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GIS-BASED ASSESSMENT OF THE DISTRIBUTION OF 2100 PREDICTED CHANGES OF PRECIPITATIONS AND INFLUENCE ON BIODIVERSITY AND NATURAL PROTECTED AREAS IN ROMANIA

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Abstract. Due to the environmental effects, clime changes constitute an important issue, particularly the assessment of their potential effects under different scenarios. This study considers the predictions for 2100 based on 2×CO_2 concentration and the CCM3 model and attempts to investigate the effects over the Romanian territory, including the spatial distribution of high, average, and low differences between predicted and actual values by landforms, eco-, bio- and geodiversity as defined by the biogeographical regions and land use, and natural protected areas. The results indicate that the highest differences occur over the central and southern part of the territory, affecting a large part of the mountain area and important agricultural areas, as well as the natural protected areas situated at high altitudes.
Key words: clime changes, ecodiversity, geodiversity, biodiversity, natural protected areas

INTRODUCTION

Clime change represent an important issue for the scientific community, regardless of the specific field, due to their environmental effects (loss of eco-, bio- and geodiversity), and impacts on the economy and human communities. Among the subjects, the assessment of particular scenarios related to changes of temperature and precipitations have a central place. Among them, of particular importance are the impacts on eco-, bio- and geodiversity. In this study, all the three concepts, eco-, bio- and geo- diversity refer to the diversity of the environment; both eco- and geo- diversity cover the macro-scale, while biodiversity characterizes at the micro-scale both natural and anthropic or anthropized systems (Ianoş, 2000; Vădineanu, 2004). The most studied effects are those on natural systems. Plants and animals are affected by the change of their habitats (Condé and Richards, 2008), interactions (Marshall *et al*., 2008), distribution, extinction rates, and reproduction or growth periods (Secretariat of the Convention on Biological Diversity, 2007). Nevertheless, some of the effects appear to favor invasive species (Dukes, 2003; Dukes and Mooney, 1999). Impacts on the ecosystems are hardly predictable; however, different studies analyzed the influence of transport vectors (Marshall *et al*., 2008), increased fragmentation of habitats (Thomas, 2003) or the effects of modified regional circulation on the local processes (Blenckner and Chen, 2003). Many changes affect alpine ecosystems (Condé and Richards, 2008) by reducing the areas occupied by characteristic species or by the loss of these species (Secretariat of the Convention on Biological Diversity, 2007). Global trends concerning glaciers, plants and insect exhibit outstanding fluctuations at high altitudes (Epstein *et al*., 1998). The impacts on agro-ecosystems include the exposure to heat stress, changes of the precipitation regime, decrease of nutrients, fires, increased erosion due do the winds, and dispersion of diseases and pests (Secretariat of the Convention on Biological Diversity, 2007). The methodology used to analyze the relationship between climate change and the loss of biodiversity include statistical correlation analyses of clime and biological data (Blenckner and Chen, 2003), micro-scale experiments based on the analysis of the dynamics of species under simulated modified precipitation or temperature regimes, identification of functional features related to the tolerance to different clime types, long term monitoring of the specific structure of communities due to clime variations (Dukes and Mooney, 1999), and clime models based on different software (Dukes and Mooney, 1999; Schröter *et al*., 2003; Epstein *et al*., 1998; Marshall *et al*., 2008). Even though the statistical approach is appropriate for smaller systems and clime models correspond to the continental scale, intermediate levels were analyzed using the Geographical Information Systems (GIS), defined as decision support systems based on the integration of spatially referenced data for resolving specific problems (Cowen, 1988). Starting from the current data on precipitations published in 2005 (Hijmans *et al*., 2005) and clime predictions for 2100 (Govindasamy *et al*., 2003), this study aims to identify the spatial distribution of areas affected by the decrease of precipitations and potential effects on biodiversity and natural protected areas.

MATERIALS AND METHODS

This study integrated five datasets, summarized in Table 1:

(1 and 2) Climate data consist of global current (1) and predicted (2) temperatures. In addition, we computed the difference between actual and predicted average temperatures for each raster cell. The analysis of differences indicated that within the Romanian territories

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all values were positive, ranging between -27 and 106 mm. Consequently, we defined three classes to describe the range of temperature differences: low (-27 - -3 mm), average (-2 - 22 mm), and high (23 - 106 mm). (3) Landforms: the main methodological issue was related to the definition of landforms by altitude. This study utilizes the following limits of the landforms: floodplain - 0 to less than 20 m, plain - 0 to less than 200 m, hill or plateau - 200 to less than 900 m, and mountain - over 900 m (Petrişor, 2009). (4) Land cover and use data: we used the first level of this classification, defining five land cover classes: artificial surfaces, agricultural areas, forests or seminatural areas, wetlands, and water bodies (Commission of the European Communities, 1995).

(5) Biogeographical regions: five of the twelve regions identified in Europe are present in Romania: Continental, Steppic, Alpine, Pannonian, and Black Sea. (6) Data on natural protected areas from Romania contain information on the following types: (a) scientific reserves, natural reserves and natural monuments, (b) national parks and natural parks (biological), (c) Sites of Community Importance, (d) Special Areas of Conservation, (e) Special Protection Areas, and (f) area where the Convention on the Protection and Sustainable Development of the Carpathians is applied, even though the latter cannot be considered a natural protected area in the true meaning of this concept, as protective actions are only recommended, but not compulsory within its perimeter. Categories (c), (d), and (e) were established through the Natura 2000 Programme of the European Union.

Table 1.

Specifications on the data used in the study: dataset, provider, location, format, remarks and transformations.

No.	Dataset	Provider	URL	Format	Remarks	Transformations
1	Climate - actual	University of Berkeley	http://biogeo.berkeley.edu/worldclim/diva/diva_worldclim_2-5m.zip	DIVA-GIS software (Hijmans *et al*., 2001)	Produced by the project WorldClim (Hijmans *et al*., 2005); 2.5 min × 2.5 min	Imported in ArcView GIS 3.X, project into Stereo 1970, subsample for Romania
2	Climate - predicted	University of Berkeley	http://biogeo.berkeley.edu/worldclim/diva/diva_wc_ccm3_2-5m.zip	DIVA-GIS software (Hijmans *et al*., 2001)	Predictions for 2100 based on 2×CO_2 concentration and CCM3 model (Govindasamy *et al*., 2003); 2.5 min × 2.5 min	Imported in ArcView GIS 3.X, project into Stereo 1970, subsample for Romania
3	Land-form	Consultative Group on International Agricultural Research - Consortium for Spatial Information	http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp	Digital Elevation Model (DEM)	Nearly 90 m × 90 m	Import into Arc GIS, then export to ArcView GIS 3.X, project into Stereo 1970, subsample for Romania
4	Land cover and use data	CORINE (Coordinated Information on the European Environment) Land Cover 2000 (CLC2000) seamless vector database	http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=950	ArcView GIS 3.X	2000 data	Project into Stereo 1970, subsample for Romania
5	Biogeo-graphical regions	European Environment Agency data services	http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=308	ArcView GIS 3.X	2001 data	Project into Stereo 1970, subsample for Romania
6	Natural protected areas	Romanian Ministry of the Environment and Sustainable Development	http://www.mmediu.ro/departament_ape/biodiversitate/	ArcView GIS 3.X	Not all types of protected areas legally defined are available	No transformation needed

The statistical analysis of the distribution of values has been based on their histograms, produced using an Excel plug-in called Histo (Dragomirescu *et al*., 2003). Ordinary kriging, method assuming that the fluctuations of a variable depend only on the spatial distribution of sampling stations (Johnston *et al*., 2001), was used to pinpoint the areas with high temperatures and low precipitations in 2100. Each 2.5 min × 2.5 min area was reduced to its center, preserving the temperature and precipitation values, and the centers were interpolated via ordinary kriging.

The datasets were overlaid for a visual and quantitative analysis of information. Quantitative analyses consisted of using GIS spatial analysis and geo-processing functions to compute areas of specific classes describing the overlapping of the three temperature intervals and either landforms, biodiversity, or natural protected areas. In addition, we computed:

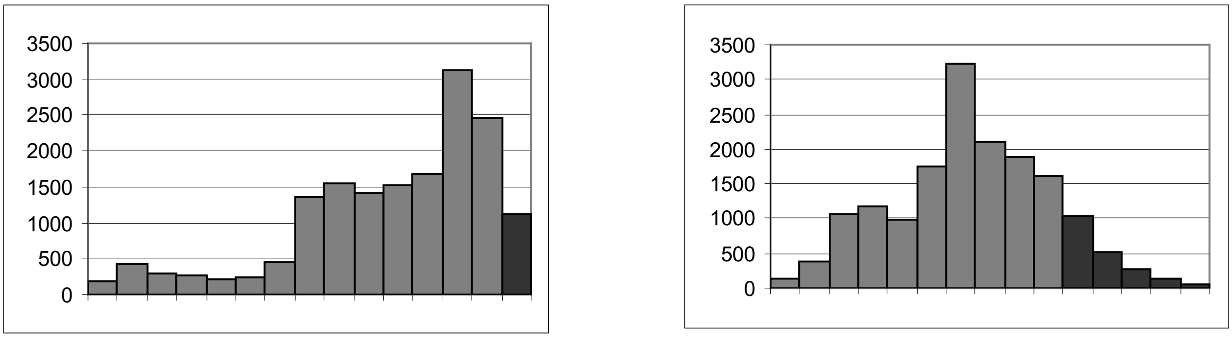
(a) the percentage represented by each combination between the temperature interval and class of specific feature from all temperature intervals, to pinpoint which temperature intervals have more influence on specific feature classes, and

(b) the percentage represented by each combination between the temperature interval and class of specific feature from all feature classes, to analyze which feature classes are more impacted by a certain temperature interval.

RESULTS AND DISCUSSION

The results are presented in Tables 2 and 3 and in Figures 1 through 5. The first two figures refer to both temperature and precipitations; Figure 1 displays the histograms indicating the statistical distribution of values, highlighting the highest differences, represented by different intervals, chosen so that the percentage of the highest values is comparable for temperatures and precipitations and does not exceed 10%. Based on these values, Figure 2 displays "hotspots" affected by very high temperatures, very low precipitations, or both, identified based on spatial prediction via ordinary kriging.

Table 2 displays the distribution of low, average, and respectively high differences between actual and predicted average precipitations by landforms, land cover classes, biogeographical regions, and types of natural protected area. Table 3 displays information from a reverted perspective, looking at the influence of the classes of differences between actual and predicted average precipitations on each type of landform, land cover class, biogeographical region, and type of natural protected area. Figure 4 displays the results of the analyses of the spatial distribution of low, average, and high differences between the predicted and actual precipitations based on the landform, Figure 5 displays the spatial relationship between precipitation predictions and biodiversity, assessed by using the first level of CORINE land cover, and Figure 6 displays the potential impact of decreased average precipitations on existing natural protected areas.



Temperature limit: 2.6869⁰C (6.80%)   Precipitation limit: 61.6667 mm (6.76%)

Figure 1. Intervals of extremely high temperatures or extremely low precipitations, chosen so that they are comparable and do not contain more than 10% of all values.

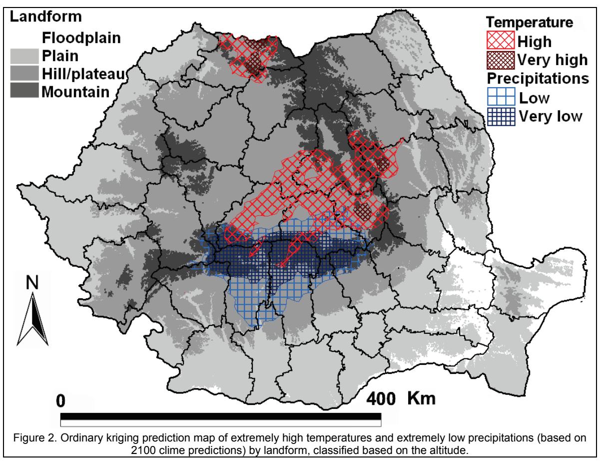


Figure 2. Ordinary kriging prediction map of extremely high temperatures and extremely low precipitations (based on 2100 clime predictions) by landform, classified based on the altitude.

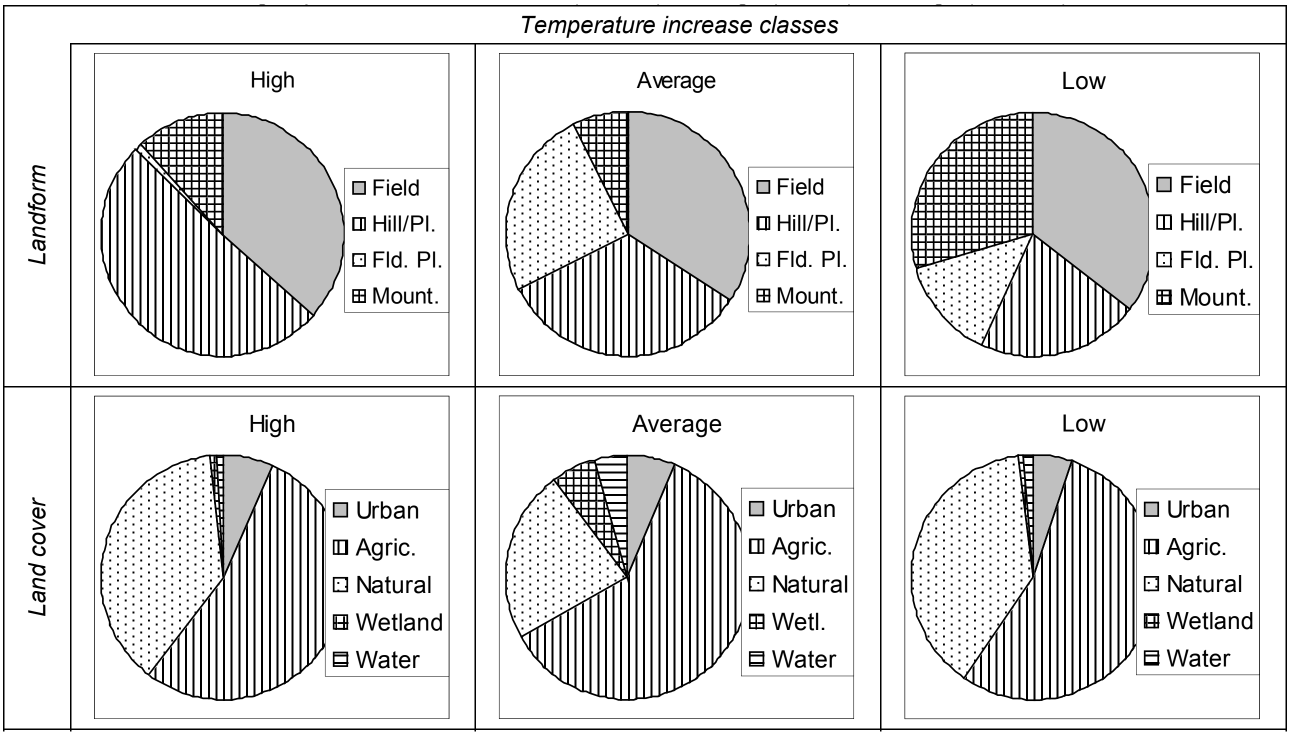
Our findings suggest that predicted precipitation changes, reflected by positive differences between the predicted and actual average values, are not distributed uniformly over the Romanian landforms (Tables 1 and 2 and Figure 4). The highest precipitation differences occurred mostly in the hill areas (50.67%), average differences in the field and hill or plateau (circa 34% each), and low differences characterized field and mountain area (35.44, respectively 29.41). With respect to the landform, floodplains were dominated by average differences (71.16%), plains by high differences (74.40%), hills or plateaus by high differences (82.33%), and mountains by high differences (69.43%).

The impact on biodiversity can be assessed by looking at the relationship between predicted precipitation differences and diversity assessed using the land cover and biogeographical regions (Tables 1 and 2 and Figure 5). In the first case, high, average, and low differences affected the agricultural surfaces (53.55%, 60.52%, and, respectively 54.71%), while high differences impacted the urban, agricultural, and natural surfaces (74.71%, 70.41% and, respectively, 78.30%) and average differences were found in wetlands and water areas (66.59% and 52.61%). With respect to the biogeographical region, high differences were expected in the Continental region (68.04%), average differences in the Steppic region (40.35%), and low differences in the Steppic and Alpine regions (42.57% and 44.56%).

The Continental, Alpine, and Pannonian regions are characterized by high differences (89.79%, 64.62% and, respectively, 84.35%), and the Steppic region was situated within the average differences range (47.64%), and the Black Sea region within average and low differences (51.07%, respectively 48.93%). Finally, the analysis of the potential impact of predicted temperature differences on the natural protected areas, summarized in Tables 1 and 2 and displayed in Figure 6, indicated that high differences affected all types of natural protected areas (50.39% to 75.65%). With respect to the difference, high and low values were found in the area under the Convention on the Protection of the Carpathians (52%, respectively 50.76%), and average differences in the Sites of Community Importance (27.36%), Special Areas of Conservation (25.09%), and the area under the Convention on the Protection of the Carpathians (26.47%).

Table 2.

Distribution of low, average, and respectively high differences between actual and predicted average temperature by landforms (field, hill or plateau - Hill/Pl., floodplain - Fld. Pl., and mountain - Mount.), land cover classes, biogeographical regions, and types of natural protected area - scientific and natural reserves and natural monuments (Res.), national and natural parks (Park), Sites of Community Importance (SCI), area under the Convention on the Protection of the Carpathians (C. C.), Special Protection Areas (SPA), and Special Areas of Conservation (SAC). Precipitation differences are grouped in three classes: low (-27 - -3), average (-2 - 22), and high (23 - 106).



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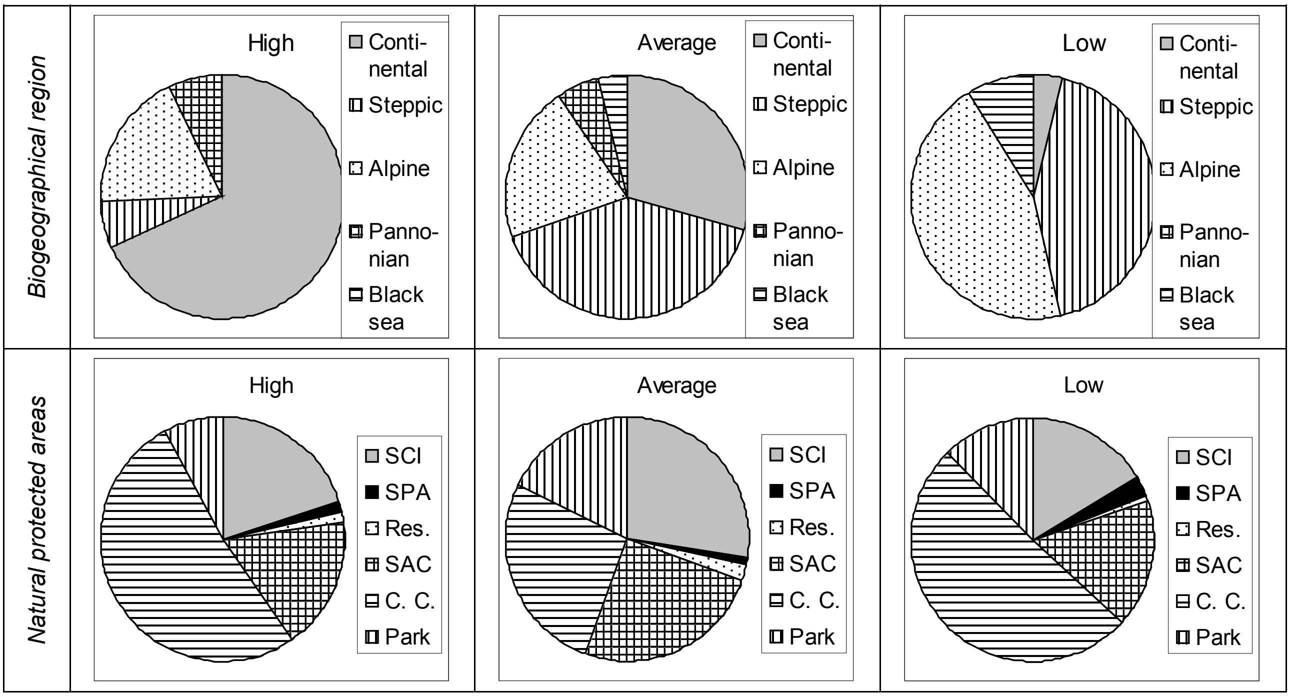
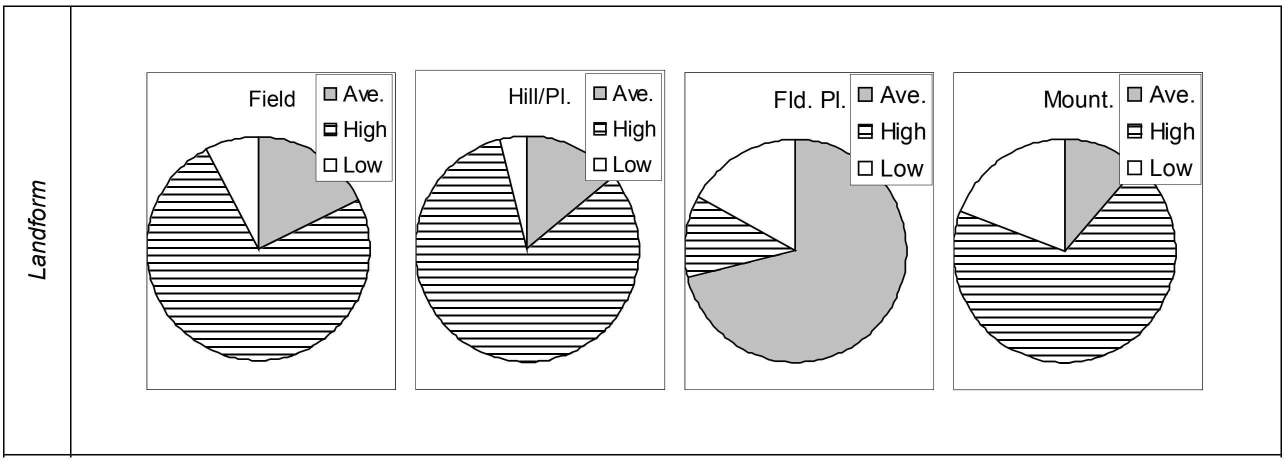


Moreover, since most of the Romanian territory is covered by agricultural surfaces, the influence of low precipitations on floodplains, hills/plateaus and plains, and on agricultural surfaces (Tables 1 and 2) will most likely result into a decrease of the agricultural production (consistent with the results published by the Secretariat of the Convention on Biological Diversity, 2007) and would potentially affect the entire economy.

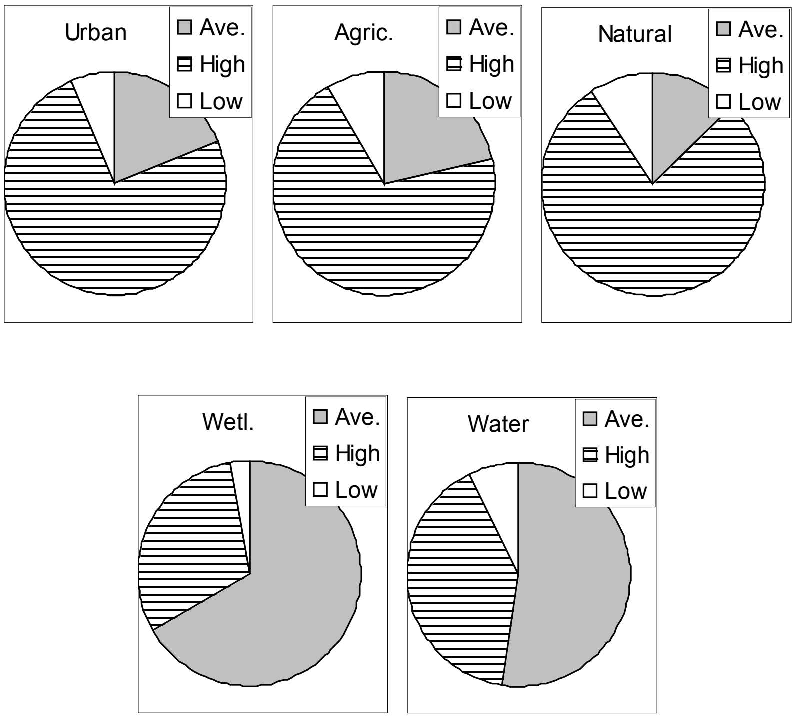
Overall, the evolution of average precipitations in Romania suggests a decreasing trend. Our results, consistent with the findings of Condé & Richard (2008) and the Secretariat of the Convention on Biological Diversity (2007), also indicate that the highest precipitation differences will occur in the mountain areas (Figure 3), situated in the Alpine and Continental biogeographical regions (Figure 5) and covered in majority by forests or seminatural areas and agricultural surfaces (Figure 4). Since most of the Romanian natural protected areas are situated at high altitudes (the percentage ranged from 55% for SACs to 93% for SPAs, excluding the area where the Convention on the Protection and Sustainable Development of the Carpathians is applied, situated exclusively at high altitudes - Petrişor, 2009), the additional pressure due to climate changes will significantly threaten the existing natural protected areas.

Table 3.

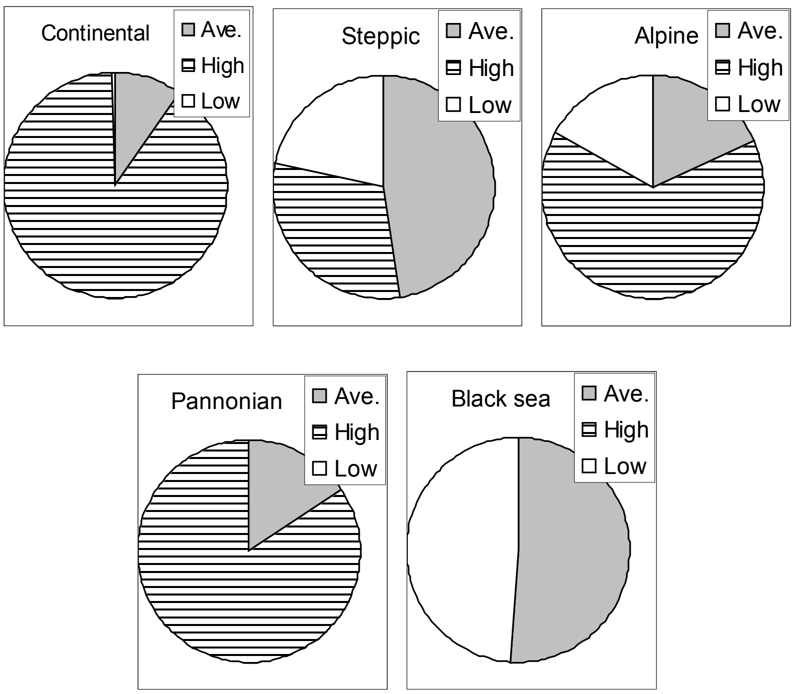
Influence of the classes of differences between actual and predicted average temperature on each type of landform (field, hill or plateau - Hill/Pl., floodplain - Fld. Pl., and mountain - Mount.), land cover class, biogeographical region, and type of natural protected area - scientific and natural reserves and natural monuments (Res.), national and natural parks (Park), Sites of Community Importance (SCI), area under the Convention on the Protection of the Carpathians (C. C.), Special Protection Areas (SPA), and Special Areas of Conservation (SAC). Precipitation differences are grouped in three classes: low (-27 - -3), average (-2 - 22), and high (23 - 106).

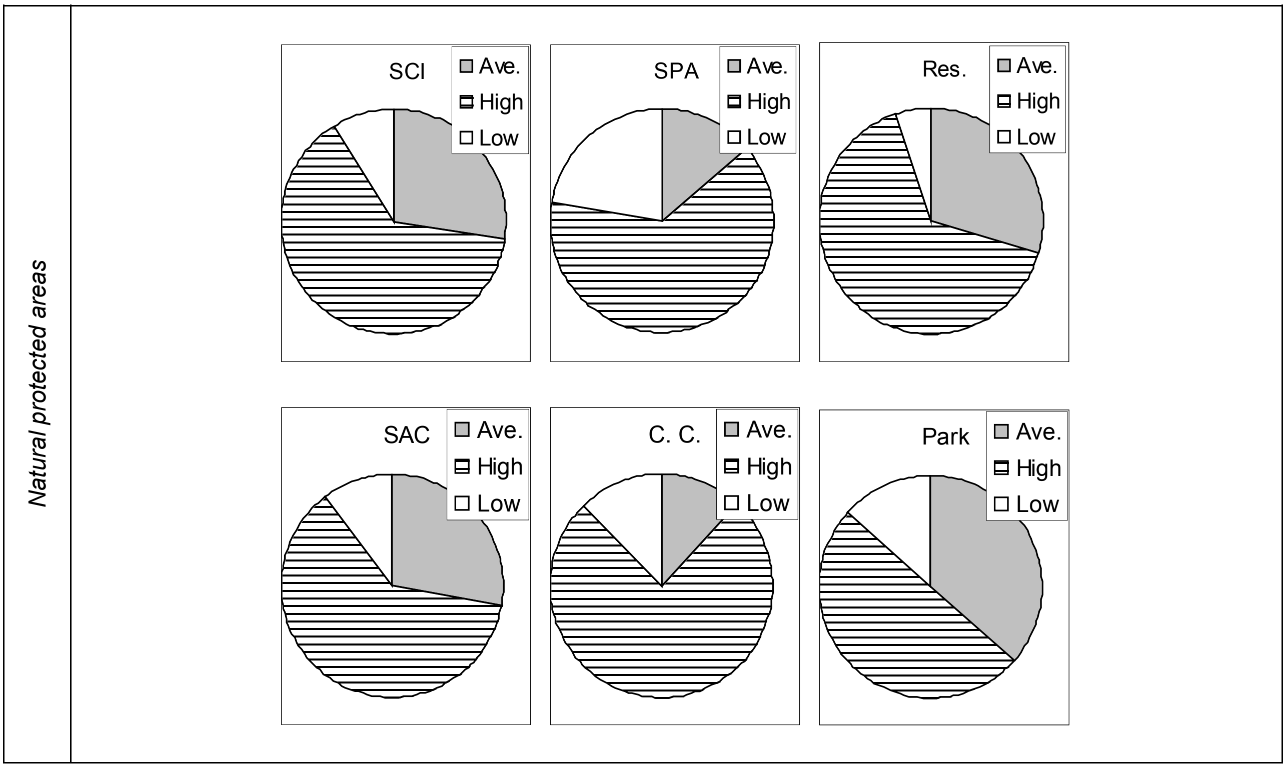


Land cover



Biogeographical region





The methodological limitations are first of all due to the underlying assumptions of clime predictions, but also due to the simplified classification of landforms based on altitude, that could result into an erroneous classification of high plateaus as mountains or of low altitude mountains (in Dobrudja) as field or plateau.

CONCLUSIONS

In summary, findings indicate that predicted precipitation changes for 2100 could possibly affect the biodiversity of Romania. Most important changes will occur in the mountain regions that are already a priority on the European environmental agenda. Other changes will occur in the continental region, which could result into the desertification of some parts of it; these changes will lead to economic consequences due to the presence of important agricultural areas. However, the later statement should be interpreted with the caveats of the predictions. Last but not least, the changes are likely to affect natural protected areas, especially those situated at higher altitudes.

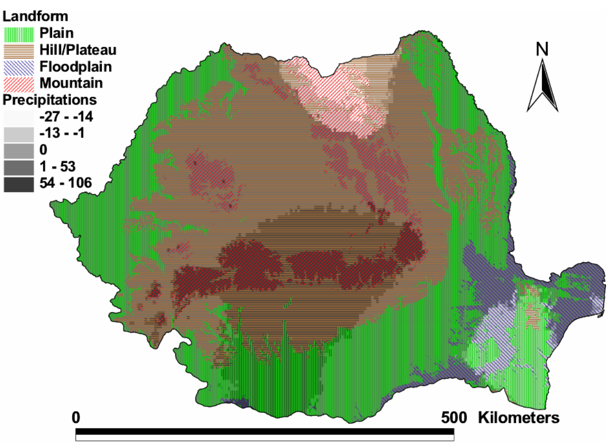


Figure 3. Distribution of 2100 predicted temperature increase by landform in Romania. The magnitude of temperature differences is displayed using gray shades; darker shades indicate higher values, suggesting an important increase of the average temperature.

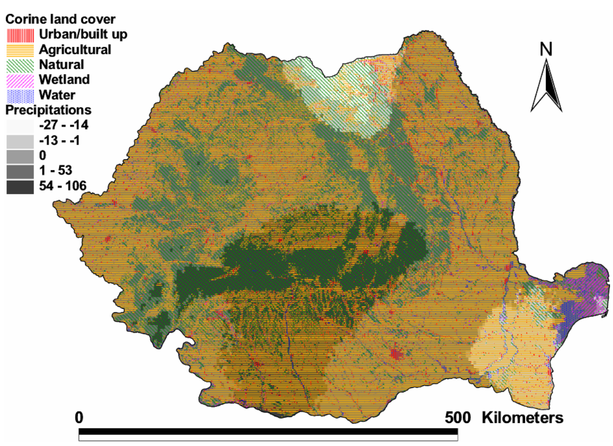


Figure 4. Distribution of 2100 predicted temperature increase by land cover in Romania. The magnitude of temperature differences is displayed using gray shades; darker shades indicate higher values, suggesting an important increase of the average temperature.

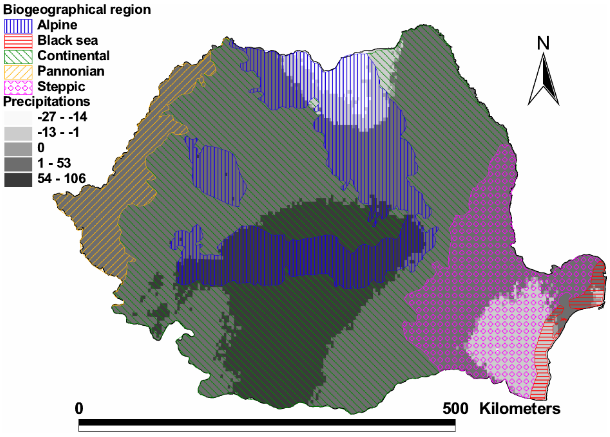


Figure 5. Distribution of 2100 predicted temperature increase in the Romanian biogeographical regions. The magnitude of temperature differences is displayed using gray shades; darker shades indicate higher values, suggesting a significant increase of the average temperature.

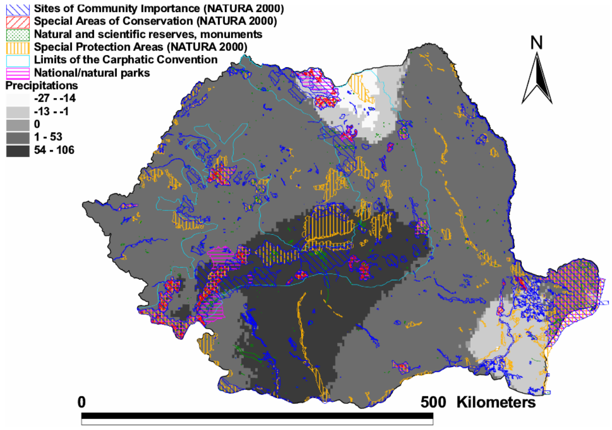


Figure 6. Distribution of 2100 predicted temperature increase in the Romanian natural protected areas. The magnitude of temperature differences is displayed using gray shades; darker shades indicate higher values, suggesting a significant increase of the average temperature.

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