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# AIR TEMPERATURE DIGITAL MAPS FOR REPRESENTATIVE CONCENTRATION PATHWAYS AND POSSIBLE IMPACTS ON POSTAVARU MOUNTAINS FORESTS

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***Abstract:*** *The paper presents an exercise of downscaling climate change scenarios, namely the temperature projections for the representative concentration pathways (RCP) included in the Fifth IPCC Assessment Report (AR5), for a mountain study area (Postavaru Mountains) located south of Brasov City, Romania, and analysing the changes of the optimum bioclimatic envelope land allocation. The digital temperature maps, for the present and future climate conditions, were created by taking into account both the lapse rate and a correction factor (quantifying the raster cells differences in potential incoming solar radiation). The optimum `envelopes` extent for the main tree species in the study area were analysed for the current situation and for predicted RCP changes in two future periods.*

***Key words:*** *temperature maps, RCP scenarios, optimum envelopes.*

## 1. Introduction

The surface atmosphere interactions and the resulting boundary layer are perhaps nowhere more intricate than in mountain regions [1], [8]. The particular mountain climate, encountered worldwide, at almost all latitudes, is characterised by very high spatial and temporal variability [2]. Consequently, the study of the local climate conditions and their effect on vegetation, in these marginal ecological areas, is a challenging task that becomes even more difficult when considering the possible climate change paradigm.

One could note that for mountain regions the climate change projections are affected by this additional source of uncertainty. But this issue could be nowadays more effectively addressed (and more accurately than other global climate experiments ambiguities, like those referring to greenhouse emissions or climate system feedbacks) by using mathematical modelling and the tools provided by the geographic information systems (GIS), especially the terrain analysis modules.

The most recent predictions of the International Panel on Climate Change (IPCC), are synthesised in the Fifth

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Assessment Report (AR5) [10], [11], which presents global and regional scenarios derived from the results of the Coupled Model Intercomparison Project Phase 5 (CMIP5).

The resolution of the grids in the Earth System Models (former Global Climate Models –GCM) is much higher than one or two decades ago, but the raster cells are still too large for a direct study of the ecological impacts [3], [9]. Thus, a down-scaling procedure, which could be statistical or dynamic [14], is required for producing regional projections (for example, cells of 50 by 50 km). Finally, in steep terrain regions, these scenarios need to be used for deriving sets of climate parameters specific to each site, taking into account the particular aspect, slope gradient and position [15], as shown in the following examples.

One of the widely used methods for studying the impact of possible climate changes on vegetation, in particular on forests, is using the comparison between the `bioclimatic envelope` thresholds and the site conditions distribution for the present situation and various future scenarios [4], [13], [16].

## 2. Material and Methods

The paper presents an exercise of downscaling climate change scenarios included in the Fifth IPCC Assessment Report (AR5), for a mountain study area (Postavaru Mountains) located south of Brasov City, Romania, and analysing the changes of the optimum bioclimatic envelope land allocation.

In AR5, the four Representative Concentration Pathway scenarios (RCP2.6, RCP4.5, RCP6 and RCP8.5), are replacing the former SRES scenarios (the well known A1, A1B, A2, B1, B2 etc.). Their name indicates the radiative forcing in year 2100: 2.6 W $m^{-2}$, 4.5 W $m^{-2}$, 6.0 W $m^{-2}$, and 8.5 W $m^{-2}$ respectively [10].

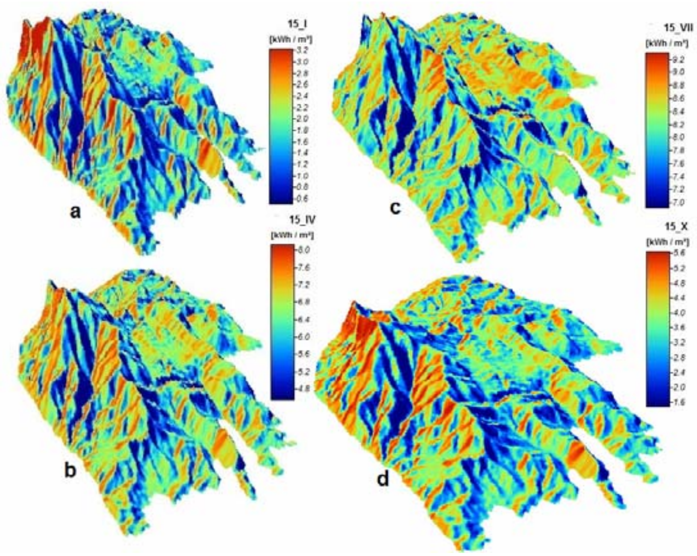


Fig. 1. *The potential incoming radiation (kWh/* $m^{-2}$*) in Postavaru Mountains, at four representative dates: January 15*$^{th}$ ***(a)****, April 15*$^{th}$ ***(b)****, July 15*$^{th}$ ***(c)*** *and October 15*$^{th}$ ***(d)***

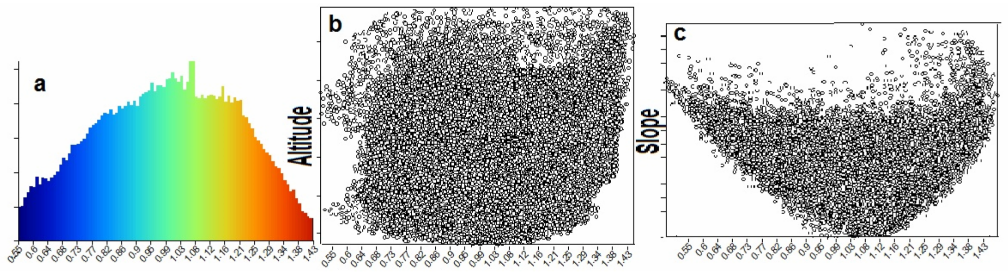


Fig. 2. *Distribution of the solar radiation correction factor values in the study area (**a**) and its relationships with altitude (**b**) and slope gradient (**c**)*

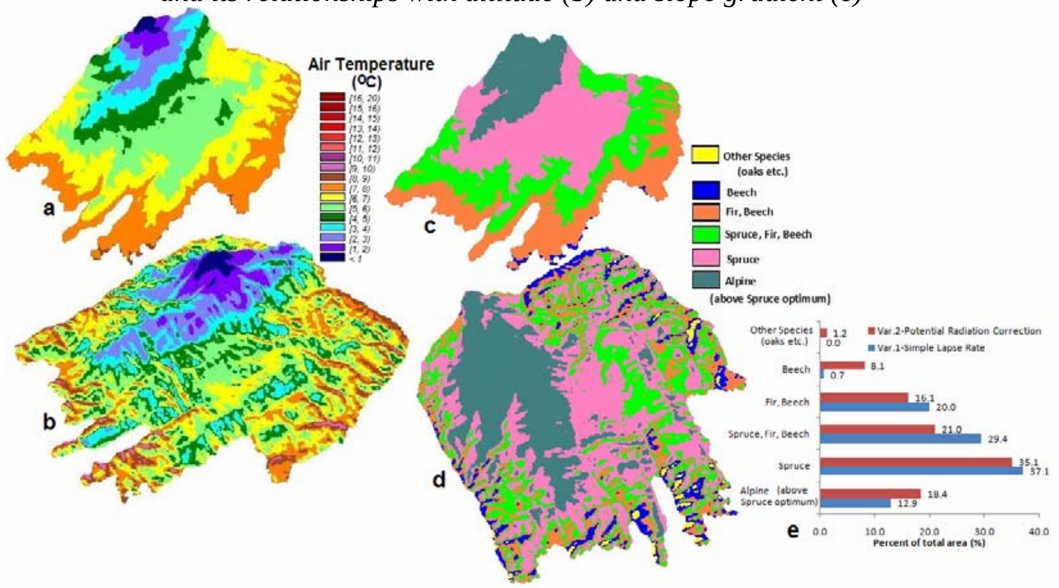


Fig. 3. *Temperature maps for the study area resulting by applying the lapse rate (**a**-Var.1) and by correcting it with the potential radiation factor (**b** –Var.2). Distribution of the study area on optimum bioclimatic envelopes (Maps:**c**-var.1 and **d**-Var.2; Chart: **e**)*

For this study, there were chosen the RCP4.5 and RCP8.5 scenarios and two periods 2046-2065 and 2081-2100, with the AR5 predicted increases of the mean annual temperature of 1.4 $^{o}$C, 2.0 $^{o}$C, 1.8 $^{o}$C and 3.7 $^{o}$C respectively. For obtaining the regional projections, these values were added to the average temperature calculated at the former Brasov-Prund weather station (7.8$^{o}$C), without other downscaling.

The air temperature digital maps were produced using SAGA (System for Automated Geoscientific Analyses), an open source software, developed primarily by a team of German researchers [6], [7].

The simplest method for producing temperature maps in mountain regions is by only considering the average lapse rate of 6.5 $^{o}$C / km (Figure 3a). Obviously, this raw result is far from being realistic, because in this approach the influence of the local conditions, affecting the input of solar energy (the most important climate genesis factor) in each cell of the raster model is not considered [5], [12].

An improvement could be achieved by calculating a correction factor [19], which accounts for the differences in the potential incoming radiation. This was calculated in SAGA, using the specific module, for representative days in winter (January, 15th), spring (April, 15th), summer (July, 15th) and autumn (October, 15th), and the resulting layers could be observed in Figure 1, in 3D views created by overlying the digital elevation model (DEM). The correction factor grid was calculated as the average of the ratios between each of those layers and the reference value for the cell location of the former Brasov-Prund weather station. As shown in Figure 2a, the values span between 0.55 and 1.43, the reference value 1 being close to the median. In all elevation sectors, the values are uniformly distributed but their scattering increases with slope (Figure 2b and c).

By applying this correction factor, the temperature map is more complex and accurate as one could observe in Figure 3b.

The thresholds for the temperature component of the optimum bioclimatic envelope for the most important tree species in the study area were extracted from reference textbooks [17], [18] as follows: 4-7°C for Norway spruce, 6-8°C for European fir and 6-9°C for European beech, cells with values below 4°C were allocated to the alpine zone (actually above spruce optimum, because treeline stands are also occurring closer to the summit) and those over 9 °C were considered to be more favourable to other broadleaved species (such as oaks).

By reclassifying the temperature maps, considering the above indicated thresholds, there were obtained the maps with the study area allocation on optimum bio-climatic envelopes (temperature component), as observable in Figure 3c, d and e.

## 3. Results and Discussions

Using the procedure described above for the solar radiation corrected temperature layer (Var.2), there were produced the temperature maps for Postavaru mountains for RCP4.5 and RCP8.5 scenarios in two periods, 2046-2065 and 2081-2100, and the grids with the subsequent partition on optimum temperature zones.

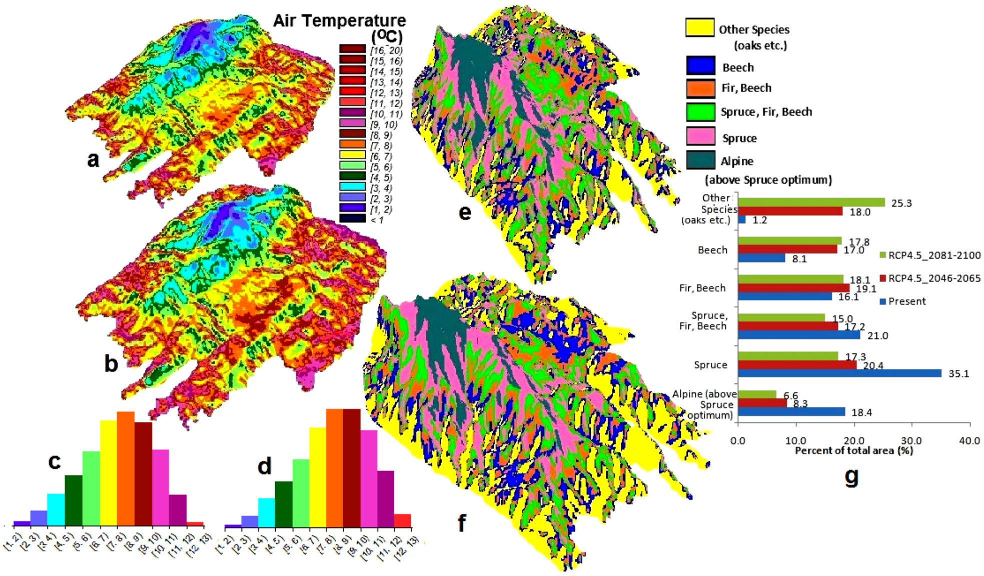


Fig. 4. *RCP4.5 air temperature maps for 2046-2065 (**a**) and 2081-2100 (**b**), with corresponding histograms (**c**, **d**) and optimum temperature zones (**e**, **f**). Study area bioclimatic allocation for the 2 periods compared with the present situation (**g**)*

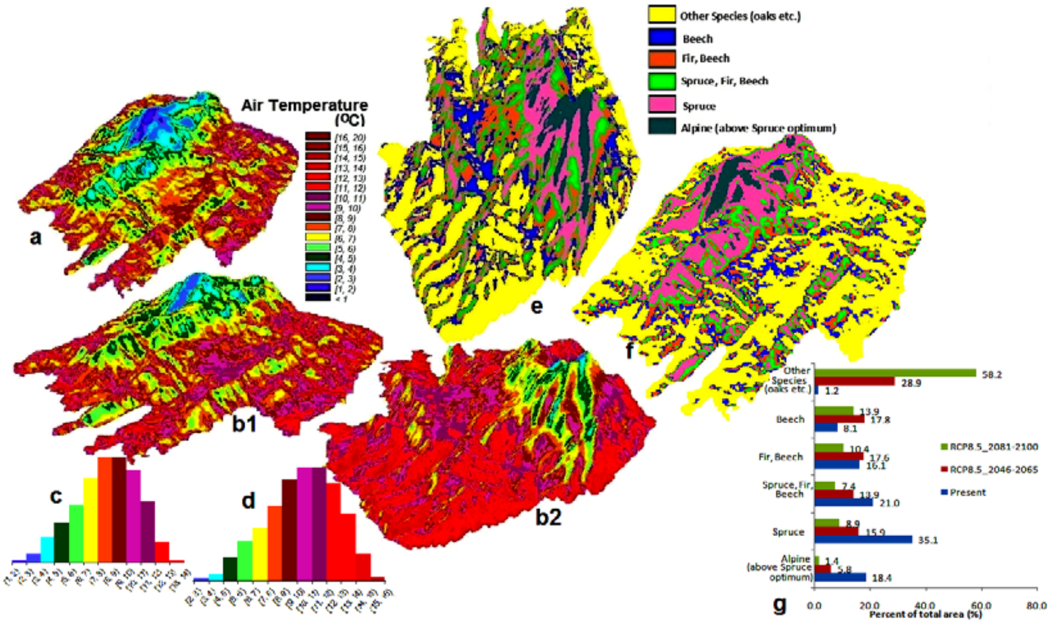


Fig. 5. *RCP8.5 air temperature maps for 2046-2065 (**a**) and 2081-2100 (**b1** and **b2**), with corresponding histograms (**c**, **d**) and optimum temperature zones (**e**, **f**). Study area bioclimatic allocation for the 2 periods compared with the present situation (**g**)*

For the RCP4.5 scenario (Figure 4) the optimum zone for spruce will decrease from 35.1% in the present to 20.4% by 2050 and to a half (17.3%) by the end of our century. For the same milestones, the alpine zone will be reduced to 8.3% and 6.6% (one third of the present 18.4%) and the area favourable to more heat loving broadleaves (about 1.2% in the present) will increase to 18% and 25.3%. An interesting simulated evolution could be noted for the fir and beech optimum zone that is going to increase from 16.1% to 19.1%, being afterwards reduced to 18.1%.

In the case of a radiative forcing of 8.5 W $m^{-2}$ by 2100 (RCP8.5), the changes of the optimum envelope zones would be even more dramatic (Figure 5). More than one half of the study area (58.2%) will be favorable for oak stands, which are presently occurring in small patches (1.2%). But even in such a case the spruce optimum areas will not disappear as some would have expected. The area of spruce exclusive optimum will be reduced to 8.9% (15.9% by 2050) and the area where this species is sharing the optimum temperatures with fir and beech would be of about 7.4% from the total study area.

## 4. Conclusions

The GIS modules are very useful tools for the study of forest–local climate interactions in mountain regions. For producing the digital temperature maps better solutions could be obtained by taking into account both the lapse rate and a correction factor (quantifying the raster cells differences in potential incoming solar radiation). By considering the temperature thresholds of the tree species optimum \`envelopes\`, their present and future extent could be easily determined.

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