

SESSILE OAK FOREST ECOSYSTEMS FROM TRANSYLVANIA IN THE CONTEXT OF CLIMATIC CHANGES

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Abstract

Climatic modelling software was used in order to measure future changes in climatic conditions. The software HYPE can realize prognosis for certain climatic factors responsible for causing extreme climatic phenomena in forest ecosystems. It was applied to study sessile oak forest ecosystems from Transylvania. Sample surfaces were installed, inventoried and followed by simulations of two future climatic scenarios. Two such scenarios were chosen, namely the climatic scenario in which the gas effect concentration will increase moderately (rcp-4.5) and the climatic scenario in which the gas effect concentration will be accentuated (rcp-8.5). The data was then processed and which led to an analysis of the way in which future climatic changes will affect forest ecosystems located in the studied area. After analyzing all three sessile oak stands, we can conclude that the Mediaş stand is the most vulnerable one to both climatic parameters.

Future climatic scenarios are necessary for other surfaces located in our country for the same species, as well as for others in order to have a bigger picture of future implications. The best management measures and decisions regarding the installment of future stands can consequently be taken based on these results.

Keywords: climate change, forest ecosystems, sessile oak, Transylvania.

1. INTRODUCTION

Due to its colossal size and its large time scales, the climatic system can not be studied through experimental methods. As a result, scientists used climatic models. These are representations based on theory that characterize or stimulate essential characteristics and mechanisms in order to explore the way in which Earth's climate functions (Edwards, 2010).

While he was trying to understand the winds' physics, Edmond Halley has published in 1686, one of the first theories that overcomes the Ptolemaic perspective of the climate based on latitude. Halley said that solar heating makes the air increase near the Equator (Halley, 1686)

These conceptual models have explained the main winds and intercepted the climate's fundamental function of transporting energy (Hadley, 1735).

Starting from 1807, Fourier elaborate the hypothesis that, by keeping heat, atmosphere maintains the a higher temperature for Earth's surface. The history of global heating refers invariably to the “serre” concept proposed by Fourier, the French term for “greenhouse” (Fourier, 1822).

Furthermore, the conceptual models of the carbon's circuit have contributed to understanding the climate. Until 1861, Tyndall concluded that geophysical cycles that involve gas heating were responsible for major climatic changes.

Chamberlin has followed this hypothesis and suggested an ample explanation for global climatic changes on geologic time levels caused by carbon dioxide (Chamberlin, 1897, 1898).

In 1895, Arrhenius has estimated the contribution of Earth's surface temperature, the heat retained by "carbon dioxide" (CO₂) and water vapors. His famous document from 1896 has calculated that doubling the atmospheric CO₂ can increase the average global temperature with 5-6 °C (Arrhenius 1896; Uppenbrink, 1996).

Immediately after the Second World War, meteorological prediction was amongst the main major applications of digital computers, strongly sustained by both military agencies, as well as by civil meteorological services (Harper, 2008).

Starting with the 1980s, climate modelling focused more on more holistic models (Meadows, 1972).

The regional climatic modelling domain was born at the end of the 1980s, as a response to the need of bringing detailed regional climatic information for studies that evaluate their impact. Starting from that moment, its development was extraordinary. Today, the most important laboratories and a large number of universities and academic institutions maintain, develop and use regional climatic models (RCM).

Climatic models are evaluated in numerous ways. The most common technique is to compare the model's production with climatic averages from observations. Another method is to set parameters (such as concentrations for greenhouse effect gases and the position of continents) that correspond to a known paleoclimate. This allows to observe the exactness in which the model reproduces a climate that is much different than the actual one. Furthermore, the climate of the XX century was tried to be reproduced by setting parameters that represent a passing growth of greenhouse gases and major volcanic eruptions.

Starting with 2000, research and operational agencies have started to collaborate more closely, searching a unified modelling framework for climate prediction. The result is a standardized, modular global infrastructure for producing knowledge about Earth's climate, organized around simulation modelling.

Even though this study was developed based on Swedish characteristics, he was used successfully in other agricultural areas where China's crop rotation is practiced. As such, the model can be used at a global level (Yin et al., 2016). HYPE is hosted and continuously developed by the Hydrology Research Unit from the Swedish Hydrology and Meteorology Institute. The HYPE Model is the main instrument of the Hydrology Research Institute, that offers new information, prognosis and knowledge regarding water resources from Sweden and from the entire world at a spatial and temporal scale. The model is addressed to a large array of users. The model's purpose is to provide information for evaluations concerning the environment and climatic changes at a high resolution. This can also be applied for conditions that lack any kind of monitoring.

Sessile oak is the most widespread oak species from Transylvania's plateau, a situation similar to the West Plain (Dinca and Cantar, 2020), The situation is different for Dobrogea's Plateau where pubescent oak predominates (Dinca et Vechiu, 2020). These stands offer numerous non-wood forest products, such as: forest fruits (Tudor et al., 2019; Tudor et al., 2021), mushrooms (Dinca et al., 2016; Blaga et al., 2018; Tiwary et al., 2020), medicinal plants (Vasile et al., 2018), and game species (Ciontu et al., 2018; Timis-Gansac et al., 2018).

2. MATERIALS AND METHODS

The present study has used the “HYPE” climate model. This was developed by the Hydrology and Meteorology Institute from Sweden, between 2005 and 2007.

The “HYPE” model and the software’s menus allowed us to introduce the entrance parameters (namely the coordinates of the interest points expressed through latitude and longitude), the type of indicator (which in our case is represented by temperature and precipitations) as well as the wished climatic scenario. Based on this, the program will calculate the values of the interest parameters. Three options are available: a scenario in which greenhouse gases have a low growth („Low – RCP 2.6”), an average growth („Moderate – RCP 4.5”) or a big growth („High – RCP 8.5”) (fig. 1).



Figure 1. „HYPE”’s menu

In addition, the simulation time period must be selected. In the present case, we have selected a maximum time of up to 2100. After this, the file can be downloaded from the “Download data” submenu.

The downloaded data are presented in a table, in a Microsoft Excel file and present daily values. It is important to mention that the historical data used for the simulation begin from 1971.

Furthermore, in simulating values from future periods, the used historical values and entry data must be corrected. The biggest advantage of this program is that this process of correcting historical values is already integrated within the simulations.

The HYPE software takes into account numerous regional climatic modelling models. Within this study, we have decided to work with the “REMO 2009” climatic model. As such, the chosen regional climatic scenario and model are represented by „CSC_REMO2009_MPI-ESM-LR_rcp45” (for the medium growth with greenhouse gases) and „CSC_REMO2009_MPI-ESM-LR_rcp85” (for

the large growth). Next, Microsoft Excel is used to process the data, leading to average monthly values for the studied period (1971-2100).

In order to represent better the impact of climatic changes on the studied forest ecosystems, the ways in which the projections will affect the ecosystems during 2020-2100 was integrated on Romania’s map. In this way, a symbol was chosen for each studied climatic factor, namely a circle for annual average temperatures and a triangle for annual average precipitations. Suggestive colors were also associated for these symbols.

3. RESULTS AND DISCUSSIONS

Data regarding precipitations and temperatures up to 2100 can be obtained for each surface by processing data obtained through the “HYPE” modelling parameters in Microsoft Excel. This data is rendered in a graphic form for the two selected scenarios – the scenario with an average growth of greenhouse gases (rcp-4.5) and the scenario with a large growth of greenhouse gases (rcp-8.5). This will result in 2 series of values for precipitations and 2 series of values for temperatures for each installed surface.

We will report to the species studied in Transylvania (sessile oak) in order to see the effect of these scenarios on the studied forest ecosystems.

As such, sessile oak is not too strict towards summer heat, preferring a transition climate from the Atlantic one to the continental one. The species is mesothermal, mesophit, and with an ecological precipitation optimum between 600-800 (850) mm/year. Sessile oak stand situated in the ecological optimum at 100 years old have a productivity of 6 m³/year/ha (Șofletea N., Curtu L., Dendrologie, 2008) (table 1).

Table 1. Ecological card (Stănescu et al., 1997) Quercus petraea (Matt.) Liebl

Ecologic factors	Vales of states for ecologic factors													
	Variation of the specie’s biologic potential based on ecological factors													
Average annual temperature (°C)	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
								l	s	s	o	o	o	s
Average annual precipitation s (mm)	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500		
		s	o	o	o	s	l	l						

where “l” represents the limit, “s” the suboptimal and “o” the optimum

It can be easily observed that the sessile oak installed in Lechința presents an increased temperature tendency for the next decades (figure 2). Of course, this growth depends on the chosen scenario. As time passes, a net difference between the two scenarios will be possible. The biggest problem is represented by the temperature interval between which the values will be recorded.

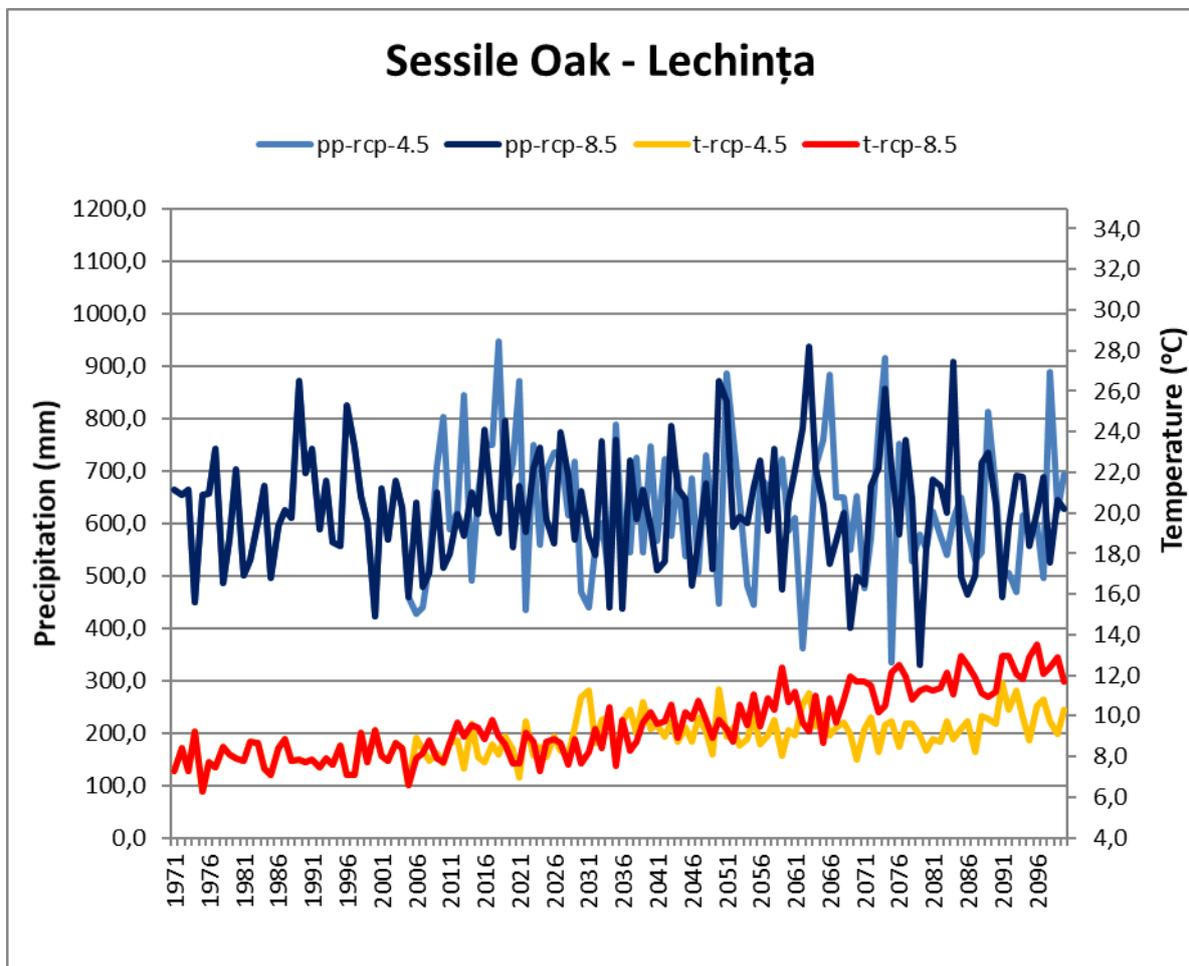


Figure 2. Climatic scenarios for the sessile oak surface from Lechința

However, serious problems do not seem to arise for this location in regard with the average annual precipitation. Most of the values are situated in the specie's extreme interval for both climatic scenarios.

As for the case of average annual temperatures from the first climatic scenario (rcp-4.5), the sessile oak forest ecosystem should not encounter big problems if we take into account the maximum values that allow the species to vegetate suboptimally. Only the rcp-8.5 scenario shows an increase of problems as greenhouse gases increase considerably from 2054, causing temperatures to exceed the limit value supported by this species.

On the other hand, the sessile oak stand situated in Mediaș presents more annual precipitation values under the tolerating threshold for both historical data and future simulations. The location records periods of 3 consecutive years with average annual precipitations under the limit. As such, the program's prediction for both climatic scenarios (rcp-4.5 and rcp-8.5) shows us that sessile oak stand from this area have low chances to survive in the following decades (figure 3).

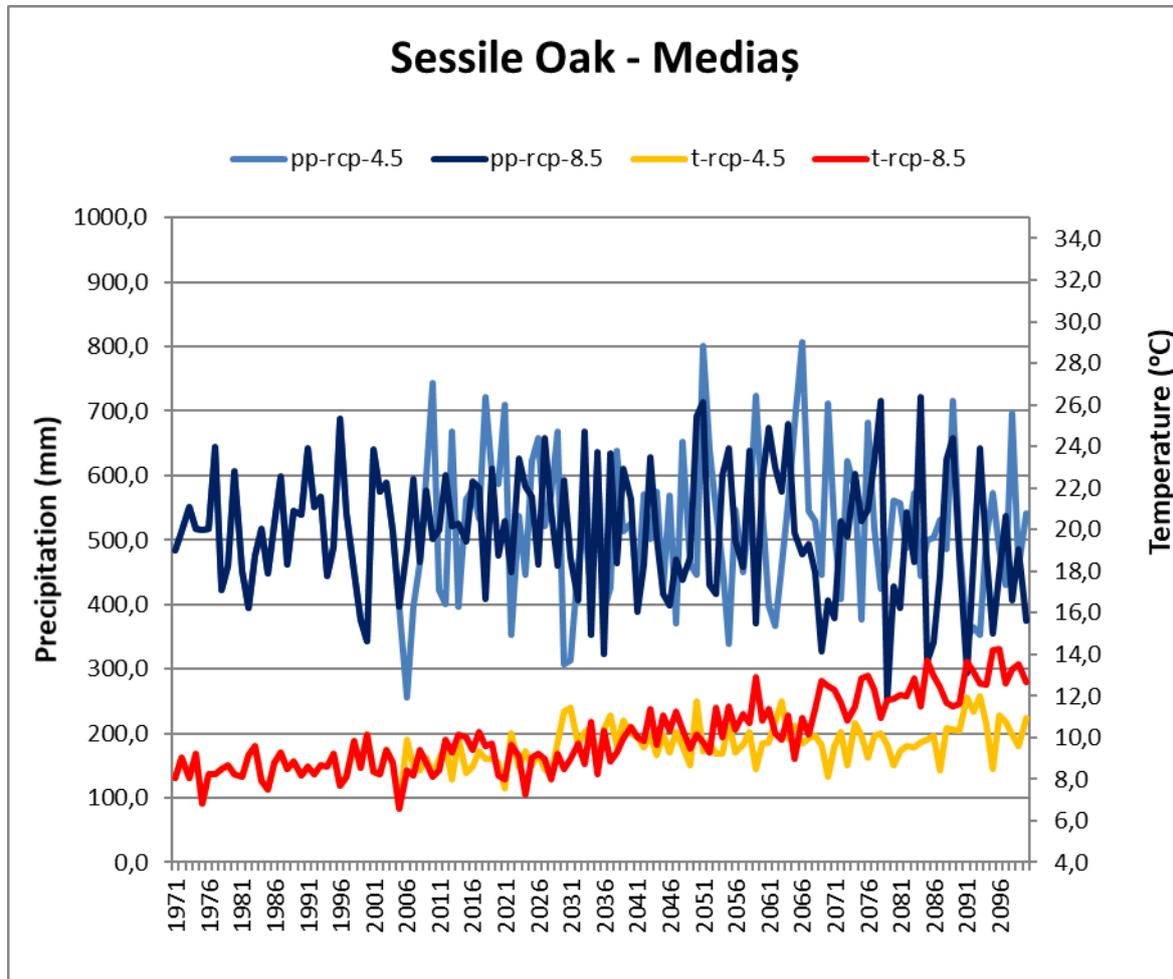


Figure 3. Climatic scenarios for the sessile oak surface from Mediaş

From the point of view of the average annual temperature evolution, the first scenario (rcp-4.5) does not present an alarming situation. Problems appear for the rcp-8.5 scenario, namely in the case in which greenhouse gases will increase significantly. In this case, starting from 2068, each year will present average annual temperatures that exceed the superior limit in which sessile oak can survive.

We can conclude that the sessile oak stand from Mediaş is the most vulnerable from the three studied stands, based on the modification suffered by the two climatic parameters.

The sessile oak stand from Vâlcele has recorded past problems caused by insufficient precipitations from certain years. This fact appears in the historical data recorded for 1983, 1985, 1994, 1998, 2000 and 2005. The data obtained from the HYPE program shows future precipitations problems (under the inferior limit) for both scenarios (figure 4).

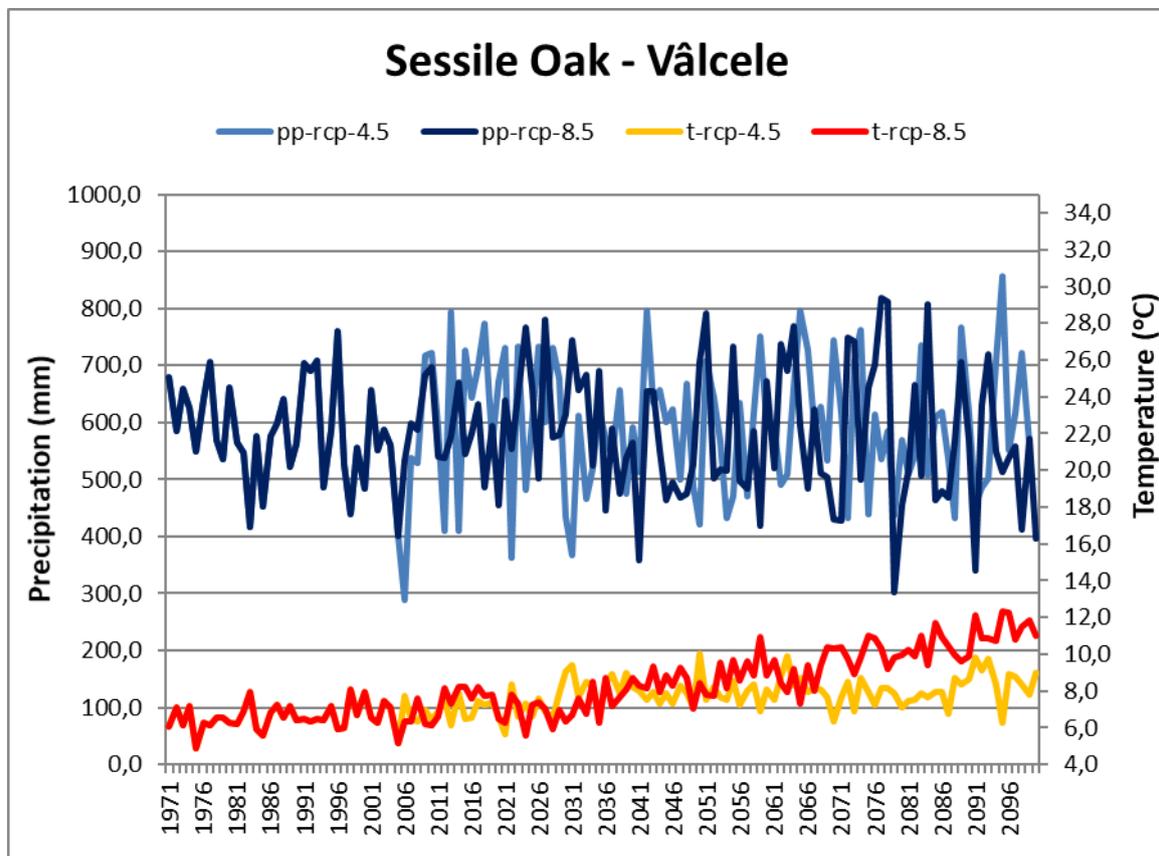


Figure 4. Climatic scenarios for the sessile oak stand from Vâlcele

As for temperatures, problems will not appear in the first scenario (rcp-4.5). Only the second scenario will have this issue towards the end of the studied interval, somewhere after 2090. To synthesize, the stand that vegetates at the experimental base from Lechința institute does not show considerable future problems in regard to the annual averages of both temperatures and precipitations. Most of the values are situated in the specie's extreme intervals for both climatic scenarios, so their impact is weak. The same conclusion can be achieved for the annual average temperature recorded in the first climatic scenario (rcp-4.5 – figure 5).

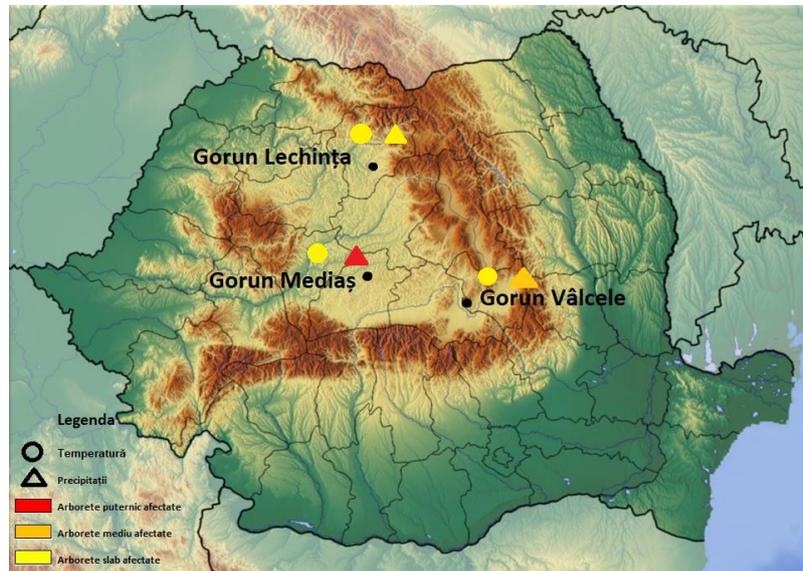


Figure 5. The impact of climatic changes on sessile oak stands for the rcp-4.5 climatic scenario

Problems are starting to appear only for the rcp-8.5 scenario, where greenhouse gases increase significantly from 2054. Temperature impact on the forest ecosystem is strong (figure 6). For the sessile oak stand located in Mediaș, the program’s prediction for both climatic scenarios (rcp-4.5 and rcp-8.5) shows us that it has few chances of survival in the following decades. Only in the first scenario (rcp-4.5), the impact is weak due to the evolution of annual average temperatures.

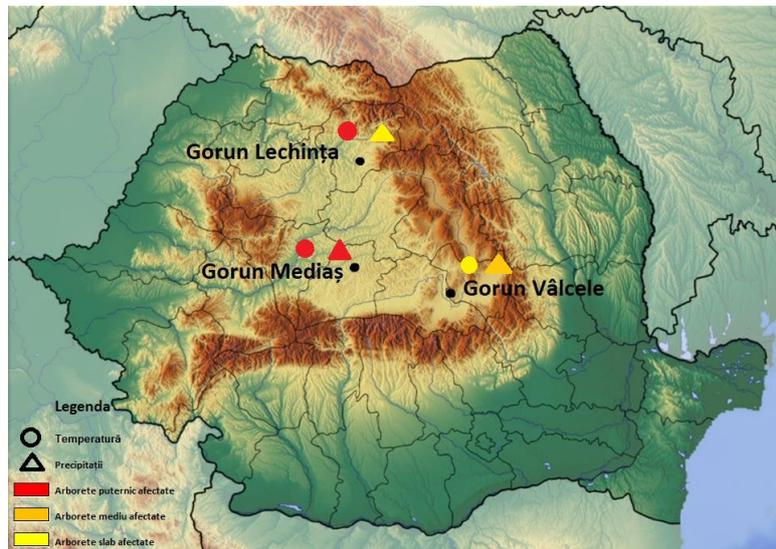


Figure 6. The impact of climatic changes on sessile oak stands for the rcp-8.5 climatic scenario

The impact on the sessile oak stand from Vâlcele will be weak in both scenarios if we consider average annual temperature and moderate if we consider average annual temperatures.

4. CONCLUSIONS

The present paper has used climatic scenarios in the context of moderate and significant changes of greenhouse gases concentrations, leading to an analysis of the effects caused on forest ecosystems located in the studied area from Transylvania's plateau.

The combination of high temperatures interconnected with years with low precipitations will be present in future decades in both climatic scenarios and will strongly test the strength of sessile oak forest ecosystems or of those where sessile oak is a main species. Of course, this situation will also affect stand productivity.

By analyzing all three sessile oak stands, we can conclude that Mediaș stand is the most vulnerable one because of the changes caused to the two climatic parameters.

In the case of the rcp-4.5 scenario, annual average temperatures will strongly affect the Medias cercevetete stand, moderately the Valcele one and only weakly the Lechinta one. In the same scenario, the impact of temperatures on cercevetete ecosystems is weak in all three locations.

As for the rcp-8.5 climatic scenario, annual average temperatures will have a strong impact on Medias and Lechinta stand. The only exception is represented by the Valcele sessile oak stand that will be weakly affected. In the same scenario, the impact of precipitations will be strong for Medias, moderately for Valcele and weakly for Lechinta.

It is necessary to verify and use future climatic scenarios for other areas of our country for the same species and as well for other ones in order to see how they will be affected in the future. Based on these results, we can take better management measures for existing stands as well as establishing decisions for installing future stands.

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