ASSESSMENT OF ROMANIAN ALPINE HABITATS SPATIAL SHIFTS BASED ON CLIMATE CHANGE PREDICTION SCENARIOS

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Key-words: Climate Change, MAXENT, DIVA-GIS, ecosystems distribution, high priority habitats, data sharing, enviroGRIDS.

Shifts in the ecosystems distribution as the result of climate change are of interest for decision-makers in biodiversity conservation at local and European level. This paper presents the use of modeling technique, Maxent (Maximum entropy modeling) and BIOCLIM (environmental envelope model), to estimate the impact of climate change on the Alpine bioregion of Continental Europe for improving the management policy in support of stopping biodiversity loss. The European Union priority habitat 6230 occurring in mountain areas and sub-mountain areas of the Carpathians was selected for modeling being of high priority conservation status in the Natura 2000 network of protected area.

Maxent and BIOCLIM were used to create spatial distribution models for Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures. Models were run with 1950–2000 averaged bioclimatic data and double atmospheric CO_2 concentration scenario in perspective of the year 2050. In our analyses we have included once all 6320 mapped habitat with Nardus grasslands. Under 1950–2000 climate scenario, both models exhibited high AUC values (> 0.9). The predicted geographical distribution of Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures coded as VNG and PON habitat modeled by Maxent and BIOCLIM shows differences between the modeling approaches, with Maxent predicting smaller areas (12% less) of suitable habitat than BIOCLIM. For the future climate scenario (double CO_2) the surface with PON+VNG decreases by 31% for Maxent and 26% for BIOCLIM. However both models show significant shifts of the *Nardus* habitat due to climate change.

The distribution maps obtained indicate vulnerability areas to biodiversity loss and of interest to be monitored. The output of models will contribute to the Black Sea Catchment Observation Systems to be further accessible to scientists, decision-makers and the general public.

1. INTRODUCTION

Prediction and mapping of potential suitable habitat for threatened and endangered species is critical for monitoring and restoration of their declining native populations in their natural habitat, artificial introductions, or selecting conservation sites, and conservation and management of their native habitat (Gaston, 1996, Guisan et al., 2002, Overton et al., 2002, Thuiller, 2004). Predictive species distribution modeling is a valuable tool for decision-makers in biodiversity conservation, invasive species monitoring and other natural resources management fields. Over the last three decades, warming has had a discernible influence at the global scale on observed changes in many human and natural systems (EEA, 2010). Mountain areas face substantial challenges including

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reduced snow cover, potential negative impacts on winter tourism and extensive species loss (EEA-JRC-WHO, 2008). It is envisaged that dedicated adaptation measures by Europe is urgently needed to build resilience against climate impacts (EC, 2009[c]). However, the EU White Paper on adaptation recognizes that limited knowledge is a key barrier and calls for a stronger knowledge base. The creation of a European clearinghouse on climate change impacts, vulnerability and adaptation with the aim to enable and encourage the sharing of information and good adaptation practices between all stakeholders is foreseen (EEA, 2010). The EEA report also concluded that improving monitoring and enforcement of sectoral and environmental policies will (i) ensure that environmental outcomes are achieved, (ii) give regulatory stability, and (iii) support more effective governance.

The aim of our work is to contribute to a better understanding of the stability and dynamics of alpine habitats, together with filling the need for knowledge and data in support of adequate conservation planning, monitoring and management. Our goal was to estimate the extent of the *Nardus* habitat in the Alpine region of the Carpathians, its spatial trend, and its vulnerability under changing climate. We produced occurrence and prediction maps that may be of use to be further integrated into a broader and holistic analysis of such vulnerable habitats. Species-rich *Nardus* grasslands was selected for modelling, being of high priority conservation status of Natura 2000 network of protected areas. This is one of the most widespread habitats in the EU, occurring in 24 Member States and 6 different bioregions. This habitat includes a huge variety of sub-types, which may be found in very different ecological situations (Galvánek D. & Janák M., 2008). An major proportion of its area is located within the Alpine bioregion (Alps, Pyrenees and the Carpathian).

The estimated surface of *Nardus habitat* in the Natura 2000 sites of the Alpine Bioregion of Europe is 80,703 ha (Galvánek D. & Janák M., 2008.), showing no data for Romania. Here it was estimated that the grassland area, dominated by *Nardus* stricta L., covers 200,000 ha (Samuil Costel & Vîntu Vasile, 2012). From our mapping inventory under the PIN MATRA (Programme International Nature Management, Dutch Ministry of Agriculture, Nature and Food Quality and Ministry of Foreign Affairs) and *Nardus* projects (Sârbu et al., 2004 and Hanganu et al., 2010) species-rich *Nardus* grasslands is covering 28,841 ha, most of them located in the Natura 2000 areas of the Carpathians, out of which 5,634 ha in the high Alpine area (over 1,800 m a.s.l.). In this habitat were found 123 plant species with high conservation status. As not all area were covered by the inventory, the real occurrence of the high Alpine *Nardus* habitat was assumed to be much larger. In the study we describe here, we are trying to assess the potential of this habitat now and under climate changes. We are testing two well-known methodologies (BIOCLIM and MAXENT) to model habitat potential distribution.

2. MATERIALS AND METHODS

2.1. Modeling techniques

For predicting of the potential distribution of "Species-rich *Nardus* grasslands" due to climate changes we use the Maximum Entropy Distribution Modeling Approach (MAXENT, software http://homepages.inf.ed.ac.uk/s0450736/maxent.html) that estimates the probability distribution for a species occurrence based on environmental constraints. We used also an environmental envelope model (BIOCLIM) using DIVA-GIS (Hijmans et al., 2012). We predicted the future habitat distribution based on a doubling of atmospheric carbon dioxide levels, which was made using an atmospheric general circulation model designed for climate research (CCM3) developed by USA National Centre for Atmospheric Research, Colorado (Govindasamy S. et al., 2003).

Maxent (Phillips et al., 2006, Pearson 2007) is a maximum entropy distribution modeling approach that estimates the probability distribution of species (described by present field database) based on environmental constraints. BIOCLIM using DIVA-GIS software is an environmental envelope model which built a climatic envelope within which a species is likely to be found. The climatic envelope is made using the occurrence of minimum and maximum species values for each climatic variable. The models are using biodiversity data (grassland alliances) and environmental data (bioclimatic variables). Model outputs give pixel values in percent and percentiles, where higher values are more suitable habitat. These models do not specify at what output threshold values probability a pixel becomes a suitable habitat. Therefore, a threshold of model prediction was used at which true positives and negatives are maximized while false positives and negatives are minimized.

2.2. Biodiversity data

Our input biodiversity dataset showing the occurrence of grassland alliances polygons was extracted from GIS Grassland database of Romania that was built from the national grassland inventory (PIN MATRA, 2004, NARDUS, 2010). The area mapped within the two projects covers 650,000 ha distributed by four Black Sea basin bioregions (Alpine, Continental, Pontic and Steppic) and includes 151,149 plant species records. Species-rich *Nardus* grasslands pastures (Habitat 6230) cover 28,841 ha on the mapped alpine area, and include 123 plant species with high conservation status. *Nardus* grasslands consist of two sub-types: Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures coded as VNG and PON, respectively (Sarbu et al., 2004). The range of PON+VNG field observation data starts from 500 m and goes up to 2,500 m. Habitats over 1,800 m a.s.l. are considered primary habitats that host a high number of endemic and threatened plant taxa that are particularly sensitive to climate change. In our analyses we have included both all 6320 mapped habitat (Fig. 1) and, separately, *Nardus* grasslands occurring at over 1,800 m a.s.l. (Table 1).

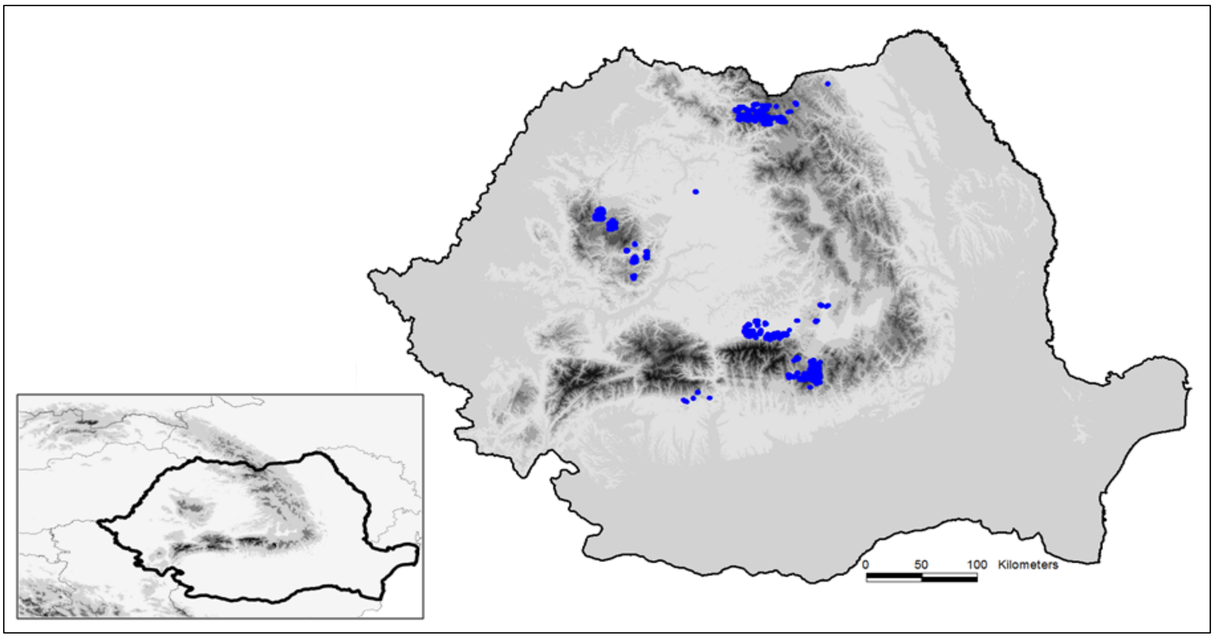


Fig. 1 – Spatial distribution of Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures (VNG+PON) observation data.

Table 1

Distribution of high altitude *Nardus* grasslands (field observation data)

Altitude (m)	Surface (ha)	Proportion
1,800 – 1,900	2,142	38%
1,900 – 2,000	1,179	21%
2,000 – 2,100	639	11%
2,100 – 2,200	639	11%
2,200 – 2,300	468	8%
2,300 – 2,400	423	8%
2,400 – 2,500	144	3%
Total	5,634	100%

2.3. Environmental data

The environmental datasets (Table 2) include 19 bioclimatic variables and four environmental layers (ESRI grids, 30 arc-seconds, ~ 1km2), digital terrain model (30m) , slope (30m) , soil map (100m) and Corine Land Cover 2006 (100 m). Present and future climate data sources of the climate data were provided by Worldclim dataset (Hijmans[a] et al., 2005), at: http://www.worldclim.org/current for current conditions (1950–2000) and http://www.worldclim.org/CMIP5 for future conditions (2000–2050 scenario) corresponding to a doubling of CO_2 emissions (Hijmans[b] et al., 2005). For Romania this future scenario corresponds to an average increase of annual mean temperature of 2.60°C (22%) and an average reduction of annual precipitation with 35 mm (6%).

Table 2

List of environmental variables (ESRI grids, 30 arc-seconds resolution, ~ 1km^2)

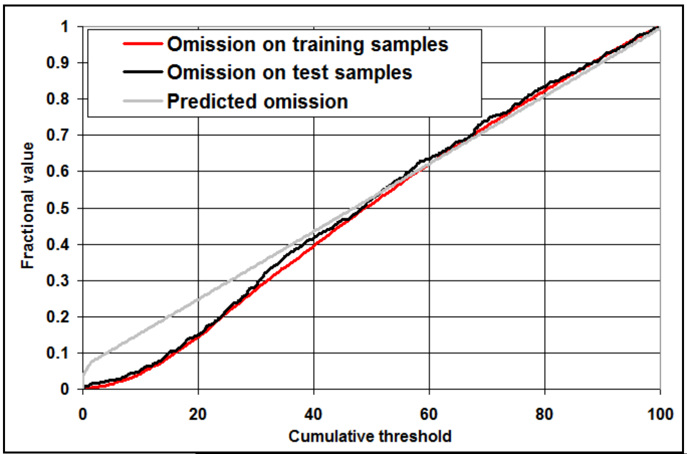
BIO1	Annual mean temperature	**BIO12**	Annual Precipitation
BIO2	Mean diurnal range (max temp – min temp)	**BIO13**	Precipitation of Wettest Period
BIO3	Isothermality (BIO1/BIO7) * 100	**BIO14**	Precipitation of Driest Period
BIO4	Temperature Seasonality (Coefficient of	**BIO15**	Precipitation Seasonality (Coefficient
BIO5	Max Temperature of Warmest Period	**BIO16**	Precipitation of Wettest Quarter
BIO6	Min Temperature of Coldest Period	**BIO17**	Precipitation of Driest Quarter
BIO7	Temperature Annual Range (BIO5-BIO6)	**BIO18**	Precipitation of Warmest Quarter
BIO8	Mean Temperature of Wettest Quarter	**BIO19**	Precipitation of Coldest Quarter
BIO9	Mean Temperature of Driest Quarter	**DTM**	Romanian digital terrain model
BIO10	Mean Temperature of Warmest Quarter	**SLOPE**	Romanian slope model
BIO11	Mean Temperature of Coldest Quarter	**SOIL**	Romanian soil map

3. MODEL VALIDATION

The Area Under the Receiver Operating Characteristic Curve (AUC) was used to examine the accuracy of models. AUC is calculated by plotting the true-positive fraction (sensitivity) against the false-positive fraction (1-specificity) for all test points across all possible probability thresholds (Fielding and Bell, 1997). The curve goes from (0.0) to (1.1) and a model that produces a curve with a high true-positive fraction at low values of the false-positive fraction is considered good. This is commonly quantified by calculating the area under the curve (AUC). AUC ranges from 0 to 1 where a value of 0.5 indicates that a model is no better than random and a value of 1 indicates that the model can discriminate perfectly between the presence and absence records. Model outputs give pixel values in percent and percentiles, where higher values are more suitable habitat. These models do not specify at what threshold probability a pixel becomes a suitable habitat. Therefore, we used a threshold probability at which true positives and negatives are maximized while false positives and negatives are minimized.

Testing or validation is required to assess the predictive performance of the models. The ideal way to estimate the models performance is to use an independent set of data. In many cases this is not possible, therefore the most usual approach is to split the data into two partitions, a training set (2,235 records, 70%) and a test set (957 records, 30%) in order to have a quasi-independent data for model testing. Background points were randomly sampled from the full area.

The omission rate and predicted area for VNG+PON as function of cumulative threshold and the analysis of variable contribution using Maxent is shown in Fig. 2. The omission rate is calculated both on the training presence records, and on the test records. The environmental variable with highest gain when used in isolation is BIO16, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when omitted is BIO15.



Variable	Percent contribution	Permutation importance
BIO15	18.2	28.9
BIO16	17.9	0.6
dtm_2	16.7	11.9
BIO18	14.8	0
BIO4	12.6	7.2
BIO11	7.3	11.1
slope_2	3.1	1.8
BIO2	2.8	2.9
BIO12	1.9	11.3
BIO19	1.4	15.5
sol_2	1	1.3
BIO3	0.9	0.1
BIO17	0.6	0
BIO13	0.4	0.9
BIO9	0.2	0.1
BIO6	0.2	3.6
BIO10	0.1	0.8
BIO1	0	0.4
BIO5	0	0
BIO14	0	1.7
BIO7	0	0
BIO8	0	0

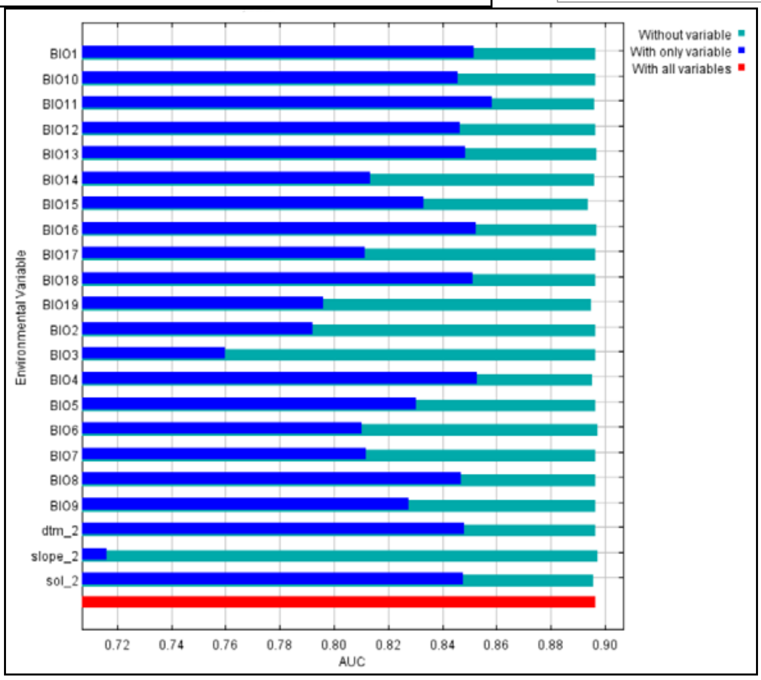


Fig. 2 – Maxent statistical outputs.

The Kappa correlation with threshold using DIVA-GIS is presented in Fig. 3.

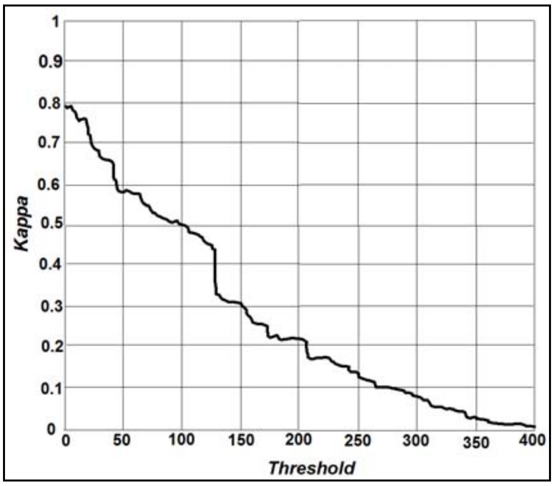


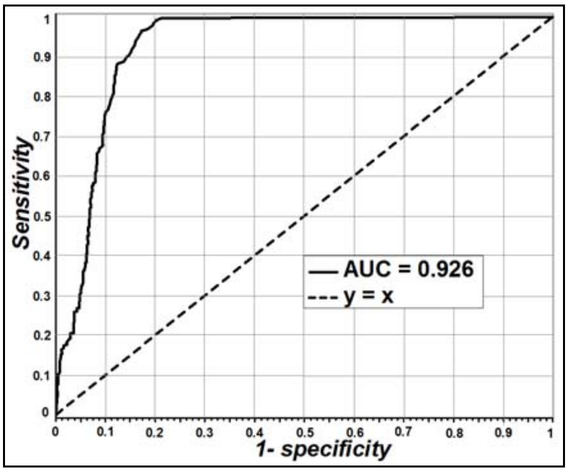
Fig. 3 – BIOCLIM (DIVA-GIS) statistical output.

4. RESULTS

Both modeling methods yielded high values of AUC under the ROC curve (Fig. 4) for predicted mesophilous oligotrophic mountain pasture PON) + subalpine oligotrophic pastures (VNG . (BIOCLIM = 0.926 and MAXENT = 0.901).

Present and future predicted geographical distributions of all PON+VNG habitats using Maxent (Fig. 5) and BIOCLIM (Fig. 6) show differences between the modeling approaches. Maxent predict smaller areas (12% less) of suitable habitat than BIOCLIM for present distribution. For the future climate scenario the surface with PON+VNG decreases by 31% with Maxent and by 26% with BIOCLIM (Figs 7 and 8).

Dynamics of changes show that both modeling techniques predict *Nardus* grasslands to be negatively affected by climate warming. The lost surface of the *Nardus* grassland habitat related to altitude for the double CO_2 scenario shows that MAXENT approach predicted higher values than BIOCLIM especially for alpine and sub-alpine areas above 1,750 m (Fig. 9, Table 3).



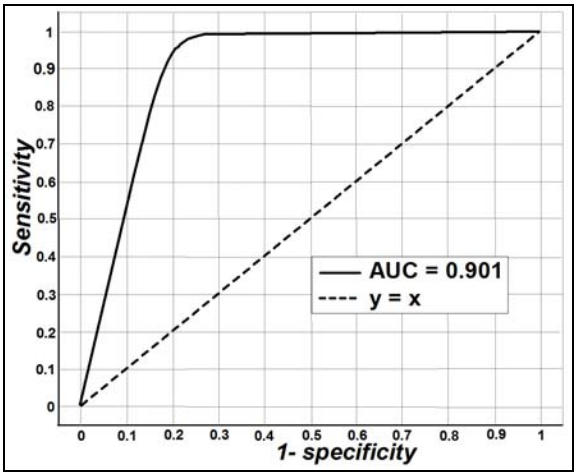
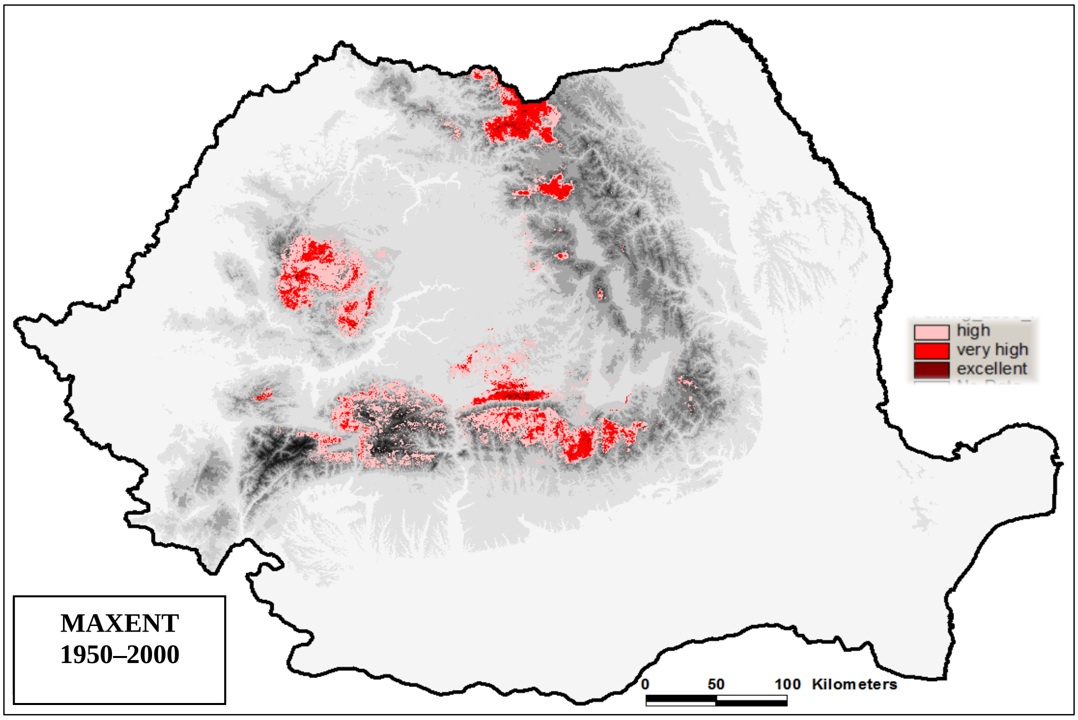


Fig. 4 – AUC values for BIOCLIM and Maxent.



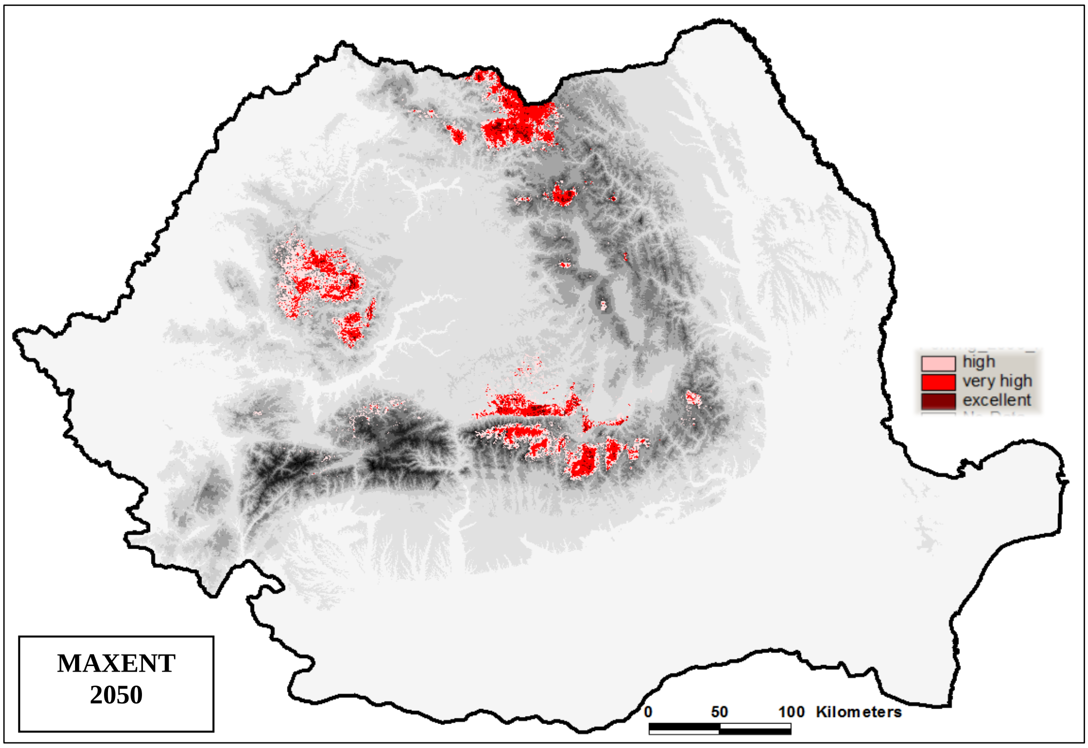
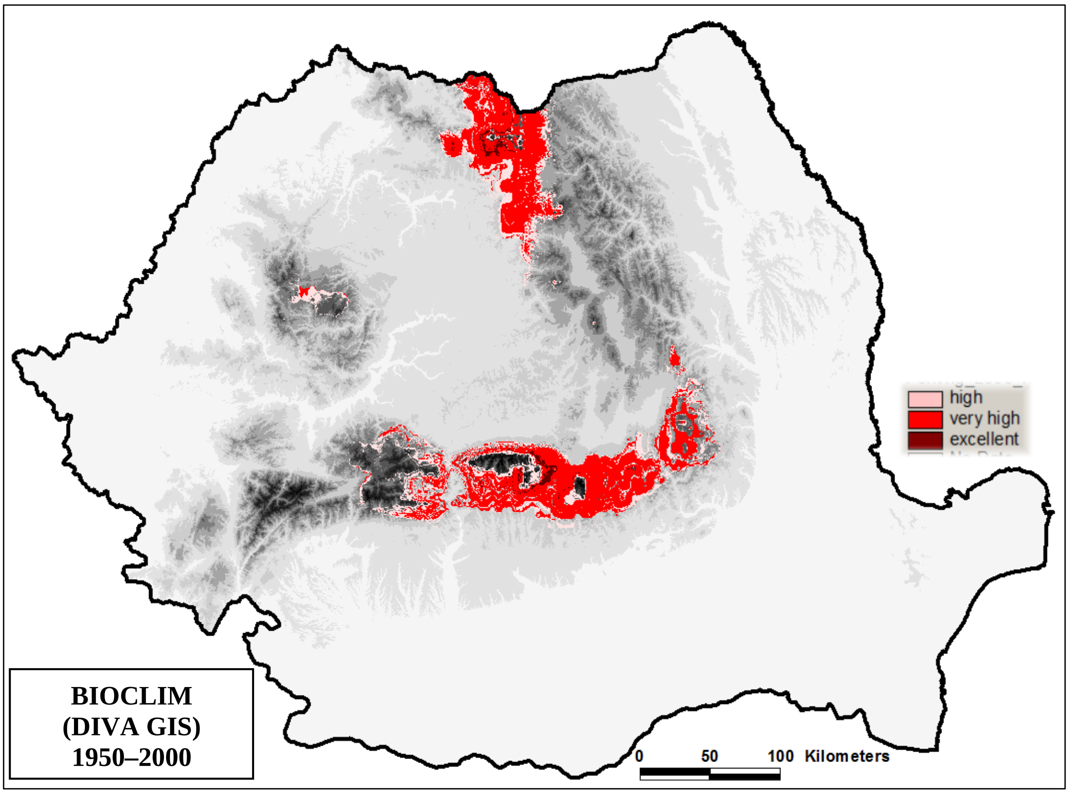


Fig. 5 – Present and predicted spatial potential distribution of PON+VNG habitats predicted by Maxent.



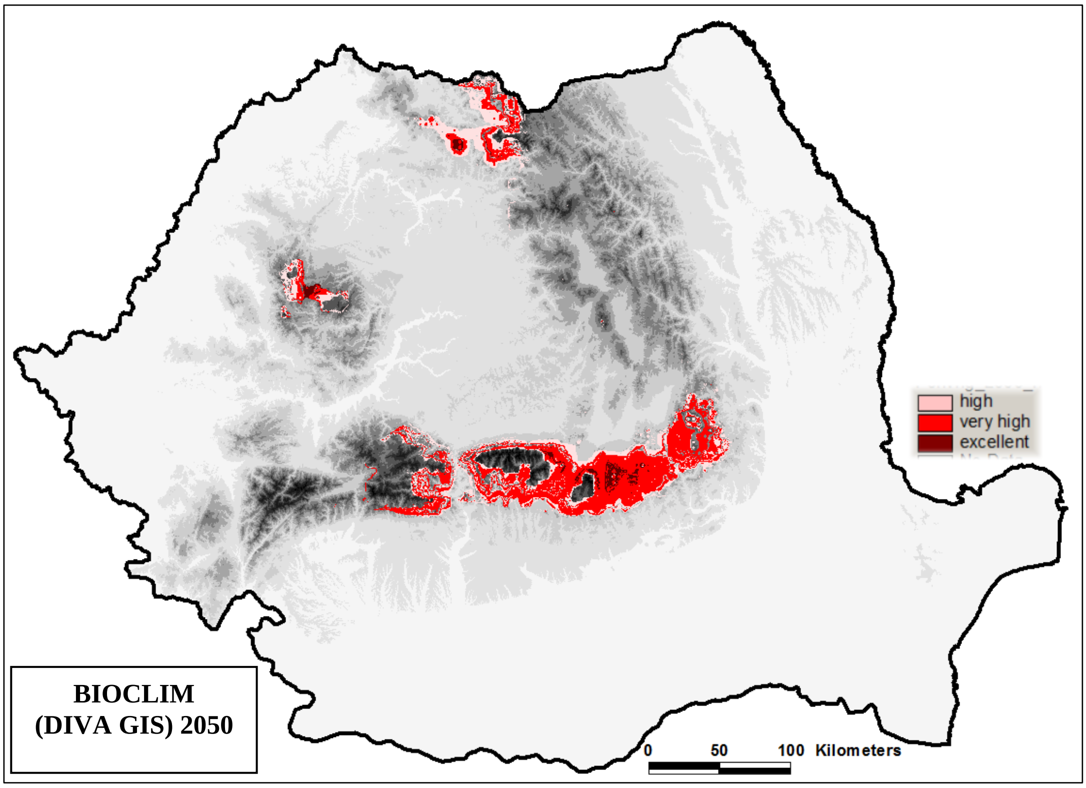
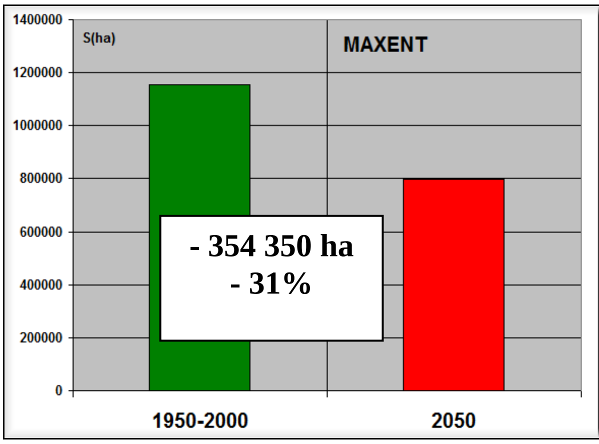


Fig. 6 – Present and predicted spatial potential distribution of PON+VNG habitats predicted by BIOCLIM.

Because model performance cannot be tested under future scenarios, it is not possible to say which modeling approach is performing better. Therefore, we combined the two results (lost areas layers for future scenario) into one spatial layer representing, with high probability, the lost surface for *Nardus* grassland habitat (Fig. 10).



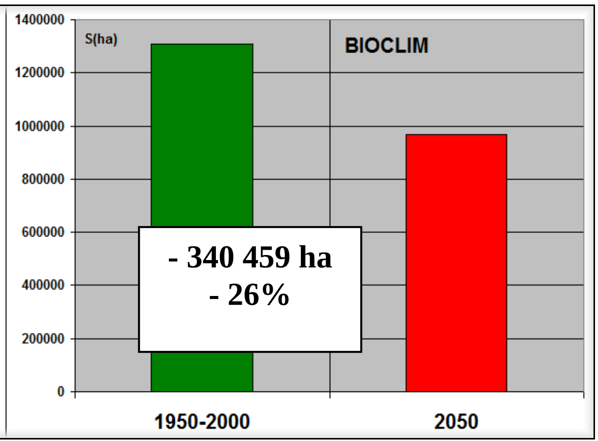


Fig. 7 – Decrease of PON+VNG surface for future climate scenario.

Fig. 8 – Spatial distribution of PON+VNG lost surface for future climate scenario.

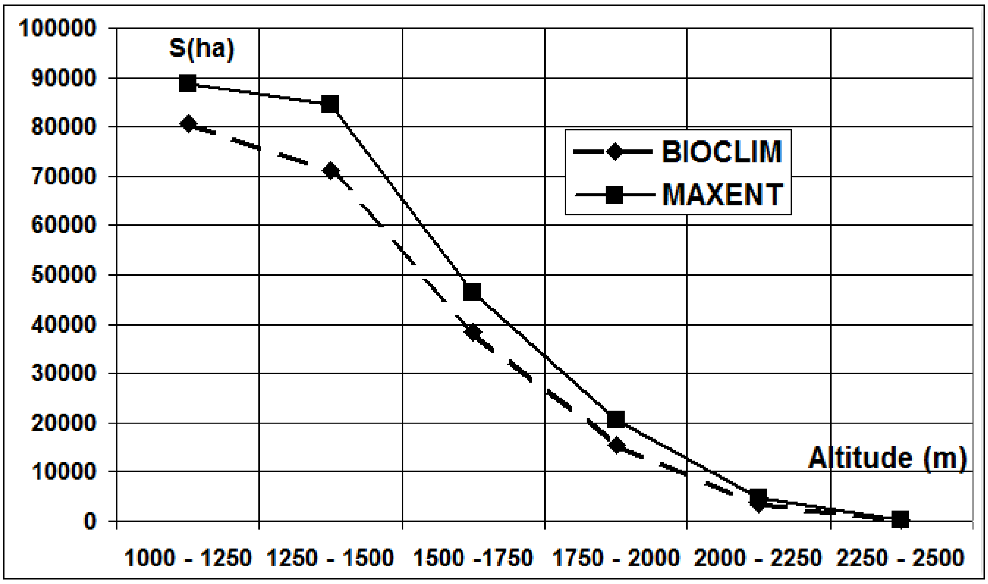


Fig. 9 – Lost surfaces of Nardus habitat (BIOCLIM and MAXENT) related to altitude.

Table 3

Lost surfaces of *Nardus* habitat (BIOCLIM and Maxent) related to altitude

	BIOCLIM	**MAXENT**	
Altitude (m)	**S(ha)**	**S(ha)**	**Difference MAXENT (%)**
1000 - 1250	80655	88703	9.07%
1250 - 1500	71240	84588	15.78%
1500 -1750	38515	46511	17.19%
1750 - 2000	15540	20396	23.81%
2000 - 2250	3433	4812	28.66%

5. DISCUSSION

5.1. Habitat distribution

It is known that the optimum condition for the *Nardus* grassland is the low trophic status of the substrate. Hence, it is believed that climate change should not cause total destruction of the habitat (Daniel Scherrer* and Christian Körner, 2011) as alpine terrain is, in fact, for the majority of species, a much safer place to live under conditions of climate change than is flat terrain which offers no short-distance escapes from the novel thermal regime. However, climate change may lead to substantial changes in the species composition of different subtypes. Sub-types in transition from wet grasslands, and those occurring in high-altitude mountainous areas, especially chionophile types, are probably the most vulnerable (Galvánek D. & Janák M., 2008). Alpine species should be at higher risk of local extinction than subalpine species or species distributed down to lower elevations, as the latter have a wider elevation tolerance and thus a lower risk of local extinction (Antoine Guisan & Jean-Paul Theurillat, 2001). Pauli et al., 2007 reported a slow shift of the species of alpine communities into nival and subnival habitats. Experiments by Herben et al., 2003, in the Krkonoše (Czech Republic), demonstrated that the weather may strongly influence competition among species on mountainous *Nardus* grasslands, and thus changes in weather resulting from climate change could lead to changes in species composition. At the level of the year 2050, our results show a decrease of the area occupied by Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures of 27% by MAXENT and 77% by BIOCLIM.

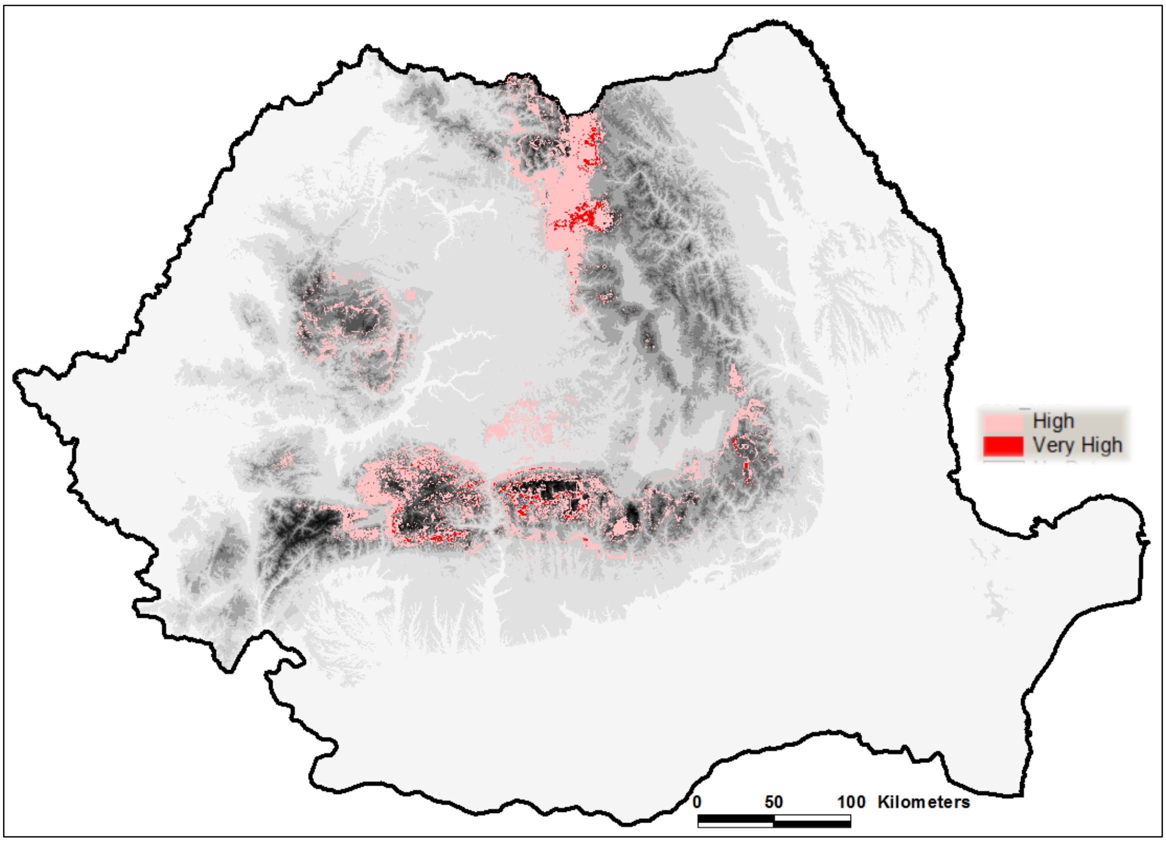


Fig. 10 – Lost surface of Nardus grassland habitat (combined Maxent and BIOCLIM).

5.2. Choice between BIOCLIM and MAXENT

Maxent predicts smaller areas of studied suitable habitat than BIOCLIM (DIVA-GIS) model does. Also, the lost surface of the *Nardus grassland* habitat related to altitude for the future scenario (double CO_2) shows that the Maxent approach predicted higher values than BIOCLIM especially for alpine and sub-alpine areas. Maxent, with a higher model strength, can be considered to have a higher likelihood of occurrence in all suitable habitat areas. In other words, the confidence in the prediction of suitable habitat is greater with all Maxent models (Elith et al., Alan, 1997). Model uncertainty can lead to choose ensemble forecasting like Biomod (Thuiller et al., Ecography 2009). Future improvements are necessary for calibration and validation of the models. The main issue is to get available *in situ* data for the species and habitats.

6. POLICY ASPECTS

Recognizing the importance of the species-rich *Nardus* 6230 habitat the European Commission (DG ENV B2) commissioned the Management of Natura 2000 network. The report (Galvánek D. & Janák M., 2008) has identified several stress factors on this habitat: eutrophication, inappropriate grazing practices, land abandonment, low management intensity, afforestation, tourism and skiing activities, and climate change effects. It is supposed that high alpine *Nardus* natural habitats do not require management measures while all other *Nardus* grassland semi-natural need active management measures mainly by adequate grazing, mowing and most importantly the ban on fertilization. In Romania, the grassland area, dominated by Nardus *stricta* L., covers 200,000 ha (Samuil & Vintu, 2012). Our estimates of high altitude *Nardus* grassland is 29,863 ha by BIOCLIM and 74,324 ha by MAXENT. The perspective of climate change for 2050 shows important reduction of Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures (habitat 6230) to 6`987 ha by BIOCLIM and 54`578 ha by MAXENT. In Romania *Nardus* stricta is mainly influenced by Ca++ concentration in soil litter (Bărbos & Sima, 2008). The disappearance or degradation of *Nardus* habitat is through change in soil pH indirectly driven by inadequate management such as overfertilization, overgrazing, and land abandonment (N. Ştefan, 2013 pers. Com.). This results in loss of species, grazing resources and landscape attractiveness. Active management such as stopping fertilization, overgrazing, or maintenance by adequate grazing and mowing can prevent degradation of semi-natural *Nardus* habitat.

We have also found that climate change may reduce the area of the high Alpine natural habitat but in this case the loss can be tackled only by global measure to prevent or reduce climate change induced by human activities. However, the trend of biodiversity is to decline globally despite a few encouraging achievements and increased policy action (CBD, 2010) (Stuart et. al., 2010). Composite Report on the Conservation Status of Habitat Types and Species as required under Article 17 of the Habitats Directive (EC, 2009[a]) enforces that “Protecting biodiversity is a priority for the European Union and for our policies to be successful we must have a comprehensive and reliable measure of the status of our biodiversity”.

Key policy instruments are the EU Birds and Habitats Directives (EC, 2009[b]) (EC, 2010.) that aim at a favourable conservation status for selected species and habitats. The second main strand of policy action is the integration of biodiversity concerns into sectoral policies for transport, energy production, agriculture, forestry and fisheries. This is aimed at reducing the direct impacts from these sectors, as well as their diffuse pressures, such as fragmentation, acidification, eutrophication and pollution (OECD, 2006). Dedicated adaptation by Europe is urgently needed to build resilience against climate impacts. Adaptation (EC, 2009[c]) “is a first step towards an adaptation strategy to reduce vulnerability to the impacts of climate change, and complements actions at national, regional and even local levels”. It has to be integrated in the policy of nature and biodiversity protection.

However, the EU White Paper (EC, 2009[c]) on Adaptation recognizes that limited knowledge is a key barrier and calls for a stronger knowledge base. To address related gaps, the creation of a European clearinghouse on climate change impacts, vulnerability and adaptation is foreseen. This aims to enable and encourage the sharing of information and good adaptation practices between all stakeholders. Our finding, mainly forecast distribution maps of *Nardus* habitat, may be of use to highlight sensitive areas at threat by climate changes warning to further take adequate measure to the negative effect of climate evolution as it is now. The results are seen to be of interest to policy decision-makers. Disseminations of the results and maps via the EnviroGRIDS portal, for example, is key for further reporting to Environmental Agencies for requesting stronger action to reduce the human impact on climate change.

7. CONCLUSIONS

Maxent and BIOCLIM were used to create spatial distribution models for Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures. Models were run with 1950-2000 averaged bioclimatic data and double atmospheric CO_2 concentration scenario for the perspective of the year 2050. In our analyses we have included once all 6320 mapped habitat with Nardus grasslands. Under 1950 - 2000 climate scenario, both models exhibited high AUC values (> 0.9). The predicted geographical distribution of PON+VNG habitat modeled by Maxent and BIOCLIM shows differences between the modeling approaches, with Maxent predicting smaller areas (12% less) of suitable habitat than BIOCLIM. For the future climate scenario (double CO2) the surface with PON+VNG decreases with 31% for Maxent and 26% for BIOCLIM. However both models show significant shifts of the *Nardus* habitat due to climate change.

Acknowledgements

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