TRENDS IN PRECIPITATION AND SNOW COVER IN CENTRAL PART OF ROMANIAN PLAIN

Adina-Eliza Croitoru[1], Florentina-Mariana Toma[1]

ABSTRACT:

Precipitation is considered to be a very important climatic element for the plain areas in Romania. Thus, variation in precipitation data ranges is more and more studied. In this paper total amounts of precipitation and the depth of the snow cover were analyzed. Annual, seasonal and monthly data were used to identify the general trends in the amount of precipitation for a period of 41 years (1965-2005) in 5 weather stations from the central part of Romanian Plain: Alexandria, Piteşti, Roşiorii de Vede, Turnu Măgurele and Videle. They are located in different areas: on the high plain in the North of the region, in the central area and on the Danube River banks. For snow cover only winter months series were analyzed. To detect and estimate trends in the time series, Mann-Kendall test for trend and Sen's slope estimates were used while for fluctuations in precipitations WASP cumulated curve was analyzed. Main conclusions that can be mentioned are: decreasing trends in total amounts of precipitation, especially for summer months and for annual values, but also with fluctuations that had upward trends in the first part of the analyzed period and than decreasing trends beginning with October 1981; increasing trends of the snow cover during winter months.

Keywords: *trends, precipitation, snow cover, Mann-Kendall test, Sen's Slope, WASP, Romanian Plain.*

1. INTRODUCTION

In the general context of climatic change, precipitation as one of the principal climatic element, play an important role together with temperature. Southern and Eastern regions of Romania are considered more and more vulnerable to different kinds of drought. The implications become more important because they are considered as main agricultural areas of the country. Thus, analysis of precipitation data series is necessary in order to identify if there are any trends.

Sector between Olt and Argeş rivers is considered by some authors (*Bordei-Ion and Bordei-Ion, 1983, Fărcaş, 1983*) as a very special area with convergence air jets from West and East and thus with higher amounts of precipitation than the eastward and westward regions. Despite this fact, there are no many studies on this issue for the region. The central part of Romanian Plain (sector between Olt and Argeş rivers) was not properly analyzed until now from climatic point of view. Specific climatic studies on precipitation cover larger areas, as entire Romanian Plain or the whole Romanian territory (including Central Romanian Plain). Some of them consider one or more weather stations in the Central Romanian Plain (*Bogdan and Niculescu, 1995, Stăncescu, 1993*), some other do not (*Ciulache and Ioanc, 2000, Iliescu, 1992, 1995, Mercier and David, 2009*).

The main aim of this study is to emphasize trends and fluctuations in precipitation and snow cover data sets in the area.

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2. DATA AND METHODS

2.1. Data

Data recorded in 5 weather stations from Central Romanian Plain were used for this study: Alexandria, Piteşti, Roşiorii de Vede, Turnu Măgurele and Videle. They are located in different areas and cover all kind of surfaces (hilly plain, river bank) as is shown in **Fig. 1**.

The data sets used cover 41 years: 1965-2005. To calculate trends of total amounts of precipitation, 17 data series were considered for each location: 12 monthly series, 4 seasonal series and one annual series. At the same time, 6 data sets of snow cover were analyzed: monthly data from November till March and winter.

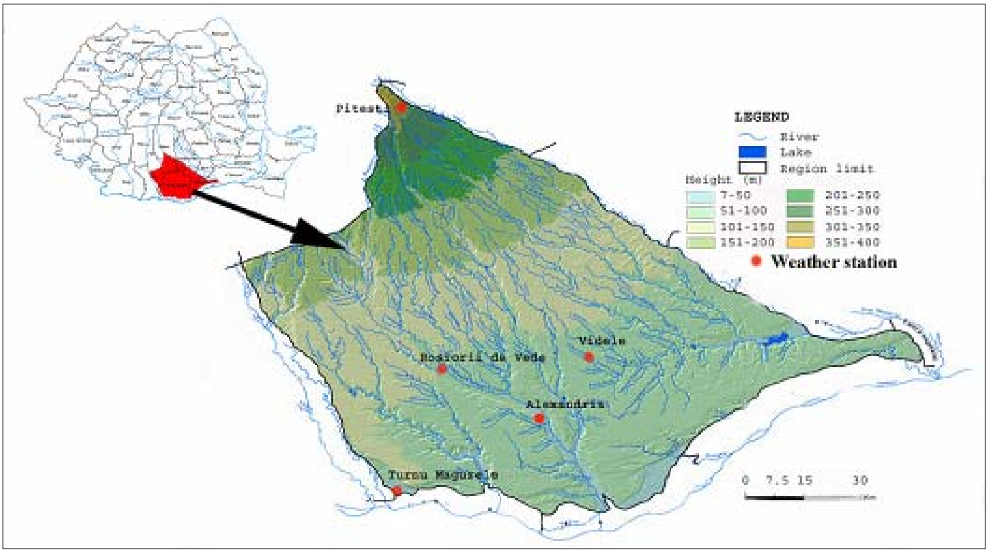

Fig. 1 Romanian Plain between Olt and Argeş Rivers

2.2. Methods

2.2.1. Mann-Kendall test and Sen's slope methods

To detect and estimate trends in the time series of precipitation and snow cover depth, an Excel template – MAKESENS (Mann-Kendall test for trend and Sen's slope estimates) – developed by researchers from Finnish Meteorological Institute (*Salmi, T. et al., 2002*) was used. In Romania, the same method and software were used with good results to identify trends in different data series (temperature, precipitations, fog) (*Holobâcă et al. 2008, Mureşan and Croitoru, 2009, Toma, 2009*). Other authors used different methods, as animated sequential trend signal detection in finite samples, to identify trends in time series, especially for very long series (*Haidu, Magyari-Saska, 2009*).

The procedure is based on the nonparametric Mann-Kendall test for the trend and the nonparametric Sen's method for the magnitude of the trend. The Mann-Kendall test is applicable to the detection of a monotonic trend of a time series (*Mann, 1945, Kendall, 1975*). The Sen's method uses a linear model to estimate the slope of the trend and the variance of the residuals should be constant in time.

The MAKESENS soft performs two types of statistical analyses:

- the presence of a monotonic increasing or decreasing trend, which is tested with the nonparametric Mann-Kendall test;
- the slope of a linear trend estimated with the nonparametric Sen's method (*Gilbert, 1987*).

Both methods are here used in their basic forms. At the same time, they offer many advantages: missing values are allowed and the data needed are not conform to any particular distribution; the Sen's method is not greatly affected by single data errors or outliers.

The Mann-Kendall test is applicable in cases when the data values *xi* of a time series can be assumed to obey the model

$$x_i = f(t_i) + \varepsilon_i \,, \qquad (1)$$

- $f(t)$ is a continuous monotonic increasing or decreasing function of time
- the residuals ε_i can be assumed to be from the same distribution with zero mean. It is therefore assumed that the variance of the distribution is constant in time.

Then the null hypothesis of no trend, H_0, is tested in order to accept or reject it. The observations x_i are randomly ordered chronologically, against the alternative hypothesis, H_1, where there is an increasing or decreasing monotonic trend.

Because the range of data is longer than 10, the test statistic Z (normal approximation) is computed. The statistic Z has a normal distribution. The absolute value of Z can be compared to the standard normal cumulative distribution to identify if there is a monotone trend or not at the specified level of significance. An upward (increasing) or downward (decreasing) trend is given by a positive or negative value of Z.

For data values close to 10, validity of the normal distribution may be reduced, if there are several tied values (i.e. equal values) in the time series.

First the variance of S is computed using the following equation (2), which takes into account, that ties may be present:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n-5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5) \right] \qquad (2)$$

- q is the number of tied groups;
- t_p is the number of data values in the p^{th} group.

Than the values of S and $VAR(S)$ are used to compute the test statistic Z as is presented in (3):

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}}, if S > 0 \\ 0, if S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}}, if S < 0 \end{cases} \qquad (3)$$

In MAKESENS the tested significance levels α are 0.001, 0.01, 0.05 and 0.1.

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear. This means that *f(t)* in equation (1) is equal to:

$$f(t) = Qt + B \tag{4}$$

Q - slope
B – constant value

To get the slope estimate *Q* in equation (4) the slopes of all data value pairs are calculated using the formula:

$$Q_1 = \frac{x_i - x_k}{j - k} \tag{5}$$

where *j>k* .

If there are *n* values x_j in the time series, we get as many as *N = n(n-1)/2* slope estimates *Qi*. The Sen's estimator of slope is the median of these *N* values of *Qi*. The *N* values of *Qi* are ranked from the lowest to the highest and the Sen's estimator is

$$Q = Q_{[(N+1)/2]}, \text{ if N is odd} \tag{6}$$

$$Q = \frac{1}{2}\left\{Q_{(N/2)} + Q_{[(N+2)/2]}\right\}, \text{ if N is even.}$$

Then nonparametric technique based on the normal distribution is used to get a 100(1-α)% two-sided confidence interval about the slope estimate. The method is valid for *n* as small as 10 unless there are many ties.

2.2.2. Cumulated curve of Weighted Anomaly of Standardized Precipitation

Climatic standardized anomaly represents a world wide used method in climatology, both for significant results it gives and for easy calculation purpose. It is recommended by WMO for the study both of wet and dry spells.

The method was successfully used especially for precipitations by many authors in Europe (*Kutiel and Paz, 1998, Maheras et al., 1999, Lyon, 2006*) and in Romania (*Cheval and Dragne, 2003, Croitoru, 2006*), and so Standardized Precipitation Anomaly is the most common name of the methods. It is calculated as:

$$SPA = \frac{x_i - \overline{x_l}}{\sigma_l} \tag{7}$$

where:

$$\sigma_l = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x_l})^2}{n-1}} \tag{8}$$

SPA – Standardized Precipitation Anomaly;
i – one term in the range of data (month) of the same type for SPA is calculated;
x_i – precipitation amount for *i* month;
$\overline{x}_l$- multiannual average amount of precipitations of *l* month;
σ_l- standard deviation of *l* month.
n – the number of terms in the range;

Recently, weighted anomaly of standardized precipitation (WASP) is calculated.

This index gives an estimate of the relative deficit or surplus of precipitation for different time intervals ranging from 1 to 12 months.

WASP index and is based solely on monthly precipitation data. It was developed by researchers of Columbia University (http://www.columbia.edu/ccnmtl/projects/iri/responding/tutorial_frame_t3p2.html). To compute the index, monthly precipitation departures from the long-term average are obtained and then standardized and divided by the standard deviation of monthly precipitation. In order to avoid the huge influence of SPA recorded in the driest or the wettest months of the year the standardized monthly anomalies are then weighted by multiplying by the fraction of the average annual precipitation for the given month (computed as average of the multiannual average monthly amounts).

$$WASP = SPA \cdot W = \frac{x_i - \overline{x_l}}{\sigma_l} \cdot \frac{\overline{x_l}}{\overline{\overline{x_a}}} \qquad (9)$$

WASP- weighted anomaly of standardized precipitation;

SPA-standardized precipitation anomaly;

W- fraction of the month compared to the annual value;

$$W = \frac{\overline{x_l}}{\overline{\overline{x_a}}} \qquad (10)$$

$\overline{x_l}$ - multiannual average of the precipitations amount for the month considered;

$\overline{x_a}$ -the annual average of precipitations amount for the multiannual period:

$$\overline{x_a} = \frac{1}{12} \cdot \sum_{j=1}^{12} \overline{x}_{lj} \qquad (11)$$

j -1,2,......,11,12 - months.

For saving time, standard deviation can be computed with STDEV function, available with Excel 5.0.

WASP cumulated curve is usually used to determine the accumulation of precipitation water excess or deficit from one period to another. Usual, in Romania, a very high or a very low amount of precipitation occurs isolated inside a longer period with an opposite trend. In this situation, one single month can't cancel the effects of the entire period characterized by anomalies with opposite signs, but with lower values.

Using WASP cumulated curve, one can identify the intervals when precipitations in excess accumulate from one month to another or, by contrary, when missing precipitations „accumulate" giving long dry period. Thus, the ascending curve is assimilated to a continuous increasing accumulation of water (in soil, in big reservoirs etc.) coming from precipitations, while a descending curve is considered a loss of water in the system.

When the curve crosses the Ox axe (the WASP value is equal to 0), it is considered a quality change, meaning that the wet or dry period diminished until 0 and a dry, respectively wet period begins. Thus, the change moment is not that of the curve peak, but that when the curve crosses 0.

To get values for WASP cumulated curve, formula (12) is used.

$$a_n = \sum_{i=1}^{n} WASP_i \tag{12}$$

WASP – weighted anomaly of standardized precipitation;

n – number of terms in the range;

a_n – cumulated value of WASP for *i* term in the range and it is equal with the sum of all previous values plus WASP values of the considered month.

3. RESULTS

Annual precipitation regime in the analyzed area is specific to temperate continental climate, with maximum amounts recorded in June or July and minimum amounts, in January (**Table 1**). The annual amounts range, generally, from 500 to 550 mm/year, with only one exception: Piteşti, with almost 700 mm/year. The altitude and the vicinity of the hilly area make the difference between this station and the other analyzed locations.

Table 1. ***Monthly and annual precipitation amounts***

Location	J	F	M	A	M	J	J	A	S	O	N	D	Year
Piteşti	37.7	36.7	36.9	58.2	79.5	**93.8**	90.9	64.3	55.3	43.7	49.5	45.6	692.7
Videle	33.0	29.0	34.1	48.9	58.9	**72.0**	66.8	51.8	48.1	35.7	41.9	35.6	535.1
Roşiori V.	31.7	30.0	34.9	39.7	57.0	**64.2**	59.6	48.5	37.7	30.3	41.6	38.3	513.6
Alexandria	31.5	28.9	32.3	42.3	57.4	67.5	**70.9**	51.4	46.0	31.7	39.4	35.0	533.8
Tr.Măgurele	35.8	33.1	35.1	40.4	56.5	58.1	**58.2**	46.6	41.7	32.9	45.0	39.9	523.1

Regarding trends in precipitation amounts, 17 data series were analyzed and there is a general decreasing trends in the area (**Table 2**).

Table 2. ***Trends in precipitation data series (mm/decade)***

Location	Piteşti		Videle		Roşiori de Vede		Alexandria		Tr. Măgurele	
Data set	Q[1]	S[2]	Q	S[2]	Q	S[2]	Q	S[2]	Q	S[2]
J	1.029		0.145		-1.854		-1.777		-2.396	
F	-1.207		-2.297		-5.649	*	-4.586	+	-4.125	*
M	1.471		2.459		1.025		0.540		-0.387	
A	1.365		1.812		-0.336		0.364		0.739	
M	-2.117		0.689		-3.520		1.386		-2.819	
J	-10.031		-2.141		-5.319		-3.209		-7.523	+
J	3.370		-0.528		-1.069		-5.101		-0.498	
A	-3.325		-7.933		-1.818		-13.976	**	-5.426	
S	5.458		4.855		3.639		6.214	+	6.739	
O	5.697		3.240		3.074		1.986		2.927	
N	-1.125		-2.012		-4.637		-2.766		-4.390	
D	1.146		2.244		-0.400		-0.602		-1.519	
Annual	-11.682		-8.943		-22.511		-30.459		-30.000	
DJF	2.889		-3.164		-9.002		-11.600	+	-12.216	+
MAM	0.825		3.277		-2.895		1.931		-3.690	
JJA	-9.010		-10.906		-6.750		-24.458	+	-14.865	
SON	8.063		9.456		4.892		7.638		8.139	

[1] – Average slope (Sen's slope)

[2] – Statistical significance: + – α= 0.1; * - α=0.05; ** - α=0.01; *** - α=0.001.

For the most part of the analyzed data series, downward trends are specific. Thus, for 51 data sets, representing 60% of the considered time series, trends are decreasing. But, what worth to be mentioned is that only 8 series (less than 10 %) are statistically significant with different chances to be real: 90% to 99%.

For six data series (annual, summer, February, June, August and September), all the stations experienced decreasing trends. General increasing trends in the area were recorded only for three data series: Autumn, September and October.

The double number of situations with decreasing precipitation amounts compared to that of the increasing trends becomes more important if economical profile of the region is considered. Thus, decreasing trends are specific to those periods which are very important for agriculture crops: February, when the water reserve is very important for germination and June and July, when water is necessary for plants growing and maturation. Actually, summer season has decreasing rate of 6...24 mm/decade. At the same time, the upward trends during autumn have slow slopes and they are not enough to balance the downward trends during summer.

The most important thing to emphasize is that the annual amounts have decreasing trends in the whole region, with highest values in the Southern part of the analyzed area.

To identify possible fluctuations in the precipitation data ranges, WASP cumulated curve was calculated for each of the five weather stations considered (**Fig. 2**).

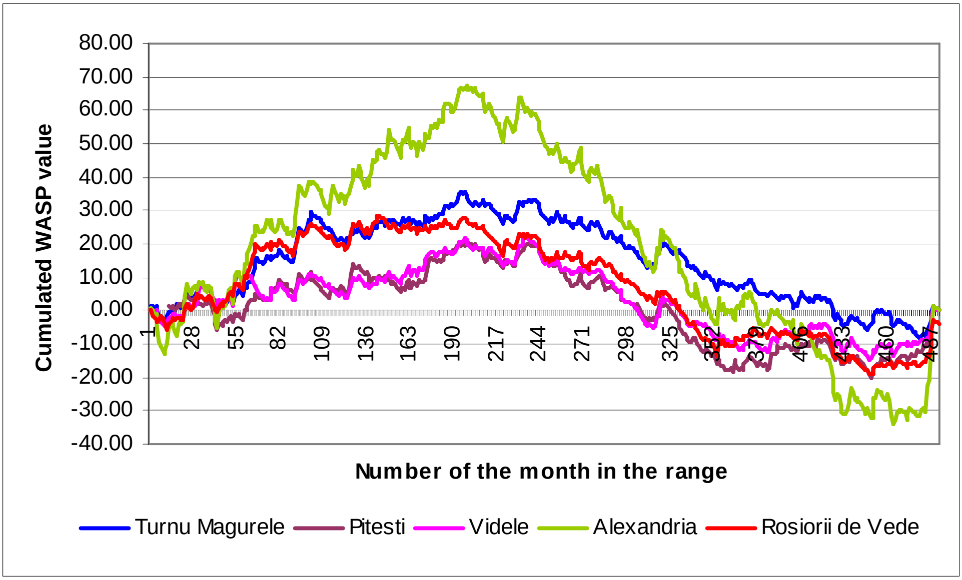

Fig. 2 WASP cumulated curve (1965-2005)

The considered interval began with a short “neutral” period, when short dry and wet spells alternated. From August 1968 a long wet period has become evident for the whole area under study. The maximum moment of precipitation accumulation was October 1981. The situation is similar to the whole country, because decade ’70 of the last century was a very wet one for the whole Romania (*Croitoru, 2006, Dragotă, 2006, Bogdan şi Niculescu, 1999*).

Then a very long period followed when precipitation in excess accumulated during the previous period diminished step by step until the end of the analyzed interval for all locations.

Cross at 0, meaning the total neutralization of precipitation excess, took place in different moments from one station to another. It began with June 1990 (Videle) and ended with July 2000 (Turnu Măgurele). From those points on, cumulated WASP values have been continuously negative, with values between 0 and –30. The minimum value was recorded in the whole region in January 2001, as a consequence of extremely dry year 2000.

Extremely wet year 2005, partially improved the recorded deficit. For the whole region, all the station experienced the same behavior, meaning the same kind of general trends. The WASP cumulated values varied from one station to another, but the curves had similar trajectories. The maximum values for wet and dry periods were recorded in Alexandria, located in the very center of the area: 67.48 and respectively –34.27. The central position and the long distance from any important rivers may be the explanation for the "maximum continentalism" expressed by the high value of the amplitude (101,75) compared to all the other analyzed stations which recorded amplitude values less than half (37...47).

The depth of the snow cover is a very important meteorological parameter to be analyzed in the studied region where agriculture, and especially crop growing, is the main economic branch. Generally, because of the continental temperate climate, when the minimum amounts of total precipitation record during wintertime, the depth of the snow cover has not very high values. The most important snow cover is specific to January and it varies, as average, from 4 to 6 cm (**Table 3**). For the extreme months (November and March), the average values are very low, usually less than 1 cm. An average around 3 cm characterizes the winter season. The maximum average in snow cover during the analyzed period were much higher compared to average values: 5…10 cm, for November and December, 10…15 cm for February, March and winter and 25…30 cm for January.

Table 3. ***Average depth of snow cover***

Weather station	Value	N	D	J	F	M	Winter
Piteşti	Average	0.9	1.7	4.5	2.7	0.8	3.0
	Maximum	11.0	8.0	31.0	16.0	13.0	13.0
Alexandria	Average	0.9	1.7	5.5	2.5	1.1	3.2
	Maximum	7.0	8.0	25.0	12.0	11.0	12.7
Videle	Average	0.8	1.5	4.4	2.1	0.9	2.7
	Maximum	7.0	7.0	24.0	12.0	11.0	12.3
Roşiori de Vede	Average	0.9	1.6	4.8	2.3	0.9	2.9
	Maximum	10.0	9.0	27.0	10.0	10.0	12.3
Turnu Măgurele	Average	0.9	2.3	5.5	2.7	0.7	3.5
	Maximum	9.0	10.0	26.0	13.0	11.0	12.3

Trends were calculated only for winter months and for winter as a season. For November and March trends could not be calculated because of the very low values of snow cover. Thus, a stationary trend of the snow cover was recorded for December data sets at 4 of the 5 locations (**Table 4).** The only exception is Turnu Măgurele, where increasing trend is specific.

Table 4. ***Trends in snow cover depth (cm/decade)***

Staţia	**Piteşti**		**Videle**		**Roşiori de Vede**		**Alexandria**		**Tr. Măgurele**	
Series	Q[1]	S[2]	Q	S[2]	Q	S[2]	Q	S[2]	Q	S[2]
D	0.000		0.000		0.000	*	0.000		0.526	**
J	0.465		0.960	**	0.572	+	0.000		1.250	*
F	0.488	*	0.274		0.000		0.000		0.290	+
DJF	0.606	**	0.667	**	0.758	**	0.145		1.212	***

[1] – Average slope
[2] – Significance level: + – α= 0.1; * - α=0.05; ** - α=0.01; *** - α=0.001.

Increasing average slopes are specific to the most part of the monthly data series. Increasing rate varies from 0.145cm/decade to 1.212 cm/decade.

Winter data series show increasing trends with 0.001…0.05 significance level recorded for each analyzed location. The only exception is Alexandria weather station, where no trend was identified for monthly data series, and a slow increasing slope without statistical significance was recorded for winter. Opposite, there is one station (Turnu Măgurele) with all data series showing statistical significance for the upward trends.

The increasing of average depth of snow cover for winter data series may be associated with decreasing trends of temperature for winter in the area. No trends identified for snow cover in December may be determined by decreasing trends both in temperature and in precipitation data series in the area (*Toma, 2009*).

4. CONCLUSIONS

Main conclusions of this paper are:

- Decreasing trends in total amounts of precipitation, especially for summer months and for annual values; only few data series of Southern stations (Alexandria and Turnu Măgurele) show statistical significance;
- Fluctuations identified on the WASP cumulated curve show an upward branch in the first part of the analyzed period (1968-1981) and than a decreasing branch from October 1981 till the end of interval;
- Increasing trends of the snow cover depth were identified in the data series both for winter months and for winter as a season for 4 of the 5 locations.

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MICROREGIONS AGRICULTURAL APTITUDE TEST METHODOLOGY

Katalin Katona-Gombás[1], Margit Horosz –Gulyás[1]

ABSTRACT:

The most frequently asked questions of our present and near future are about "property, size and efficiency". Without these, it is impossible for the Hungarian zone system to be thought on, to be corrected effectively or make the system profitable and competitive. It takes us to the known idea of the agricultural-enviroment protection. The agricultural potencial test of microregions conceives proposals for the farmers regarding which agricultural-enviroment protection programme should be joined and what the tasks are to form a complex rural living area. This purpose is served by the enviromental management which can only operate on the principle of the multifunctional agriculture. This work offers proposals as well as possible solutions on how to test the agrarian-ecological potential.

Keywords: *microregion, agricultural suitability, environmental sensitivity, watershed, Lake Velence.*

1. INTRODUCTION

Hungary is a full member of the European Union, and thus belongs to the European internal market.

If we wish to be involved in agriculture, environment, rural policy and the process of reorganization taking place in the European Union, then we must develop the rural development and regional development approach based on the land usage system and to help rural areas in such development (*Szabó, 2004*). The appearance of the agrarian-environmental protection is linked to the EU Common Agricultural Policy reform. The mainstream of the reform is the gradual transfer of the main support from direct aid to the production (export subsidies, product subsidies, import duties) to non-productive (environmental, social, occupational, cultural, etc..) support (*Ángyán, 2008*).

2. GEOGRAPHY OF THE WATERSHED

Lake Velence is the third largest natural lake of Hungary. However, it is undoubtedly placed second if economy and tourism are concerned. It is a major target of both Hungarians and foreigners.

The lake has special features. Being shallow with reed plots around, it gets warm quickly in summer and is suitable for swimming. Furthermore, the water quality improving in the past few years has a significant role in the case of foreigners.

The watershed area of Lake Velence is rich in scenic beauties represents an outstanding value of the state as it was expressed by designating Vértes mountains as landscape protection area, as well as by establishing the Lake Velence – Vértes holiday resort area and creating several arboretums. In 1977 thermal water was found in Agárd at the southern shore of the lake. It is of exceptional importance as it enlarges the number of touristic resources and extends the season. The preliminary work of designating further areas as protected is in progress. The area of the Bird Reserve might be enlarged and the Császár-water valley, the green corridor spreading from the Vértes to the Dinnyési-Morass might be protected in a short time. The Zámoly reservoir and its vicinity will be designated as

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conservation area. Taking the longer view, the enlargement of the Dinnyési-Morass and the protection of the Velence mountains are also planned.

Lake Velence is a freshwater lake in the southwest-northeast flat depression at the foot of the Velence mountains. It is a shallow lake with an average water level of 189 cm. The length of the lake is 10.8 km and its average width is 2.3 km.

The lake has a relatively large watershed area. The total surface of the lake is 24.2 km2 when the watermark post at Agárd is on 160 cm (watermark post “0” = 102.615 m.B.f.). The watershed area spreading on 602.2 km2 (including the lake) is approximately 25-fold of the lake area (**Fig. 1**).

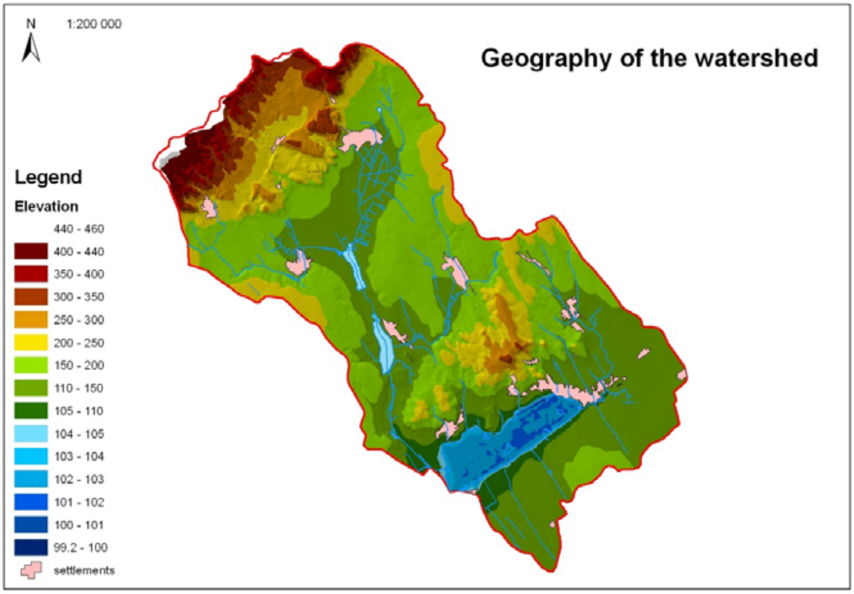

Fig. 1 Geography of the watershed

The distribution of the slope categories can be seen in **Table 1** and the cultivation categories in **Fig. 2**.

Table 1. ***Distribution of slope categories in the watershed***

Slope categories	Distribution in %
0-5 %	62,4
5-12 %	19
12-17 %	8,9
17-25 %	7
above 25 %	2,7
SUM	100,0

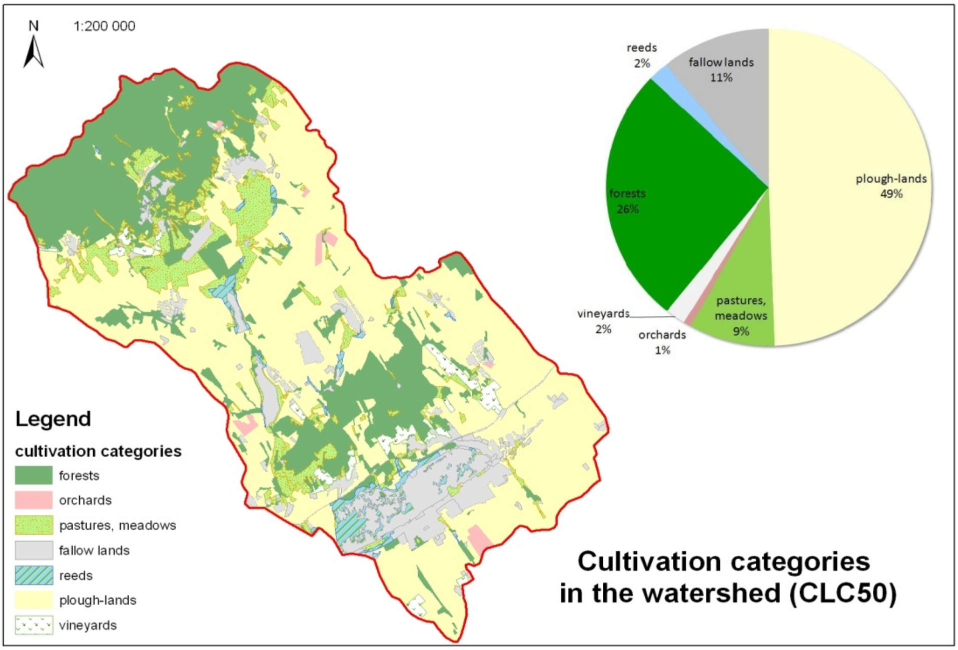

Fig. 2 Cultivation categories in the watershed

3. MATERIALS AND METHODOLOGY

Over the testing process of microregions' environmental sensitivity, we produced the environmental sensitivity map of the test area. Precise delimitation is necessary on the marked fields to determine the target locations of The National Agrarian-environmental Programme.

The programmes are distinguished by security objective thus they are different from programmes of important areas such as conservation, landscape, water as well as habitats. The agricultural-suitability of microregions is also depicted on the map, which shows the parts of microregions in terms of agricultural-suitability and environmental sensitivity **(Fig. 3, 4)**.

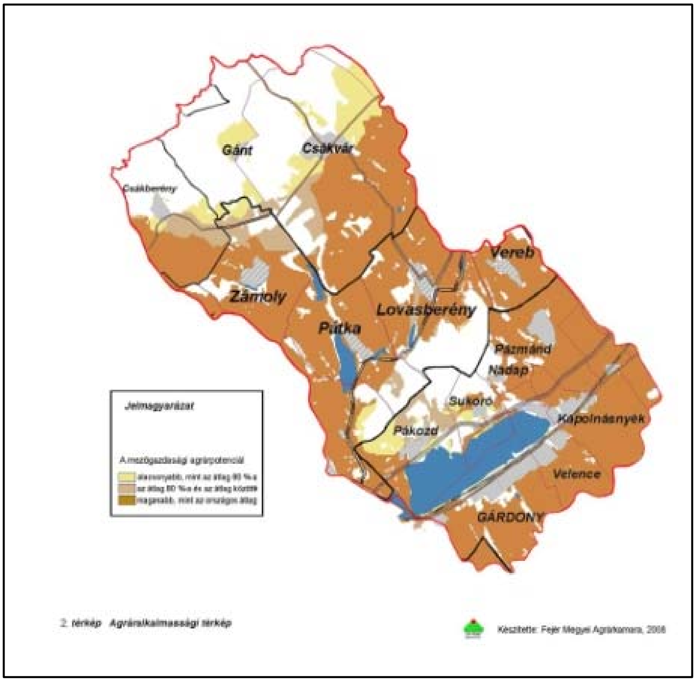

Fig. 3 Agricultural suitability map of Lake Velence watershed

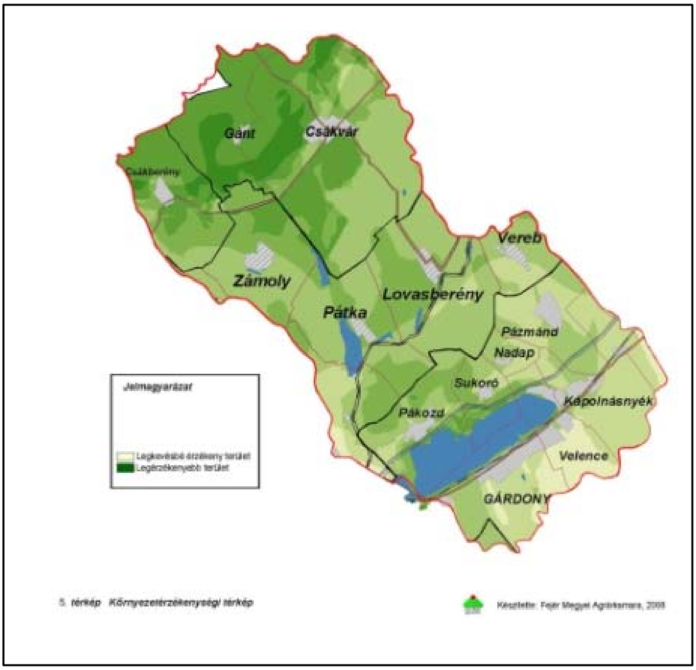

Fig. 4 Environmental sensitivity map of Lake Velence watershed

4. RESULTS

The study found that 67.5% of the microregion, in terms of environmental sensitivity, could be target area where the soil, the water and the wildlife require protection (in Fejér County, this number is 55.4%). The rate of the protected area in the region is 8.5%.

According to the agricultural aptitude test of Lake Velence watershed area, without surface water, forest, and artificial surface, 72.8% of the area is high quality, the rate of agricultural suitability value is greater or equal to the national average (65.2% in Fejér county). 8.2% of the area's agricultural suitability value does not reach the national average of 80%. The agricultural-zone belonging to the area takes 80.2% of the total area. Production functions have priorities and the area is suitable for intensive exploitation. The size of the double determined area is 11.3% in the region. Because of the capabilities of the area, extensive use is proposed in a significant proportion of the region, and the other part of the conservation area would be the buffer zone.

On Lake Velence watershed area the protection category is represented by nature and landscape conservation whereas the most important resources are represented by soil and water conservation. The possible development opportunities appear primarily in the holiday tourism, but agriculture has a similar role in the area. Besides the developing economic functions, the development of urban environment is also an important element of balanced spatial development , which includes residential, urban infrastructure and service improvements. The categories of protection, development opportunities and the context of needs can be examined and arranged in a matrix. (**Table 2**)

Table 2. ***Matrix of the strategic development in the utilization area (WAREMA 2006-2008)***

Tool / Aim		Life quality improvement of the inhabitants on the watershed area			
		Development / Resource	Tourism	Agriculture and forestry	Urban environment, services
Sustainable development	Value conservation usage	Water	1. Water quality conservation of Lake Velence 2. Harmonisation of water management 3. Lake side and lake pool regulation tasks (dredging considering tourism and environmental issues) 4. Wellness tourism development	1. Changes of the land use categories (meadow, forest) in order to protect the surface water quality 2. Incensement of water storage capacity of soils through suitable agro-techniques 3. Consideration of the irrigation and fishery's requirements	1. Development of a water quality improvement action plan for water management in urban and in natural areas 2. Sewage system and water cleaning plant development 3. Elimination of illegal waste deposits
		Soil	1. Sludge deposit considering soil protection aspects 2. Thermal wastewater management	1. Change of land use category due to soil protection 2. Liquid manure management considering soil conservation 3. Reconstruction of former melioration works 4. Land consolidation in bottom up approach	1. Restriction of urban developments 2. protection of intensive agricultural areas
		Natural, environmental and cultural endowment	1. Development of eco tourism possibilities (training centres, presentations) 2. The sustain of water supply of Dinnyési Wetland 3. Improvement of natural status to develop tourism (landscape management of the abandoned mines, reconstruction of the whole landscape) 4. Protection and development programmes of the cultural values	1. Development of nature protective agriculture and forestry (structural changes in land use, extensive farm management) 2. Implementation of nature friendly reed management 3. production of regional agricultural and forestry products	1. Improvement of quality tourism (reconstruction of housing possibilities, development of the institutional background 2. Improvement of rural tourism together with making the traditions alive (wine roads, equestrian tourism) 3. Improvement of tourism cooperation (travel infrastructure improvement, programme coordination, marketing development

5. CONCLUSIONS

The rural microregion is not only the agricultural production platform but also biological and social living environment as well. The interdependence of nature, agriculture and rural areas will make coordination and transformation of protection, production and consumption for environmental use to reform the system inevitable. There is a growing need to consider the environmental management in terms of rural microregion development as well as the much broader interpretation of agricultural concept. It means that the nature and the environment (stabilization), production, and social-service functions must be considered. In the long term, only the management can be regarded to preserve values in which these functions are examined. This purpose is served by the multifunctional European agricultural model. The multifunctional agriculture embedded in the ecosocial market economy requires new solutions so that realistic lifestyle choice, the complex reality of rural living environment should be realized on the long-term.

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A NEW GRAPHIC FOR THE DETERMINATION OF THE VULNERABILITY AND RISK OF GROUNDWATER POLLUTION

**N. Khérici[1], H. Khérici-Bousnoubra[1] ,
E.F. Derradji[1], A.K. Rouabhia[2], C. Fehdi[2]**

ABSTRACT:
Through the world, methods of vulnerability estimation and risk of groundwater pollution are very numerous. They use the parametric systems with numerical quotation, the cartographic superposition or the analytical methods which are based on the equations. The analysis of the vulnerability and the risk of groundwater pollution presented in this paper were carried out based on the combination of two criteria: the index of self-purification and the index of contamination. It is summarized with a new graphic method, in the form of abacus, simple and rapid of use. It is an abacus made up of two diagrams of triangular form connected to a third of rectangular form identifying the degree of vulnerability and the risk of underground pollution waters. On one of the triangles are represented the index of self-purification of the soil and the thickness of the unsaturated zone and on the other triangle are represented the indices of organic and mineral contamination of groundwater.

Keywords: *vulnerability assessment, groundwater pollution risk, index of self-purification, index of contamination.*

1. INTRODUCTION

The estimation methods of groundwater vulnerability to pollution are very numerous, each one working out its method according to its needs. The methods can be divided into three groups (*Rouabhia, 2006*): the cartographic methods which are based on the superposition of maps, methods of the parametric systems which use a numerical system of quotation and, the analytical methods.

According to *Vrba and Zaporozec (1994)*, from a qualitative point of view, it is possible to indicate the correlation between three factors, according to the type of method (the density of the points, the quality of information, and the denominator of scale). Thus the complex analytical methods are used on a small scale and require an important density of points. For an average density of points, a method with numerical quotation will be preferably used. Lastly, in the zones where the quantity of information is less, it is a cartographic method on a large scale which will be recommended (*Rouabhia, 2006*). The number of parameters varies also from one method to another: it often ranges between 3 and 4, but it is seldom higher than 7. A method using a significant number of parameters does not require inevitably more information than another while using less.

From one author to another, a parameter is not given in same manner, with the same processes and properties.

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2. METHODOLOGY AND RESULTS

The method suggested is given in the form of abacus and is articulated around the purifying capacity of the soil (Index of self-purification) and of the index of contamination. The components of the soil arise under three essential phases: constituent minerals and organics a solid phase, a liquid phase (water) and a gas phase (air, gas …).

The recognition of a soil is based on a good description of the geological profile (*Rehse and Bolsenkotter in Detay, 1997, Lallemand-Barrès and Roux 1999…*) such as: thickness, porosity, permeability and; mineral and organic composition of the soil. These parameters are important to appreciate the dispersive and purifying capacities soil, with respect to an effluent.

Other physic-chemical factors implicated, act on the transport of solid particles and on the displacement of bacteria and viruses. Geochemical phenomena interfere on the transfer of solutes by adsorption/desorption, precipitation/dissolution. It follows then a degradation of organic compounds in a complex middle with the presence of organic matter, colloids, oxides etc.

If the purifying capacity of the soil, then that of the unsaturated zone is efficient, the concentration of a pollutant can be considerably reduced before reaching the aquifer.

Before describing the methodology of the study, it appears important to point out some definitions (*Kherici 1993, Vincent et al. 2005*):

- The notion of vulnerability is based on the idea which the physical middle in touch with the aquifer, gives a more or less high degree of protection with respect to pollutions, according to the characteristics of this middle.
- If vulnerability exists, the risk of pollution results then from the crossing of one or several dangers and from one or several stakes.

To establish the abacus for determining areas of vulnerability and risk of pollution, one bases essentially on the index of contamination (*Bousnoubra 2009; Kherici 1993, 1996; Rouabhia 2006*) and on the index of self-purification (*Rehse and Bolsenkotter in Detay, 1997*).

2.1. Index of self-purification

The index of self-purification is taken of the method of Rehse; it needs:

- The purifying capacity of the section of soil surmounting the aquifer
- The thickness of the unsaturated zone.

The principle of calculation of the method of Rehse is simple: we consider that the purification varies according to crossed mediums and proportional to covered distance. This precondition is expressed by the relation (1).

According to Rehse (*Detay, 1997*):

$$E = h_1\, i_1 + h_2\, i_2 + h_3\, i_3 + \ldots h_n\, i_n \qquad (1)$$

E - Total purification during the transfer
h - thickness not wet of the different soils encountered
i - characteristic index linked to each type of ground

If E is superior than 1 (*Detay, 1997*), we consider that the purification is complete. In the contrary case, it is enough to define the complementary horizontal distance to optimize purification. It is obvious that the not very permeable soils (marly or clay) will have a higher power purification than the very permeable soils. It should therefore be interpreted according to the characteristics of potential pollutants and hydrodynamic conditions of the middle.

2.2. Contamination Index

The abundance of the organic and inorganic chemical elements could be related to the human activity (factory, breeding, spreading of fertilizers etc. By admitting class-intervals in mg/l, for each element and by adding them, one can locate the indices of contamination (*Khérici 1993, 1996; Rouabhia 2006*). More the index is higher; more the water point is contaminated, consequently vulnerable and presents a risk of pollution.

In the abacus proposed, one considers two indices of contamination: an organic index of contamination (ICO) and an index of mineral contamination (ICM). The organic index of pollution is based on some parameters resulting from organic pollution: nitrates (NO-3), ammonia (NH4+), nitrites (NO2-), orthophosphates (PO4---) and the DBO5. The index of mineral contamination is based on the parameters resulting from mineral pollution: lead (Pb++), chromium (Cr6+) etc.

For each one of these parameters, 3 classes of contents are distinguished having an ecological significance according to limits of WHO. The indices (ICO and ICM) are the average of the numbers of class for each parameter and the values obtained are divided into 6 levels of pollution. These levels are much more important if one takes more than 4 parameters. Thus these indices make it possible to give an account (of manner synthetic) of organic and mineral pollution existing at the intake points.

In order to facilitate the use of the abacus, an application to two organic pollutants and the two inorganic pollutants (mineral pollution) most significant from the contents point of view are required. Taking account of this precondition one will present a demonstration to identify the contamination. At first approximation one will define 03 classes according to the contents:

Contents of the pollutant(mg/l)	Traces	←→	Natural	←→	Limit WHO	→
Classes		1		2		3

These three classes are defined according to some contents (in mg/l) thresholds (Traces, Natural, Limit WHO) (*Katrin et al. 2008; Janet 1996; Montserrat et al. 2007; Rivett and al. 2007; Puckett and all. 2005, Rouabhia and al. 2008; Renwick and al. 2008*).

To define the threshold of the natural contents, we takes account of the importance of the concentrations in each types of aquifer (shallow or deep: the nitrates for example tend to decrease in-depth) or by the natural presence of concentrations. Also certain thresholds resulting from library searches or will be calculated by interpolation.

The classes thus defined, depend on the indices of organic and mineral contamination.

2.2.1. Combinations of the ICO or the ICM

Considering these classes (1, 2, 3) one can have the combinations of the following indices of contamination (**Table 1**).

Table 1. ***Index of contamination classes according to the combinations of ICO alone or in the ICM only***

Classes ICO1 ou ICM1	1	1	1	2	2	2	3	3	3
Classes ICO2 ou ICM2	1	2	3	1	2	3	1	2	3
Indice of contamination	**2**	**3**	**4**	**3**	**4**	**5**	**4**	**5**	**6**

For example: NO3- identifies ICO1; Pb++ identifies ICM1; DBO5 identifies ICO2; Cr6+ identifies ICM2.

According to table1, some is the made combinations of classes ICO1 or ICM1 and of ICO2 or ICM2, one can have only the following indices of contaminations:

2*: this value indicates that the water point is not contaminated.
3: with this value the contamination is felt: low grade
4: this value indicates a contamination: moderated grade
5: this value indicates a contamination: moderated grade
6: this value indicates: high grade

2.2.2. Combinations of the sum of the Index (ICO and ICM)

Based on table1 we can establish the various combinations of the sum of the indices of contaminations of the ICO and ICM (**Table 2**).

Table 2: ***Total index of contamination (ICT) based on the sum of classes combinations of the ICO and ICM***

Classes **ICO**	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6
Classes **ICM**	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
ICT *	**4**	**5**	**6**	**7**	**8**	**5**	**6**	**7**	**8**	**9**	**6**	**7**	**8**	**9**	**10**	**7**	**8**	**9**	**10**	**11**	**8**	**9**	**10**	**11**	**12**

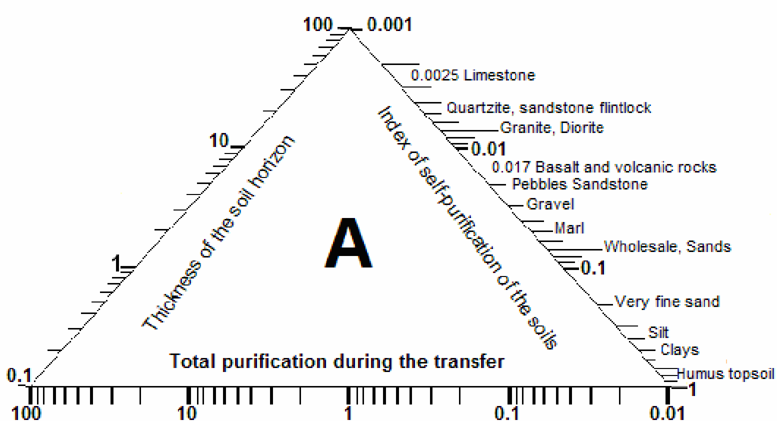
***ICT**: Indice of Total Contamination

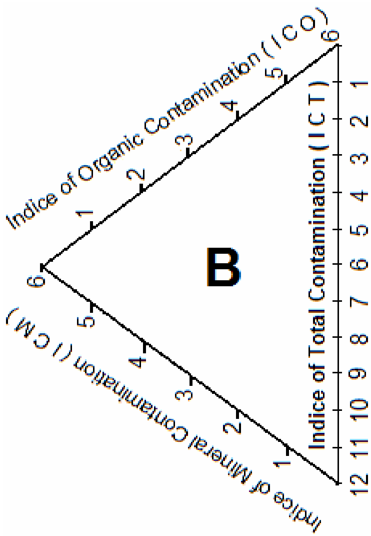
According to **Table 2** the sum of the indices of contaminations (ICO and ICM) can be only of:

Sense of increasing contamination ↓

4: This value indicates that the point of water is not contaminated
5: with this value contamination arises (low grade)
6: this value indicates a contamination
7: this value indicates a contamination
8: this value indicates a contamination
9: this value indicates a contamination
10: this value indicates a contamination
11: this value indicates a contamination
12: This value indicates contamination (high grade)

Having information necessary on the indices of contaminations (organics and mineral) and on the index of self-purification of the unsaturated zonem, it is possible to represent these data on the abacus proposed (**Fig.1**). The state of vulnerability and risk of pollution of the water point studied is defined by the Cartesian coordinates of the point of its total index of contamination and of the point of its total index of self-purification, defined on the two triangular diagrams (**Fig.1**).





Zone I Protected Zone, non vulnerability to pollution, without risk of pollution	Zone II Vulnerable zone with weak risk of pollution (Absence of vertical self-purification). Vulnerable zone far from all human activities
Zone III Protected zone in surface (satisfactory vertical Self-purification), possibility of risk of pollution groundwater	Zone IV Vulnerable zone with risk of pollution. (*Absence of vertical self-purification*)

Fig. 1 Determination of vulnerability and risk of waters pollution zones (*Kherici, 2008*)

The triangle A which indicates the total index of self-purification: equal to the product thickness by the index of self-purification. The triangle B represents the total index of contamination: equal to the sum of the indices of organic contamination (ICO) and mineral (ICM).

From the abacus, 4 zones of vulnerability and risk of pollution will be then defined:

Zone I: Zone protected nonvulnerable to pollution without risk from pollution.

Zone II: Vulnerable zone with weak risk of pollution (Absence of vertical self-purification (self-purification in the nonsatisfactory unsaturated zone), vulnerable zone far from all human activities.

Zone III: Protected zone surfaces some (satisfactory vertical Self-purification), possibility of underground risk of pollution.

Zone IV: Vulnerable zone with risk of pollution (absence of vertical self-purification).

Two cases of application are represented for better illustrating the method of determination of the vulnerability and risk to the water pollution:

1. First case: unsaturated zone made up with only one geological facies
2. Second cases: unsaturated zone made up with several geological facies

Example 1: The unsaturated zone with a water point consists of 10 meters of sands.

NO3- = 3 mg/l; DBO5 = 1 mg/l

Pb++ = Traces; Cr6+ = trace

Example 2: The unsaturated zone with a water point consists of 4 meters of coarse sands and 5 meters gravels.

NO3- = 56 mg/l; DBO5 = 2 mg/l

Pb++ = Traces; Cr6+ = 0.1 mg/l

* For NO3- (ICO1) the classes will be the following ones:

Polluant organique1 (NO3-) (mg/l)	Traces	00-10	Natural	10-50	Limit WHO	>50
Classes		1		2		3
Example 1		1				
Example 2						3

* For DBO5 (ICO2) the classes will be the following ones:

Polluant organique2(DBO5) (mg/l)	Traces	00 - 01	Natural	01 - 05	Limit WHO	>05
Classes		1		2		3
Example 1		1				
Example 2				2		

* For Pb++ (ICM1) the classes will be the following ones:

Pollutant minéral1(Pb) (mg/l)	Traces	00-0.0	Natural	0.0-0.1	Limit WHO	>0.5
Classes		1		2		3
Example 1		1				
Example 2		1				

* For Cr6+ (ICM2) the classes will be the following ones:

Contents of the organic pollutant(mg/l)°	Traces	00-0.0	Natural	0.0-0.0011	Limit WHO	>0.05
Classes		1		2		3
Example 1		1				
Example 2						3

-In example 1 the index where:

ICO (ICO1+ICO2) = 1 + 1 = 2 (class 1 for NO3- et class 1 for DBO5)

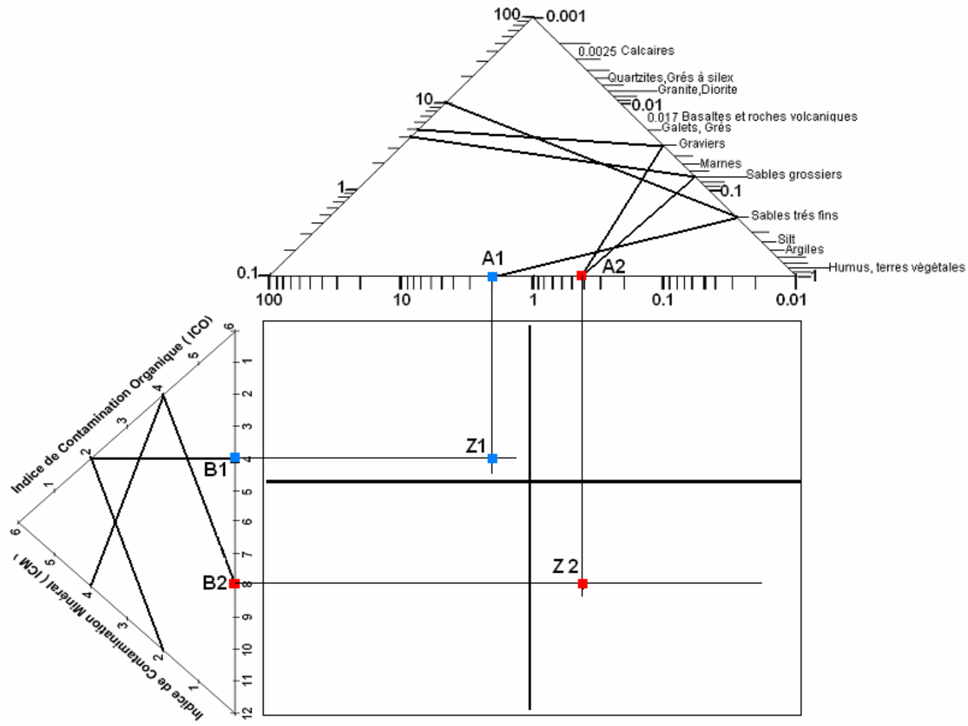
ICM (ICM1+ICM2) = 1 + 1 = 2 (class 1 for Pb++ et class 1 for Cr6+)

-In example 2 the index where

ICO (ICO1+ICO2) = 2 + 2 = 4 (class 2 for NO3- et class 2 for DBO5)

ICM (ICM1+ICM2) = 1 + 3 = 4 (class 1 for Pb++ et class 3 for Cr6+)

The representation of these two examples is illustrated in **Fig. 2**. The two examples illustrated in this article are enough to show the potential of the application to support the exploration and the simple and fast analysis of the vulnerability and the risk of groundwaters pollution.



Legend:
Z 1 [A 1 = 2; B 1 = 4] : Protected Zone, non vulnerability to pollution, without risk of pollution
Z 2 [A2 = 0.43; B 2 = 8] : Vulnerable zone with risk of pollution. (Absence of vertical self-purification)

Fig. 2 Example of determination of vulnerability and risk of waters pollution zones

3. CONCLUSIONS

To show the state of vulnerability of the aquifers and the risk of pollution; sometimes the data call upon treatment rather complex and heavy of use. The recourse to various diagrams and graphs is thus rather frequent. Some diagrams are suitable to study very specific risks, others only determines the vulnerability of middle. For this purpose a new method was developed. It uses, simultaneously, the qualitative data of water and the physical data of soil. The new diagram proposed, is formed by two triangles, one representing the natural agents (thickness of the unsaturated zone, geologic facies, degree of self-purification) and the other anthropogenic agents (organic and inorganic pollutants). The diagnosis is then rapidly. This method can be generalized to several parameters (pollutants) by multiplying combinations of classes, which requires a simple reorganization of the diagram indices of contamination

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EMPIRICAL MODELLING OF WINDTHROW RISK USING GIS AND LOGISTIC REGRESSION

L. Krejci[1]

ABSTRACT:
This paper is attempting to shed light on the basic approaches and methods (observational, empirical and mechanistic approach) of assessing wind damage hazard using widely available GIS software. The paper describes data acquisition and building dataset, determination of dependant and independent (explanatory) variables, creation of sample units and application of basic statistical methods to assess windthrow risk. The statistical method of logistic regression is used to predict the probability of this hazard. Logistic regression is one of the most commonly used tools for applied statistics and data mining and has proven to be a useful tool to estimate the probability of windthrow. Variables and coefficients of logistic model are calculated using statistical software SAS 9.1. Stepwise method is applied to aid in the formulation of model and finding the most important explanatory variables. Logistic regression formulas are incorporated into GIS and a windthrow hazard map is then derived from the model using raster calculator in ArcGIS Spatial Analyst. The potential for spatial prediction of wind damage using logistic regression, and it's results are discussed at the end of the paper.

Keywords: *windthrow, GIS, natural hazard, logistic regression, probability.*

1. INTRODUCTION

In the last decades, we have witnessed a serious surge in windthrow occurrence caused by wind, snow and ice which has resulted in damage to our forests. Wind damage results in both direct costs (serious financial loss, additional cost of harvesting and reduced timber value) and indirect costs (increasing erosion, impact on water regime, disappearance of original biotopes and species etc.). In spite of the fact that windthrows are natural event and their occurrence have been well-known for a long time, it is partially possible to reduce their impact and damage. Advanced technologies like geographical information systems (GIS), Spatial decision support systems (SDSS) and predictive models provide enhanced and dedicated tools which allow effective assessment of forest areas and help reduce wind damage.

Windthrow damage can possibly disrupt forest management plans. Documentation of the relationship between occurrence and biophysical and management factors enables damage predictions and thus developing lower risk harvesting plans (*Mitchell et colab, 2001)*. The damaged areas are more vulnerable from attacks of insects and windthrows often lead to the development of bark beetle populations on disturbed areas. The quality of wood harvested from damaged areas is poor whereas harvest costs are much higher. Operating in windthrow areas also brings significantly higher risk of accidents at work then in undisturbed forests.

Wind damage isn't only a significant problem in forests in the Czech Republic. It is believed that the damage caused by wind costs European countries more than 15 million euros a year and in some extreme cases dramatically more. For example, storms in Northern Europe in December 1999 overturned more than 300 million m3 of timber. In

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January 2005, storms overturned more than 85 million of timber (http://www.forestresearch.gov.uk /fr/INFD-639A92).

Czech forests have been badly hit by extreme storm events many times in the last decades, with the Šumava mountains being among the most affected areas. The most extreme windstorms in the Šumava mountains in the past include the storms between the years 1868 – 1878 and 1955-1962. In each period over 3 million cubic meter of timber was damaged (*Jelínek, 1985; Vicena, 1964*). Four extreme storms have affected Šumava forests since 1985, emphasising the urgency and scale of the problem (catastrophic windstorms in 1984, 2002, 2007-Kyrill, 2008-Emma).

2. WINDTHROW RISK ASSESSMENT APPROACHES

The risk can be defined as the probability of a tree or stand being blown down by an extreme wind and in terms of engineering risk integrates the probability of an event with consequences of the damage. The consequences include, for example, changes in the water regime associated with stand loss resulting in the reduction of retention of watershed and flooding (*Gardiner, 2008*).

Generally there are three main ways of assessing windthrow risk: empirical, mechanistic and observational. The resulting models then relate scale of damage or probability to one of following: tree, site, stand, topographic and climate variables. Empirical approach uses a qualitative assessment which have been widely adopted by decision-makers to assess wind damage risk. Empirical models usually relate the occurrence of wind damage in sample unit to the attributes of these units. Empirical models can provide quite accurate results in specific locations and may be easy transferred to other locations with similar conditions. Mechanistic approach is based on calculation in two separate stages. The first stage is to calculate the above-canopy "critical wind speed" which is required to break trees and in the second stage is calculating the probability of a such wind occurring at the location. Most of the mechanical models currently available on the market can be regarded as hybrid models due to the fact that the component calculations include both empirical relationships and physical relationships.

A wide range of empirical, mechanical models and observational methods have been developed since the eighties to assist forest managers better assess the risk of windthrow. An example of a widely used empirical method is windthrow hazard classification (*Miller, 1985*) used in Great Britain. WHS provide a method to assess risk, based on a scoring assessment of four site factors (wind zone, elevation, exposure and soil). Hybrid mechanistic/empirical models can be represented by HWIND model *(Peltola, 2007)* and ForestGALES (*Gardiner, 2004*) which have been accepted within the research community. The main advantage of ForetsGALES (see **Fig. 1**) is the fact that it can be adopted for use outside of Great Britain where it was originally designed. The current version has been successfully adapted for use in New Zealand, south-west France, Japan, Canada and in terms of project Stormrisk in countries of North Sea Region (Denmark, Sweden, Germany, Norway). An example of this method being used to evaluate damage risk to forest stands for conditions in the Czech Republic would be a complex regional wind damage risk classification (WINDARC) developed by Lekes and Dandul (*Lekeš, 1999*). The method uses an airflow model for calculating terrain exposure classification and permanent exposure classification. A consequence of combination both classifications results in a complex regional wind damage risk classification which represents a wind damage risk to forest stands.

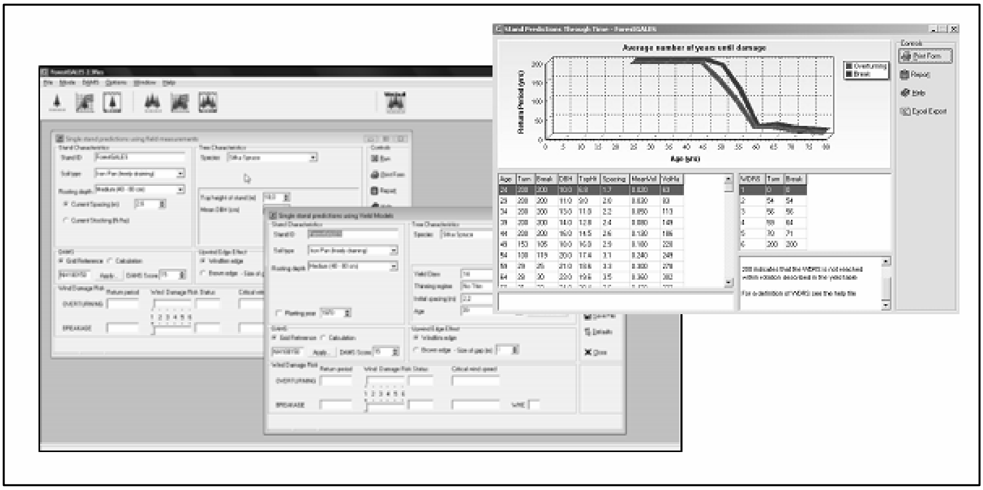

Fig. 1 ForestGALES working environment (*Gardiner, 2004*)

3. DESCRIPTION OF STUDY AREA

In this study, the chosen area is located in south-west part of National Park (NP) Šumava Mts. (Bohemian Forest Mts.) in the Czech Republic. National Park (NP) Šumava Mts. (Bohemian Forest Mts.) together with the Bavarian National Park on the border with Germany and with buffering zone has been declared as Šumava Protected Landscape Area (90,000 ha) and represents one of the largest protected area in Europe (*Ulbrichová, 2006*).

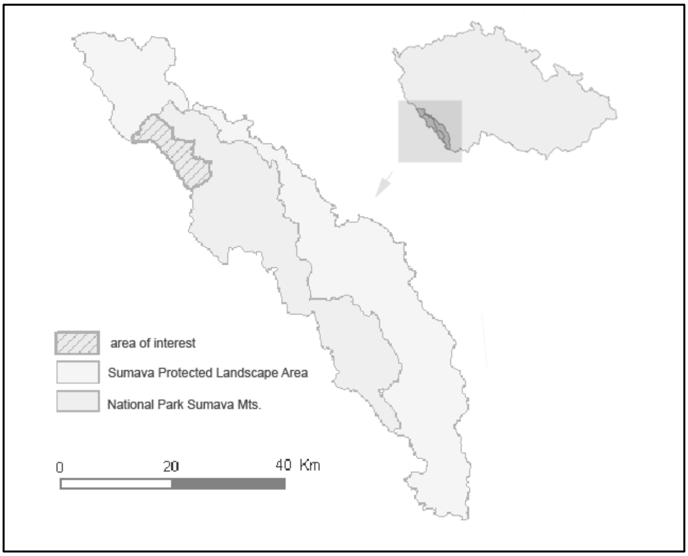

Fig. 2 Area of interest in SW part of Czech Republic

The location of the study area displayed in **Fig. 2** was chosen particularly because of a high occurrence of windthrows, who's number is repeatedly growing and resulting in considerable damage in forests of Šumava. It is bounded on the south by German National Park Bayerischer Wald (Bavarian Forest) and on the north and west by the Protected Landscape Area Šumava (CHKO).

According to the established geomorphological divison of the Czech Republic (*Demek, 1965)* study area in the hierarchical assortment had been incorporated in to the Geomorphological Province Česká vysočina. It belongs to geomorphological whole Šumava, its sub-wholes Šumavské pláně (Šumava Plains) and Železnorudská hornatina (Železná Ruda Highlands). It is about 55 km long, at most 20 km wide and its area is about 670 square km. The Železnorudská hornatina (Železná Ruda Highlands) is about 200 square km large and it is situated in the most western part of the Šumava mountains in the surroundings of Železná Ruda. The highest peak of this part is Jezerní hora (Lake Mount - 1,343 m) above Černé jezero (Black Lake).

The Šumava Mountains in the tested area are represented by a relief range running from uplands to highlands. The highest peaks of the mountain range, in the borders areas reach a altitudes of over 1300 meters above sea level (Debrník 1337 m, Ždánidla 1308 m, Poledník 1315 m). To the north the mountain range slopes down to a depression around the river Křemelná, which flows from west to east. The altitudes there reach around 700 meters above sea level (*Kolejka, 2008*).

The climate of study area is wet and cool with mean annual precipitation 900-1050 mm and mean annual temperature 4,5 – 5,5˚C in elevation between 800-970 m. In elevation between 970-1210 m annual precipitation is 970-1210 mm and mean annual temperatures are 4,0 – 4,5˚C. The high altitude areas has annual precipitation higher than 1200 mm and mean annual temperature between 2,5 and 4,0˚C (*Tolasz et colab., 2007*).

The study area can be considered very interesting from a hydrological point of view especially due to the fact that is situated in the main European water-shed between the North and Black sea. There can also be found two of five glacier lakes developed on the Czech side of the mountains. Most of the area falls into the Labe watershed but the small area around Železná Ruda falls into Dunaj (Danube) watershed. Lake Laka, the smallest and the most elevated lake in Šumava mountains, lying 1096 m above sea level, can be found inside the study area below the Debrník Mountain. The lake Prášilské jezero is situated in a glacier rock basin under 150 meters high cliff of Poledník. Its dike consists of nine-meters wall of granite boulders and two moraines. The lake is up to 15 meters deep.

The study area is under populated and there is only one built-up area (Prášily) situated inside the area of interest. Administratively area belongs to the Plzen (Pilsen) region and Euroregion Šumava.

4. METHODS AND MATERIALS

Methods and materials included data acquisition and building dataset, determination of dependent and independent (explanatory) variables, creation of sample units, data screening, application of statistical method of logistic regression using statistical software and incorporation of logistic regression formulas into the GIS. The windthrow hazard map was then obtained using raster calculator in ArcGIS Spatial Analyst.

4.1. Data acquisition and building dataset

The data used for this study were derived or obtained from aerial photographs, field inventory, digital elevation model, forest maps and topographic maps. Digital elevation model (DMR) created using Topo to Raster interpolation method specifically designed for the creation of hydrologically correct DMR was used in the study (digital contour data in the interval 5 m and point elevation map were provided by the Šumava National Park). The windthrow areas were detected and identified by aerial photographs taken in 2006 and in 2007 (aerial photographs used in study from 2007 were acquired especially for purposes of monitoring wind damage caused by hurricane Kyrill immediately after the calamity occurred). Forest data used for wind damage assessment included Regional Plans of Forest Development (RPFD) data (typology map, map of forest vegetations levels, map of functional forest potential etc.), forest stand map and information regarded to logging history. Most of data, spatial layers and information related to the wind risk assessment were obtained from the Šumava National Park.

4.2. Basic statistical analysis

The basic statistical analysis of a data set was applied initially to asses factors which influence the occurrence and scale of windthrow damage. Due to a wide range of values in data layers, it was necessary to reclassify each data layer into the following predefined categories: the total percentage of categories, percentage of windthrow areas caused by hurricane Kyrill and the proportion of categories in windthrows damaged areas to categories in study area were calculated within every layer. The basic statistical analysis provided initial information regarding the importance of each layer. The initial findings indicate the number of damaged areas increased with increasing elevation, forest stand height, forest stand age, forest stand density, mean diameter of the stand, site humidity and the percentages of Norway spruce in the stand. The most damaged areas caused by windthrow occurred between 1101-1200 and 1201-1336 meters above sea level/elevation (see **Fig. 3** and **Fig. 4**), then in categories 20,1-25; 25,1-30 and 30,1-30,8 meters/forest stand height, in categories 24,1-32; 32,1-40 and 40,1-66 centimetres/mean diameter of the stand, and then in stands with forest stand age above 140 years and in stands with the percentages of Norway spruce in the stand over 80%.

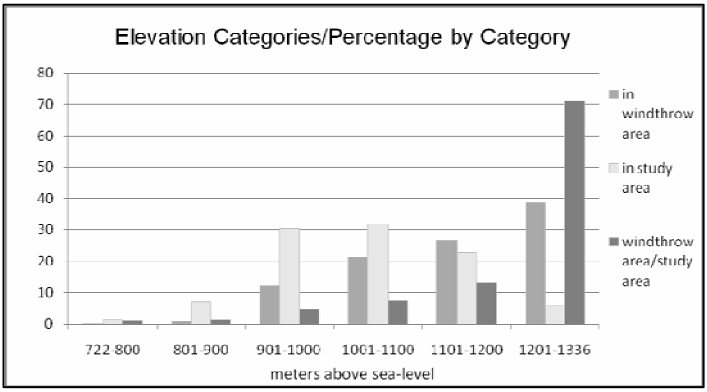

Fig. 3 Elevation Categories/Percentage by Category in windthrow and study area

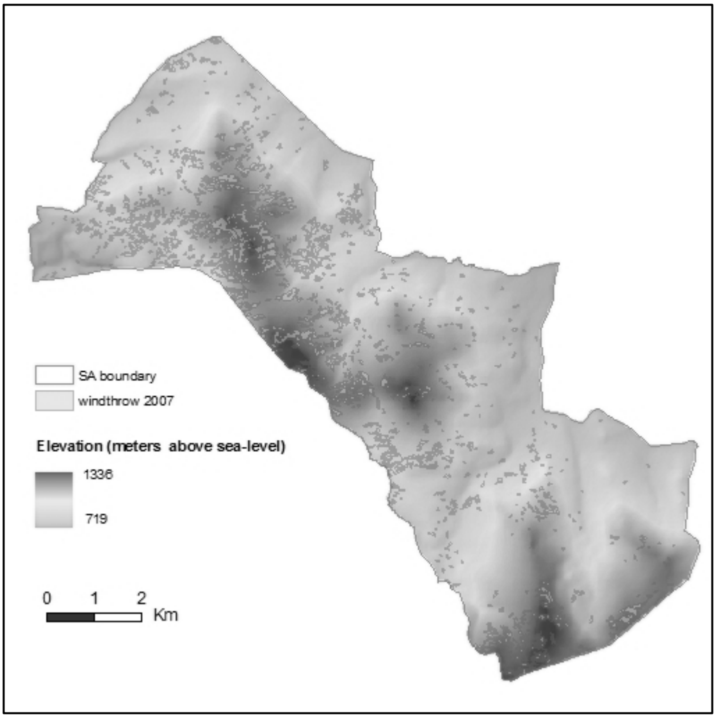

Fig. 4 Digital elevation model of study area

4.3. Data sampling, screening and determination of variables

Due to the fact that occurrence of windthrow is a rare event and measures of damage (for instance percentage of segment area loss) are not normally distributed, approaches based on normal regression are not appropriate for prediction of windthrow. Logistic regression allows to predict discrete outcomes (sample unit damage/undamaged) and are better suited to the problem of rare occurrences such as windthrow. It uses the method of maximum likelihood to estimate parameters and takes the model form (http://luna.cas.usf.edu/~mbrannic/files/regression/Logistic.html):

$$Y = \frac{e^{g(x)}}{1+e^{g(x)}} = \frac{e^{g(x)}}{1+e^{-g(x)}} \tag{1}$$

where:

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p \tag{2}$$

and:

$\beta_0, \ldots, \beta_p$ - parameter estimates, and

x1, … , xp - predictor variables.

Logistic regression has proven to be a useful tool to estimate the probability of windthrow. It has been utilized by Valinger and Fridman (1999), Jalkanen and Matilla (2000), Canham et al. (2001), Mitchell et al. (2001), Peterson (2004), Lanquaye - Opoku and Mitchell (2005), and Scott and Mitchell (2005) to predict the probability of windthrow on an individual tree level (*Drake, 2008*).

This statistical method was therefore used in this study to assess windthrow risk and generate the probability of windthrow occurrence for each sample unit of study area.

In order to perform logistic regression using statistical software it was necessary to create a set of dependent variables which represent the presence of damage. As stated above, the dependant variable is usually dichotomous and can take the value 1 with a probability of success or the value 0 with the probability of failure. Sets of dependant variables were then derived from the spatial layer containing attributes related to occurrence of windthrow. In the second step a set of independent variables was created. Unlike the dependant variables, the independent variables in logistic regression can take any form, and logistic regression makes no assumptions about the distribution of the independent variables.

The creation of sample units was crucial before construction a segment database, which included both independent and dependent variables. Sample units were generated using ArcGIS Spatial Analyst extension and study area was then subdivided into sample units (25 x 25 m). The segment database was extracted by overlaying layer onto the other using ArcGIS Analysis Tools from ArcToolbox. Each segment from the segment database contained a centroid (a point situated in the centre of sample unit). The entire dataset contained 110 864 points (each point/centroid represented 25 x 25 m segment). In the next step were removed non-forest segments and the final dataset contained 85 141 segments.

4.4. Statistical analysis

Logistic regression was performed using SAS 9.1 with the logistic procedure. The list of potential independent (explanatory) variables was refined to include the relevant variables only.

Pearson correlation coefficients were applied to identify variables which were highly correlated with the other variables to minimize multicollinearity. After a suitable list of potential independent variables was obtained, the stepwise selection methods were chosen to aid in the formulation of a model. As a result of the stepwise method of variable selection, ELEV, VEK, ZAKM, SM_H, VLHK, HLOUB and ZAST_S were found to be the most important explanatory variables (the parameters were estimated using the method of maximum likelihood). The variables and coefficients used in logistic model and calculated using SAS 9.1 are displayed in **Table 1**.

The likelihood-Ratio Test and the Wald test were used to test hypotheses in logistic regression. The likelihood-ratio test uses the ratio of the maximized value of the likelihood function for the full model over the maximized value of the likelihood function for the simpler model and it is recommended statistic test to use when building a model using stepwise selection model. A Wald test was used to test the statistical significance of each coefficient in the model.

Table 1. ***Variables and coefficients in logistic model***

Parameter	Estimate	Standard Error	Wald Chi – Square	Pr > ChiSq
Intercept	-16,0743	0,2574	3900,2361	<,0001
ELEV	0,00794	0,000149	2833,7505	<,0001
VEK	0,0221	0,000433	2607,6719	<,0001
ZAKM	0,1198	0,0160	55,6719	<,0001
VLHK	-0,1379	0,0118	136,7561	<,0001
HLOUB	0,3226	0,0143	510,2636	<,0001
ZAST_S	0,0156	0,00127	152,8259	<,0001

5. RESULTS

A windthrow hazard map was derived from the model using raster calculator in ArcGIS Spatial Analyst and it is displayed in **Fig. 6**. The logistic regression formula incorporated into the ArcGIS map calculator took the form:

log (p/(1-p)) = (-16.0743 + ELEV * 0,00794+ VEK * 0,0221+ ZAKM * 0,1198-VLHK * 0,1379+ HLOUB * 0,3226+ ZAST_S * 0,0156

or

p = exp (-(-16.0743 + ELEV * 0,00794+ VEK * 0,0221+ ZAKM * 0,1198-VLHK * 0,1379+ HLOUB * 0,3226+ ZAST_S * 0,0156)/(1 + exp(-16.0743 + ELEV * 0,00794+ VEK * 0,0221+ ZAKM * 0,1198-VLHK * 0,1379+ HLOUB * 0,3226+ ZAST_S * 0,0156)

p – probability of windthrow hazard
ELEV – elevation
VEK – forest stand age
ZAKM – forest stand density
VLHK – site humidity
HLOUB – soil depth
ZAST_S – % of Norway spruce in stand

The logit (log of the odds) was calculated and then converted to a probability. A large part of study area has a low (0-0,05) risk and occupies more than 50% of study area. The concentrations of higher risk areas are evidently visible on the map and both high risk categories (0,25-0,45;0,46-0,89) occupy approximately 11% of study area. The remaining probability categories (0,06-0,10;0,110,15;0,16-0,25) with medium risk occupy approximately 37% of area. The categories of probability for number of 25x25 m cells of forested portions of study area are displayed in **Fig. 5**.

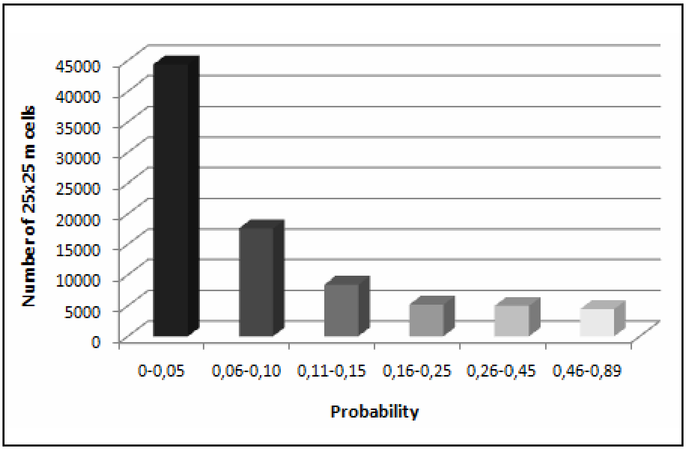

Fig. 5 Number of 25x25 m cells for forested portions of study area occupied by each damage probability range

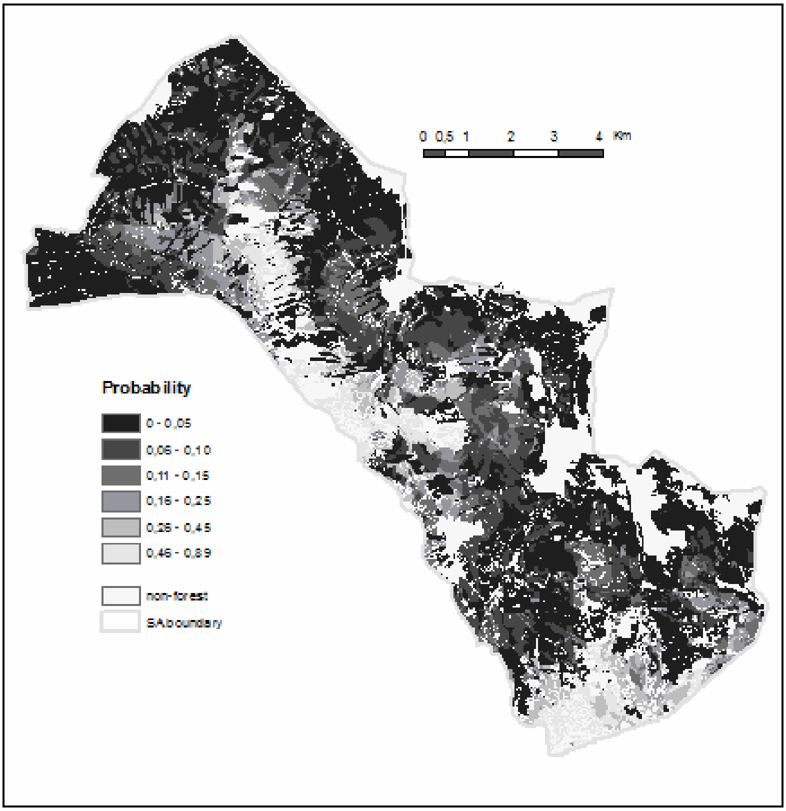

Fig. 6 Windthrow hazard map

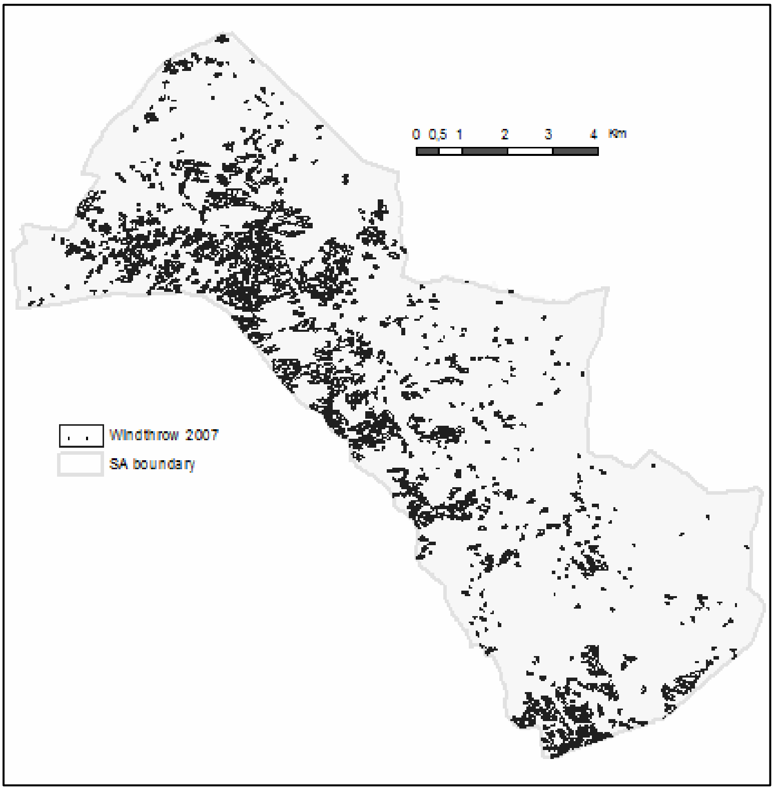

Fig. 7 Windthrow areas caused by hurricane Kyrill in 2007

The proportion of damaged segments increased with increasing of elevation (ELEV), forest age (VEK), forest stand density (ZAKM), soil depth (HLOUB), site humidity (VLHK) and the percentages of Norway spruce in the stand (ZAST_S). There is clearly visible overlay between the segments with high probability calculated using logistic regression and areas damaged by hurricane Kyrill in 2007 which can be seen in **Fig. 7**. This proves the fitness of chosen logistic regression model and methods used in this study. These results were expected and are consistent with prediction with other researchers.

6. CONCLUSIONS

Windthrows are influenced by many factors at the tree, stand and landscape levels and sometimes the interaction can possibly complicate the assessment. The important fact for managing windthrows is not only the knowledge on how various factors relate to windthrow but also how they can relate to each other. One of the main aims of this study, apart from using GIS and logistic regression for assessing wind hazard damage, was also to understand how the factors affect the occurrence of such a rare event as windthrow.

This paper attempted to shed light on the basic approaches and methods used by researchers and forest managers to asses potential wind risk. The process of assessing wind damage hazard using widely available GIS software ArcGIS 9.2 was described in the paper. The potential of statistical method of logistic regression was examined and logistic regression itself was described in the text. The results obtained by using GIS and logistic regression were discussed at the end of the paper.

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ADVANTAGE OF CARPOOLING IN COMPARISON WITH INDIVIDUAL AND PUBLIC TRANSPORT. CASE STUDY OF THE CZECH REPUBLIC

I. Ivan[1]

ABSTRACT
The decline of public transport usage is a typical development of last few decades in most countries in modern world. This can cause many traffic (congestions, public transport providers' sales), environmental and other problems. Carpooling can be defined as the shared use of a car by the driver and one or more passengers, usually for commuting. It is a new transport system where the main goal is to maximize the usage of cars, a thing that could bring many other positives. Main benefit of this paper is the calculation of the performance of carpooling to 95 main employers in three NUTS3 Regions in the Czech Republic. For this purpose new special extension for the OpenJump software was developed and almost 124,000 scenarios were simulated. From these results performance of carpooling was compared with individual car transport and public transport from the distance and financial aspects.

Keywords: *carpooling, public transport, NUTS3, OpenJump, Czech Republic.*

1. INTRODUCTION

In EU15 member states, the volume of individual car transport use significantly increased and on the other hand the volume of public transport use significantly decreased between 1970 and 2002 (*Seidenglanz, 2007*). The increase of car transport use increased to more than 80% in this era, while the share of the public transport use decreased bellow 10% (bus transport 8.8%, railway transport 6.6%). But there are evident some differences between these EU15 member states. The biggest increase reached the Great Britain and Portugal (87%), Netherlands or France (86%) and the smallest was in Austria (74%) and Greece (77%) (more in (*Seidenglanz, 2007*)). Similar development is also evident in the Czech Republic, where the rate of individual car transport use rose and the usage of public transport continuously declined during last decades. In 1970, only 5% people used the car transport for commuting out of the residential municipality. About 30 years later, in 2001, it was more than 30 % (*Čekal, 2006*). In case of railway transport, number of transported people per year declined about more than 22 % from 228.7 million in 1994 to 177.4 million in 2008. More significant decline happened in case of bus transport where the decline was almost 40 % from 663.5 in 1994 to 401.7 million in 2008 (see *Ministry of Transport. Transport Yearbook in the Czech Republic 1999, 2003, 2008*). Current development of public and individual transport use endangers the transport system by congestions or environmental problems and the public transport providers suffer by the insufficient size of sales and subsequent over-dependence on subsidies (*Smítal, 2007*). Rodrigue (*Rodrigue et al., 2006*) points out that these congestions do not endanger only the car transport but the public transport as well, because both of these transport types share the same road network. Many new transport systems has been developed to reduce this massive increase of individual car transport, to make the public transport more attractive, to reduce negative environmental influences of car transport and generally to reduce the volume of car

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transport primarily in urban space. Vonka (*Vonka et al., 2001*) lists the basic description of these systems: Park and Ride, Bike and Ride, Kiss and Ride, Park and Bike, Park and Go, Hail and Ride, Call and Ride, Park and Pool, Door-to-Door, Carpooling, Car-sharing, Ride-sharing, ICARO project etc. But it is problematic to define some distance or time enlargement or some price decline if some of these new transport systems are used. Just carpooling is selected for this paper and general factors of this transport mode are compared with public and individual transport. Price and distance of journey to chosen employers in particular NUTS3 Regions belong to these factors (see chapter 3).

American geographer Rodrigue (*Rodrigue et al., 2006*) defines carpooling as an agreement where two or more passengers share the use and cost of privately owned cars by travelling to and from pre-defined locations. The basic advantages of two previous types of transport are combined in this type of transport. Price of journey is smaller than in case of individual car transport, even though the distance of journey is longer, because the financial costs are divided between all passengers. Also the journey does not have to be so time-consuming and distance so long as in case of public transport. Carpooling should not be substituted with car-sharing, which is organized and the providers are a professional private organizations who own car park just for this purpose (more in (*Bergmaier et al., 2004; Drdla, 2008*)). The main difference is in the institutional guarantee – car ownership. In terms of carpooling could be conducted the ride-sharing (next R-S) or car-sharing (next C-S). R-S could be generally translated as shared journey. Its main goal is to achieve the maximal utilization of the vehicle to minimize the economic cost of the journey. At least two passengers must take part carpooling and the vehicle is usually owned by one of them. It is not important whether commuters use only the car owned by one passenger or whether they change the passengers' cars in regular intervals. It is important to share at least part of the journey. This type of transport has to substitute at least one car journey in a similar direction and the passenger must have driving licence and under other circumstances he would use own car for commuting (*Eckersley, 2004*). In addition, two types of R-S can be distinguished: formal (a provider for the R-S organization) and informal (two co-passengers commute together by a private car) (*Vonka, 2001*). The main goal of C-S is the sharing of the vehicle in order to reduce the economic costs of using cars by as many participants as possible. For this mode of transport it is characteristic that the car is on loan or hired and the car owner doesn't have to travel at all. So car-sharing by family members within household can be considered as an informal C-S, while a car rentals or taxi (taxi driver can be considered as a part of the car with some degree of generalization) can be considered as a formal C-S.

For cars with two or more passengers various stimulating mechanisms are created to increase the popularity of carpooling in some world cities. So-called High Occupancy Vehicle lanes (HOV) belong to these advantages and these lines have been used since 1969. HOV provide a separate road strip which can be used only by cars with two and more passengers. First HOV in Great Britain was created in Leeds in 1998. Special parking place is other interesting advantage for carpooling people. But Vonka (*Vonka, 2001*) suggests that these actions still lead to an increase of car transport use and therefore it is not advisable. Stimulating mechanisms for participation in C-S or R-S should not be based on favouritism of conditions for these types of travelling. However, even C-S or R-S could reduce the car use more than the classical individual car transport. According to the results of the International Energy Agency from 2005, in case that each commuter would be joined by another passenger, the potential benefits of R-S use in OECD countries would lead to reductions in overall oil consumption by 7.7% or 2,223 barrels of oil per day and to reduce the number of kilometres travelled by a car by 12.5%, what implies a further numbers of advantages (*Caulfield, 2009*).

There is only one data source about carpooling use in the Czech Republic - the census data. In 2001, there were 6.3% (almost 123,000) of all commuters who commute by carpooling. But about 75% of all cars were occupied only by commuting driver and even bigger ratio of cars occupied only by driver is in case of intraurban commuting in the Czech Republic. It is impossible to analyze a development of carpooling popularity, because it was not explore the transport vehicle of commuting in census 1980 and 1991. But it is evident that carpooling is not as popular as it should be and commuting of single car drivers is really often especially in urban space in the Czech Republic. Based on the Census results in Ireland (2006), even only 4% of all commuters are using carpooling for daily morning commuting to Dublin (*Caulfield, 2009*). For the first time, carpooling was officially used in the Czech Republic by Panasonic's subsidiary in Pilsen. This company has guarded parking places with limited capacity and with the growing number of the employees' its capacity wasn't sufficient. Therefore, carpooling helps to solve problems with parking and a parking place is always reserved for commuters who carpools. Employees who participate in the system find it very positively and the company's management is therefore satisfied with the results and experiences from the operation of shared services and they support the whole system (*Vonka, 2001)*.

2. ROUTES GENERATOR FOR OPENJUMP

Extensions Routes Generator was developed to simulate the distance and cost of commuting by carpooling, it was developed by Martin Prager. This is an extension of the open source GIS software OpenJUMP. It is implemented as OpenJUMP ThreadedPlugin. Implementation of this class would be easier able to cope with prolonged processes that occur by the carpooling simulations. In addition to basic components and JTS library (Java Topology Suite) which is one of the basic components of OpenJUMP, it is used also other open-source library Jgrapht. This library constructs weighted graph from the road network layer and it calculates the shortest route between the origin and destination (concretely the implementation of the class WeightedPseudograph). The entire process is performed in one thread without any persistence. So the number of calculations depends on computer memory. In general, this extension calculates the shortest path distance between the origin and destination through defined number of randomly selected stops which are located in x kilometres buffer area around the shortest path between the origin and the destination.

The main form of this extension can be divided into three main parts (**Fig. 1**). The first part contains the definition of origins and destinations of commuting. These can be selected either randomly or by using a value of selected attributes. In these analyses, origins were selected randomly from all buildings within particular LAU1 Districts or micro-regions. Destinations were selected according to the address of the chosen employer (see chapter 3). Attributes of the transport network are chosen in the second part of the form – node of origin and node of destination of particular transport segments and their length. The third part contains the details of the simulation. Firstly, the maximal time limit for each simulation is defined; in this case the limit is set to 60 seconds. If the duration of particular simulation exceeds this time limit, current calculation is interrupted and next simulation will start. Buffer size defines the width of the buffer zone around the shortest route between the origin and destination when particular stops for carpooling can be chosen. This area cannot be too large because the detour could be too significant and could even double the total length of journey and in this case the price reduction wouldn't bring any advantages compared to individual car transport. Number of stops is defined in the last text box of the main form. If random buildings selection is chosen, it is possible to enter the minimum distance between the origin and destination in metres.

It is possible to monitor the progress of calculations during simulations in the output window; there is information about particular steps (**Fig. 1**). Input parameters are generated in the first step, the origin and destination is selected. Furthermore, it is found the shortest path between these two locations and selected a defined number of stops along this route. Next step is finding the shortest path between the origin and the first stop, then between the first stop and another stop or the destination. In the last step, all results are saved in four output layers.

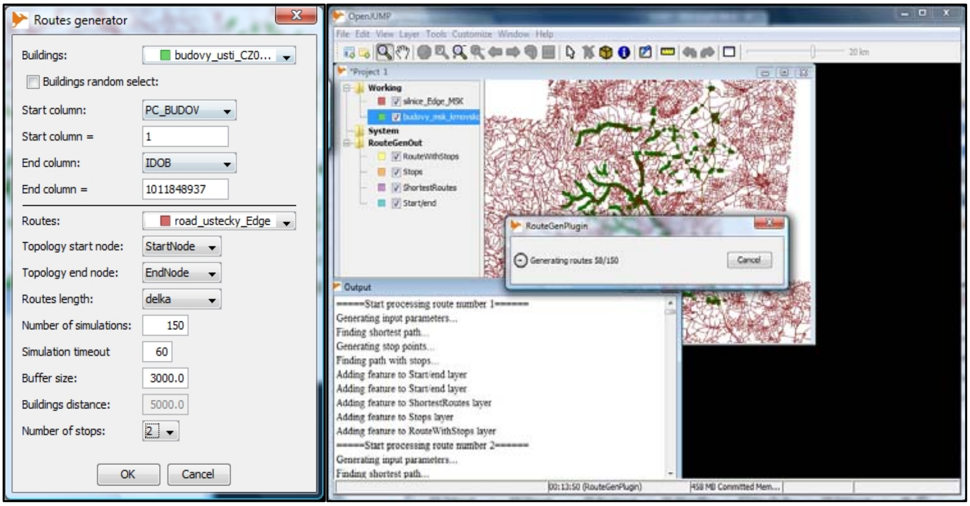

Fig. 1 Form with specifications of carpooling simulations and Routes generator in use

3. METHODOLOGY

As case study areas within the Czech Republic three NUTS3 regions were selected – Moravian-Silesian Region (MSK), Usti Region (ULK) and Vysocina Region (VYS). Results were analyzed on two spatial levels. Regional level provides a general overview; results are analysed and compared between particular NUTS3 Regions. The second spatial level is focused on particular employers within LAU1 Districts in the NUTS3 Regions (ULK and VYS). In case of MSK, this second level is focused on employers within so-called working micro-regions, which were created according to the methodology of socio-economic regionalization of the Czech Republic in 2001 (*Hampl, 2005*). Two different administrative dividing were chosen because of improper dividing of MSK into LAU1 Districts (urban District of Ostrava-city almost without suburbs, large Districts Frýdek-Místek and Bruntál). LAU1 Districts are more homogeneous in VYS and ULK and their size is generally very similar. Five employers were chosen in each District (LAU1) or in each micro-region in the case of MSK. These employers belong to the biggest in each NUTS3 Region. The selection of these employers was influenced by the number of employees, which had to be bigger than 250 (February 2008) but finally more than half of

these companies had more than 500 employees. These employers should be located out of the influence of urban public transport, which is not included in the analysis. The last condition for selection of employers was connected with an effort to maximize their spatial distribution. Overall, 95 employers were chosen within three NUTS3 Regions (**Fig. 2**).
Methodology for calculation of commuting distance and cost by public transport and individual car transport is described in (*Ivan, 2009*).In general, GIS and network analyses were used for calculation of commuting distances by individual car transport between each building in the LAU1 District/micro-region and each employer in the same LAU1 District/micro-region. In case of PT, commuting distances were calculated according to valid timetables. Commuters have the possibility to choose one of five nearest public transport stops near their residence and near the workplace. Final commuting distance includes also walking distance to or from the chosen stops (door-to-door approach, more in (*Ivan, 2009*)) and it is the shortest one from 25 possible residence-workplace combinations.

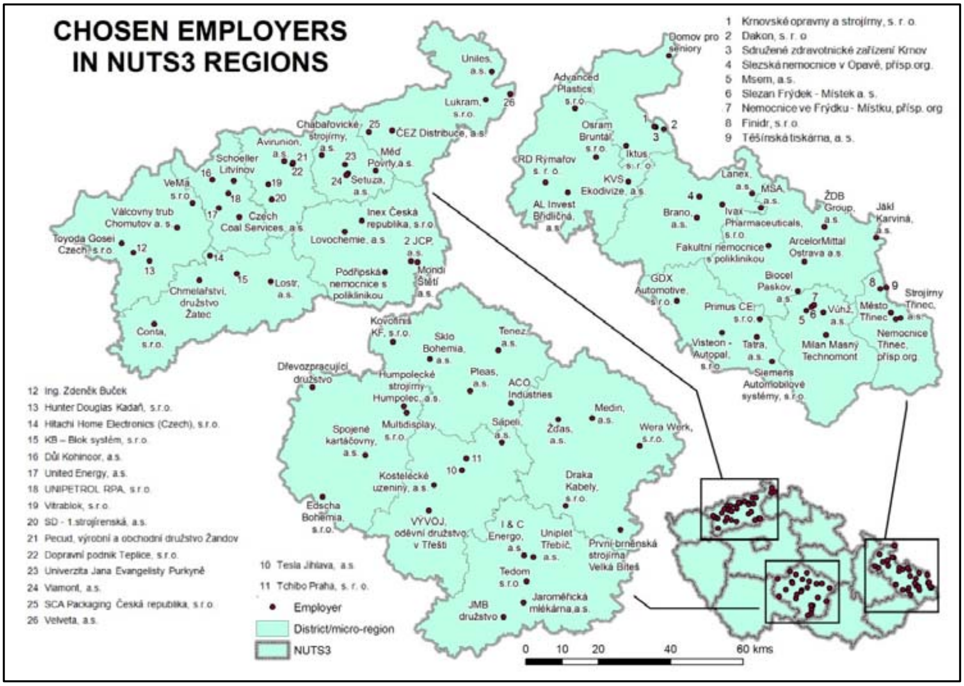

Fig. 2 Selected employers

The carpooling simulations were done in the series of groups. Overall, 285 possible cases of journeys were simulated – three carpooling types were simulated to all 95 employers – with one stop (the driver shares the car with one passenger), with two stops (the driver stops at two different places and shares the journey with two passengers) and with three stops (car is occupied by 4 people and the driver stops at three different locations). Buffer zone along the shortest route between residence and workplace was defined as 3,000 meters along each side of the shortest route and commuter can travel only within this area. This size seems to be appropriate to use the advantages of carpooling – bigger price reduction than enlargement of the journey. Number of simulations per one combination is other important parameter that needs to be set. After testing, minimal number of simulations per combination was defined as 300. However finally, it was simulated often more than 400 simulations for each combination. Overall, it was done more than 45,000 simulations in ULK and MSK and 32,000 simulations in VYS, so 123,437 simulations. The picture below (**Fig. 3**) shows an example of simulation of carpooling in the Decin District, it is shown the straight commuting route, the shortest commuting route and commuting route by three stops commuting.

For defining of commuting price, a hypothesis was accepted that passengers share the commuting costs equally. The commuting price by one stop carpooling is equal to half of price by individual car transport. In case of two stops carpooling it is one-third and in case of the three stops carpooling it is one quarter of the price.

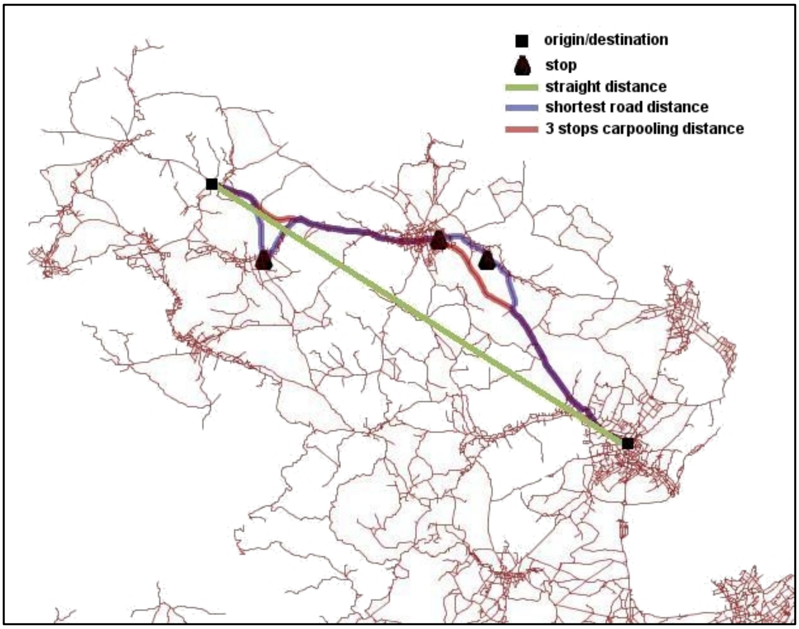

Fig. 3 Example of three stops carpooling

4. COMMUTING DISTANCE

This chapter provides the comparison of distance of commuting according to used transport mode. Overall, the smallest commuting distances are in the case of individual car transport. Absolute distances of commuting by particular transport modes are not comparable, because they are too sensitive on the size and shape of the area and on the spatial distribution of employers and buildings. Finally, absolute and relative (equation below) enlargement against distance of commuting by individual car transport was used to compare particular transport modes.

$$S_p = \frac{(S_x - S_{ICT})}{S_{ICT}} * 100[\%] \quad (1)$$

where sp defines relative enlargement, sx is distance of commuting by chosen transport mode and sICT is distance of commuting by individual car transport. Distance enlargement of commuting by public transport against commuting by individual car transport is very similar and it is about 22% (3.3 - 4.4 kilometres). In VYS, commuting distances by public transport is very similar to commuting by one stop carpooling. On the other hand the situation in MSK is quite different, because the distance enlargement of commuting by one stop carpooling is only about 10%. Also two other types of carpooling have the smallest enlargement of commuting distance what makes the carpooling in MSK very useful, mainly one stop carpooling. Commuting by carpooling is quite variable in ULK, one stop carpooling has still quite small enlargement, but all two other variations have the biggest enlargements of all Regions. In case of three stops carpooling, it is more than 43% against individual car transport. But the three stops carpooling enlarges commuting distance about more than a third in all NUTS Regions.

Table 1. ***Distance enlargement according to used transport mode***

Region	Carpooling (1 stop)		Public transport		Carpooling (2 stops)		Carpooling (3 stops)	
	Absolute*	%**	Absolute*	%**	Absolute*	%**	Absolute*	%**
Moravian-Silesian	1,560.2	9.9	3,377.2	21.4	3,384.9	21.5	5,507.1	34.9
Usti	2,011.6	13.5	3,481.2	23.3	4,450.5	29.8	6,486.0	43.5
Vysocina	3,808.0	19.4	4,420.7	22.5	5,637.9	28.7	7,507.1	38.2

enlargements of distance in metres; distance of ICT = 100 %*

Table 2 contains top 5 employers with the smallest and biggest enlargement of commuting according to used transport mode in all three NUTS3 Regions. Color of particular cells describes the membership to the Region. MSK has the biggest frequency of companies with the smallest enlargements and 75% of all employers in top 5 with smallest enlargements are located in MSK (the darkest color). One member is also from VYS – in case of Sapeli, Inc. it is very useful to commute by carpooling because of really small enlargements of commuting distances.

Other employer with really useful potential commuting by carpooling is Biocel Paskov, Inc. (MSK) with the smallest enlargements by three stops carpooling (less than 20%) and it is better than in case of commuting to some employers by one stop carpooling. Really interesting situation is the commuting to Domov pro seniory in Osoblaha (retirement house). Commuting by public transport belongs to the worst in all three NUTS3 Regions (about 44% longer than by individual car transport), but on the other hand, commuting by carpooling of all types belong to the best. Completely different situation is in case of commuting to Setuza (ULK) with really useful public transport accessibility, but carpooling is almost useless because of huge enlargements of distance – almost about 130% longer against individual car transport. In general, carpooling cannot be recommended for carpooling to some employers in ULK, because all members from the worst groups are located in this Region.

Table 2. ***Top 5 employers with the smallest and biggest enlargement of distance against individual car transport***

	Public transport		Carpooling (1 stop)		Carpooling (2 stops)		Carpooling (3 stops)	
	Employer	%	Employer	%	Employer	%	Employer	%
1.	Finidr	4.2	**Domov pro sen.**	3.9	AL Invest Břidličná	10.9	**Biocel Paskov**	19.6
2.	Město Třinec	4.7	RD Rýmařov	4.4	**Domov pro seniory**	11.4	**Domov pro seniory**	19.8
3.	Těšínská tisk.	4.7	ŽDB Group	4.8	**Biocel Paskov**	12.1	Žďas	22.4
4.	Slezan FM	9.0	**Sapeli**	5.1	Osram Bruntál	14.9	**Sapeli**	24.1
5.	**Setuza**	10.7	**Biocel Paskov**	6.0	**Sapeli**	15.0	Dakon	26.1
….	….	….	….	….	….	….	….	….
91.	**Domov pro sen.**	44.4	Uniles	45.7	Uniles	73.1	Dopravní Podnik Teplice	89.7
92.	Czech Coal Ser.	46.3	Lostr	46.8	SCA Packaging	73.2	Měď Povrly	94.1
93.	UNIPETROL	48.4	Velveta.	47.5	Univerzita J. E. P.	80.3	Univerzita J. E. P.	108.4
94.	Fak. nem. s pol.	51.7	**Setuza**	48.5	Viamont	81.4	Viamont	124.2
95.	Technomont	54.9	SCA Packaging	59.3	**Setuza**	86.4	**Setuza**	129.6

5. COMMUTING PRICE

Many commuters find the price of transport as the most important parameter of their transport mode choice and especially in case of socially deprived people, who commute to low-paid jobs. Actual timetables were used as the source of the public transport price and it contains the fares discount for rail transport. Financial costs of individual car transport were calculated according to the average fuel price based on the legislative of the Ministry of Labour and Social Affairs from the 1st of January 2009 (No 451/2008). So the average price of petrol is 26.8 CZK and this price will be increased by amortization of the vehicle. The same legislative states this amount to 3.9 CZK per 1 kilometre but this amount is not realistic in case of voluntary commuting, so the half amount was used as the costs of the vehicle amortization. With an average consumption of 8 litres per 100 kilometres the price of 1 kilometre is equal to 4 CZK. In comparison with commuting distance, where the individual car transport was the best transport mode, in case of commuting price the situation is opposite.

The calculation method of price reductions cp is similar to calculation of distance enlargement sp, where cx defines price of commuting by particular transport mode x and cICT is price of commuting by individual car transport.

$$c_p = \frac{(c_{ICT} - c_x)}{c_{ICT}} * (100)\ [\%] \qquad (2)$$

The development of transport price according to the transport mode is similar in all three Regions. The second most expensive mode transport is carpooling with one stop, but this mode is still about 40 – 45% cheaper than the commuting by individual car transport and the biggest price decline is in MSK. The price of commuting by public transport and two stops carpooling is very similar and it reduces the price of individual car transport about 60 % (averagely about 34 – 49 CZK). The general development of reductions suggests that the biggest reductions are provided by one stop carpooling. The other more significant change of reductions is between one and two stops carpooling (other 13 – 17%). The difference between two and three stops carpooling is not so significant and averagely it is about 7%. The biggest reductions by carpooling are in MSK and by public transport in VYS.

Table 3. ***Price reductions according to used transport mode***

Region	Carpooling (1 stop)		Public transport		Carpooling (2 stops)		Carpooling (3 stops)	
	Absolute*	%**	Absolute*	%**	Absolute*	%**	Absolute*	%**
Moravian-Silesian	28.4	45.0	36.5	57.8	37.6	59.6	41.8	66.2
Usti	25.8	43.2	34.8	58.3	33.9	56.8	38.3	64.2
Vysocina	31.7	40.3	48.5	61.7	44.9	57.1	51.4	65.4

** price in CZK; **price of ICT = 100%*

Also in case of price reductions, top five employers with the biggest and smallest reductions are displayed in **Table 4**. Four members from five employers with biggest reductions in case of public transport use are from VYS. Together with one member from MSK, reductions by commuting to these employers is bigger than 75%.

Table 4. ***Top 5 employers with the smallest and biggest price reductions against individual car transport***

	Public transport		Carpooling (1 stop)		Carpooling (2 stops)		Carpooling (3 stops)	
	Employer	%	Employer	%	Employer	%	Employer	%
1.	ACO Industries	81.8	**Uniles**	61.2	**Uniles**	65.0	**Uniles**	75.4
2.	VÝVOJ	76.6	**Velveta**	52.9	**Velveta**	64.1	Biocel Paskov	70.1
3.	GDX Automotive	76.3	ČEZ Distribuce	52.0	ČEZ Distribuce	63.9	**Domov pro seniory**	70.1
4.	Humpolecké stroj.	76.1	SCA Packaging ČR	50.3	AL Invest Břidličná	63.0	**Velveta**	69.8
5.	Kovofiniš KF	75.1	**Domov pro seniory**	48.5	**Domov pro seniory**	62.9	Žďas	69.4
….	….	….	….	….	….	….	….	….
91.	Medin	43.2	Avirunion	30.3	Dopr. Podnik Teplice	45.2	Dopr. Podnik Teplice	52.6
92.	Nemocnice ve FM	41.1	**Univerzita J. E. P.**	29.6	**Avirunion**	43.4	Měď Povrly	51.5
93.	Msem	40.1	**Viamont**	27.4	**Univerzita J. E. P.**	39.9	**Univerzita J. E. P.**	47.9
94.	Czech Coal Serv.	38.8	Lostr	26.6	**Viamont**	39.5	**Viamont**	43.9
95.	Technomont	28.5	**Setuza**	25.8	**Setuza**	37.9	**Setuza**	42.6

On the other hand, companies with the smallest reductions are located in LAU1 Frydek-Mistek in MSK (3 members) with the smallest reduction only about 29%. In the case of carpooling, some employers are again evident, where it is much cheaper to commute by carpooling than by individual car transport. This is a case of two companies from ULK – Uniles, Inc. and Velveta, Inc., which are located in LAU1 Decin and the commuting cost by using three stops carpooling are beyond 75%. As well as in case of distance enlargement, similar situation exists in case of price reductions by commuting to Domov pro seniory in Osoblaha (Retirement house). Commuters to one of these top five employers can save more money using one stop carpooling than by three stops commuting to some employers from the worst group. It is interesting, that only employers from NUTS3 ULK are located in these groups with the smallest price reductions by carpooling use (4 of them from LAU1 Usti nad Labem).

6. CONCLUSIONS

Although there is only one data source in the Czech Republic that would monitor the use of carpooling, it would be certainly interesting to make a questionnaire survey to quantify the real situation of carpooling use for commuting. Census data from 2001 suggests that 6.3% of all commuters are using carpooling for commuting. Based on interviews with personnel officers of two companies in Opava mico-region (Lanex, Inc. and MSA, Inc.) it results that their employees are normally using carpooling for commuting and they mostly share a car with two or three other employees. They note that the size of carpooling use would be bigger, but the significant problem is in different shift schedule of particular workers (*Vojta, 2009*). Carpooling with one stop enlarges the distance against individual car transport averagely (three analyzed NUTS3 Regions) about 14%, but the price of commuting is reduced by almost half. In case of the MSK the enlargement is even less than 10% and the discount is about 45 %. Two stops carpooling is averagely about 27% longer and another 12% have to be added in case of three stops carpooling. Contrary the price discount is really significant and almost exceeds 60 % of price of individual car transport (two stops carpooling). But the difference in price reduction between two and three stops carpooling is not so significant and distance enlargement is bigger.

Table 5. ***Price reductions and distance enlargements according to used transport mode***

Region	Carpooling(1 stop)		Public transport		Carpooling(2 stops)		Carpooling(3 stops)	
	Distance	Price	Distance	Price	Distance	Price	Distance	Price
Moravian-Silesian	9.9	45.0	21.4	57.8	21.5	59.6	34.9	66.2
Usti	13.5	43.2	23.3	58.3	29.8	56.8	43.5	64.2
Vysocina	19.4	40.3	22.5	61.7	28.7	57.1	38.2	65.4

ICT = 100 %, values in %

Results for particular employers proved that the use of carpooling significantly depends on local conditions. There are some companies in concrete LAU1 districts where carpooling does not save commuting costs so significantly like in others. From all these results there are evident the main advantages of carpooling. Generally, each type of carpooling can significantly reduce the price of commuting against the individual car transport and usually distance is not so significantly enlarged. Applicability of this transport mode was proved for more than 95 % of all analyzed employers.

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VULNERABILITE DES ETABLISSEMENTS HUMAINS AUX EVENEMENTS PLUVIOMETRIQUES EXTREMES DANS LE BASSIN DE L'OUEME A BONOU (BENIN)

R. Ogouwale[1], B. Donou[1], C. Houssou[1], M. Boko[1]

ABSTRACT:

This research analyzes the changes in extreme events in the Ouémé River basin and their impact on the socio-economic populations Basin to Ouémé Bonou. The methodology used consists of technical statistical data of the rainfall series 1951-2000. On this series, the maximum depth of precipitation in 24 hours was determined by the theory of large numbers. From the series of maximum depth rainfall indices such as average and the deviation from the mean were determined. Moreover, the vulnerability of human settlements to the maximum rainfall was assessed as a result of field investigations and use of the matrix of Leopold et al, 1971. Analysis of these data shows that the watershed of the river Ouémé had on the series 1951-2000 rainfall variability, marked by a high occurrence of extreme events. This situation leads to increased frequency of floods that cause major damage like ecosystem degradation, loss of crops and the decimation of livestock products box (poultry, goats, pigs). This weakens the economic fabric of the basin and therefore creates a context of food insecurity. In situations of extreme rainfall, people adopt proactive strategies and reactive, like early harvests, temporary migration of the crops to non-flooded plateaus and summary accommodations for the crops.

Keywords : *Benin, Ouémé river, extreme rainfall events, socio-economic impacts.*

RÉSUMÉ:

La présente recherche analyse la variation des événements extrêmes dans le bassin du fleuve Ouémé et leur incidence sur la vie socio-économique des populations du bassin de l'Ouémé à Bonou. Le processus méthodologique utilisé est constitué des techniques de traitement statistique des données pluviométriques de la série 1951-2000. Sur cette série, les hauteurs maximales de pluie en 24 heures ont été déterminées par la théorie des grands nombres. À partir de la série des hauteurs maximales, il a été déterminé des indices pluviométriques tels que la moyenne, l'écart à la moyenne. Par ailleurs, la vulnérabilité des établissements humains aux pluies maximales a été évaluée à la suite des investigations de terrain et à l'utilisation de la matrice de Léopold et al, 1971. L'analyse de ces données montre que le bassin versant du fleuve Ouémé a connu sur la série 1951-2000 une variabilité pluviométrique, marquée par une occurrence très élèves des évènements extrêmes. Cette situation entraîne l'augmentation de la fréquence des inondations dont les incidences se manifestent par la dégradation des écosystèmes, les pertes des cultures et des récoltes et la décimation des produits de l'élevage de case (volailles, caprins, porcins). Cette situation fragilise le tissu économique du bassin et par conséquent crée un contexte d'insécurité alimentaire. En situation d'extrêmes pluviométriques, les populations adoptent des stratégies pro active et réactives qui se résument aux récoltes précoces, à des migrations temporairement vers les plateaux non inondés et aux aménagements sommaire des champs.

Mots-clés : *Bénin, bassin du fleuve Ouémé, Evènements pluviométriques extrêmes, incidences socioéconomiques.*

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1. INTRODUCTION ET JUSTIFICATION DU SUJET

Au Bénin, la variété des régimes pluviométriques saisonniers entraîne une variété de régimes hydrologiques saisonniers (*Boko, 1988*). Les précipitations se caractérisent par une forte irrégularité interannuelle dans leur abondance comme dans leur répartition. Cette irrégularité se manifeste soit par des sécheresses climatiques qui se traduisent souvent par des étiages graves, soit par des averses génératrices de crues puissantes (*Frécaut et Pagney, 1983*).

Dans le bassin du fleuve Ouémé, le cours supérieur du fleuve et de ses différents affluents sont soumis à un climat de type tropical humide à deux saisons, tandis que le cours inférieur connaît un climat de type subéquatorial à quatre saisons. Ils enregistrent des gonflements hydrologiques exceptionnels à la suite des averses répétées mouillant une grande surface du bassin versant (*Agossa, 1994*). Ces crues ou gonflements hydrologiques causent de nombreux dégâts sur leur passage : destruction des champs, des routes, des ponts, des maisons, etc. ayant pour corollaire les maladies hydriques, la disette, etc. Aussi, les mutations environnementales subies par la région du fait des changements climatiques augmentent la vulnérabilité du milieu naturel et humain en cas d'inondation.

Face à cette situation, il importe de mener une étude sur la vulnérabilité des établissements humains face aux événements pluviométriques extrêmes et dans le bassin en vue d'une prévision des risques liés à la fréquence des inondations dans le bassin du fleuve Ouémé. Ce bassin s'étend entre la latitude 06°54' et 10°12' nord et la longitude 01°50' et 3°50' est. Il couvre une superficie d'environ 46 990 km^2 (DGE, 2003). Il est drainé par les eaux du fleuve Ouémé et ses affluents depuis le nord jusqu'à l'amont de son delta (**Fig. 1**).

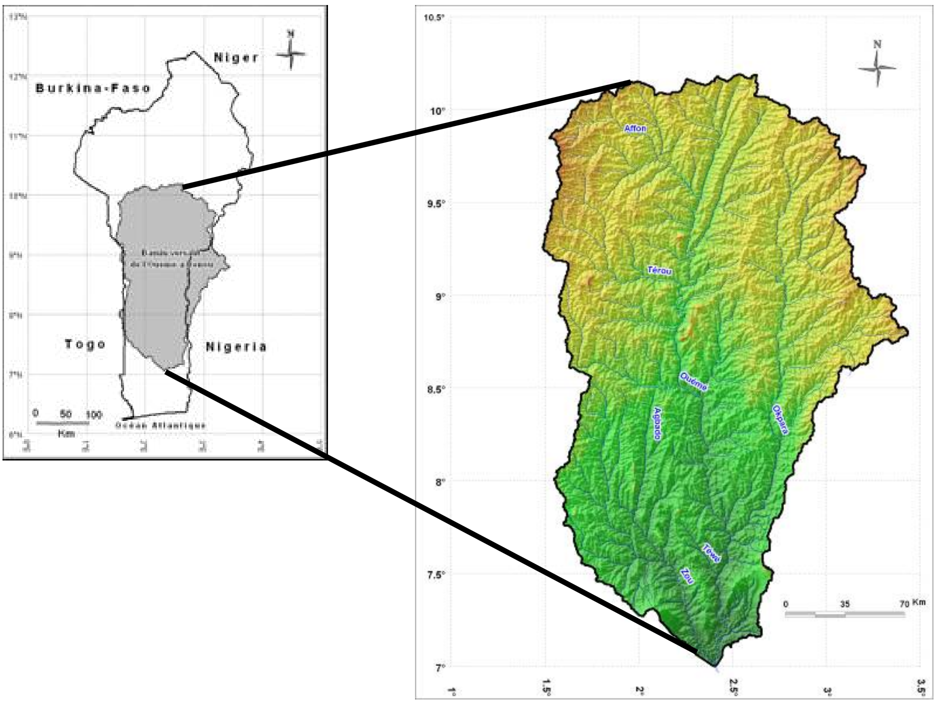


Fig. 1 Bassin versant du fleuve Ouémé, Source : DGE, 2003

La présente recherche vise à analyser la vulnérabilité des établissements humains face aux inondations causées par les événements pluviométriques extrêmes dans le bassin de l'Ouémé et d'évaluer les incidences de ces inondations.

2. APPROCHE MÉTHODOLOGIQUE

Les données utilisées dans le cadre de cette recherche, sont constituées des données pluviométriques, extraites des fichiers de l'ASECNA-Cotonou, pour caractériser le régime pluviométrique dans le bassin de l'Ouémé.

Les stations météorologiques de Parakou, Bétérou, Ouèssè, Savè, Bohicon et Bonou ont permis d'étudier la répartition spatio-temporelle des précipitations. En ce qui concerne les statistiques hydrologiques, elles sont tirées des données hydrométriques de Direction Générale de l'Eau (DGE) sur la période 1951-2000. Ces statiques ont été complétées par les données et informations sur les incidences des crues et inondations et des stratégies endogènes recueillies sur le terrain. Pour déterminer la variabilité des événements pluviométriques extrêmes, les hauteurs pluviométriques maximales annuelles des stations du bassin ont été analysées. Le diagnostic des séquences pluvieuses a été fait à partir de l'analyse des indices pluviométriques sur la série 1951-2000.

Pour l'étude du régime des crues dans le bassin de l'Ouémé à Bonou, la méthode débit-durée-fréquence de Galéa (1994) a été utilisée. La méthode d'échantillonnage utilisée est celle du maximum annuel où l'échantillon constitué est composé des plus forts débits instantanés de chaque année hydrologique.

Pour la détermination de la relation pluies/débits de crue, l'utilisation du coefficient de corrélation linéaire de Bravais-Pearson a permis de détecter la présence d'une relation linéaire entre les précipitations (P) et les débits de crue (Q). Cette relation s'écrit :

$$r(P,Q)=\frac{\frac{1}{N}\sum_{i=1}^{n}(Pi-\bar{P})(Qi-\bar{Q})}{\sigma(P).\sigma(Q)} \quad (1)$$

N est le nombre total d'observations,
Pi et Qi les valeurs des séries pluviométriques et hydrométriques,
$\bar{P}$ et $\bar{Q}$, leurs moyennes, σ (P) et σ (Q) étant leurs écarts-types.

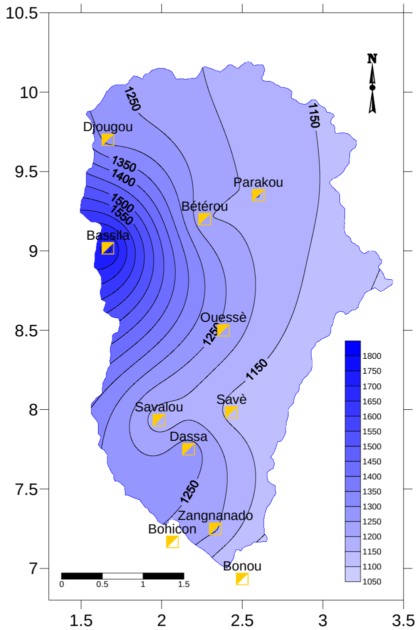
Le test de corrélation de Kendall a permis de vérifier le degré de signification de la corrélation entre les pluies et les débits de crue. Ces un test non paramétrique bilatéral où la p-value est comparée à la moitié du seuil de signification de 0,050.

L'évaluation de la vulnérabilité des établissements humains aux inondations a été faite grâce à la détermination des indicateurs de vulnérabilité à l'aide de la matrice de *Léopold et al, 1971* et utilisée par *Donou, 2007*. L'utilisation de cette approche méthodologique a permis d'obtenir un certain nombre de résultat.

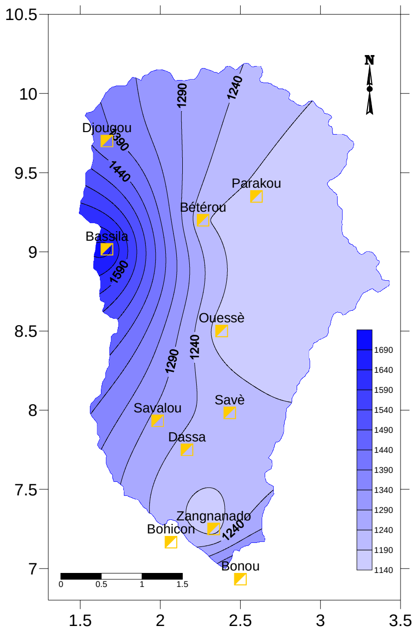
3. RÉSULTATS ET ANALYSE

3.1. Variabilité pluviométrie dans le bassin de l'Ouémé à Bonou

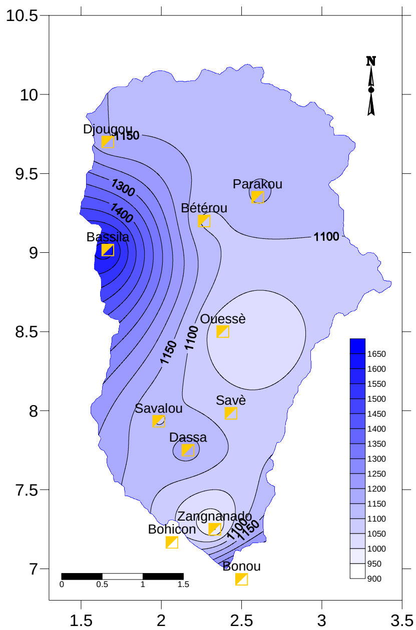
Les résultats de l'analyse décennale de l'évolution des hauteurs de pluie aux différentes stations du bassin sont présentés sur la **Fig. 2**.



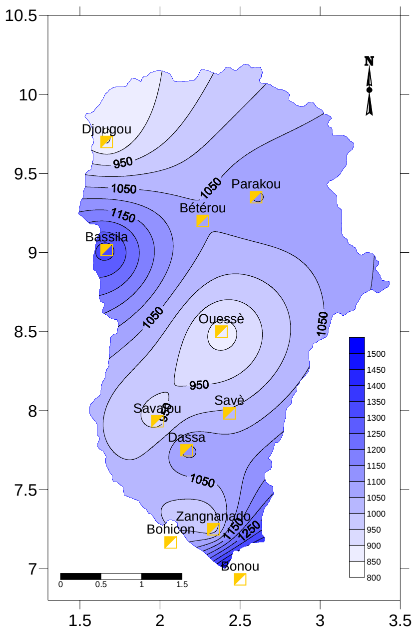
a) 1951-1960



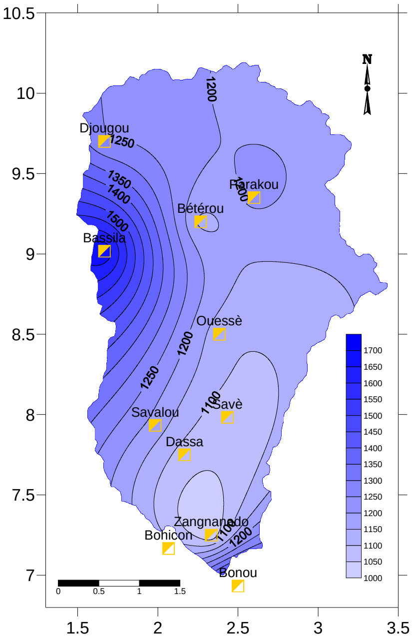
b) 1961-1970



c) 1971-1980



d) 1981-1990



e) 1991-2000

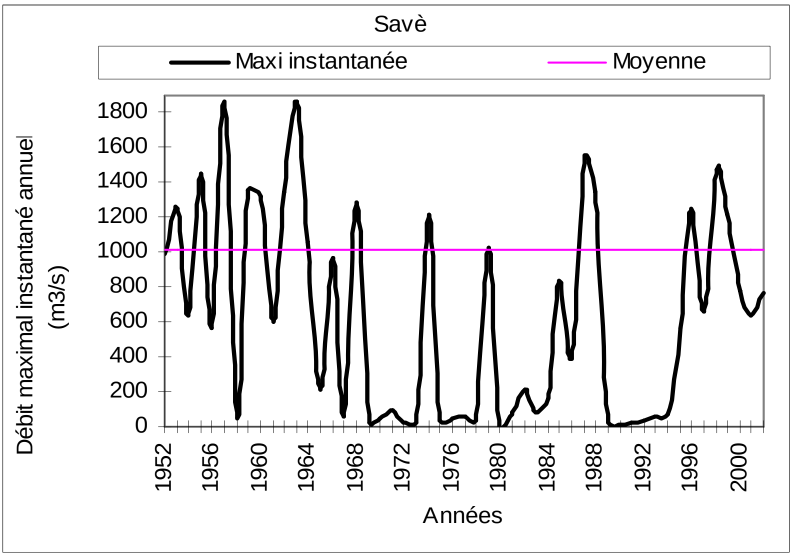
Fig. 2 Pluviométrie moyenne décennale du bassin de l'Ouémé à Bonou entre 1951 et 2000 (a, b, c, d, e)

Sur l'ensemble du bassin comme l'a déjà montré Boko (1988) et Afouda (1990), les pluies augmentent selon un gradient est-ouest. Ainsi, les faibles pluviométries ont été enregistrées dans les stations situées à l'est du bassin. Le secteur occidental du bassin est plus pluvieux sur les cinq décennies avec des isohyètes de 1300 et 1400 mm.

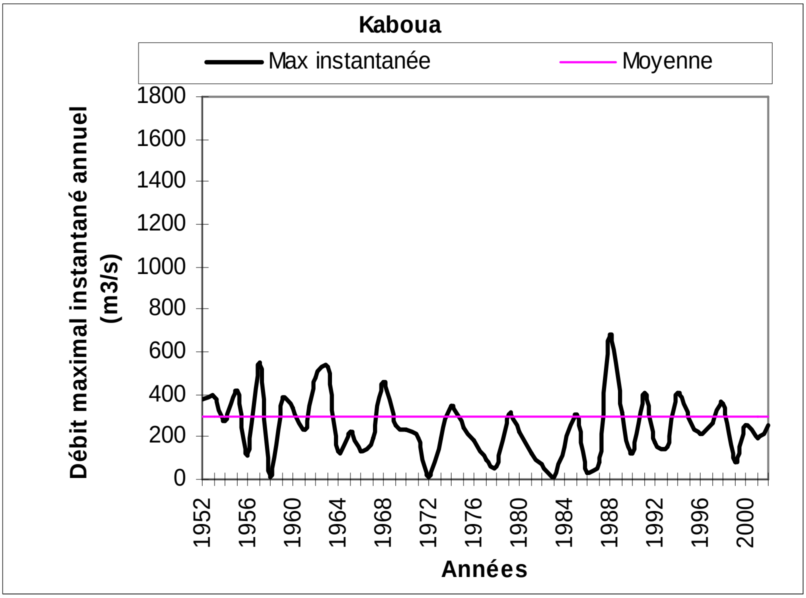
3.2. Analyse du régime des crues du bassin

L'analyse de l'évolution des débits maxima instantanés interannuels aux différentes stations hydrométriques du bassin est traduite par la **Fig. 4**. Sur l'ensemble des stations du bassin, l'évolution des débits maxima instantanés annuels n'est pas linéaire. Leur importance varie en fonction de la taille du sous bassin drainé. Le débit de seuil de crue (moyenne des débits maximaux instantanés) est de 1000 m^3/s à Bonou, 1020 m^3/s à Savè, 300 m^3/s à kaboua, 500 m^3/s à Atchérigbé et 450 m^3/s à de Bétérou.

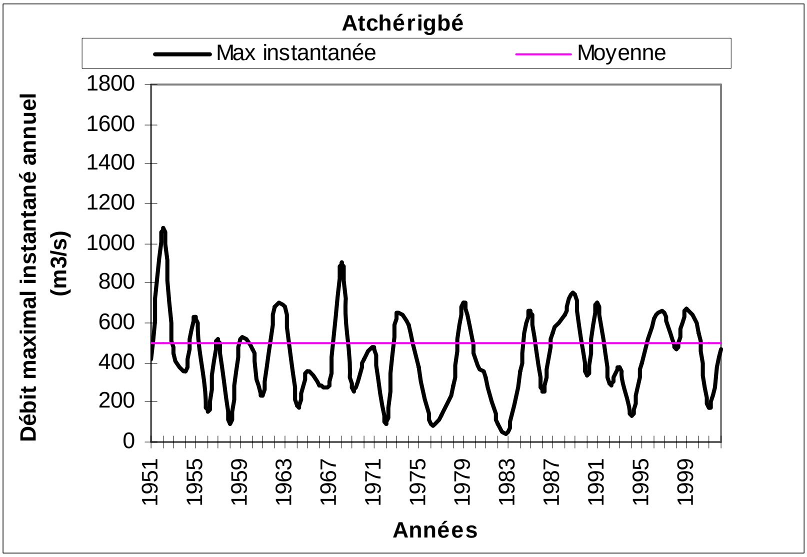
Toutes les années dont les débits maxima instantanés sont au-dessus de ces valeurs seuil sont considérées comme des années de crue.



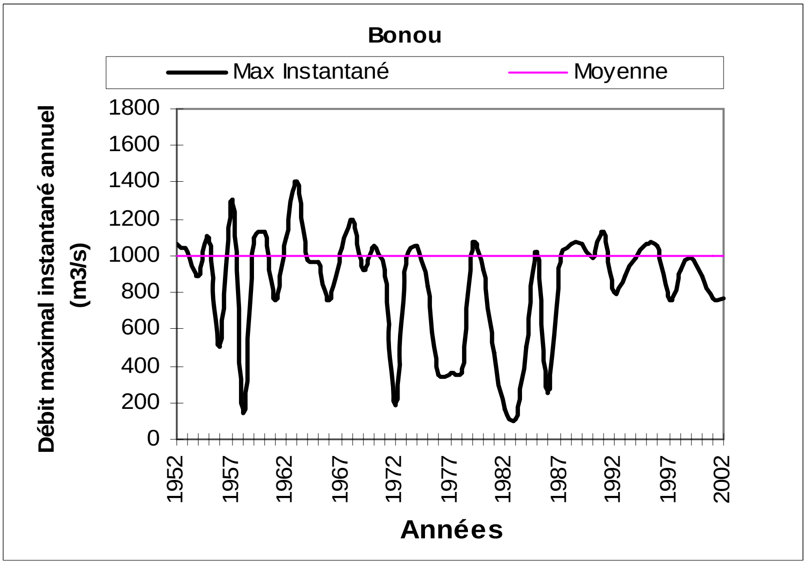
a)


Kaboua
Max instantanée
Moyenne
Débit maximal instantané annuel (m3/s)
1800
1600
1400
1200
1000
800
600
400
200
0
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
Années

b)


Atchérigbé
Max instantanée
Moyenne
Débit maximal instantané annuel (m3/s)
1800
1600
1400
1200
1000
800
600
400
200
0
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
Années

c)



d)

Fig. 3 Evolution des débits maximaux instantanés inter annuels dans le bassin de l'Ouémé à Bonou (a, b, c, d)

L'analyse de ces débits maxima a permis de dégager les débits de pointe par sous-bassin pour les années de crue (**Fig. 4**).

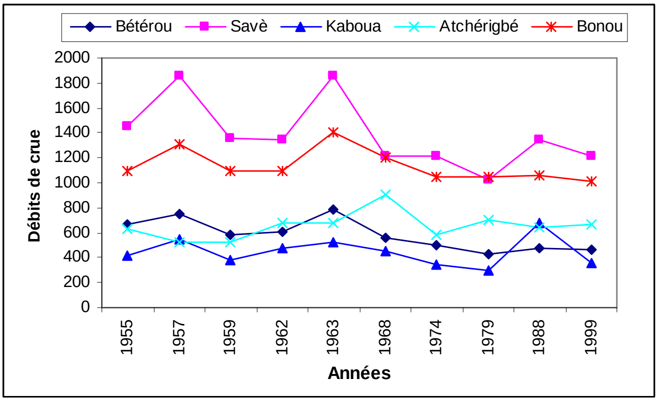


Fig. 4 Evolution des débits de crues dans le bassin de l'Ouémé à Bonou

Les débits de crue dans le sous-bassin de Bonou sont compris entre 1000 et 1400 m^3/s avec une moyenne de 1137 m^3/s. A la station de Savè, ces débits sont compris entre 1020 et 1860 m^3/s avec une moyenne de 1388 m^3/s. A Bétérou, les débits de crue sont moins importants que dans les deux sous-bassins précédents avec une valeur moyenne de 581 m^3/s.

Par ailleurs, le calcul du coefficient de corrélation linéaire de Bravais-Pearson entre les hauteurs de pluie extrêmes et les débits de crue à Bonou sur la série 1951-2000 a donné les résultats du **Tableau 1**.

Tableau 1 : ***Coefficient de corrélation entre pluie et débits de crue et résultat du test de Kendall***

Stations	Corrélation pluie-débit	Test de kendall
Bonou	r = 0,13	P – value = 0,23 α/2 = 0,025
Savè	**r = 0,65**	P – value = $4{,}07.10^{-6}$ α/2 = 0,025

La corrélation entre les hauteurs de pluie extrêmes et les débits de crue du fleuve à Bonou n'est pas significative (0,13 < 0.5). Ce qui est justifié par le test de kendall où p–value (=0,23) est supérieure à α/2 (=0,025). Les crues du fleuve Ouémé à Bonou ne dépendent donc pas des précipitations à Bonou. Par contre, la corrélation entre pluie et débits à Savè est significative (0,65) et confirmé par la valeur de p – value, $4{,}07.10^{-6}$ largement inférieur à α/2.

En somme, les crues engendrées par le fleuve Ouémé à Bonou sont dues aux précipitations et aux apports d'eau du fleuve de la partie septentrionale du bassin. Ces crues provoquent d'importants dégâts sur les installations humaines.

3.3. INCIDENCE DES CRUES DANS LE BASSIN DE L'OUÉMÉ À BONOU

Les crues détruisent les habitations, les édifices publics ou occupent des villages entiers (**photo 1 et 2**).

Photo 1 Maisons détruites à Lokossa
Source : *Clichée DONOU B., octobre 2006*

Photo 2 Inondation d'une école primaire à Kodonou
Source: *Cliché DONOU B. octobre, 2008*

L'inondation des écoles en pleine année scolaire entraîne la cessation des activités académiques dans ces écoles durant des périodes variant entre 2 et 3 dans l'année scolaire de 9 mois.

Par ailleurs, la vulnérabilité des habitations est favorisée par le caractère traditionnel des constructions faites en matériaux locaux qui opposent une très faible résistance aux eaux d'inondation (**photo 3**).

Photo 3. Habitation en matériaux locaux détruites à Kpoto-Zagnanado
(Source : Cliché *LECREDE, octobre 2003)*

Dans la plupart des cas de destruction de maisons, les populations sont contraintes de migrer vers les terres exondées et sont dépourvues de moyens matériels et financiers de survie. Les localités sinistrées sont généralement coupées les unes des autres et les populations isolées et difficilement accessibles par les acteurs d'assistance sociale. La principale cause de cet isolement est la dégradation des voies de communication terrestres (**photos 4.1**, **4.2** et **4.3**). Selon les investigations en milieu réel, cette situation crée environ 50 % de déficit économique pour les populations.

Photo 4 : Routes inondées à Affamè (4.1) à Dékamè wô (4.2) et à Akpadanou (4.3)
(Source *: Clichée DONOU B., octobre 2006)*

En outre, les inondations augmentent les risques sanitaires dans les localités du bassin. En effet, dans le domaine sanitaire, l'avènement des crues est suivi de l'augmentation de la prévalence de plusieurs maladies d'origine hydriques notamment la diarrhée, les maladies cutanées, le paludisme, le choléra, etc. (**Fig. 5**).

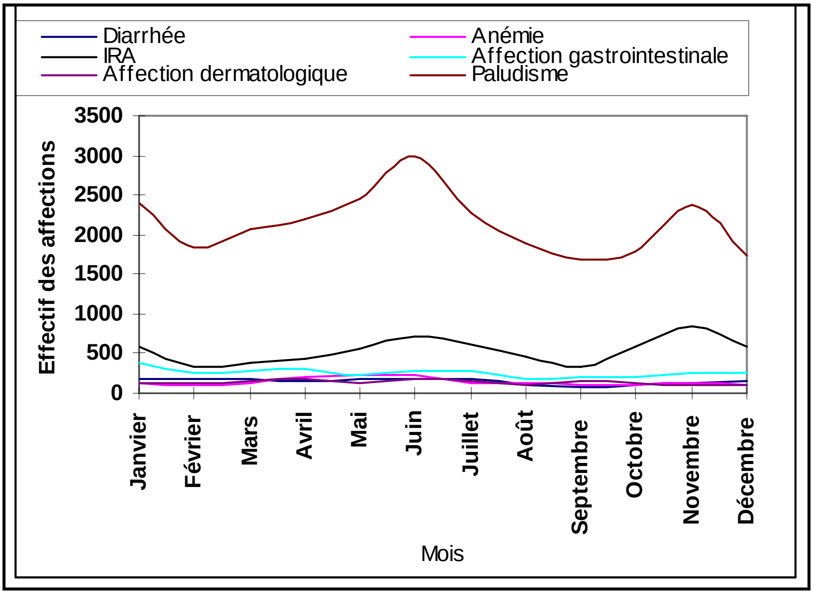


Fig. 5 Evolution intermensuelle des principales affections à Bonou de 2001 à 2008
Source des sonnées : *MSP, 2008*

Au total, les eaux de crue engendrent de nombreux impacts sur la vie sociale des populations de la localité de Bonou. Leurs incidences sont d'ordre social, sanitaire, économique, etc. Les populations adoptent des stratégies pour faire face à aux effets de ces inondations. Les mesures proposées permettront de renforcer ces stratégies endogènes et de limiter les dégâts causés par les eaux de crue du fleuve Ouémé dans la localité de Bonou.

4. CONCLUSIONS

Le bassin de l'Ouémé à Bonou connait une variabilité pluviométrique marquée par, une dizaine d'années très humides qui ont été à l'origine de l'avènement des crues. L'analyse de l'évolution des débits maximaux instantanés annuels sur la série 1951-2000 a permis d'identifier des débits de crue. La concordance entre les années de pluviométriques humides et celles des crues permet d'affirmer que les précipitations ont un impact direct sur les écoulement et débits de crue dans le bassin. Ces débits de crue donnent lieu à des écoulements dont les eaux inondent la plaine alluviale du fleuve surtout dans sa partie sud et notamment dans la localité de Bonou.

Les eaux d'inondation du fleuve provoquent d'importants dégâts socio-économiques dans la commune de Bonou. Ces dégâts vont de la dégradation des établissements humains et du système économique des localités de Bonou.

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APPLICATION OF GIS IN RE-INTRODUCTION OF RED DEER IN NATIONAL PARK FRUŠKA GORA (VOJVODINA, SERBIA)

Z. Ristić[1], V. Marković[1], V. Barović[2],
B. Ristanović1[1], Danijela Marković[3]

ABSTRACT:
Reintroduction of European deer is of high importance for Fruška Gora ecosystem. In realization of this project, the evaluation of possibility to introduce a deer must be complete and precise regarding taxonomy of introduced species, health state of game, location of shelter, possible ways of migration and all the negative influences. The GIS is the software and hardware package that makes easy to carry out certain actions within the project, contributing to more appropriate decision making. The first results are encouraging, because numbering of deer game at the end of November confirmed that since January/February 2009, when all individuals were brought to a shelter/quarantine, the herd increased by reproduction for another 25 young deer. The herd increased during less than a year from 36 specimens (31 females and 5 males) to 61 specimens.

Keywords: *GIS, reintroduction, red deer, ecosystem, Fruška Gora Mt.*

1. INTRODUCTION

Successful development of hunting tourism in given hunting-touristic location is conditioned by presence of appropriate number of quality game (Ristić et al, 2009). In order to neutralize effect of negative factors on development of hunting tourism, an idea emerged to form repro-centers for game, in order to improve general quantity and quality of the game, and especially its trophy value. Game repro-centers are a special kind of breeding centers in closed hunting grounds, formed in order to produce individuals with high quality genetic potential and with high trophy value. They would be introduced into hunting grounds in order to increase number of certain species, enhancing its trophy value and to improve psychical, physical and health conditions of the game (*Ristić, 2007*).

Re-introduction is a breeding method for preserving the species by artificial introduction of preserved parts of certain population to areas where it was obliterated from. Re-introduction of large mammals became important breeding measure in hunting management and it is always a long, complex and very expensive procedure (*Bigalke, 1984*).

The hunting tourism importance of existence and activity of repro-centers is in providing high quality individuals of different game species, in order to increase quality of offer, to improve and enlarge touristic revenue in hunting grounds of Vojvodina, and mostly to enrich ecosystem of Fruška Gora Mt. Moreover, valorization of deer as a nature resource within socio-economic aspects has extra importance due to improvement of touristic and touristic-educational offer (organization of photo-safari tours and a range of educational programs for visitors).

According to written records, deer was present in Fruška Gora Mt and it was bred at estates of Counts Odeskalki, Kotek and Palavičini. After World War Two and up to 1970-s, deer was bred at Fruška Gora in hunting grounds above Ležimir, and it was present in

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Janok, Testera and Paragovo. Fruška Gora is a favorable area for European deer; according to available data deer population in Fruška Gora ranged between 50 and 170 individuals, and some of those had remarkable trophy value. Since deer had vanished from area of National Park Fruška Gora, and importance of this species is well known from ecology, economy, social and scientific point of view, the need was obvious to introduce this game species in the same area, or precisely to re-introduce it, as a part of breeding measures for preservation of this species.

Fig. 1 Position of Fruška Gora Mt in Serbia
(Source: *Google Earth*)

2. PROJECT REALIZATION STAGES

Feasibility study is the basic document for management of the project "Re-introduction of European deer into National Park Fruška Gora". By this project, a way is defined how to reach desired aim and to fulfill this investment. Geographical information systems were found useful, especially in carrying out certain stages of the project where they facilitate project realization.

The project envisages realization of deer re-introduction within three stages:

1. Building the shelter
2. Acquiring and socialization of individuals
3. Monitoring state of the population

GIS was implemented in first and third stages of this project, and it has important part in optimal building of the shelter and, finally, in following the state of populations.

Fig. 2 Deer during transport from Hungary to Fruška Gora
(Source: *Pap, 2009*)

3. METHODS AND DATA

In this project, the software package ArcGIS 9.3 by ESRI company was used in digitalization stage.The process of making digital physical map of Fruška Gora was done in following stages: collecting of material, scanning, georeferencing, database building, digitalization, development of 3D model.

Collecting of material. For making a digital map basis, topographic maps were scanned, in 1:25000 scale. Sections NS-3-1 and NS-3-2 were used.

Maps were made in Gauss-Krieger projection, Bessel ellipsoid with Greenwich starting meridian. They were printed in 1976.

Georeferencing is a process of assigning geographic coordinates to scanned map, and to show it in realistic space. Georeferencing was done manually, in such a way that scanned maps were first given a projection, and then control points were defined (*Seferović, 2006*). Every map had ten control points, in order to enhance precision. The basic measure units were given in meters, with error tolerance of one meter.

Database building. After georeferencing, geographic objects were entered. Objects were given as layers. Layers were entered as dots (peak elevation points), and lines (contour lines, shelter fence).

Digitalization or process of transferring information from scanned map into digital format.

Making a 3D model for re-introduction shelter. After finalization of digitalization, a digital elevation model was created using a database. A surface area was represented using TIN (Triangulated Irregular Network), a network of irregular triangles, which is a model obtained by conversion of contour lines and trigonometry points (*Ilies, 2006*)

Building of the shelter. In choosing a location for shelter building, factors were examined regarding natural food sources, peace, winter shelters and similar. After detailed examination, location named "Ravne" was chosen within management unit "Ravne". This locality is situated at the municipality Beočin territory, within KO Grabovo, at cadastre lots No. 918, 919 part, 921 part, 922, 930 part, 931, 932, 933, 934 and KO Manđelos at cadastre lot 1/1 part, comprising following sections: class 10 as part of section "e", 12 clearing 1, class 15, class 16 (section "e", "f" and clearing 3), class 18 (sections "a", "b", "c", "d") and 20 class. Total area is 108.80 hectares, from which meadows are 10.31 hectares, and the rest of area is under woods (*Ristić, 2009*).

4. RESULTS AND CONCLUSIONS

4.1. Role of the GIS in a shelter building stage

The role of GIS in a shelter building stage was mostly due to defining location of a fence, i.e. the shelter itself. If a building stage was done before terrain digitalization within the GIS (as was the case in re-introduction of deer in Fruška Gora), using GIS may help to judge position and characteristics of a location chosen and in such way to use all advantages and minimize all disadvantages.

Location that had been chosen is located in center of Fruška Gora Mt, and some objects already exist and may be used for shelter functions, but those are in very poor condition. Access roads are in good condition and barriers were constructed in order to prevent free access to the locality. Natural feeding conditions in a hunting ground were deer breeding in quarantine/shelter is envisaged, after transport and before releasing into nature, are very favorable due to vegetation diversity. In this area (Srem) the water supply for agricultural needs is low for the most part of the year, so this is unfavorable for game too. Nevertheless, in the hunting grounds, at the very place were deer game will be quarantined, and after that in an open part of a hunting grounds, enough supply of natural water is provided. Having all this in mind, it may be concluded that conditions for breeding of deer game are favorable since the basic factors are provided: food, shelter and peace.

Favorable conditions regarding feeding are determined mostly by a good grazing in meadows and grasslands (10.31 ha) which are 9.48% of total area of fenced part (108.80 ha; Ristić, 2008). Only unfavorable thing is that during a winter, snowfall is sometime even over 30 cm in height, but with intensive additional feeding by previously prepared food, game may successfully live through this period.

Having in mind all these factors, it may be concluded that habitat conditions for game breeding are favorable since basic factors are provided: food, water, shelter and peace in fenced part of the hunting grounds.

By using GIS, it is possible to analyze a factor that is also very important for hunting game, especially during a winter. It is insolation of terrain, which influences health conditions, fitness, diet, trophy value etc.

Fig. 3 shows fenced part of "Ravne" within the hunting grounds of National Park "Fruška Gora". Due to digitalization of parts of Fruška Gora and by combination with GIS applications, a view of exposition of given terrain is obtained. Since the map is georeferenced, i.e. during digitalization original coordinates were entered, state at the computer screen shows real-life data regarding terrain exposition in nature. In **Fig. 3**, blue color shows parts with the least insolation, while purple, red and orange shades (from dark to lighter) show terrains with more and more insolation and finally, yellow color represents terrain with most exposure to the sun. By analyzing this figure, it is possible to find parts with different insolation. Since importance of insolation was already explained, it is possible to assume in which parts of closed reservation "Ravne" a deer grouping may be expected during winter months.

By using logic and the rule that game always groups at the sunny slopes i.e. in parts with more Sun exposure and therefore more heat, it is possible to assume locations with higher game density. This information maybe used for location of game management objects or for their easier finding (*Marković, 2009*).

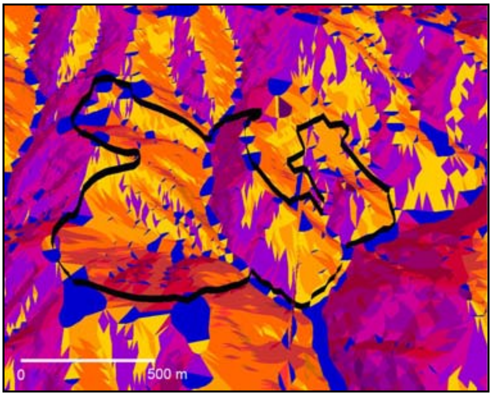

Fig. 3 Exposition of fenced reservation for deer game in NP "Fruška Gora"

Except for the shelter location, GIS gives possibilities to make geographic profile of any part of the hunting grounds. In this way, a precise and clear insight may be obtained for horizontal, vertical or diagonal section of a hunting grounds, as a graph that may be used later for location of hunting-management or hunting-technical objects.

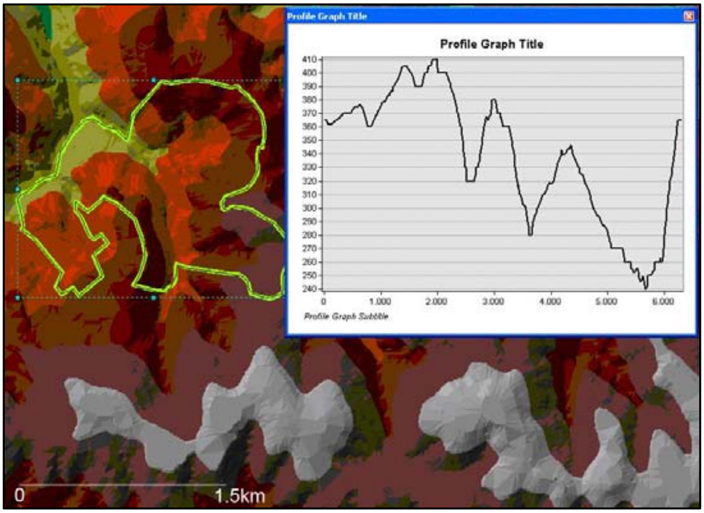

Fig. 4 Location profile for the fence of "Ravne" shelter

Fig. 4 shows location profile for the shelter fence, where on the basis of a graph obtained is visible that a fence length is approximately 6.5 km. This information may be used in revitalization of the fence, which helps in determination of a budget needed.

The second information obtained by profile is an altitude of every spot included. Therefore, the profile from **Fig. 4** shows that a lower part of the border is 240, and the highest 410 m. In the same way, it is possible to make terrain profile between feeding and watering points, salt points, from fence to fence and so on.

Profile making gives insight that is more detailed in altitude differences of any terrain (*Cracu and Popescu, 2008*). Moreover, it has possibility to show terrain slope in a more graphic way, so it is possible to tell a difference between gentle and steep ones after a single glance to the screen, and this enables location of hunting-management objects in a most optimal way.

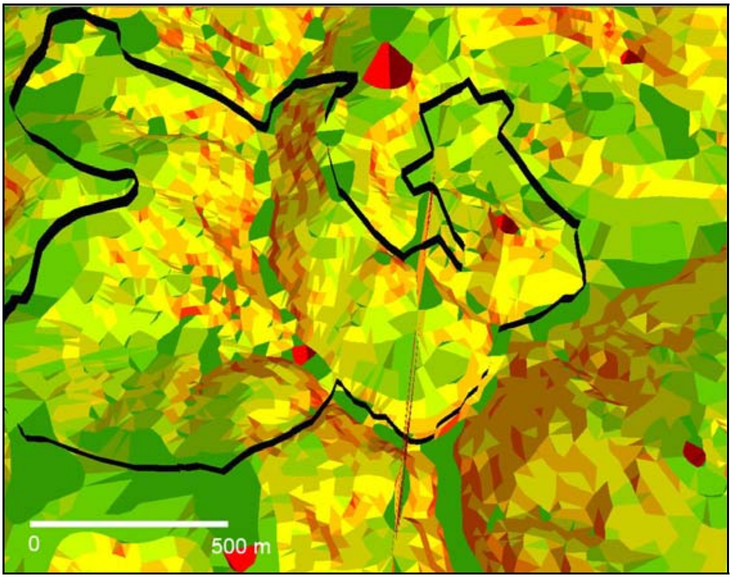

Fig. 5 Terrain slope in "Ravne" shelter

Fig. 5 shows terrain slope within "Ravne" shelter; different colors represent terrain slope. Dark green represents terrain with 0-3.5 degrees slope, yellow is 17-21 degrees, and dark red represents 60-90 degrees terrain. These information may be used not only for optimal location of hunting-breeding objects but also for guessing the paths game uses.

4.2. Role of GIS in decreasing negative influences within the hunting grounds

Anthropogenic and natural negative influences on biodiversity of the National Park are:

1. Disturbances, ranged at the first place since it is highly destructive factor. Previous experiences are very negative, and disturbances significantly increased, even in protected areas, because a number of stray dogs appeared at the Park, and the jackals are more and more present, which must be taken into consideration in re-introduction of deer game in this hunting grounds.
2. Pollution is a increasing factor also. In several last years there had been efforts, through educative workshops with local populations and in schools, to prevent pollution, i.e. throwing all kinds of garbage in the Park, in order to reduce pollution to minimum. These actions are especially often during May holidays and other public holidays, when the park is full of visitors, even tens of thousands, and numerous workers are responsible to take care of garbage after picnics and to transport it out of Park immediately.

The GIS may contribute to decrease hazards to biodiversity in a hunting grounds. By creating buffer zones, i.e. influence zones of a phenomenon that may have negative influence on hunting and hunting tourism (as appearance of jackals in a hunting grounds, or stray dogs, poachers, illegal waste dumps, incidence of contagious diseases et cetera), a graphic view is obtained of spreading the certain phenomenon and domain of its influence. After entering the point or line of influence of a negative phenomenon, and the power of its influence, zones "affected" by this phenomenon are obtained, as well as border zones (*Marković, 2009*).

As an example, if it is known that jackal's moving area in usual situations (if it is not forced to migrate in search for food) is up to four kilometers from its lair, then in **Fig. 6** buffer zones may be observed regarding jackal influence radiating from a point where its lair was found. The first circle around the center spot (lair) is a "target zone" with 1600 m diameter. In this zone, other game is most endangered by a jackal presence, so it demands most attention by game wardens and hunters. This is also a zone most favorable for transmission of some contagious diseases. Second zone, i.e. "endangered zone", is susceptible to jackal influence. It is highly probable that jackal will appear within this zone during its daily migrations. Third zone is "border zone", and in normal circumstances it is a jackal-free zone, although there always are chances that jackal leave its territory due to food shortage. If in a single ground two or more jackal liars are found not far from each other, their buffer zones are intersecting and these parts will be the most endangered ones.

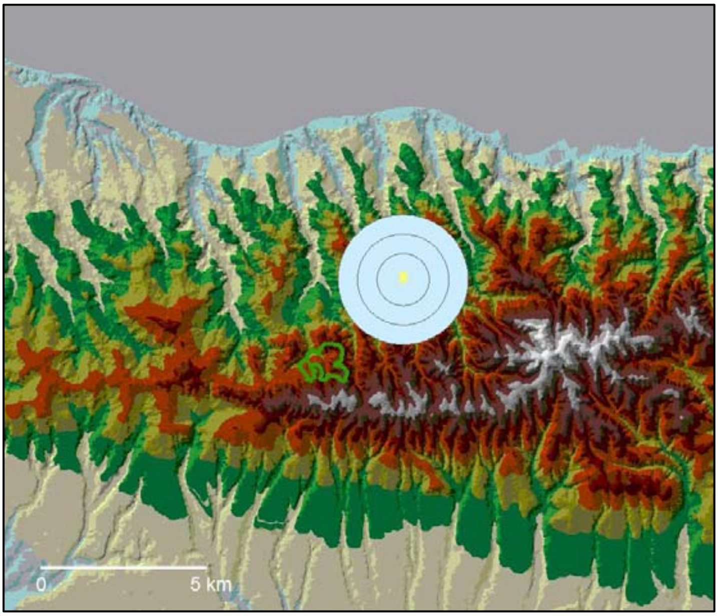

Fig. 6 Buffer zone around a jackal lair

Application of buffer zones is useful in providing peace for game, which are one or more influential factors in game management. It is known that National Park "Fruška Gora" is bordering human settlements in a number of places, or those are situated not far from the Park. Although majority of these settlements is relatively small, with low population, and not industrially oriented, there are exceptions (Beočin), but main cause of peace interruption within a hunting grounds is a traffic noise. The Fruška Gora Mt is intersected by roads, and most problematic is a regional road between Irig and Sremska Kamenica. The more important the roads are for transport of people and goods, the more they interrupt peace within the hunting grounds.

Fig. 7 shows a part of roads that influence peace around "Ravne" shelter. Relatively to importance and traffic of these roads, different buffer zones were obtained for every of them.

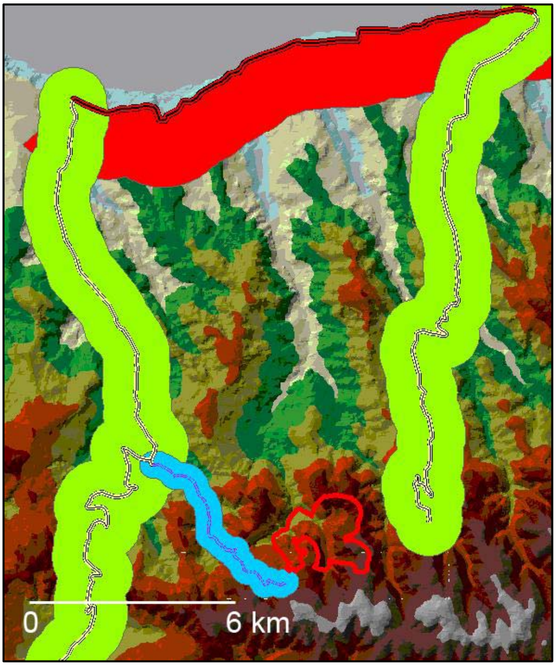

Fig. 7 Roads around "Ravne" locality

Fig. 7 shows that the largest buffer zone, i.e. the zone with widest negative influence, is the road between Petrovaradin and Ilok, which is the busiest road in this part of Fruška Gora. Its buffer zone is marked red and it is 1000 meters wide. Upper part of the red buffer zones is not shown because it is located at the territory of Danube river and has no important influence on deer game. Second buffer zone is marked green and it shows lower rank roads, i.e. roads between Čerević and Andrevlje, as well as between Banoštor and Ležimir; this buffer zone is 500 meters wide at both sides of the road, i.e. its total width s 1000 m. Blue buffer zone marks 200 m on the left and right side of a local road between Ravne and Ležimir-Beočin road.

On the basis of all these facts, it may be noted which zones around the shelter are endangered by traffic and noise, so it is possible to assume that after releasing deer from the shelter they will not form groups close these buffer zones.

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SPATIAL INTERPOLATION OF MEAN ANNUAL PRECIPITATIONS IN SARDINIA. A COMPARATIVE ANALYSIS OF SEVERAL METHODS

D. Secci[1], C. V. Patriche[2], A. Ursu[3], L. Sfîcă[3]

ABSTRACT:
Our study attempts to test several spatial interpolation methods used for the purpose of mapping the mean annual precipitations in the island of Sardinia (Italy). The spatial modelling is based on data from 243 meteorological stations. We tested the usefullness of regression analysis, ordinary kriuging, cokriging and residual kriging. The performance of each method was assessed by crossvalidation. Our results show that better results are achieved using residual kriging with altitude as predictor.

Keywords*: spatial interpolation, mean annual precipitations, kriging method, regresion analysis, Sardinia.*

1. INTRODUCTION

The first official rainfall measurements began in Sardinia in 1922, carried out by the *Hydrographic Institute of Sardinia*. The institute, now called the *Sardinian Hydrographic Agency for Protection and Management of Water Resources*, works with over 250 meteorological stations, from which 92 are automatic temperature-rainfall weather stations, evenly distributed in the territory. The data collected through this network was used for preparation of the first publication regarding the climate of Sardinia (*Pinna, 1954*). It includes the first maps showing the spatial distribution of precipitations in Sardinia, drawn using manuals methods (**Fig. 1**).

Since 1995, the *Regional Department for Hydro-Meteo-Climatology* has become operational within the *Regional Agency for Environmental Protection of Sardinia (ARPAS)*, specialized in agro-meteorological data collection and modelling using over 50 automatic weather stations. This department has started the processing of data through GIS softwares, therefore publishing more accurate climatic maps. One of the latest works on the average rainfall in Sardinia is included in *The climate of Sardinia* by P. A. Chessa and A. Delitala[4]. where the authors used an interpolation method to derive the mean annual precipitation map (**Fig. 2**). Other studies are also published periodically by this department, including periodic summaries, monthly reports and analysis of extreme events.

2. MATERIALS AND METHODS

The island of Sardinia is situated in the central-western part of the Mediteranean Sea, along the paralel of 40^{o}N and the meridian of 9^{o}E, covering a surface of about 23600km^2. The input data used in our study is represented by the mean annual precipitation values for a 70 years period (1922-1991), recorded at 243 meteorological stations and made available

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through the courtesy of the *Hydrographic Agency for Protection and Management of Water Resources*. Compared to the surface of the island, this stations network is quite dense, therefore ensuring the accuracy and stability of our statistical spatial models. The network of Voronoi polygons indicates that the mean surface around a station is about 97km^2, the values ranging from 18km^2 to 244km^2.

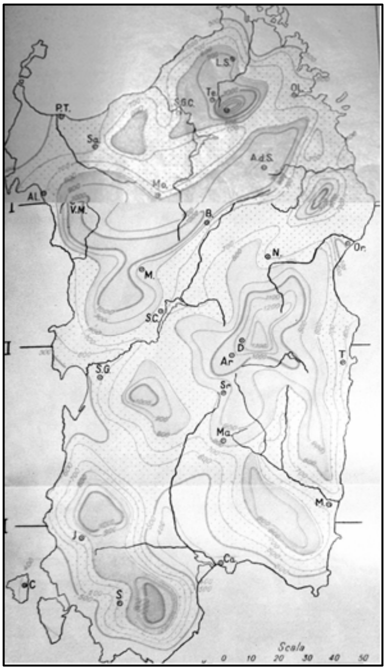

Fig. 1 The first mean annual precipitations map of Sardinia drawn using manuals methods (M. Pinna, 1954).

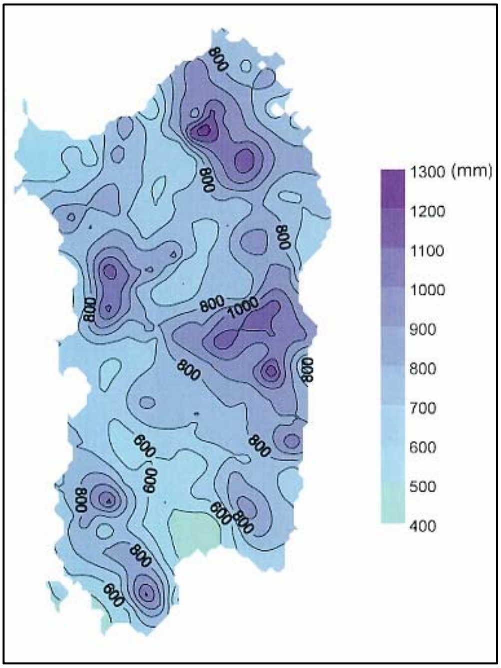

Fig. 2 The mean annual precipitations digital map obtained by interpolation techniques (P. A. Chessa, A. Delitala, http://www.sar.sardegna.it)

The spatialization methods we used belong to 2 broad categories, namely regression analysis and kriging. Numerous studies have proved that, among the various spatialization methods, the the ones mentioned above yields the best spatial models for climatic variables (*Dobesch et colab., 2007; Hengl, 2007; Lhotellier, 2005; Patriche, 2009*). We tested the usefullness of multiple stepwise linear regression, ordinary kriging, cokriging with altitude as auxiliary variable and universal kriging with a locally derived 3rd order polynomial trend surface. The perfomance of all these methods was assessed through the *cross-validation*. Cross-validation is the "leave one out" validation procedure. For a certain point, it implies the comparison of the real value with the one estimated when the point value was not included in the analysis. The root mean square error (RMSE) of the cross-validation procedure was further used as a synthetic quality parameter in order to assess the acuracy of our spatial models.

A digital elevation model (DEM) with a 69x69m resolution, derived from the SRTM global model (*USGS, 2004*), was used in order to obtain secondary terrain data, potentially usefull for explaining the spatial distribution of mean annual precipitations: slope, exposition, altitudinal range within 1x1km moving windows, terrain exposure towards the dominant winds (computed in SAGA-GIS software). We also tested the influence of the distance from the coastline.

The spatial analysis was perfomed in ArcGIS v9.3 software, using the Geostatistical Analyst extension for interpolation. As mentioned before, we also used SAGA-GIS v2.0.4 to derive the wind effect parameter.

3. GENERAL PLUVIOMETRIC CHARACTERISTICS OF SARDINIA

Located in the heart of the Mediterranean Sea, in the temperate climate zone, Sardinia is characterized by a subtropical climate with rainy winters and hot dry summers. By Köppen classfication, the island is characterized by a Mediterranean climate (group C), the "Csa" type being characterizing most of the region. The "Csb" type is present in the internal areas above 800-1000 m of altitude.

Generally, there can be distinguished a rainy season from October to May and a dry season from June to September, but the dry season can be reduced to only two months in the higher areas of the island (July and August) and can start from May to October in the southern areas. Also, one can be observe that precipitations in Sardinia are extremely variable, considering both their temporal variation and their intensity (G. Torre, 1977). The temporal distribution of rainfall is related to the changes in latitude of the main pressures systems. In May, Sardinia gets under the influence of subtropical high pressures systems, which determine conditions of clear skies and dry weather. In September, when the band of high pressure drops in latitude, the island is under the influence of Atlantic and Mediterranean depressions, therefore under unstable weather conditions.

The maximum mean monthly precipitation is recorded in December and the minimum is recorded in July. In May and in June, there is a clear North-South gradient. In this period, the latitudinal position is more important than in other periods of the year. The spatial distribution of precipitations is governed almost exclusively by the island's relief and by the position in relation to dominant atmospheric circulation. The prevailing humid and warm westerly circulation is responsabile for most of the precipitation distribution patterns in the island, obviously favoring the western sectors. However, low pressures systems coming from North Africa, generate easterly winds that cause more precipitations in the eastern sector, where the 24 hours amounts of precipitations are very high and sometimes exceptional, also compared to all the italian national territory (*Torre, 1977*). This type of pressure system occurs rarely, but it can induce flood events for two reasons:

1) air masses of this kind are warmer than the western ones and their absolute humidity is higher;

2) the eastern sector presents a more complex topography, characterized by hills overlooking the sea that favor windward precipitations, which are intense and sometimes persistent.

The largest mean annual precipitation amounts are recorded on the main mountains, located in 4 areas: Gallura in the North-East, Gennargentu in the central-eastern area, Campeda – Montiferru – Marghine in the North-West and Iglesiente in the South-West. The precipitation amounts are smaller in the South of the island, where the particular topography induces foehn effects to both the western and the eastern air currents. The driest place is Capo Carbonara, in the extreme South-East of the island, where the mean annual precipitations value is 381.4 mm. The rainiest place is located in the North-East of the island (Valliciola) which receives 1343,6 mm.

The season of highly 24 hours rainfalls corresponds, for most of Sardinia, with the rainfall season. The probability of high amounts of precipitations increases once the eastward extention of Azores high-pressure cell collapses, especially in the west part of the Mediterranean basin, with a sudden drop in pressure that occurs during the second half of October (*Barry and Chorley, 2003*). The synoptic conditions of reaching maximum 24-hour precipitations can be synthetised in the 3 following main types:

1) **Cut-off lows**. Under anticyclonic conditions over the continent, cut-off lows can be splitted from the circumpolar vortex in altitude and remain isolated over eastern Europe from which they are being triggered clockwise over western mediteranean. Here, the steep temperature contrast between the warm waters of the Mediterranean Sea and the cold air in altitude leads to a very unstable troposphere. Convective cells extends over Italy and western Mediterrana, including Sardinia, where high amounts of precipitations can occur upon the whole island, but especially upon the easterly slopes of mountain ranges. In the later stages of cut-off evolution a weak cyclone can appear on the sea level (**Fig. 3**). In this manner are measured the absolute maximum 24 h precipitations over Sardinia (for instance, in such conditions, from 11 to 15 of November 1999 the weather station of Muravera situated on the East coast gathered 461,6 mm, Decimommanu on the South 537,4 mm, but just 19 mm at Sindia on the west sector).

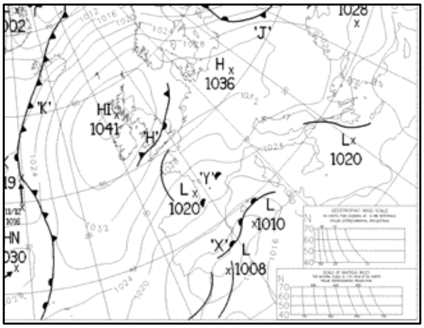

Fig. 3 Weak cyclone at ground level, enhanced by cut-off low in western Mediterrana on November 12, 1999

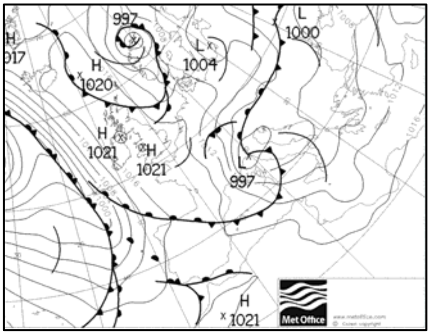

Fig. 4 Genoa cyclone developing after atlantic mP air invasion on January 5, 2003

2) **Genoa type cyclones**. The potential for high amounts of precipitation grows in Sardinia because of its position in the center of the western Mediterranean basin, in the near proximity of the most important region of cyclogenesis from subtropical latitude – The Gulf of Genoa. Within the rainy season, the often invasions of cold atlantic air (mP) above the warmer waters of Genoa gulf leads to cyclogenesis in this area, Sardinia being positioned in winter on the so called Mediteranean front (**Fig. 4**). There is an average of 60 cyclones per year that develop in this region (*Meteorological Office, 1962*).

In this situation, precipitations in Sardinia are generated primarly from multiconvective cells that move from South-West to North-East in the warm sector of the cyclone centered in the Genoa Gulf. Thus, the highest 24 h precipitation amounts are generally recorded in the South-West of the island and along the South-West orientated slopes of the mountain ranges. Also, the eastward movement of the cyclone leads to the passage of the cold front over Sardinia determining considerable amounts of precipitation in the North-West of the island (122.7 mm between 7 and 9 of January 2003 at Sindia weather station in the West of the isle and 17.2 mm in the same period at Tortoli weather station on the east coast). This is the dominant cause for precipitation occurring when cyclonic conditions over the continent prevail, the Azores maximum being driven over the Atlantic or even eradicated by the Icelandic low.

3) **Warm season convection**. In the warm season, especially under anticyclonical conditions, the contrasting warming of the island and of the sea around determines the convective mixing of the two air masses, leading to appreciable amounts of precipitation over island, especially in the mountain area (for instance 47,4 mm at Colonia Penale Sarcidano and 40.4 mm at Sadali on 23 August, 1997).

4. SPATIAL MODELS OF MEAN ANNUAL PRECIPITATIONS

Regression analysis is a global spatialization method, which uses all the data from the region of interest and correlates it with different quantitative terrain aspects in order to derive a single prediction equation for the dependent variable. This approach has the advantage of explaining the spatial distribution of the analysed parameter through the predictors integrated in the regression equation.

The main disadvantage is that the regression model does not keep the values of the predictand in the known points. Moreover, because it is a global spatialization method, the regression is uncapable of rendering spatial anomalies, which are important for precipitations.

These limitations could be minimized by using a local regression approach, such as the Geographically Weighted Regression – GWR (*Fotheringham et al., 2002*). Also, one must pay great attention in choosing the right predictors, which may be statistically significant, but may also have a contribution to the overall degree of explanation of the model too small for them to be regarded as real predictors.

In our case, from all the tested terrain aspects, the terrain altitude proved to be the only certain predictor for the mean annual precipitations, explaining 53% of its spatial distribution. The other variables, though some of them statistically significant, did not contribute with more than a few percents to the overall degree of explanation.

The regression equation infers a vertical pluviometric gradient of 44.6mm/100m, starting from a mean precipitation value of 598mm/year at sea level (**Fig. 8**). The latter aspect is a limitation of the method, as there are many stations dispaying precipitation values lower than this threshold. The mean difference between the real and the predicted values (RMSE) is 115.6mm/year (116.7mm/year for the cross-validation chart). To sum up, the altitude is a real and important predictor, but the altitude in its self is not enough to obtain an acurate spatial model of mean annual precipitations.

Opposite to regression, kriging is a local interpolation approach, based on the spatial autocorrelation of the analysed parameter. The main advantages of using kriging are the its capability of rendering spatial anomalies and the fact that the values in the known points are presearved. The main disadvantage is the fact that the spatial distribution is not actually explained e.g. the method does not infer an altitudinal gradient.

There are many types of kriging analysis. Three of them were tested in our study, namely the ordinary kriging, cokriging and universal kriging. The fourth method, that of residual kriging (regression kriging) is a mixed approach and it will be discussed later.

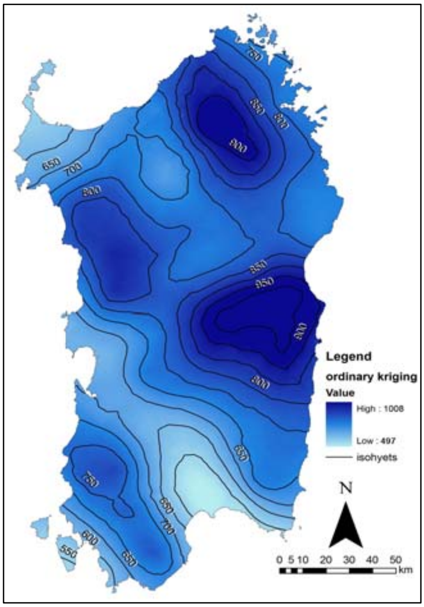

Fig. 5 Mean annual precipitations map obtained by ordinary kriging (RMSE=120.2mm/year)

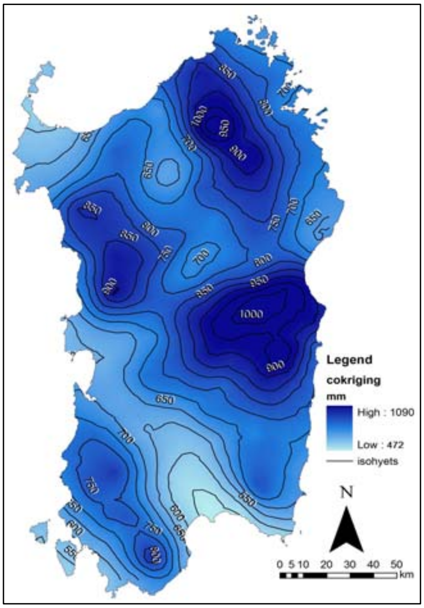

Fig. 6 Mean annual precipitations map obtained by cokriging (RMSE=103.1mm/year)

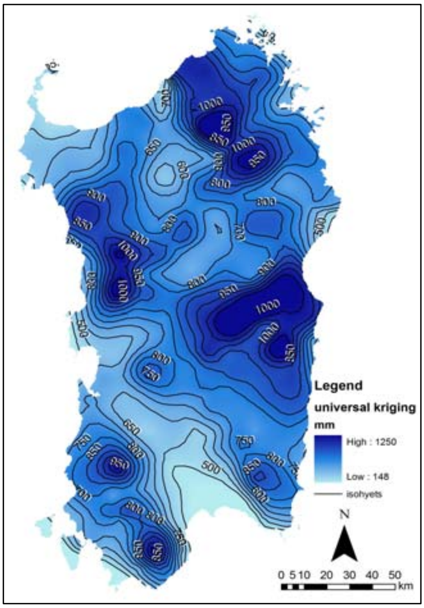

Fig. 7 Mean annual precipitations map obtained by universal kriging (RMSE=104.3mm/year)

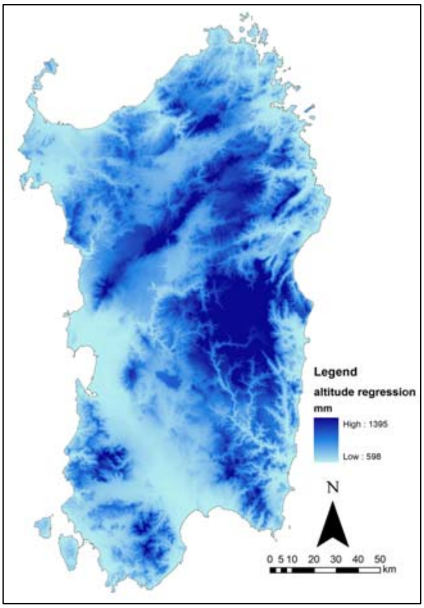

Fig. 8 Mean annual precipitations map obtained by altitude regression: P=598.3+0.446·H (RMSE=116.7mm/year)

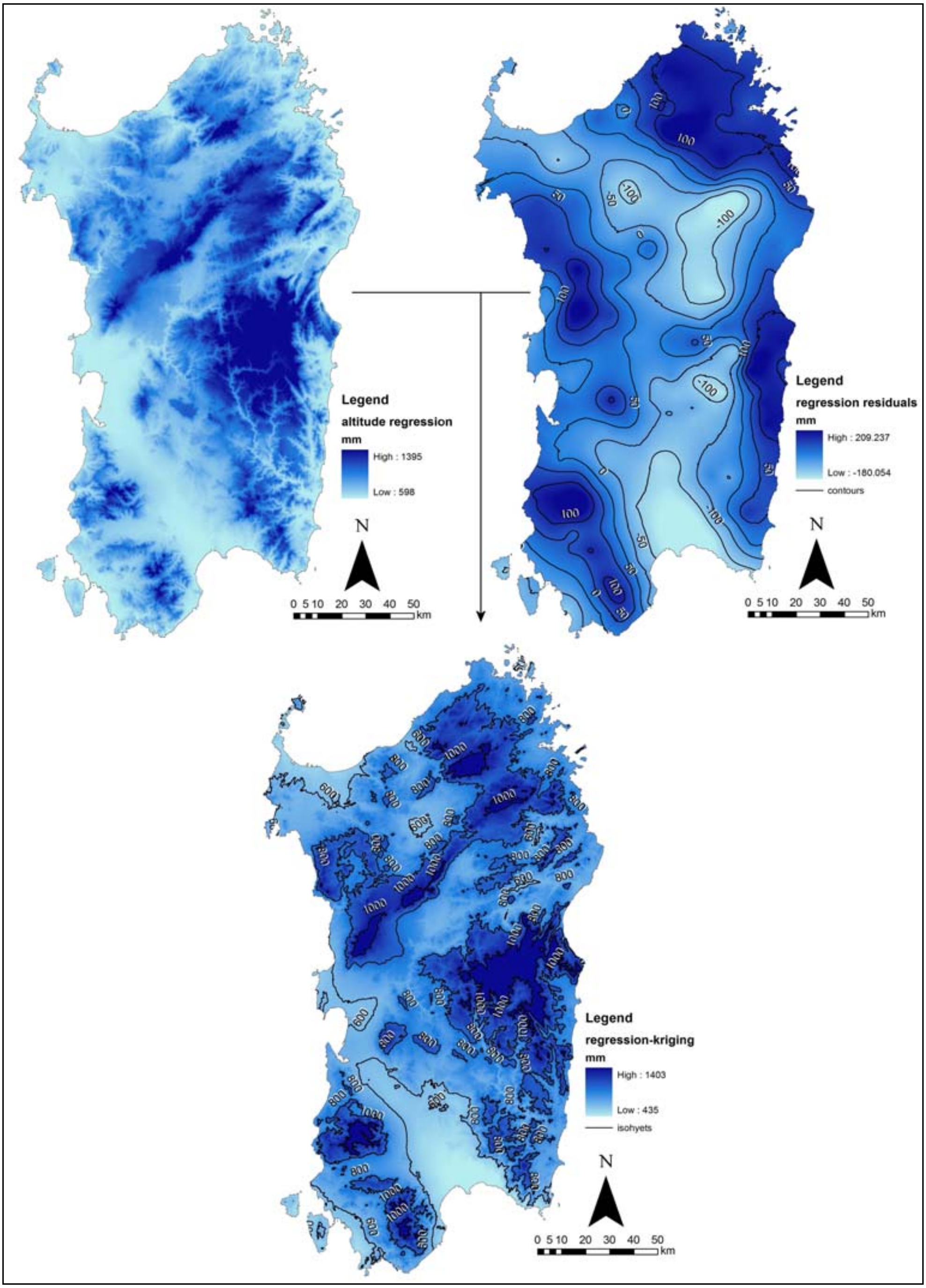

Fig. 9 The residual kriging approach and the resulting mean annual precipitations map (RMSE=86.2mm/year)

Ordinary kriging is the simplest approach. It does not take into account any terrain aspects, the interpolation being based only on the values associated to the points. The outcome of this method is shown in **Fig. 5**. We may notice that the spatial variation of precipitations is quite smooth and we can broadly differetiate the moutainous area from the lowlands. This method has the highest RMSE value (120.2mm/year).

Cokriging with altitude as auxiliary variable slightly improves the spatial model, the RMSE of the cross-validation chart being 103.1mm/year. We may notice that the terrain relief is better accounted for (**Fig. 6**).

Universal kriging is a three-stages approach. During the first stage, a polynomial trend surface is extracted from the data, then the differencies from this surface (residuals) are interpolated, generally by ordinary kriging and finally the trend surface and the residuals are added up, resulting the spatial distribution. Our analysis found that better results could be obtained using a 3rd order polynomial locally derived trend surface (**Fig. 7**). The RMSE is similar to the one of previous method (104.3mm/year), but the precipitations field (**Fig. 8**) displays more variation and also some unrealistic values (e.g. the minimum raster value is 148mm/year, while the minimum station value is 381.4mm/year).

Residual kriging (regression-kriging) is a mixed approach, combining regression and kriging in a single method. This integration eliminates the disadvatages of both these methods. Therefore, such an approach is able to both explain the spatial distribution by means of the predictors integrated in the regression equation and to render spatial anomalies. The method operates in a manner similar to the universal kriging, but instead of using polynomial trend surfaces, it uses the spatial model achieved by regression.

In our case, the residuals from the altitude-precipitations model were interpolated by ordinary kriging, then the altitudinal and the residuals models were added up in order to obtain the final precipitation map (**Fig. 9**). Judging by the RMSE of the cross-validation chart (86.2mm/year), this approach seems better than the previous ones

5. CONCLUSIONS AND PERSPECTIVES

Our study shows that, from all the spatialization methods we tested, the residual kriging (regression-kriging) approach seem to yield better results, the method displaying the minimum RMSE value for the cross-validation procedure. Our intention is to extend our analysis to the mean monthly precipitations. Further reasearch will focus on deriving new predictors to improve the regression model, on testing other spatialization method, such as the GWR (*Fotheringham et al., 2002*).

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RELATING LAND COVER AND URBAN PATTERNS TO AQUATIC ECOLOGICAL INTEGRITY: A SPATIAL ANALYSIS

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ABSTRACT:
Landscape change affects natural ecosystems and poses major challenges to natural resource managers and planners. Studies have shown that streams and rivers are often the ecosystems most affected by stressors associated with urbanization, and composition within a watershed has been found to account for much of the variability in aquatic ecological integrity. While studies have shown that type and quantity of land cover within a watershed can account for much of the ecological conditions in streams, few have investigated how the land mosaic influences stream ecological integrity. In ecological research there remains debate on how spatial structure and spatial dependence affects spatial statistics and statistical modeling of the species-environment interaction. In this paper, we study the relationships of seven landscape variables on an averaged Fish Index of Biological Integrity (F-IBI) in 49 watersheds in Southeastern Wisconsin, USA. Spatial clustering statistics: local Moran's I, local Geary's C, local Anselin Moran's I, and local Getis-Ord Gi* were used for variable and overall comparison. Standard least squares regression and geographically weighted regression (GWR) were used for ranking landscape variables and comparison. Local Anselin Moran's I statistic was found to best capture the association between average F-IBI and landscape variables. The standard least squares regression and GWR analyses identified percent urban and landscape shape index (LSI) as the most important predictors of aquatic environmental integrity, respectively.

Keywords: *landscape pattern; fish index of biotic integrity; spatial statistics; spatial autocorrelation; spatial analysis.*

1. INTRODUCTION

The design, function, and dynamics of contemporary ecosystems are profoundly influenced by human activities (*Alberti, 2005*). Understanding and managing the integration of natural and human landscapes is more important now then ever (*Alberti, 2008*). The Fish Index of Biological Integrity (F-IBI) has been welcomed as a robust method for investigating landscape-aquatic interactions (*Roset et al., 2007; Novotny et al., 2005; Karr and Yoder, 2004*) and can help diagnose causes of ecological impacts and suggest appropriate management actions (*Roset et al., 2007; Karr and Chu, 1999*).

The catchment or watershed management paradigm started in the mid 1970s changed the way stream ecologists look at the landscape. “In every respect, the valley rules the stream” (*Hynes, 1975*). “Rivers and streams serve as a continent's circulatory system, and the study of those rivers, like the study of blood, can diagnose the health not only of the rivers themselves but of their landscapes” (*Sioli, 1975*). Recently, research has suggested that catchment scale land-use and land cover management would be more effective in improving stream quality than other management scales (*Alberti, 2007; Wang et al., 2006; Potter et colab., 2005; Wang et colab., 2003; Roth et colab., 1996*).

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The importance of spatial autocorrelation in ecological research has been addressed in recent papers (*e.g., Diniz-Filho et colab., 2003; Legendre et colab., 2002; Lichstein et colab., 2002*). Autocorrelation is the lack of independence between pairs of observations at given distances in time or space and is found commonly in environmental data (*Legendre, 1993*). Lennon (2000) called attention to the problems associated with autocorrelation in ecological research ('red herrings') and argued that virtually all geographic analyses had to be redone by taking into account spatial autocorrelation. To date, there are multiple techniques for taking into account spatial autocorrelation at both the global and local levels. Global spatial statistics (e.g., Moran's *I*, Getis-Ord General *G*) calculate the spatial autocorrelation across the entire study area; local spatial statistics (e.g., local Anselin Moran's *I*, local Getis-Ord *Gi**) go one step further to depict local clustering patterns and measure local spatial autocorrelation (*Anselin, 1995; Getis and Ord, 1996; Sokal et colab., 1998*). Spatial autocorrelation index scores vary from each other (*see Lee and Wong, 2001; Wong and Lee, 2005* for more information); however, positive scores indicate similar values are spatially clustered and negative scores indicate unlike values are spatially clustered (*Rybarczyk and Wu, 2009*). When addressing species-environment relationships, it is important to take into account that natural systems are influenced by many different processes over space. Boots (2002) stated that when species are influenced by several different processes over their range, the assumption of stationarity of the global statistics are not fulfilled and spatial characterization should be performed using local spatial statistics.

While studies exist that address the relationships between watershed composition and configuration, few have addressed the question of how urban patterns influence aquatic ecological integrity (*Alberti et colab., 2007*). Further, of those studies, even less have addressed how spatial statistics relate to this species-environment relationship. In the following research, we develop a study that 1) compares local spatial autocorrelation models for landscape-aquatic research; and 2) examines the relationship between landscape variables and an averaged Fish Index of Biological Integrity (F-IBI) for 49 watersheds in Southeastern Wisconsin.

2. STUDY AREA AND DATA DESCRIPTION

2.1. Study area

We have focused our spatial analysis in 49 watersheds of Southeastern Wisconsin (**Fig. 1**). Several geographic characteristics make this region ideal for this study. Between 1970 and 2000, the population of the 15 counties crossed by the study area has increased by roughly 14 percent (*USCB, 2000*). This population growth has had a major influence on land-use and land cover change, resulting in a variety of landscape patterns throughout the study area. Primarily, this patterning is a result of suburban and exurban growth consuming agricultural lands surrounding the two largest cities in the state: Madison and Milwaukee. In the 15 counties crossed by the study area, there was a loss of 23 precent agricultural land from 1970 to 2000 (*NASS, 2000*).

The existing land cover in the study area is overwhelmingly agricultural; albeit, this region is know for its very fertile soil and productive agricultural uses. The pre-settlement land cover for this area was primarily prairie with small patches of woodlands and scattered wetlands throughout (*Martin, 1965*). The surface geology is predominantly affected by the Wisconsin glacial recession; albeit, with pockets of glacial till, lacustrine basins, and large areas of pitted and unpitted outwash plains (*Dott and Attig, 2004*). The elevation ranges from 200 to 300 m above sea level, with mainly flat to slightly rolling topography. Due to its low relief, and agricultural legacy, this region has many floodplain alterations, including drainage tiling, channelizing, diking, and filling. Most of the streams and rivers within this study have some type of hydrologic modification. Beyond the last century, this area was first subject to landscape alterations primarily for agricultural uses; however, now landscapes are being modified again for urban associated uses.

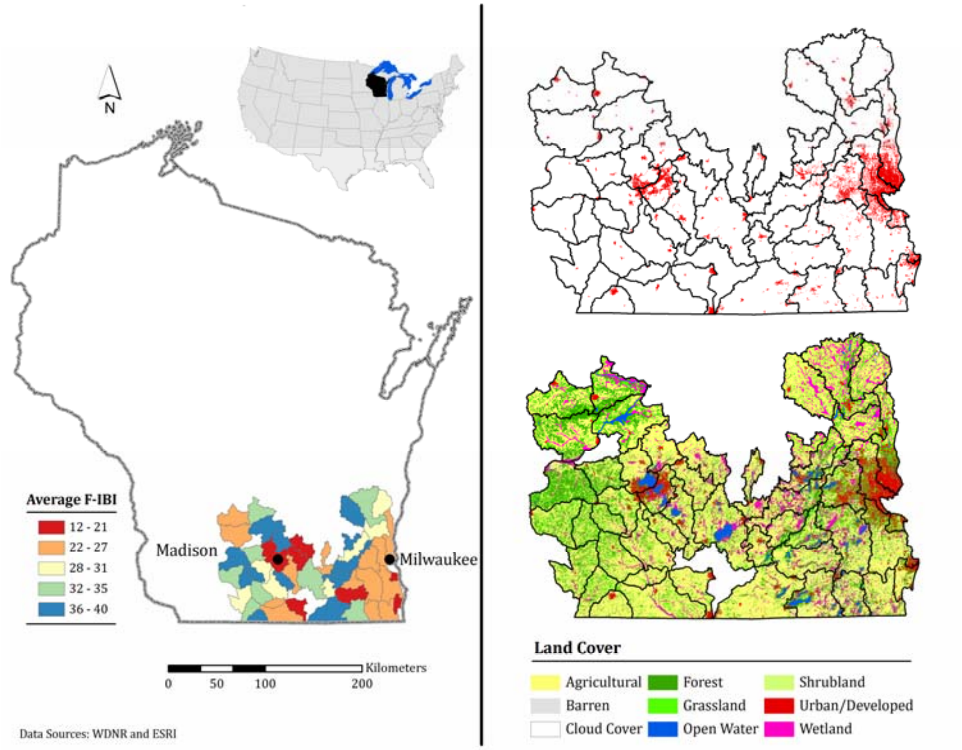

Fig. 1 Study area watershed landscapes within Wisconsin, USA

2.2. Selected watershed basins and F-IBI

The nested study watershed basins were selected based on 427 fish sample sites and preserving an urban to rural gradient. The fish sample sites used in this analysis are managed by the Wisconsin Department of Natural Resources (WDNR). Fish data collected over a span of four years (2001-2005) were used to calculate the Fish Index of Biotic Integrity (F-IBI) for each sample site. Due to geographical affects on speciation, the F-IBI is based off of John Lyons (1992) fish community research for the state of Wisconsin. Those data used in this analysis were collected and calculated by the WDNR. Following the Wisconsin method for wadeable streams, fish samples are collected from a segment of stream with length equal to thirty-five times the mean stream width. This method usually includes different habitats. The F-IBI for Wisconsin is calculated for an individual sample from each stream segment and calibrated by comparing the observed values of each metric with values expected in comparable streams of high environmental quality (*Lyons et colab.,1996; Lyons 1992*). The Wisconsin F-IBI scales between 0 and 100, with increasing scores equaling higher environmental quality. For the 427 fish sample sites used, F-IBI scores ranged from 10 (very poor) to 50 (good). F-IBI scores were averaged by watershed to obtain an overall rating of aquatic integrity by watershed basin for this analysis (**Fig. 1**).

The study area is comprised of 49 HUC-10 watersheds with varying size and shape. HUC is the acronym for Hydrologic Unit Code (HUC). Every hydrologic unit is uniquely identified through its code (2 to 12 digits) based on its scale within the hydrological system (*USDA, 2002*). The watersheds are divided up between seven separate stream systems. Referred to as 5th level watersheds, the HUC-10 watersheds used in our analysis have an average size of 359 km^2 with a total study area of 17,600 km^2. The HUC-10 watersheds chosen in this analysis were published in shapefile format by the WDNR in 2002. These data were digitized by interpreting USGS 7.5-minute (1:24,000) topographic and hydrologic paper maps. The 49 watersheds used in this analysis should be considered as individual landscapes.

2.3. Land cover data

The land cover data used in this analysis was published by the WDNR in 1998 as part of a larger project for the Upper Midwest Gap Analysis Program (UMGAP) Image Processing Protocol. The land cover data, entitled WISCLAND, is a raster representation of vegetation and land cover for the entire state of Wisconsin that was acquired from the national Multi-Resolution Land Characteristics Consortium (MRLC). The WISCLAND data was created using dual-data Landsat Thematic Mapper (TM) imagery data primarily from 1992. The original pixel size of the TM source data is 30 meters; however, excluding urban areas, patches were generalized to areas no smaller than four contiguous pixels (roughly 0.4 hectares). After processing, the data have a minimum mapping unit of 5 acres, delineating land cover features roughly 1.6 hectares in the data. WISCLAND was designed to be used between scales 1:40,000 and 1:500,000 for a wide variety of resource management and planning applications. Its land cover data is classified into a three level hierarchy modeled after *Anderson et colab. (1976)* land use and land cover classification system with level one being most broad (9 classes) to level three being most detailed (30 classes). Focusing on urban and forest composition and urban land patterning, and due to misclassification error being reduced at broader scales, we chose to employ level one for our analysis. An accuracy assessment was performed by the WDNR to reveal that level one land cover classification has an estimated accuracy >95%. A map of varying and land cover for the study area can be found in **Fig. 1**.

3. METHODS

3.1. Land cover and urban pattern metrics

Land cover variables (composition) and urban patterns (configuration) were calculated using landscape ecology metrics developed for quantifying the spatial arrangement of land cover and land use (*McGarigal et colab., 2002; Turner et colab., 2001; McGarigal and*

Marks, 1995; Turner, 1989). FRAGSTATS version 3.3 (*McGarigal et colab., 2002*), a free and publicly accessible software, was used for computing urban pattern metrics for each watershed landscape (*see Leitao et colab., 2006; Tischendorf, 2001; Hargis et colab., 1998*). A map of urban patch patterning for the study area is provided (**Fig. 1**). The land cover data was converted from raster to vector to raster format, preserving a 30m resolution during data processing. Two major land cover variables (percent urban, percent forest) and five urban pattern class metrics (LSI, AREA_MN, PARA_MN, AI, PLADJ) were computed for each of the 49 watershed landscapes used in the subsequent spatial analysis. For more information on the selected urban landscape class metrics see *McGarigal and Marks, 1995; McGarigal et colab., 2002; Leitao et colab., 2006; Alberti et colab., 2007*.

3.2. Local spatial clustering analysis

Spatial statistics are the most useful tools for describing and analyzing how geographic phenomenon occur or change across a study area (*Lee and Wong, 2001*). Traditional exploratory data analysis can reveal visual patterns to identify potential clusters of spatially autocorrelated data, but autocorrelation statistics provide methods to statistically and quantitatively analyze those spatial patterns. Global spatial statistics average values across a study area to determine the total degree of autocorrelation, but do not give you locations where autocorrelation exists. In the presence of global spatial autocorrelation across a study area, as the case of a majority of variables used in our analysis, several statistics are used to depict significant local clustering patterns and assess local spatial autocorrelations and non-stationarity (*Anselin, 1995; Getis and Ord, 1996; Sokal et colab., 1998*). Local indicators of spatial association (LISA- coined by *Anselin, 1995*) include local Moran's *I*, local Geary's *C*, local Anselin Moran's *I*, and local Getis-Ord *Gi**.

Both the local Moran's *I* and local Geary's *C* statistics produce similar results that characterize whether local neighbors have similar, dissimilar, or no association in the values of the variable under investigation (*Getis and Ord, 1996; Fortin and Dale, 2005*). Local Moran's *I* and local Geary's *C* do provide insight on local spatial structure, however they do not provide information about local high and low clusters across the study area (*Fortin and Dale, 2005*). Local Anselin Moran's *I* and local Getis-Ord *Gi** statistics do offer information about local high and low clustering by comparing the sum in the variable under investigation within a local neighborhood relative to its corresponding global sum for the study area (*Wong and Lee, 2005*). Because there is limited knowledge on which local clustering technique is better suited for landscape-aquatic relationships, we have chosen to implement all four statistical techniques for comparison.

Using ESRI's ArcView 3.2 Spatial Autocorrelation menu tool we calculated the local Moran's *I* and local Geary's *C*; using ESRI's ArcMap 9.3.1 Spatial Statistics toolbox, we calculated the local Anselin Moran's *I* and local Getis-Ord *Gi** for all of the variables used in analysis. To identify which local clustering statistical method is most relevant for investigating landscape-aquatic interaction, we grouped all variables Z-scores into three equal intervals for matching comparison (**Fig. 2-5**). Matching analysis was conducted by comparing the groupings for all landscape variables to the groupings of averaged F-IBI by each watershed landscape for each local spatial statistical type. A matching status was assigned if the landscape variable's Z-score group corresponded with the averaged F-IBI's Z-score group (e.g., high urban Moran's *I* Z-score – high F-IBI Moran's *I* Z-score = matching). A not matching status was assigned if the landscape variable's Z-score group did not correspond with the averaged F-IBI's Z-score group (e.g., high urban Moran's *I* Z-score – low F-IBI Moran's *I* Z-score = not matching).

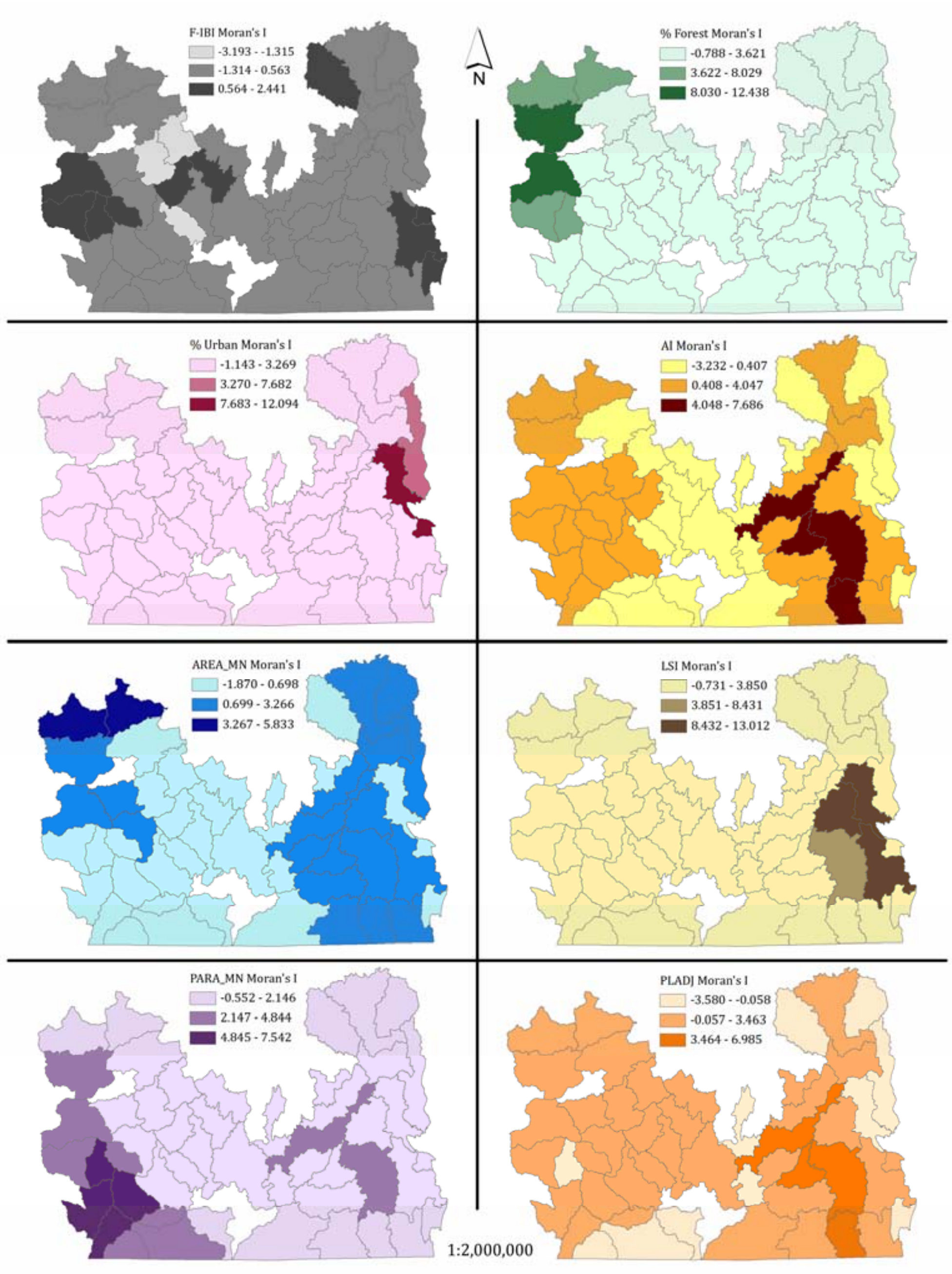

Fig. 2 Local Moran's *I* displaying Z-score spatial clustering of variables

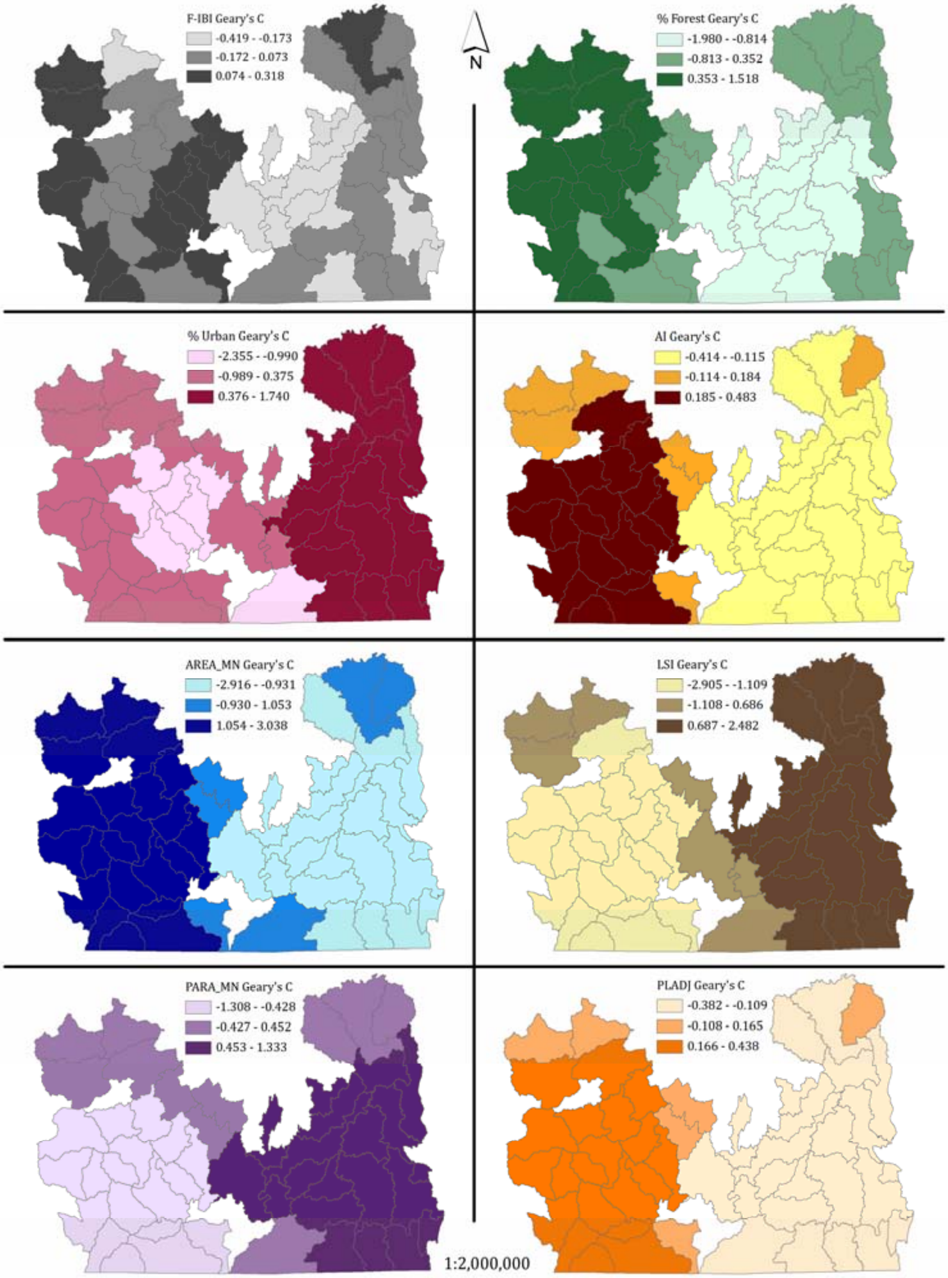

Fig. 3 Local Geary's *C* displaying *Z*-score spatial clustering of variables

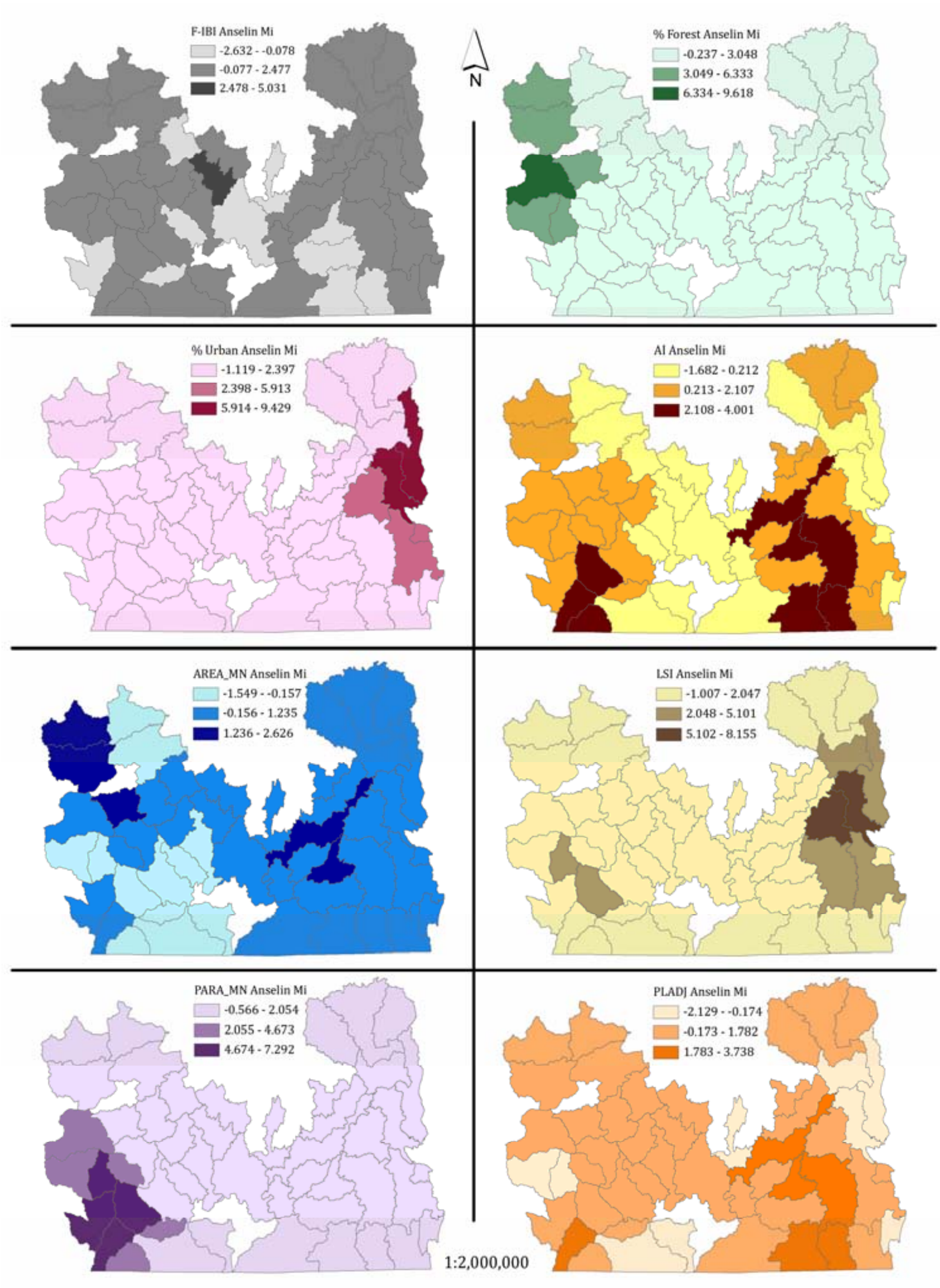

Fig. 4 Local Anselin Moran's *I* displaying Z-score spatial clustering of variables

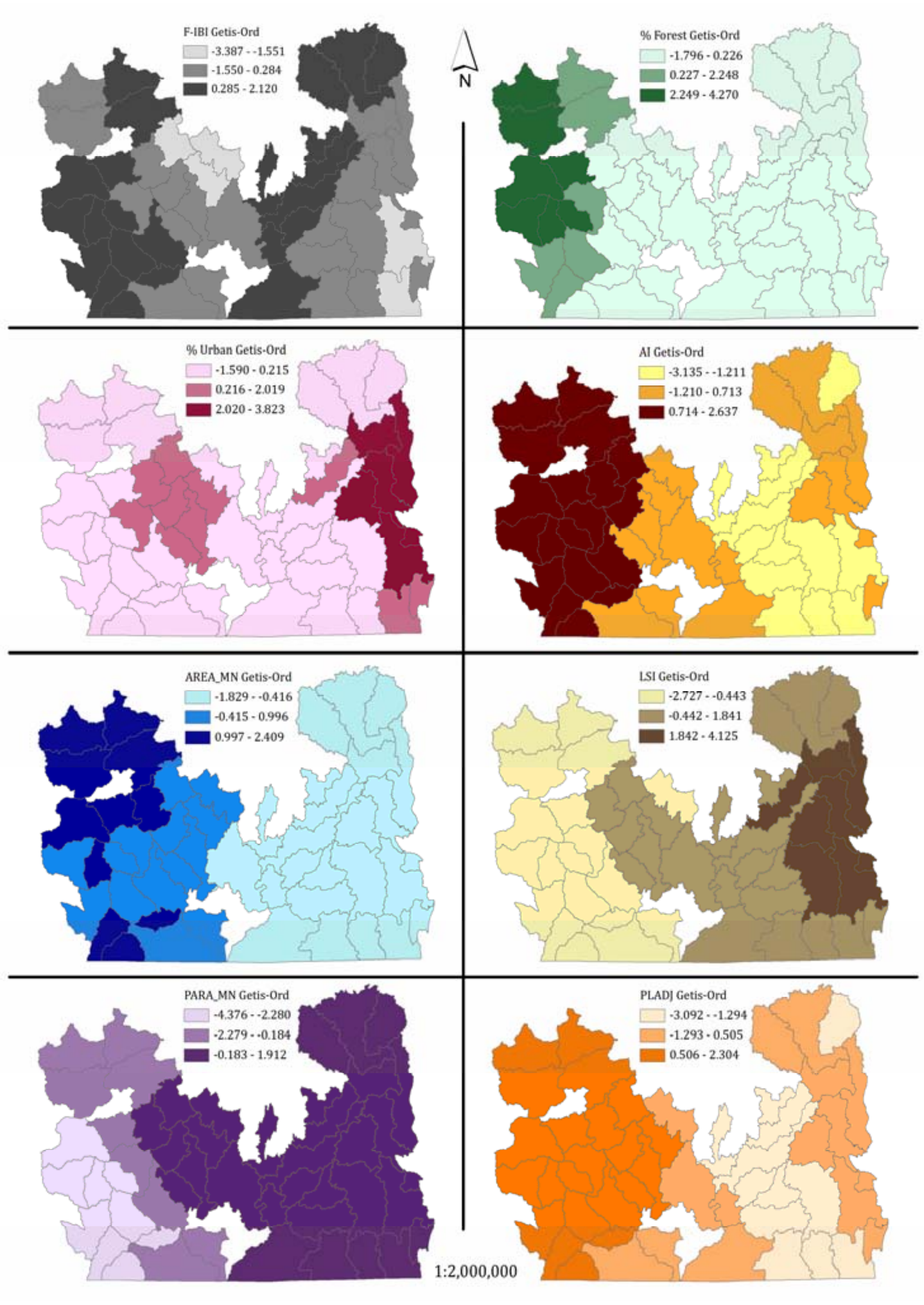

Fig. 5 Local Getis-Ord *Gi** displaying Z-score spatial clustering of variables

3.3. Regression analysis

Since standard least squares regression, a traditional global regression technique, is well documented, we describe here only the background for the geographically weighted regression (GWR) method. Spatial autocorrelation is problematic for classical statistical tests like standard least squares regression for violating the assumption of independently distributed errors (*Haining, 1990; Legendre, 1993*), and the standard errors are usually undervalued when positive autocorrelation is present and Type *I* errors may be strongly exaggerated (*Legendre, 1993*).

To circumvent these 'red herrings' and for statistical comparison, GWR was also implemented in this analysis. GWR is a technique that expands standard regression for use with spatial data. Using a Bayesian-modified linear regression technique, GWR utilizes a distance decay weighting philosophy (*LeSage, 1999*). The assumption with traditional statistics is that the relationship under study is spatially constant, and thus, the estimated parameters remain constant over space. However, in environmental research most relationships vary over space. GWR assesses local influences, allowing for a spatial shift in parameters and a more appropriate fit (*Wang et colab., 2005*). Although the technique does not allow for extrapolation beyond the region in which the model was established, it does allow the parameters to vary locally within the study area and may provide a more appropriate and accurate basis for descriptive and predictive purposes (*Foody, 2003*).

To investigate the relationship between landscape variables and a measure of ecological integrity, both standard statistics and spatial analysis statistics were used. Using JMP version 8 (SAS Institute, 2008), standard least squares regression was performed to measure the relationship between averaged F-IBI (dependent variable) and each of the seven landscape variables (independent variables). Using ESRI's ArcMap 9.3.1 Spatial Statistics toolbox, GWR was calculated to measure the relationship between averaged F-IBI (dependent variable) and each of the seven landscape variables (independent variables). Additionally, global Moran's *I* was performed on the residuals for each GWR to indicate if the models were successful at accounting for all of the spatial correlation. This type of method has been supported for species-environment research (*Wagner and Fortin, 2005*), and proven as a standard technique in geographical analysis (e.g., *Green et colab., 2003*).

4. RESULTS

4.1. Local spatial clustering analysis

The Z-score values show various degrees of departure from a random pattern for the variables analyzed in the study area. The greater the Z-score deviates from zero, the more dispersed (negative) and more clustered (positive) the variable values under investigation becomes (*Lee and Wong, 2001; Wong and Lee, 2005*). Furthermore, by looking at the Z-score the significance of local clustering is portrayed.

The results of our local spatial statistics matching analysis (**Table 1**) show that local Anselin Moran's *I* best captured the association between average F-IBI and the seven selected landscape variables. Based on the comparison method employed, local Anselin Moran's *I*, local Geary's *C*, local Getis-Ord *Gi**, local Moran's *I*, reported 39, 33, 29, and 25 percent matching, respectively.

Table 1. ***Local spatial clustering statistics- matching comparison results***

Model Rank	Model Type	L. Variable	% Matching	% Total Matching
1	Local Anselin Moran's *I*			39
	AMI	% Urban	27	
	AMI	% Forest	31	
	AMI	LSI	33	
	AMI	AREA_MN	53	
	AMI	PARA_MN	24	
	AMI	AI	47	
	AMI	PLADJ	57	
2	Local Geary's *C*			33
	LGC	% Urban	16	
	LGC	% Forest	57	
	LGC	LSI	4	
	LGC	AREA_MN	51	
	LGC	PARA_MN	10	
	LGC	AI	45	
	LGC	PLADJ	47	
3	Local Getis-Ord *Gi**			29
	LGO	% Urban	14	
	LGO	% Forest	22	
	LGO	LSI	24	
	LGO	AREA_MN	33	
	LGO	PARA_MN	31	
	LGO	AI	51	
	LGO	PLADJ	47	
4	Local Moran's *I*			25
	LMI	% Urban	6	
	LMI	% Forest	10	
	LMI	LSI	10	
	LMI	AREA_MN	40	
	LMI	PARA_MN	20	
	LMI	AI	39	
	LMI	PLADJ	50	

4.2. Regression analysis

The results of the standard least squares regression analysis (**Table 2**) show that percent urban (R^2=0.18, P=0.0022) and percent forest (R^2=0.1, P=0.0285) were the best landscape variables for predicting average F-IBI. PARA_MN (R^2=0.08, P=0.05) indicated marginal significance at predicting averaged F-IBI. Landscape variables LSI, AREA_MN, AI, and PLADJ all proved to be insignificant at predicting averaged F-IBI.

Table 2. ***Standard least squares regression results between landscape variables and averaged Fish Index of Biological Integrity (F-IBI)***

Model Rank	Dependant	Independent	$R2$	P-value
1	F-IBI	% Urban	0.18	0.0022
2	F-IBI	% Forest	0.1	0.0285
3	F-IBI	PARA_MN	0.08	0.05
4	F-IBI	LSI	0.05	0.1096
5	F-IBI	AREA_MN	0.01	0.5445
6	F-IBI	AI	0	0.8769
7	F-IBI	PLADJ	0	0.8813

The results of the GWR analysis (**Table 3**) showed that LSI (R^2=0.52, P<0.0001) was the best landscape variable at predicting averaged F-IBI. With the exception of LSI, all regression equations generated using GWR had residual spatial autocorrelation, indicating that the regression models were not successful in fully accounting for all the spatial correlation of the averaged F-IBI.

Table 3. ***Geographically weighted regression (GWR) results between landscape variables and averaged Fish Index of Biological Integrity (F-IBI)***

Model Rank	Dependant	Independent	$R2$	P-value	R. A.
1	F-IBI	LSI	0.52	<0.0001	N. S.
2	F-IBI	% Urban	0.19	0.0018	p<0.05
3	F-IBI	PLADJ	0.11	0.0183	p<0.05
4	F-IBI	% Forest	0.1	0.0285	p<0.10
5	F-IBI	PARA_MN	0.08	0.05	p<0.05
6	F-IBI	AI	0.08	0.0559	p<0.05
7	F-IBI	AREA_MN	0.01	0.5421	p<0.01

R. A. is the regression residual autocorrelation- significance from Moran's I statistic

5. DISCUSSION AND CONCLUSION

The first law of geography states that things that are near are more similar (autocorrelated) than things that are farther apart (*Tobler, 1970; Fortin and Dale, 2005*). While landscape modifications are linked to ecological degradation, they are by no means homogenous over a study area. In this study we postulated that local models of spatial autocorrelation differed in their relationships when investigation landscape-aquatic interactions. Further, we examined the relationships of landscape composition and configuration on an averaged index of ecological condition- investigating how traditional and spatial analysis statistics (e.g., GWR) differ in results.

The findings of this study show that all local spatial clustering statistics are relevant for capturing species-environment interaction; however, local Anselin Moran's *I* proved to be substantially better at capturing the landscape-aquatic relationship. This research is by no means all encompassing, but it does suggest that the different types of local spatial autocorrelation provide different results and should be investigated more explicitly.

The findings of our regression analyses show that both composition and configuration of landscapes play an important role in aquatic ecosystem function. As in other studies (e.g., *Albert et colab., 2007*) our research shows that configuration of urban patterns proved to be highly significant in explaining the variation in an index of aquatic ecology integrity. In the GWR portion of our study, a negative relationship was found between landscape shape index (LSI) and averaged F-IBI. LSI is a simple measure of urban patch clumpiness or aggregation; the greater the value of LSI the more the landscape consists of a single compact urban patch (*McGarigal and Marks, 1995*). The results of this phenomenon are interpreted as: The amount of urban land (composition) is important to aquatic ecological integrity; albeit, the location of those urban lands to each other (configuration) is significantly more important to aquatic ecological integrity.

With that said, our findings show substantial differences in results based on type of statistical method employed. Again, this research is by no means all encompassing, but it does suggest that type of regression and other spatial analyses should be compared and investigated more explicitly.

Since the 49 watersheds represent a cross-section of varying levels of landscape patterning in Southeastern Wisconsin, the results can be transferred to other watersheds of similar size, geography, and ecology.

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THE FIRST AGROGEOLOGICAL MAP (1909) OF THE ROMANIAN KINGDOM, TODAY AFTER 100 YEARS

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ABSTRACT:
Our aim was to commemorate the first Romanian Agrogeological Map, which was compiled over 100 years ago and presented at the First International Agrogeological Congress. That period was the beginning of the international reputation of the Romanian institutional geology. This proves that the establishment of Geological Institute of Romania was necessary and in proper time in 1906. In this article we made a calibration of the mentioned map and we laid over the digital terrain model (SRTM) and also presented a 3D view of the tarnished map.

Keywords: *raster map, digital terrain model, georeferencing, 3D view.*

1. INTRODUCTION

Soils are major support systems of human life and welfare. Not so long ago, soil, water, fuel and mineral resources were simply that – resources. Of course, economies and societies are built upon soils and most Earth science activity is devoted to obviously useful activities that support the economy. In the case of soil science, this means supporting many different activities, including agricultural production, civil engineering, water supplies, water and air quality, sanitation and waste disposal to achieve the sustainable use of this finite and delicate system.

Soil science has greatly contributed to the exponential increase in agricultural production and, as a result, to feeding, housing, and clothing the people of the world. Supporting agriculture remains an important research thrust but, nowadays, soil science includes precision agriculture, organic farming and carbon sequestration (by forested and agricultural systems) as well as grappling with restoring degraded land and issues of sustainability. Since the 1970s, soil science has been integral to environmental research issues like soil pollution, climate change, the maintenance of effective hydrological cycles, the role of soils in urban areas, and sustaining biodiversity. There are great challenges ahead for soil science as burgeoning human population and aspirations increase pressures on land and water. Both the spatial and temporal characterisations of soils, and their functioning within ecosystems, are vital for our understanding of the Earth as a global system. Wise use of natural resources requires an expanding knowledge base that accommodates the dynamics of a rapidly changing world.The Geological Institute of Romania (GIR) was established in 1906. The purpose of the Institute was the developing of an accurate geological infrastructure for exploration, mining and construction works in the country. Thus, the geological mappings fulfilled first the main role of the GIR, to which also agrogeology, geophysics, geochemistry, engineering geology were successively added.

The first International Agrogeological Congress was held on 14-24 of April 1909, in Budapest, hosted by the Geological Institute of Hungary. This event provided one of the first possibility for the Geological Institute of Romania to present its scientific results on an international forum. This Congress was convicted based on the early international exigency of standardisation concerning the terminology, methodology for the European countries.

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2. FIRST AGROGEOLOGICAL MAP OF THE ROMANIAN KINGDOM

The soil as a primary resource for the human being were considered that need to be studied in more detail and it was examined by several international famous researchers and the pedology/ agrogeology science was born. In this international background the new established Geological Institute of Romania representatives were present on the mentioned Agrogeological Congress in Budapest.

Dr. Murgoci G. the head of the Agrogeological Department on this important event presented the First Agrogeological Map (**Fig. 1**) of the Romanian Kingdom (*Murgoci, 1909*), which was the result of the intensive work of the department between the 1906-1908.

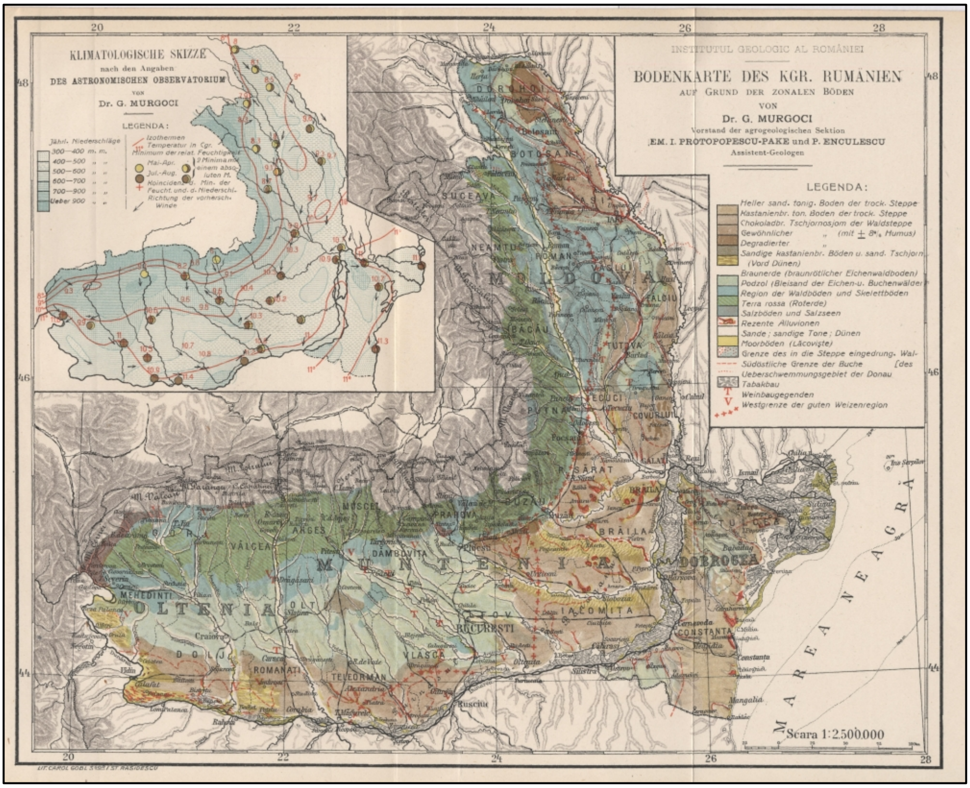

Fig.1 First Agrogeological Map of the Romanian Kingdom, compiled under the supervision of Dr. Murgoci G. together with Protopopescu-Pake Em. I. and Enculescu P. in 1909

Professor Dr. Gh. Murgoci, started to acquire his geological knowledge from the famous teacher and researcher L. Mrazec from the Bucureşti University. After several year studies abroad (Austria and Germany) he returns in Romania with a doctorate (PhD) from the University of München. His passion was the mineralogy-petrography, he found and described the lotrit mineral for the first time in the world. In 1920 he became the head of the Mineralogical Department. Meanwhile he draws the stratigraphic position for hydrocarbon occurrences in Oltenia region. So, we are the witnesses of a scientist with the interest of a wide variety in speciality. We can found him among the starting personalities of the organisation of the "Researchers from România" (Cercetaşii României). He is also among the founder of the South-Eastern European Studies Institute in Bucharest. Thus it is not outstanding that this historical map about the soils is also linked to his activity. This is the reason why he is considered the founder of the Romanian Pedology. According to his proposal was established the Pedological Department of the Geological Institute of Romania.

Dr. Murgoci was a follower of the modern idea of V. Dokuchaev, concerning that the geographical variation in soil type could be explained in relation not only geological factors, but also to climatic and topographic ones. On the mentioned Fig., in the top left corner one can find the climatologically sketch of Romania, with isotherms and precipitation rates, which influence the pedological footprints of a region. This also proves that Murgoci was a real modern natural scientist, not only geologist, pedologist or petrographer. According to his merit and international reputation, he was elected as president for the international Pedological Cartographical Committee in Prague in 1923. Further more, in 1924 became the executive president for the European Pedological Map Committee, which task was the compilation of the mentioned map.

The Romanian Agrogeological Map is a detailed map, in the mentioned publication (*Murgoci, 1909*) there is only a brief- sketch at scale 1: 2 500 000. On the original map the main types of the soils, their extent are also valid nowadays too. Actually some changes have been introduced from 1909, but as a complete map with a unified legend was the very first one.Based on the above mentioned we consider that the map is a product of the Romanian specialists compiled on a high level and represents a great performance that in several years after the Institute establishment a complete agrogeological map was presented on the First Agrogeological Congress.In the description of the map Dr. Murgoci concluded that the vegetation, especially the forests has a major influence upon the soils of a region and a minor influence to the microclimate.

3. DIGITAL TERRAIN MODEL AND THE AGROGEOLOGICAL MAP

Nowadays it is well known that the relief, the geomorphological pattern also has an important effect on the soil evolution. In this article we present a trial to link the shown agrogeological map with the elements of the relief. Thus we used the SRTM database (*Timár, 2003.*) available from the net (**Fig. 2**).

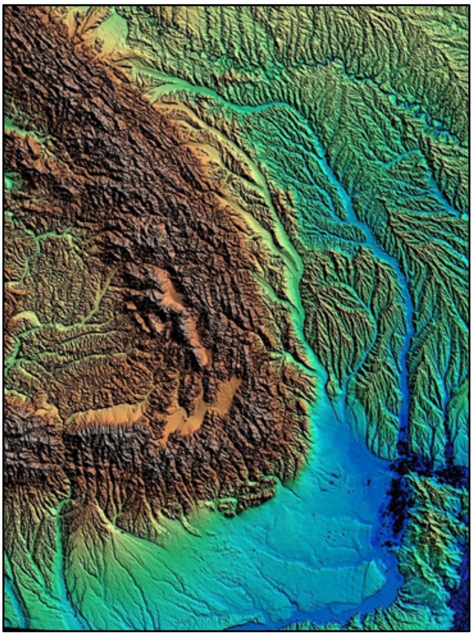

Fig. 2 Digital terrain model generated from the SRTM database

3.1. Calibration of the map

In order to perform such a task firstly we calibrated the historical agrogeological map, thus it was transformed in the same geodetic projection like the DTM was UTM35/WGS84. The points with the same coordinates were overlapped.

The calibration we performed based on the geographical coordinated after the recalculation transforming in WGS84/UTM35 with the aim of the "Viteaz" coordinate transformation program (*Timár, 2004*). This program VITEAZ is an MS Excel table that allows you to convert UTM, Soviet-type Gauss-Krüger, Romanian Stereo-70 and old Hungarian "Marosvásárhely" Stereographic coordinates.

We began the transformation with 11 points and the accuracy of the rectification was quite insufficient RMS (Root Mean Square) over 3. Selecting further 10 points on the river confluences we reached to reduce RMS value very close to 1, with the maximum of less than 2 pixels. At this point we considered the accuracy good enough.

3.2. The overlay operation

The ER Mapper software makes it possible to overlay the DTM and the Agrogeological map as a calibrated raster file. This way the agrogeological content of the map compiled in 1909 was laid over the DTM, highlighting the geomorphological patterns (**Fig. 3**).

The **Fig. 4** shows the Muntenia agrogeological map, but the in the background there is a coloured DTM. This facilitates a soil distribution analysis depending with the elevation. The same thematic is zoomed out for Moldova (**Fig. 6**).

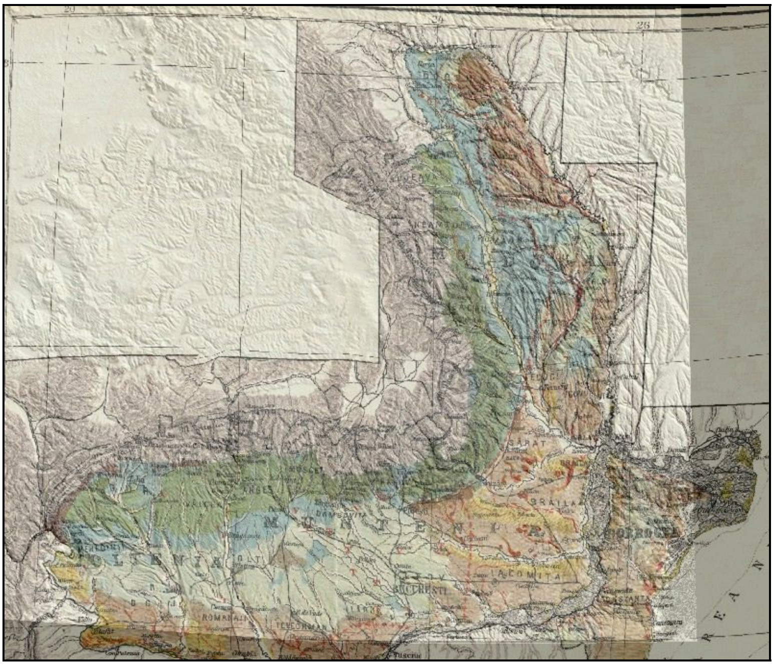

Fig. 3 The Agrogeological map of Romania (1909) laid over the greyscale DTM

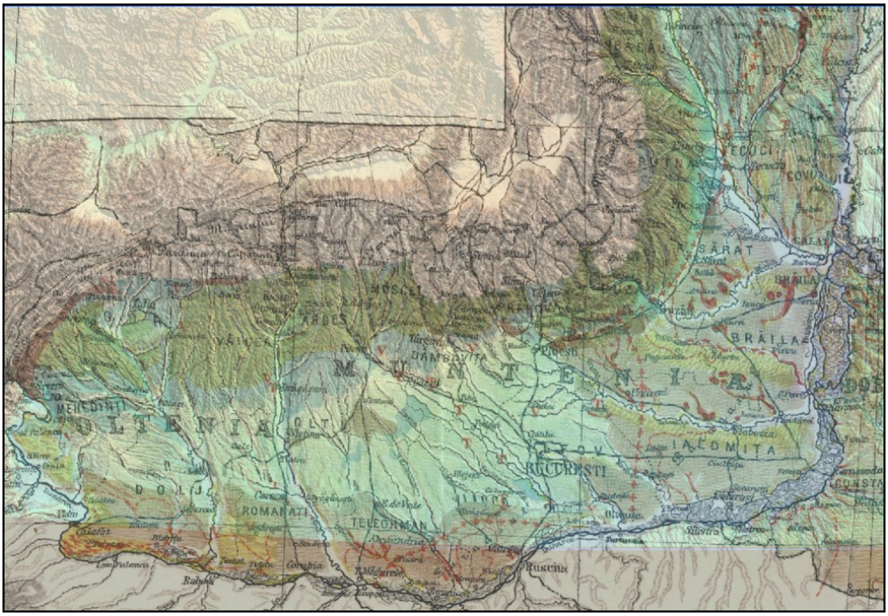

Fig. 4 The Agrogeological map of Muntenia (1909) laid over the greyscale DTM

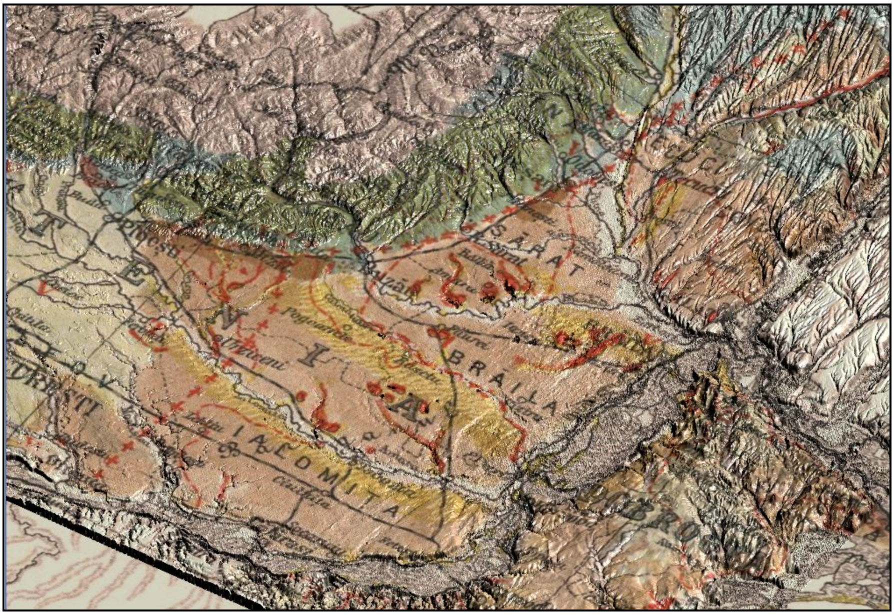

Fig. 5 The perspective view from SE of the Bărăgan plain and the adjacent hilly regions.

These electronic generated maps let us to create the 3D view of a region, which is presented on the **Fig. 5** where a South-Eastern view highlights the Bărăgan Plain with the soils and the geomorphological elements.

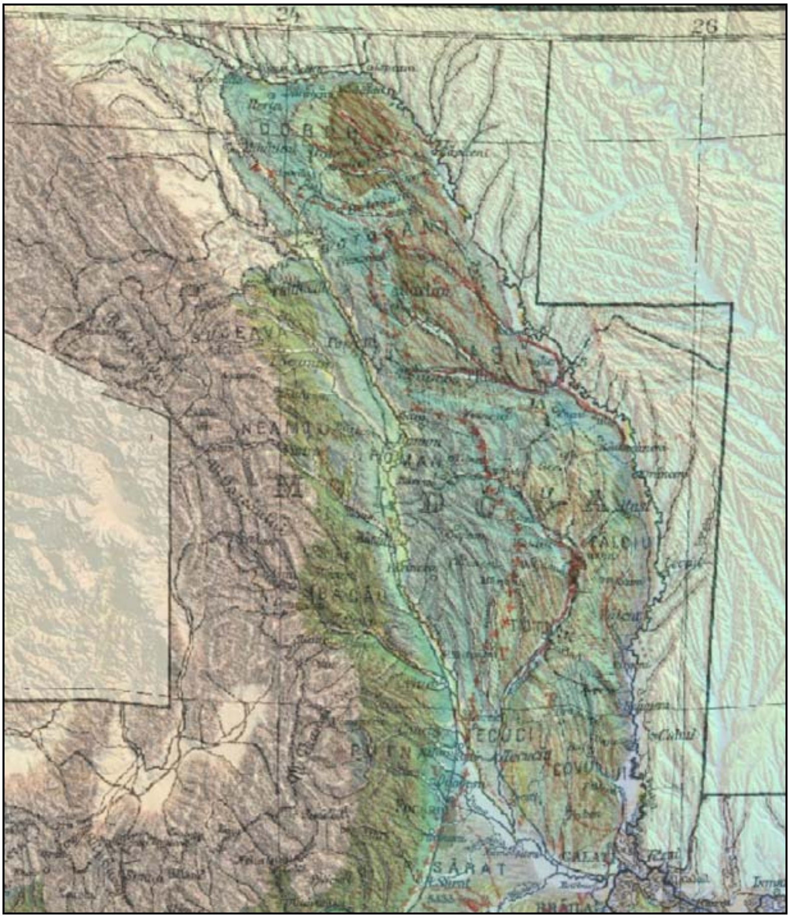

Fig. 6 The Agrogeological map of Moldova (1909) laid over the coloured DTM

We wonder if Dr. Murgoci should see this display, whether he would change his final conclusions?

For sure other starting point and other methods should they consider and use in a new Agrogeological Map compiling. In those over 100 years have been changed a lot. Irrigation activity and the intensive, so called "socialist" planned soil exploitation generated some changes. New effect appeared like soil property changes under influence of anthropically induced pollution from industrial pollution (non ferrous metallurgic industry, chemical industry) and agriculture (excessive fertilization and pesticides). The pedology became an individual science, research centre was found, which roots are coming from this historical Agrogeological map (http://www.asas.ro/istoric.html).

The extended drainage works in the territories in which the water excess appears in the rainy years have to be conceived. Thus the soil function as water reservoir presented moisture deficit in normal or dry years.

The implementation of irrigation works compensated the moisture deficit. The irrigation can generate a leaching of soluble components or of some colloids, an increase of the soil hidro-saline balance accompanied by the hazards of water excess formation, changing salinity, alkali minerals content or affecting the erosion.

4. CONCLUSIONS

The importance of the mentioned Agrogeological Map of Romania is someway linked to the importance of the 1st Agrogeological Congress from Budapest, and the just ended Year of Planet Earth:

- it was expressed that soil science has it's own community, terminology and methodology;
- defined – even nowadays – valid problems, and highlighted the actual risks and responsibilities;
- started and launches an international cooperation and mapping program;

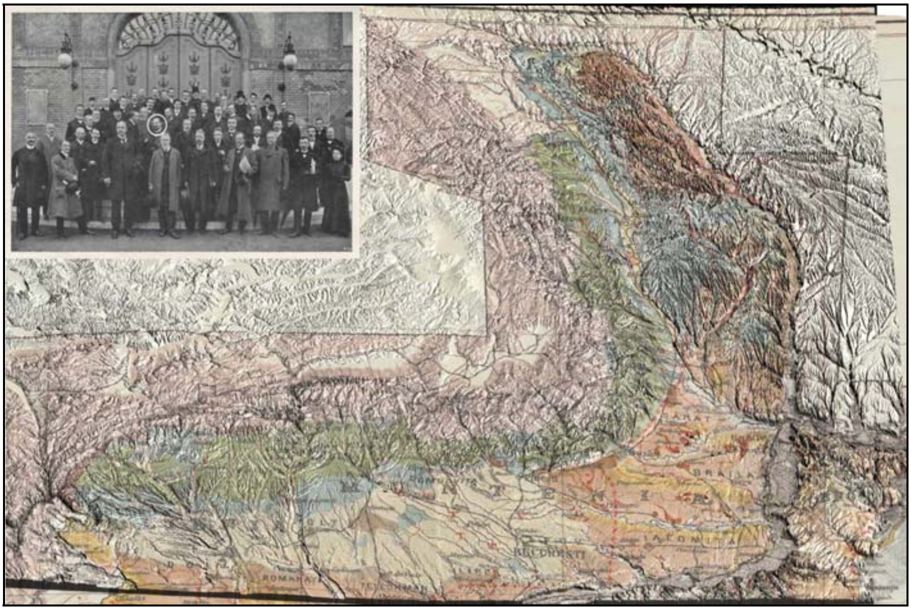

Fig. 7 A 3D view of the initial Agrogeological Map with an imbedded photo with the participants of the First Agrogeological Congress. The white circle marks the author of the map presented on this Congress

Unfortunately the premature death of Murgoci in 1925 didn't allow him to finish the European Soil Map, but finally it was edited in 1937 based on his initial ideas. This activity is followed, appreciated and reconsidered in the end of the international Year of Planet Earth.

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