545.5	347466	231728	274238	75283.2	91595.2	433549	266597	256357	216183	162801	423898	909664	562666

According to the two tables (**Table 1** and **2**), the values obtained are equivalent market value of property in LEI. ID field is the corresponding value of the unique identifier that relates the results obtained with graphic file that contains information about properties.

Table 2. ***Property market value for land parcels with constructions resulted after running the second conceptual model***

ID	4	5	8	9	10	11	17	20	22	23	28
Property market value LEI)	1734700	1761870	787831	759298	5298300	720176	1517620	2679700	1152780	9565150	562350

Table 3. ***Sample of the validation process of results***

ID	**Location**	**Comparative values (EUR)**	**Model Resullts(LEI)**	**Converted value(EUR)**
17	Gruia	410000	1517620.000	360899.860
		429000		
		235000		
		269000		
		350000		
18	Marasti	90000	266597.000	63398.492
		100000		
		65000		
		73000		
		63000		
		57000		
19	Centru	70000	256357.000	60963.354
		53000		
		75600		

Checking the models' results

This step involves validating the results obtained from running the two models. To browse this stage we consulted real estate market, using the *comparative method* to compare the results with transaction values for similar properties. Using the nominal asset land valuation method, there have been analyzed a total of 26 samples, of which 69.23% (18 properties) are valid compared with the range determined from the analysis of market value, through comparative method, and to 30.77% (8 properties) can not assign a better accuracy due to lack of information on the property market for similar properties. As it has been concluded the approached method is valid at a rate of 69.23%.

4. CONCLUSIONS

The conceptual model should be regarded as an integration of ideas in social practice, or as the hardware setting of the operating system corresponding to a particular function, to be used. Since this is a conceptual model of real estate valuation and property assessment has become an essential requirement in any normal market, especially in a market in a situation of crisis, the implementation of an application based on models such like these can be successfully asimilated by specialized public in this sector, especially since the geospatial component is involved. Property valuation, when realistic, leads to a good orientation of economy that unlocks the credit movement, contribute to hardening investment, promote development of property, and development of the industrial business of all kinds. The aim was achieved, namely to determine market value for a number of properties, located in city of Cluj-Napoca, using geospatial modeling methods and functions, all encapsulated in a conceptual model.

REFERENCES

Bălteanu D., Driga B., Cheval S., Chendeş V., Dumitraşcu Monica, Ciupitu D., (2001), *Sistem informaţional geografic (GIS) pentru studiul dezastrelor naturale*, Expert Publishing House, Bucharest, ISBN 973-8177-42-1.

Comitetul pentru Standarde Internaţionale de Evaluare (IVSC – International Valuation Standards Committee), (2007), *International Valuation Standards (IVS)* , editia a opta, IVS1 – Market Value Basis Of Valuation.

Dobrică Liliana, Colesca Sofia Elena, (2009), *Managementul datelor geografice în sistemele GIS,* ASE, ECONOMIA - seria MANAGEMENT, nr. 2, pp. 196-207.

Frăsineanu Corina, (2004), *Perfectionarea metodelor de evaluare a patrimoniului*, Editura ASE Bucureşti.

Haidu I., Haidu C., (1998), *S.I.G. - Analiză spaţială*, Editura *H*G*A*, Bucureşti.

Imbroane A.M., Moore A., (1999), *Iniţiere în S.I.G. şi teledetecţie*. Presa Universitară Clujeană.

Mihăilescu I.A.M., (2008), *Cadrul international al activitatii de evaluare a proprietatilor imobiliare*. RevCAD – Revista de cadastru, Universitatea „1 Decembrie 1918", Alba Iulia.

Nick French, (2004), *The valuation of specialised property: A review of valuation methods*, Journal of Property Investment & Finance, Vol. 22 Iss: 6, pp.533 - 541.

Yomralioglu T., Nisanci R., (2004), *Nominal Asset Land Valuation Technique by GIS*, FIG Working Week 2004 Athens, Greece, May 22-27.

http://www.estimatori.ro/informatii_utile/Ce_este_evaluarea_imobiliara_1.html

http://www.gsd.harvard.edu/gis/manual/raster/index.htm

http://www.romacor.ro/standarde-evaluare-imobiliara-intreprindere.html

SPATIO-TEMPORAL GIS-DESIGN FOR REAL-TIME PROCESSES

Erich WILMERSDORF[1]

ABSTRACT:
New technologies in Information and Telecommunication Processing have created an effective infrastructure which enables the penetration of real-time processes with monitoring features. GIS is faced with new fields of applications dealing with the dynamics of spatio-temporal processes. The fully integration of spatial modeling into the workflow of the process is the adequate response. GIS is faced with screening of data bases with continuous updating of georelated data. Dynamic geo-data input has to be analysed on-the-fly. So permanently changes in the spatial status can be explored. To cope with the need for information services GIS analysis discovers special „events" by self-diagnosis based on a catalogue of rules and conditions. These are the starting point for generating adequate information products. The adaptive compilation of the geographic context enables the system to generate an event oriented, made-to measure information service. The output is adjusted to the current phenomenon of the process and to the interests of the recipient according to the user's profile. This is applied also to the complex cartographic visualisation process marked by event- and user-oriented compilation. GIS represents a helpful tool in the stage of real-time cartographic modeling including a self- checking routine, which takes care of a good perceptive faculty of the cartographic image ready-made by automated procedures. Complex requirements occur, when a cooperative coordination among „players" on an adaptive interaction platform has to be installed, where participants of a user group has to be supported by GIS. Due to these features GIS can provide new ways of geographic information delivery on the fly effectively dealing with the complex nature of dynamic spatial processes.

Keywords: *on-line geo-monitoring, event controlled communication, adaptive GIS for information services, automated cartographic modelling, spatial processes.*

1. INTRODUCTION

1.1. The challenge for Geographic Information Systems (GIS)

Recent developments of information and communication technology enable synchronous monitoring and even interacting with dynamic information processes. Effective methods of geodata acquisition, dynamic updating of geo-data bases, which represent real world with increased resolution and topicality, create a sound basis for generating real-time infor-mation. An increasing availability and continuous update of geospatial data over the past decades could be observed due to the advances in the field of storage technology. Time is stored in geo-data bases more and more frequently, so that spatial developments in the course of time can be observed in the data of objects and their attributes. So timely aspects are requested to be analysed by automated procedures. Additionally geo-related messages mostly compiled in cartographic images have to be distributed via telecommunication in a fraction of time. These demands of such a powerful infrastructure promote the IT-assisted modelling of time-critical workflows in space.

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That means, that GIS has to step forward from static analysis tasks into monitoring and analysis of dynamic geo-data flow. Together with the infrastructure of ICT networks and their remote data base access GIS is faced with the modeling, analysing and deploying the information about space-time-attribute changes. On the other hand - due to the short response time of real time processing - GIS becomes able to penetrate new fields of application, which ask for exploring dynamic spatial changes synchronously.

1.2. The response of GIS: The trend to real-time processing

As a matter of fact continuous geo-related data acquisition, update procedures and storage in a spatio-temporal DBMS became an integral part of data processing and modeling. GIS has to move from a static view to supervise continuous geo-related data acquisition and updating. Sensors like GPS offer digital geo-data capture directly into data bases. So fast updating services could be implemented for georelated dynamic processes. This fact raised the ability of GIS to offer quick response with topical analysis. This engagement creates the prerequisites for on-line geo-monitoring synchronously of georeferenced processes. Remote data base access, data integration in a computer network and new output facilities (e.g. cellular phones, internet access) promote this progress. The integration of GIS into spatio-temporal modeling procedures creates a sound basis for the monitoring of dynamic georelated information processes. For dynamic processes the broad scope of functionality and versatility of GIS-tools is very helpful. Due to changes of position, geometry, topology or attributes GIS procedures examine the impact on the spatial situation on the whole.

2. THE SYSTEM DESIGN

2.1. Spatio-temporal conceptual model

Due to dynamics the key issue of GIS is focused on the spatial change management in the process by the time. Monitoring dynamics GIS has to take special care of time in the Geodata Warehouse of the process. Characteristics of objects may have timely dependence, being active only in a certain life cycle. So time parameters are in the focus of analysis. Time can be stored in different ways in the geodata base. There is a broad scope of object´s data with time stamps:

- object itself as entity is time dependent
  e.g. opening hours of a restaurant, important for Location based Services (LBS) period of legal validity of a traffic sign (no parking during special hours)
- geometry
  e.g.the propagation polygon of a fire at a special point of time
- position
  e.g. fleet management: approach of a driving ambulance vehicle
- topology
  e.g. blockade of a segment in the street network during a certain period because of a leakage in a pipeline network
- attribute (quantitative or qualitative values)
  e.g. air pollution: percentage of noxious gas in the air

The time axis drives the observation of each change in space. A temporal dynamic segmentation method can be applied, in order to compare the current status with a previous spatial one (space-time paths of objects to describe a route of a person or vehicle) (*Hongbo, 2006*).

Dependent on the spatial diffusion of the process by the time positional, geometrical, topological and attributive changes are observed and analysed by GIS. Due to the dynamics the area of interest is not stable but variable dependent on changes in location and on its inflicted objects in the neighbourhood area (e.g. the expansion of poisonous gas according to the weather conditions). So GIS is faced with requirements of spatial and thematic adjustment in coordination with the data bases of the process model, to manage the supervision of the process. An adaptive GIS is the adequate tool to follow the spatial development during the process automatically.

2.2. Geomonitoring and the diagnosis of special events

The simultaneously accompaning by GIS-tools is the key issue. Continuously the process has to be X-rayed in terms of spatial monitoring. Changes of the geographic context, where the process is going on, and its impact on objects are in the focus. But the penetration of GIS-tools in such dynamic processes has to take care of special requirements of change management and its demand for information services. Milestones, so called „events" are key nodes for the information management of the process. Each event represents a classified phenomenon with a special geographic constellation and is a starting point for deploying georelated information about the process.

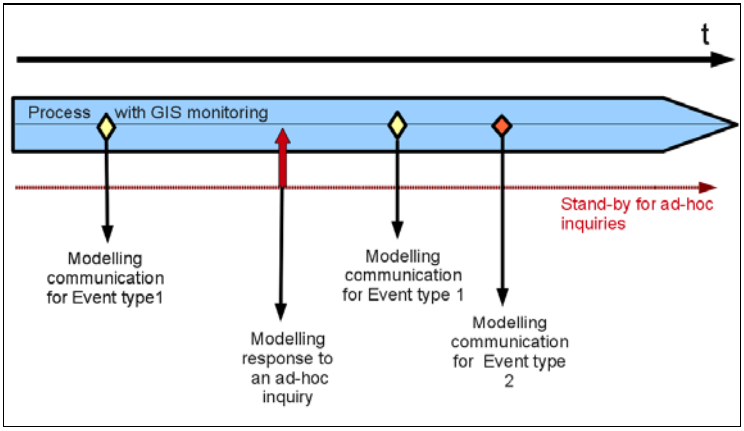

Fig. 1 Event-oriented communication

Two different types of events are possible:

A. Events by Interaction

Information are requested individually on call. It represents an „ad hoc event".
A participant asks for a current insight into the spatial status of the ongoing process. GIS-tools are activated and analyse the process to prepare the adequate answer. This communication process is marked by an individual inquiry to get information.

B. Events discovered by GIS-based self diagnosis

This type of event is discovered by GIS automatically in the continuous run of the geo-monitoring procedure: a special state of geographic context (significant changes in the state of objects and their attributes) or a time threshold is the reason (time slice).

Informations are derived out of the monitoring process automatically (e.g.route guidance by a car navigation system dependent on the current node in the street network). Special scenarios of changes are defined by a framework of rules and conditions. According to the phenomenon of the event the production of messages or of reports to the user´s community is launched.

2.3. Framework for information services

The special scenarios of an event are defined by the catalogue of eventoriented criteria.In the catalogue conditions, rules and criteria are summarized, which GIS needs to know in order to recognize a special event. GIS-analysis helps to explore the attributive, topological, geometrical or positional changes of an event which are defined in this catalogue. If such a remarkable scenario occurs, the system starts a communication process. Reasons for distributing knowledge about the process may be caused by several circumstances: avoiding critical changes, legal requirements, technical or timely reasons. Additional to the geographic characteristics of an event also a description of the correspon-ding information services are defined. They establish the foundation for eventoriented modeling and form a guideline for automated rendering of geo-information about the region of significance.

3. EVENT-ORIENTED MODELING FOR GEO-INFORMATION SERVICES

3.1. Analysis of information needs

The task deals with the investigation of information needs and it represents an integrated approach for an adaptive GIS-framework for information rendering and transfer. The survey of the event's scenario and its geographic context expose the detailled information needs. The knowledge about the geographic phenomenon is the basis for the automated distribution of information about the process itself. The question „what is where?“ must be answered by geo-information processing. There are tough requirements of this communi-cation task: user-oriented information must be generated and deployed to selected participants just in time where it is needed. That means, that it is a task of automated procedures with no interactive manipulation.

Dependent on the characteristics of the event type the parameters of the information package has to be adjusted to the purpose. The design of the information service and the parameters of the procedures can be derived. Dependent on the concrete data of the event's analysis customized report functions and user participation have to be specified finally. On the basis of an adaptive GIS-framework rendering procedures for the adequate information service are composed.

Aspects for the rendering procedure of geo-information are:

Purpose of information rendering

- Snap shot

Deploying information about the current status of space for spatial orientation

- Monitoring

The evolution of the process with its spatial impact has to be observed

- Controlling

Criteria for interactive interference have to be delivered

- Evaluation

GIS ought to deliver characteristic data, statistical and criteria values

- Decision making

GIS has to deliver criteria for decisions

- Planning variants

future scenarios are simulated

- Documentary reasons

establish a durable evidence about the event

Dependent on the characteristic features of the event the parameters of communication has to be adjusted to the purpose.

What is where?

The geographic context of the phenomenon is in the focus. What is the spatial impact of the current status affected by the changes. What are the subjects of interest?

Time as a referencing system for the information

- point of time
- time slice of a period
- looking back, comparison with past
- current status
- prospect into the future (for planning purpose)
  dynamic simulation: prognosis of rising flood

For whom?

Who is afflicted and ought to be informed? In the event manager the selection of recipients can be defined in advance but also the concrete analysis data of the geographic context can show, that additional users have to be informed. User referenced demands for information can be derived from the geographic context, if e.g. inhabitants, special objects of interest, legal rights are afflicted by the process, e.g. in case of emergency a blockade of a street network may be necessary which affects a bus route. The public transport company must be informed additionally.

User profile

Each user is referenced to a user profile.

- What are his individual information needs?
  Point of view of the customer:
  area and objects of interest
  geographic context (timely or spatially)
- Which type of thematic analysis is expected?
- Access rights (interactive or passive role)

Types of user may have different fields of interest. The user profile reflects the individual point of view, responsibilty, competence, technical equipment,etc. (*Hongbo, 2006*). The profile of the recipient influences the generation of user-oriented information until to the adequate layout.

The user-profile reflects the role of the participants in the process. Some examples for members in a dynamic process (*Andrienko, 2007*) are e.g.:

- responsible actors
- controller
- coordination manager
- owners of objects
- inflicted people (physical and legal persons)
- analyst
- decision maker
- planner
- endangered people
- observer

Thematic selection

What are the objects of interest of the recipient of the information?

The geographic context is classified according to the thematic importance of object classes: What is the foreground/background information? According to these guidelines the components of the information product are distinguished by graphic parameters.

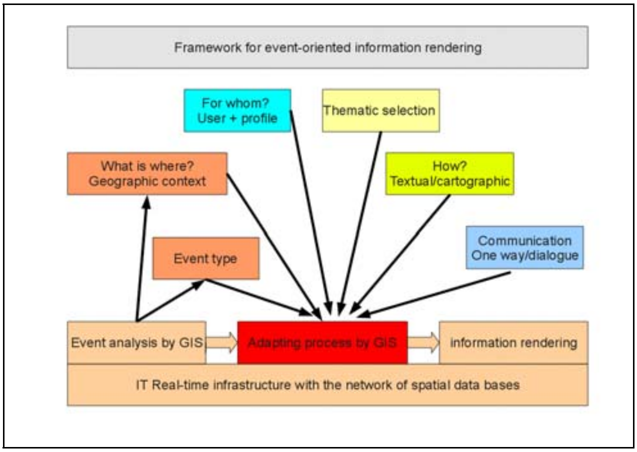

Fig. 2 GIS-supported adapting process for information rendering

In this stage a predefined catalogue of product services dependent on „What if" scenarios is obtained. All these aspects together reflect the information needs and form a complex framework which serves as guidelines for rendering event-oriented information services. It is achieved by an integrated approach which takes into consideration the geographic context of the event but also the purpose of communication with users, their individual interest in the spatial impact. These aspects are taken into consideration when the information processing routine of an event is designed. Procedures for the user dependent data selection and classification of data for output modeling are derived. The adaptation modeling is guided by a set of parameters influencing the design of made-to-measure products offered as real-time information service to users. All in all, these aspects ought to be considered coherently by a comprehensive conceptual modeling for each request for getting knowledge about the ongoing process (*Bin and Xiaobai, 2006*).

3.2. Design of communication

The type of communication with the user is predefined in the user profile, which describes the access-rights of the user. The scope of communication between computer and user (transaction type) reaches from passive reception until active interference in terms of controlling the process:

- passive one-way of information (reports)

transmitting information with passive reception e.g. mailing of information about status

- two-way:

opening a dialogue for gathering additional information or even to allow an active interference into the going-on of the process e.g.a dialogue-oriented request for controlling or decision making.

If controlling of the process is necessary responsible actors are asked to interfere by remote control. So telecommunication should provide access to databases in computer networks remotely in a space-time context. A further step could be the introduction of webbased GIS for the analysis on the fly and applying tele- communication for the simultaneaous transfer of geo-data over distances.

Web 2.0 with two-ways communication is a further milestone of an IT- infrastructure useful for geographic tasks.

- one to many

Dialogue between the process model and a collaborating user group

In this case a platform for interaction has to be installed (*Mathieu,2008*). In such applications of corporate interaction a platform for monitoring, analysing, controlling and interference by user-groups may be necessary. Categories of cooperation and their standards for the level of cooperation have to be defined (editing features for special object classes, attributes) etc. The roles settle the access to data bases and the degree of interference for controlling the process modeling. In such cases GIS has to cope with utmost requirements of spatio-temporal processes for generating current information in real time. GIS-functionality is offered for spatial decision making or controlling in a corporate dialogue.

The cartographic image on the display take over the function of a hyperlink via active map objects to the geo-data bases. This cartographic user-interface supports a platform for geographic communication among the participants of the user group supporting interactions with the data bases of the process. GIS helps to analyse the consequences of envisaged measures, e.g. in case of emergency: evaluation of different proposals of a blockade of traffic in a disaster zone. The impact on public transport, evacuation of inhabitants. Based on a cartographic Web-editor for geographic input a participant can describe the spatial attributes of his proposal geographically defined.

Generally the design of communication guarantees that geo-information is deployed in real-time on to the very place, where the information is needed.

4. REAL-TIME CARTOGRAPHY

4.1. General aspects

As cartographic visualisation is an excellent way for geographic communication, information supply about space and its changes are compiled most preferably in mapbased output. This way of information transfer is a very impressive, but on the other hand a complex task. Especially in dynamic processing it is a challenging procedure, to compose a map-image conveying complex spatial content fully by software: the result must be delivered without manipulation i.e. modeled fully automatically in real-time. So this stage is faced with utmost requirements for visualisation, as ready-made, purpose-oriented customized maps have to be generated.

4.2. Cartographic modeling

According to the thematic guidelines of the event cartographic modeling procedures start. For the modeling procedure the knowledge of the parameters of the cartographic design phase is necessary. So the current spatial data of the event enables the system to find out the concrete parameters for the construction of the map. At first the content of the thematic foreground and the reference data (e.g. street network) of the background (*Andrienko, 2007*) must be selected.

The objects for the foreground have to be selected and thematically classified for visualisation. The content of the background is chosen as spatial reference to the subject of the information. Dependent on the size of the area of interest the appropriate sheet configuration (sheet size, multiple sets of maps), scale and the adequate degree of detail are defined. Routines for generalisation, reduction of text elements and geometry, adjusting the scale of symbols, etc have to be defined.

In addition to the analysis capabilities GIS offers thematic mapping capabilities also. GIS- tools offer functions dealing with the compilation and symbolisation for a thematic map. According to a set of rules and guidelines for the purpose oriented outfit cartographic modeling software is predefined in the design process. On the basis of the characteristics of the event a task is started, to produce appropriate geometric and semantic information (*Gartner, 2007*) dependent on the current geo-data of the process. According to the concrete spatial data characterising the geographic context and the current situation (e.g. new objects of interest: points and area, zones of interest on the fly or the changes after the last screening) the parameters for the cartographic modeling (scale, scope of classification for the thematic presentation) are derived.

The predefined framework of rules for thematic layout works as guideline for the compilation. For the visualisation process an appropriate classification of data has to be carried out. Then the map image is constructed by applying algorithms for adequate symbolization of objects, symbolization routines for creating additional cartographic objects (e.g. placing text and labels derived from attributes, vector geometry for moving objects, a legend for the interpretation).

In this stage the influence of the output device (large or small display, printer) has to be taken into consideration. Especially the adjusting of a map on mobile devices (*Blankenbach* *and Ferdinand, 2008*) due to the small display can afford additional routines for generating a multimedia output. Even printed maps may be necessary for documentation purposes.

In such a case a complete separate compilation is afforded in comparison with the cartographic design for a display with less size and resolution.

It may be necessary in the case of one event to launch multiple cartographic modeling for different user oriented products (e.g. the public must be informed about a disaster zone and its impact on public transport. Different thematic requirements are reflected in the different map products, one for the experts of the fire brigade, the other for the citizen).

4.3. Quality check of the cartographic model

In such a way a cartographic image can be constructed fully automated step by step. For each object class symbolization routines are applied for creating additional cartographic objects. Therefore in the final stage the overall compatabilty of cartographic objects together has to be checked. So the cartographic modeling process culminates in an evaluation of the complete map image constructed by software. That step represents a self diagnosis task, to detect conflicts of readability of the map image. Places of accumulation of cartographic objects e.g. overlapping text and symbols impede the comprehension of the content. So a redesign in the conflict zones is necessary.

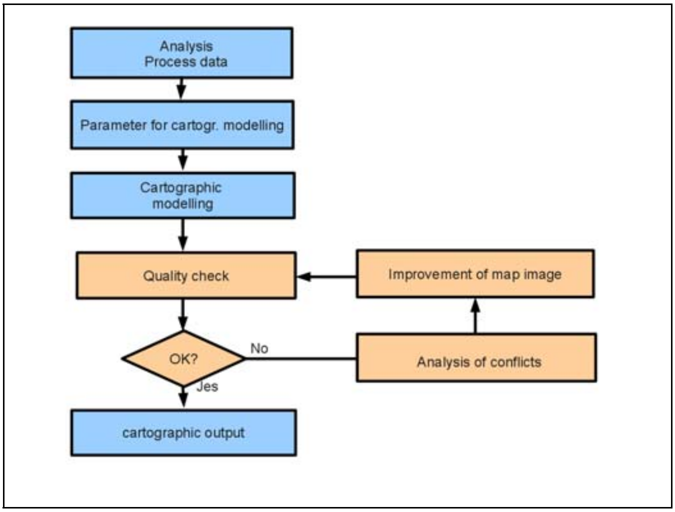

Fig. 3 Cartographic modeling

After the step of self-diagnosis a step follows, where self-correcting features are applied. A scope of refinement procedures supports the enhancement of the cartographic image e.g. on-the-fly adaptation of symbol scale, simplification or generalization. The quality of the map is finally the indicator for gaining sufficient knowledge about the process. A challenge for geographic communication is the dynamics of the process. Therefore geographic visualisation has adopted methods of computer graphics: animations. Cartographic animations are expected to offer an effective supplement for real-time insight into dynamic spatial processes. A powerful IT-infrastructure provided this technique becomes another adequate possibility for illustrating changes in spatio-temporal processes.

5. FIELD OF APPLICATIONS

A broad scope of computer assisted processes - marked by a dynamically changing spatial situation - represents new fields of application for GIS with real-time design. Such fields of applications can be supported by GIS effectively, where previous unsatisfactory manipulation and delivery time could not fit the requirements of reacting. Especially suited are time-critical processes such as controlling of a traffic congestion, of transportation logistics (fleet management), of disaster management, emergency support for the fire-brigade. Location based Services (LBS) are faced with the mobility of the user and the analysis of time-relevent near-by services on call (*Gartner, 2007; Bin et al., 2006; Blankenbach and Ferdinan, 2008*). The range of applications is not reduced to time critical processes but also covers cases of complex spatio-temporal problems, where interdisciplinary coordination is necessary e.g. the coordination of corporate construction works under and on the ground in the street network of a city. But also complex spatial managing tasks offer just-in time information services e.g. managing of public and private use of densely exploited street areas in municipalities (*Wilmersdorf, 2003*), e.g. the temporarily leasing of areas for commercial purposes, plots for a newsstand, etc. GIS-tools also support planning tasks of complex zoning regulations for new urban areas by interdisciplinary evaluation of envisaged exploitation of space (*Wilmersdorf, 2003*).

6. CONCLUSIONS

In this paper major GIS-design issues are identified in the run of a dynamic process. The continuous geo-monitoring by GIS on the fly used for the self-diagnosis of events, which are important milestones for information services. Instant analysing the geographic context of an event and the adaptive GIS framework support the purpose- and user-oriented creating of information products provided just-in-time. This fact signals a new basis for getting knowledge about spatio-temporal processes. Finally in the stage of real-time cartographic visualisation GIS supports the automated modeling of map images. This study sees in the visual presentation of geo-analytics approach the great advantage of gaining transparency into dynamic processes.

So it is evident, that GIS is not only an efficient spatial analysing tool but also an important tool for real-time communication especially for rendering sophisticated information as the the cartographic visualisation shows. On the whole GIS is expected to improve dynamic real-world monitoring and decision making.

In this field of dynamic processes research efforts may focus on:

- temporal GIS analysis functions and multiple aspects of time in data bases
- Real-time cartography ought to be improved especially for mobile devices (e.g. scale dependent construction of map images, especially automated generalization)
- Visualization methods of dynamics concerning the geographic context (animation, multimedia)
- Collaborative GIS emerges as an efficient, spatial decision-making tool. Platforms for an adaptive GIS-framework in a Web 2.0 environment would be favourable.

REFERENCES

Gartner G., (2007), *LBS and Telecartography*, *about the book,* Location Based Services and Telecartography, Springer 2007, ISBN 13 978-3-540-36727-7.

Bin J., Xiaobai Y., (2006), *Location based Services and GIS in perspective*, Computers, Environment and Urban Systems, Elsevier 30(6).

Andrienko N., Andrienko G., (2007), *A Framework for decision-Centred Visualisation in Civil Crisis Management,* Location Based Services and Telecartography Springer 2007, ISBN 13 978-3-540-36727-7.

Hongbo Y., (2006), *Spatio-temporal GIS design for exploring Interactions of Human Activities*, Cartography and Geographic Information Science Vol. 33, No.1.

Mathieu P. et al., (2008), *An adaptive Interaction Architecture for Collaborative GIS,* Cartography and Geographic Information Science Vol. 35/No.2.

Blankenbach J. und Ferdinand T., (2008), *Mobile Geoinformation jederzeit und überall. Echtzeitfusion von Geo-Daten und -Diensten für mobile Szenarien,* Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 43.

Wilmersdorf E., (2003), *Geocoded information incorporated into urban on-line services – the approach of the City of Vienna,* Computers, Environment and Urban Systems 27, pp. 609-621 Elsevier Science Ltd.