Muzeul Olteniei Craiova. *Oltenia. Studii şi comunicări. Ştiinţele Naturii.* Tom. 27, No. 1/2011 ISSN 1454-6914

GEOSTATISTICAL ANALYSIS OF THE SPATIAL DISTRIBUTION OF AREAS AFFECTED BY CLIME CHANGE IN ROMANIA BASED ON 2100 PREDICTIONS

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Abstract. Clime change issues are at the order of the day due to their strong environmental and economic impacts. Among the methods used to predict their effects, the assessment of possible consequences of scenarios resulted from modelling clime processes play an important role. This paper summarizes the results of predicting via geostatistical tools the location of 'hotspots' with low precipitations and high temperatures in Romania. Their location suggests that mountain regions will be most affected, with the methodological limitation of delineating them only based on the altitude and the intrinsic limitations of the scenario.

Keywords: clime change, ordinary kriging, GIS modelling, geostatistics.

Rezumat. Analiza geostatistică a distribuţiei spaţiale a suprafeţelor afectate de schimbări climatice în România pe baza predicţiilor pentru 2100. Problemele legate de schimbările climatice sunt la ordinea zilei datorită impacturilor ecologice şi economice puternice. Printre metodele utilizate pentru a previziona efectele lor, evaluarea posibilelor consecinţe ale unor scenarii rezultate din modelarea proceselor climatice deţin un rol important. Această lucrare prezintă rezultatele predicţiei cu ajutorul metodelor geostatistice a locaţiei „punctelor fierbinţi" caracterizate de precipitaţii scăzute şi temperaturi ridicate din România. Localizarea lor sugerează că regiunile montane vor fi cele mai afectate, cu rezervele delimitării acestora doar pe baza altitudinii şi a limitelor intrinseci ale modelării.

Cuvinte cheie: schimbări climatice, kriging obişnuit, modelare SIG, geostatistică.

INTRODUCTION

Due to the strong environmental impact (loss of biodiversity and eco-diversity), economic impact and consequent effects on human communities, clime change constitutes a top priority of the science community, disregard of the discipline. Among issues related to clime change, the assessment of different scenarios, particularly related to the evolution of temperature and precipitations, plays an important role.

Clime change influences territorial systems through the modification of natural systems. The most important changes affect natural ecosystems directly and indirectly (BLENCKNER & CHEN, 2003; MARSHALL et al., 2008; PETRIŞOR, 2010; THOMAS, 2003). Impacts on agricultural systems include exposure to high temperatures, changes in the regime of precipitations, decrease of nutrients, exposure to fire, increased erosion due to the winds, and the dispersion of agricultural diseases and pests (Secretariat of the Convention on Biological Diversity, 2007; PETRIŞOR, 2010).

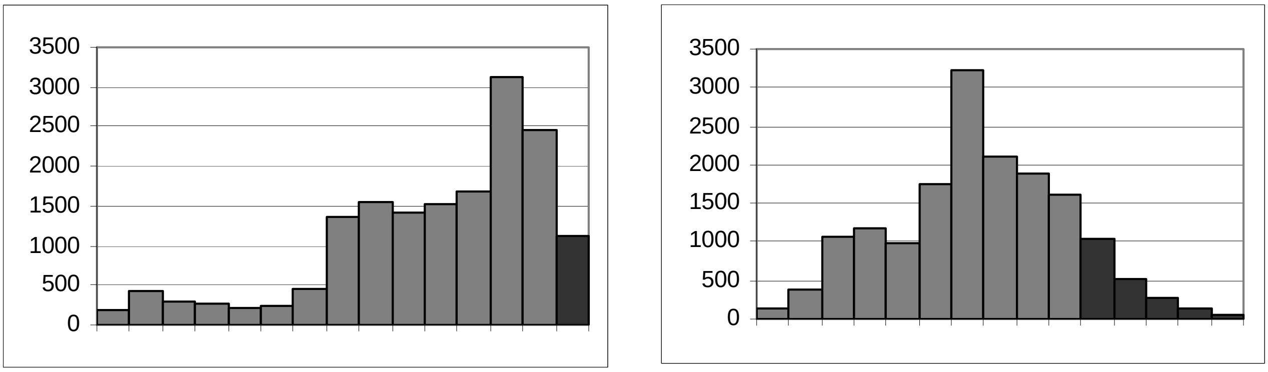
The study of such changes relies on the analysis of correlations between clime change and loss of biodiversity based on climatic and biological data (BLENCKNER & CHEN, 2003), micro-scale experiments based on the dynamics of species under modified precipitations or simulations of increased temperatures, identifying functional details regarding the tolerance of different clime types and long-term monitoring of the structure of communities correlated with clime variation (DUKES & MOONEY, 1999), and software-based models of the clime (DUKES & MOONEY, 1999; MALCOLM, 2003; SCHRÖTER et al., 2003; EPSTEIN et al., 1998; MARSHALL et al., 2008). Though statistical approaches are more appropriate for large systems and models for the spatial scale of a continent, intermediate analyses could be performed using the Geographical Information Systems, which are decision-support systems relying on the integration of spatially referenced information to resolve specific problems (COWEN, 1988), by spatially overlaying information layers.

Starting from the temperature and precipitation data published in a study by HIJMANS et al. (2005), reflecting the current situation, and in another study by GOVINDASAMY et al. (2003), reflecting 2100 clime predictions, this study aims to use geostatistical methods to depict on a map the regions most affected by high temperatures and low precipitations in Romania.

MATERIALS AND METHODS

The study uses two data sets, presented in the introduction, freely available from the University of Berkeley (current values can be found at http://biogeo.berkeley.edu/worldclim/diva/diva_worldclim_2-5m.zip and predictions at http://biogeo.berkeley.edu/worldclim/diva/diva_wc_ccm3_2-5m.zip) in a DIVA-GIS format (HIJMANS et al., 2001). Current data are an output of the WorldClim project (HIJMANS et al., 2005), and 2100 predictions are based on double CO_2 concentrations and the CCM3 model (HIJMANS et al., 2005). Both temperature and precipitation data were used to compute the difference between actual and predicted values for each 2.5 min × 2.5 min cell of the data grid. Due to the format, data had to be imported ArcView GIS 3.X, projected to Stereo 1970, and clipped for the Romanian boundaries.

The statistical analysis consisted of looking at the distribution based on analysing a histogram built using Sturges' formula to compute the length of the interval, ic: $ic \approx (x_{max} - x_{min})/(1+10/3\times\log_{10}N)$, where N is the sample size, and x_{max} and x_{min} are maximum, respectively minimum values of the series (DRAGOMIRESCU, 1998). The extreme intervals were chosen so that they would cover not more than 10% of the total and contain almost the same share of temperature and precipitations values. Based on these considerations, the discrimination limits were chosen (Fig. 1): high temperatures are those corresponding to an increase of at least 2.6869^0C compared to actual values, while low precipitations correspond to a decrease of at least 61.6667 cm^3/year compared to actual values. In both cases, the extremes represent 6.8% of all temperatures, respectively precipitations.



Temperature: 2.6869^0C (6.80%) Precipitations: 61.6667 cm^3/year (6.76%)
Temperatură: $2{,}6869^0$C (6,80%) Precipitații: 61,6667 cm^3/an (6,76%)

Figure 1. Intervals with extreme temperature and precipitation values determined based on histograms such that no more than 10% of the values are included, and include almost the same share of temperature and precipitations values.
Figura 1. Intervale cu valori extreme ale temperaturii şi precipitațiilor stabilite pe baza histogramelor, astfel ca acestea să nu reprezinte mai mult de 10% din total şi să fie comparabile pentru temperatură şi precipitații.

To identify the regions most affected by high temperatures and/or low precipitations, compared to the actual values, two methods were used.

1. “Ordinary kriging” prediction – method assuming that the average of a random variable is unknown and constant, and its random fluctuations depend only on the position of the sampling stations. The mathematical model is: $Z(s) = \mu + \varepsilon(s)$, where μ is unknown and constant (JOHNSTON et al., 2001). To apply the method, each 2.5 min × 2.5 min cell was reduced to its centre, preserving the temperature and precipitation values of the original area, and subsequently all these values were interpolated.

2. GIS modelling started from the fact that each resolution unit (2.5 min × 2.5 min) has the same area, therefore the number of such units per county reflects the share of area affected, indicating the size of impact. The mathematical model relies on counting the cells by (1) clipping them upon the administrative boundaries, (2) dissolving their limits within each county in order to count them, and (3) assign the value to each county. Following some conversions required by modelling (vector to raster, reclassification), temperature and precipitation data were overlaid with equal weights, *i.e.*, 50% (Fig. 2).

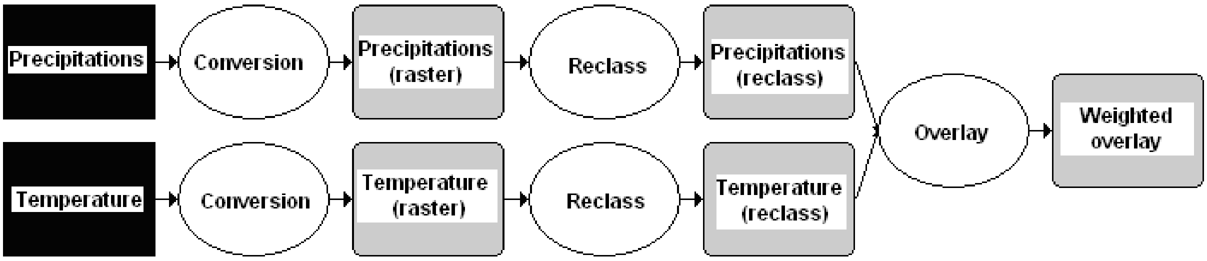


Figure 2. Model for the GIS-based assessment of the exposure to high temperatures and low precipitations in Romanian counties.
Figura 2. Model de evaluare a expunerii la temperaturi ridicate şi precipitații scăzute a județelor României în Sistem Informațional Geografic.

RESULTS AND DISCUSSIONS

The results of statistical analysis indicate that high temperatures would affect mountain regions of the Eastern Carpathians, especially the north (Maramureş County) and south (Vrancea County), while low precipitations would occur in the Southern Carpathians, extending to the south in Oltenia (Fig. 3). Ordinary kriging predictions confirm the results, but restrain the affected area to the Southern Carpathians (Fig. 4). GIS modelling based on the areas equally affected by high temperatures (Fig. 5) and low precipitations (Fig. 6) within each county (Fig. 7) pinpoints two average risk areas, one situated in Maramureş County and another spanning from the centre of Romania to the South. All results suggest that predicted changes would affect mostly the mountain area, resulting into increased temperatures and/or reduced precipitations.

Of particular importance is in this context the situation depicted in figures 3 and 4. The images suggest that species from the mountain areas, more vulnerable to clime changes (PETRIŞOR, 2010) could be threatened, regardless of their inclusion into natural protected areas covering extensively the same regions (PETRIŞOR, 2009). Plant species can suffer first, since physiological dryness is a characteristic of the mountain areas (MALCOLM, 2003; SCHRÖTER et al., 2003).

The next three figures (5; 6; 7) indicate the counties potentially most affected by clime changes. Both northern and southern counties potentially exposed to the stress due to high temperatures and low precipitations host important habitats and species, including European Union Priority Habitats and Red List species (CONDÉ & RICHARD, 2008). For this purpose, many protected areas were declared, but protection could be ineffective to the impacts induced by clime change (PETRIŞOR, 2009).

Methodological limitations are related by the assumptions involved by clime predictions, but also to the kriging technique, since the locations used in extrapolation are not uniformly dispersed within the extrapolation area. Questions could address the simplified classification of landforms based on the altitude, resulting into a geomorphologic misclassification of units (*e.g.*, high plateaus are classified as mountains, while low mountains, such as those in Dobrudja, are classified as plateaus).

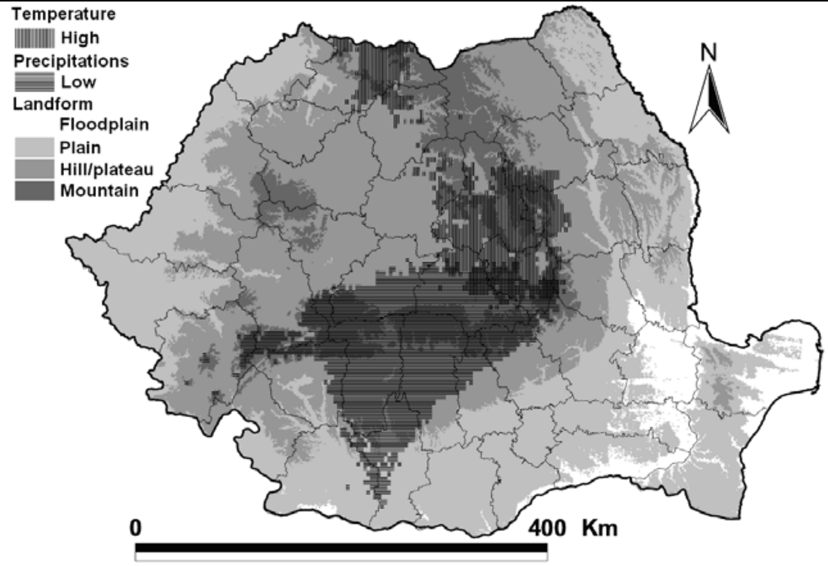


Figure 3. Location of areas possibly affected by high temperatures and/or low precipitations according to 2100 clime predictions based on landform, determined based on the altitude.
Figura 3. Localizarea exactă a regiunilor posibil afectate de temperaturi ridicate şi/sau precipitaţii scăzute conform predicţiilor climatice pentru anul 2100 în funcţie de relief, determinat pe baza altitudinii.

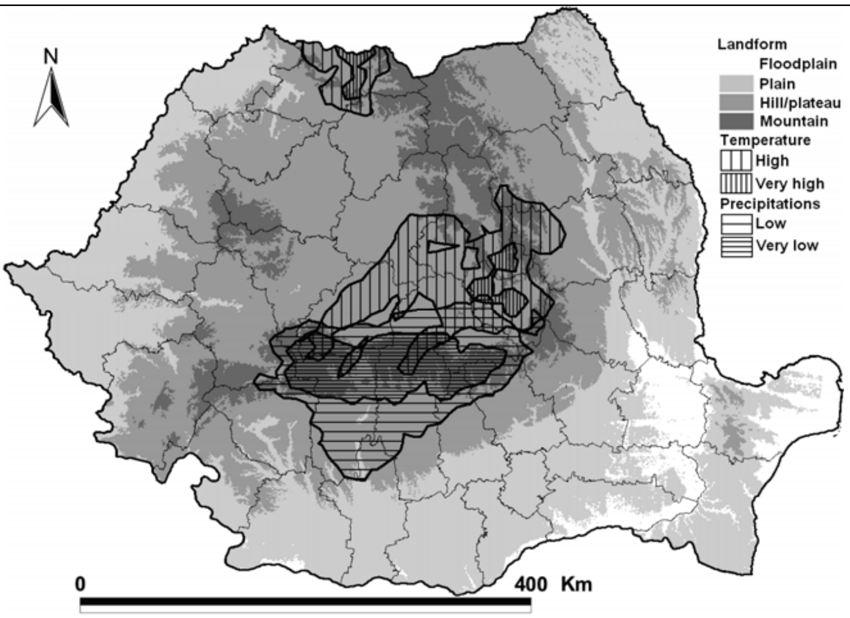


Figure 4. Predicted location of areas possibly affected by high temperatures and/or low precipitations according to 2100 clime predictions based on landform, determined based on the altitude.
Figura 4. Hartă de predicţie a localizării regiunilor posibil afectate de temperaturi ridicate şi/sau precipitaţii scăzute conform predicţiilor climatice pentru anul 2100 în funcţie de relief, determinat pe baza altitudinii.

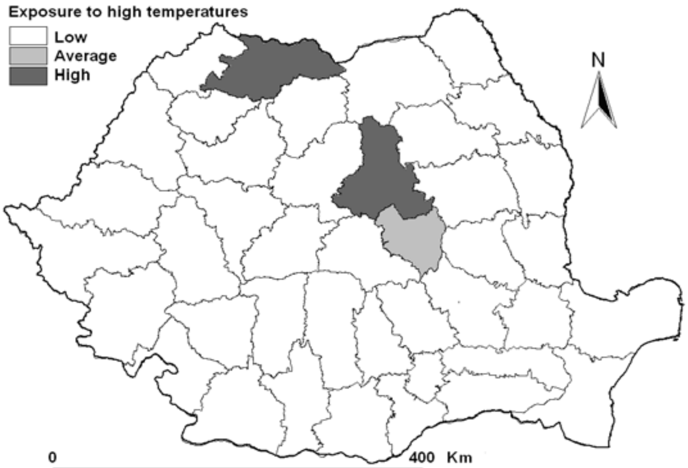


Figure 5. Location of counties possibly affected by high temperatures according to 2100 clime predictions.
Figura 5. Localizarea judeţelor posibil afectate de valori ridicate ale temperaturii conform predicţiilor climatice pentru anul 2100.

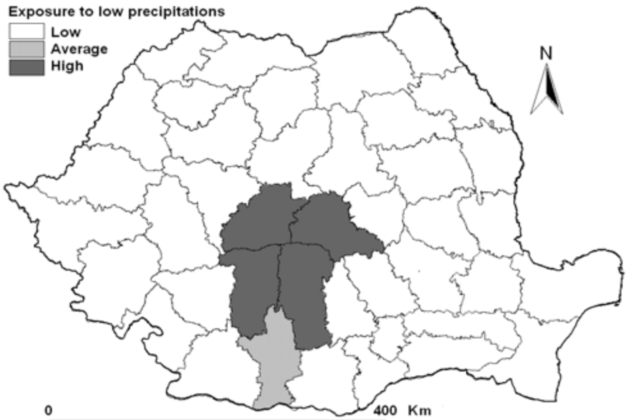


Figure 6. Location of counties possibly affected by low precipitations according to 2100 clime predictions.
Figura 6. Localizarea judeţelor posibil afectate de valori scăzute ale precipitaţiilor conform predicţiilor climatice pentru anul 2100.

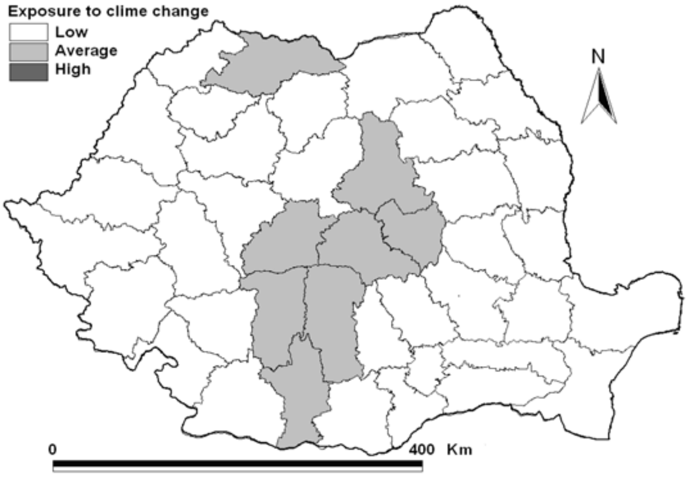


Figure 7. Location of counties possibly affected equally by high temperatures and low precipitations according to 2100 clime predictions.
Figura 7. Localizarea judeţelor posibil afectate în mod egal de valori ridicate ale temperaturii şi de valori scăzute ale precipitaţiilor conform predicţiilor climatice pentru anul 2100.

CONCLUSION

The location of the critical areas characterized by low precipitations and/or high temperature according to the 2100 prediction for Romania suggests that mountain regions will be most affected, with the methodological limitations related to their delineation based only on the altitude and the intrinsic limitations of the clime scenario.

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Received: March 2, 2011
Accepted: July 28, 2011