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OAK REACTION TO FUTURE CLIMATE CHANGES IN CENTRAL AND EASTERN ROMANIA

Vlad CRISAN[1], Lucian DINCA[1], Cosmin BRAGA[1], Sorin DECA[2]

[1]National Institute for Research and Development in Forestry "Marin Drăcea", 13 Closca Street, Brasov, Romania
[2]Romanian Academy of Advanced Studies, 125 Calea Victoriei Street, Bucharest, Romania

Corresponding author email: vlad_crsn@yahoo.com

Abstract

The extent of changes in future climatic conditions for oak forest ecosystems has been determined using a climatic modelling software. The HYPE software is able to forecast how certain climatic factors that lie behind extreme climatic phenomena affect forest ecosystems. The software was used to study oak forest ecosystems across sample surfaces within the Transylvania and the Moldova plateaus. The following step was to create simulations for two future climatic scenarios. In the first scenario, the increase of green house gases would be moderate (rcp-4.5), while in the second scenario, the increase would be accentuated (rcp-8.5). After the data processing, there resulted an analysis which focuses on the future changes within the climate which affect forest ecosystems located in the studied area. By analyzing all six oak stands, we can conclude that the Traian stand will be the most vulnerable one. The oak forests will be more affected in Moldova plateau then in Transilvania plateau in the future decades. These results can be used for applying the best management measures for current stands as well as for establishing decisions for installing future stands at the regions studied.

Key words: *climate change, forest ecosystems, oak, Transylvania plateau, Moldova plateau.*

INTRODUCTION

In 1895, Arrhenius has calculated that if the amount of atmospheric CO_2 doubles, this can increase the average global temperature with 5-6°C (Arrhenius, 1896; Uppenbrink, 1996).
Early mathematical climate models have dealt with the issue of global warming by calculating the balance between the solar energy received and the heat output, trying to isolate the determinants. Astronomical cycles have clearly played a role according to Hide and Kuo (Hide, 1953; Kuo 1960).
The idea revived in the 1920s when Milankovic showed that three major astronomical cycles - the eccentricity of the Earth's orbit (a period of 100,000 years), the axial tilt of the Earth (a period of 41,000 years) and the precession of the Earth's axis (a period of 26,000 years) could explain recurrent climate change. These cycles interact, producing large variations of up to 20 or 30% in the amount of insolation at a given latitude (Muller and MacDonald, 2000).
It is difficult to study the climatic system by means of experimental methods because it is very complex and it requires a large time. Therefore, climatic models have been used by scientists (Edwards, 2010). Understanding climate has been made easier due to the use of conceptual models of the cycle of carbon. Chamberlin states that carbon dioxide is the main factor for the global climatic changes (Chamberlin, 1897; Chamberlin 1898). From 1964 onwards, Kasahara and Washington studied Global Climatic Models and they initiated three models between 1963 and 1980 (Harper, 2008; Leith, 1965; Kasahara and Washington, 1967; Washington et al., 1979). Because the first models were limited and generated errors, a number of experiments were run within the regional climatic simulation (Dickinson et al., 1989). In this way, scientists have reused the models's code in order to reduce time and model more complex tasks (Edwards, 2010).
The climatic model used in this study is known as "HYPE" and it was initiated and continuously developed by the Swedish Meteorological and Hydrologic Institute between 2005 and 2007. Two main characteristics of this model are the large array of users and a high resolution in assessing the

environment and climate changes for conditions in which no monitoring is realized.

In silviculture, climatic changes are more and more noticeable (Dincă et al., 2020; Ducci et al., 2021; Kutnar et al., 2021) having a negative impact on trees, soil, logging (Cantar et al., 2022) but also on wildlife and the entire regional landscape (Fedorca et al., 2020; Fedorca et al., 2021). One of the most affected species is the pine (Constandache & Dincă, 2019; Silvestru-Grigore et al., 2018; Vlad et al., 2019), the Norway spruce (Dincă et al., 2019; Murariu et al., 2021), as well as the the sea buckthorn (Constandache et al., 2016; Dincă et al. 2018).

The present research paper aims to analyze 6 oak forest ecosystems which are representative for the Transylvania and Moldova plateaus regarding the future climate changes (Figure 1).

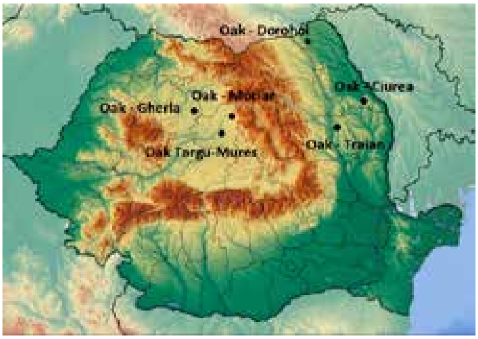

Figure 1. Location of oak plots

MATERIALS AND METHODS

The current paper uses the "HYPE" model and its software menus with the purpose of introducing entrance parameters. In this way, we introduced the coordinates of points (latitude and longitude), the indicator type (in our case temperature and precipitations) as well as the wanted climatic scenario.

The representative concentration pathway (RCP) estimates that global warming will vary between 1 and 3.7°C. Subsequently, the database to which the simulations refer (present day 1986-2005) will be exceeded with values between 1.0 (RCP 2.6) and 3.7°C (RCP 8.5) by the end of the 21st century (Quante and Colijn, 2016).

The HYPE software offers a range a of three scenarios: the greenhouse gases have a low growth ("Low - RCP 2.6"), a moderate growth ("Moderate - RCP 4.5") or a high growth ("High - RCP 8.5") (Figure 2).

After we chose the scenario, we had to choose a convenient timeframe (in our case 2100) and then we had to download the file from the "Download data" submenu.

The downloaded data are in the form of a Microsoft Excel table and represent monthly values. The data introduced in this software belongs to the six oak stands in the Transyilvania and Moldova plateaus.

The HYPE Software is related to a number of regional climatic models. REMO 2009 is a regional atmospheric model (REgional MOdel) which was originally developed by the Max Planck Institute for Meteorology (MPI-M) in Hamburg. Szépszó and Horányi assessed the performance of the REMO model for Hungary (Szépszó and Horányi, 2008).

The REMO 2009 model was chosen for this study because it is the most recent hydrostatic version (Jacob & Podzun, 1997; Jacob, 2001).

The next step was to use Microsoft Excel for processing data, with the purpose of obtaining average monthly values for the studied period (1971-2100).

Figure 2. "HYPE" program menu

RESULTS AND DISCUSSIONS

The results obtained by means of the HYPE modelling program have been introduced in Microsoft Excel. After processing the data, mean annual precipitations and mean annual temperatures have been identified for each stand up to the year 2100. The two scenarios are represented in a graphical form: i.e. an average growth of greenhouse gasses (rcp-4.5) and a high growth of greenhouse gases (rcp-8.5). Each scenario has its own set of values for

precipitations and for temperatures corresponding to each installed stand.
The oak species' variation of biological potential was taken into consideration according to ecological factors: temperature and precipitation (Şofletea & Curtu, 2008) (Table 1). In order to observe the effects of these two scenarios on the forest ecosystems under study, the oak was chosen as a species.

As such, oak – *Quercus robur* L has an adaptability to the continental climate being a mesothermic-euthermic species. The ecological optimum is found in areas where the average annual temperature is between 8-10 (10.5) °C and with an ecological precipitation optimum between 600-800 mm/year (Şofletea & Curtu, 2008) (Table 1).

Table 1. Ecologic card (Stănescu et al., 1997) *Quercus robur* L.

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

where l represents the limit, s the suboptimum and o the optimum

The above data in Table 1 reflects the time period in which the annual average level of temperature and precipitation which is representative for the existence of oak. According to the future climatic scenarios there will be years when the annual averages do not confine within the species' existence interval.
Three intervals were established so as to observe how the oak forest ecosystems will be affected in the next 80 years. The three intervals correspond to three different impact levels: severe, medium and minimal. Consequently, oak forests will be severely affected by future changes if we discover that more than 40 values related to precipitation are below the limit (Table 1). The impact will be moderate if the number of values is between 20 and 40, and minimal if there are less than 20 values. The same intervals should be established for temperature: if there are more than 40 values which exceed 11°C (Table 1) the impact level is severe. If the number of values is between 20 and 40, the impact level is moderate and it it is less than 20, the impact level is minimal.
The Mociar oak stand can be analyzed from the perspective of annual average precipitations. The results show that the values under the established limits were present over periods of time with years characterized by a lack of precipitations (1974, 1975, 1978, 1981, 1982, 1985, 1988, 1994, 1998, 1999, 2000, 2005, 2011-2014 and 2018).

By applying the climatic scenarios resulting from the HYPE modelling program, we can notice that in the future there will be many years that record an annual deficiency of precipitations. Annual average temperatures do not predict a better future - starting from 2070, the average temperature will increase over the species' limit within the rcp-8.5 climatic scenario (Figure 3).
On the other hand, if we take into account the oak stand situated in Targu Mures, the annual precipitation values are lower than the tolerating threshold for both historical data and future simulations.
The oak stand installed in Târgu Mureș reveals a tendency towards an increase in temperature for the next decades (Figure 4). Nevertheless, this growth depends on the chosen scenario. With the passage of time, a major difference between the two scenarios is possible. When analyzing the evolution of the average annual temperature, the first scenario (rcp-4.5) does not reflect an alarming situation. However, for the second scenario (rcp-8.5), starting from 2068, each year will present annual average temperatures that exceed the superior limit for the survival of sessile oak.
Problems appear also in the case of precipitation for both scenarios, namely in the case in which greenhouse gases will increase significantly. As such, the program's prediction for both climatic scenarios (rcp-4.5 and rcp-8.5) shows us that oak stand from this area

have low chances to survive in the following decades (Figure 4).

Regarding the oak stand in Cluj county from Gherla, it is different in terms of the values of the 2 climatic factors.

Concerning the precipitations, the following 80 years do not seem to pose any problems (Figure 5). Supposing the greenhouse gas concentration increases moderately (as in the rcp-4.5 climatic scenario), the annual average temperatures will not represent a problem for the Gherla oak stand.

The only situation in which the greenhouse gas concentration increases considerably is the rcp-8.5 scenario. In this case, the annual average temperature limit will be exceeded starting from the year 2069.

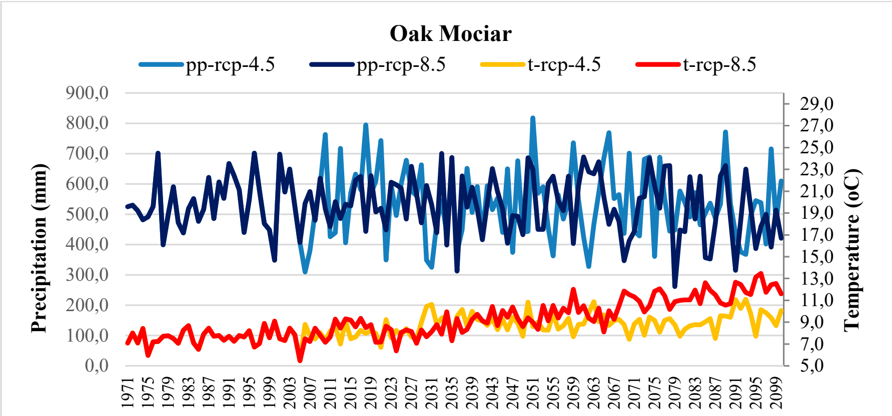

Figure 3. Climatic scenarios for the oak surface from Mociar (Reghin)

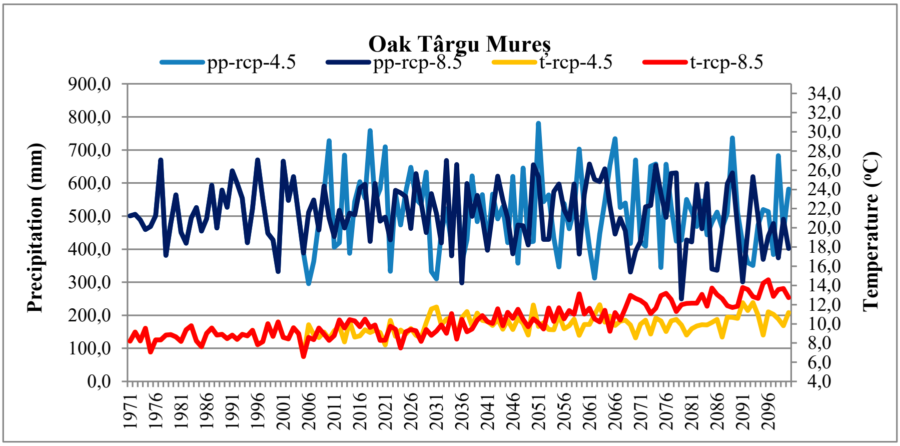

Figure 4. Climatic scenarios for the oak surface from Târgu Mureș

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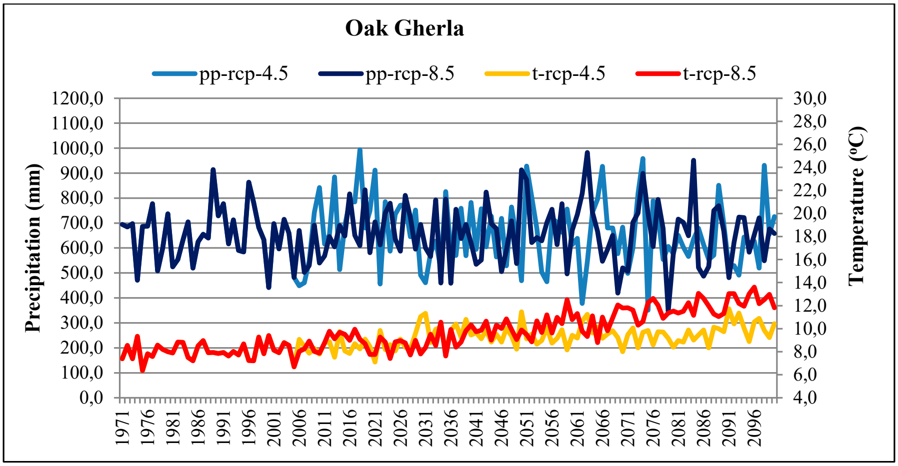

Figure 5. Climatic scenarios for the oak surface from Gherla

The oak stand in Gherla (Cluj County) reveals a different situation from the ones in the Mureș County and this is an advantage for oak forests because it means that there are areas that will not be so affected by climate change.

From all the oak surfaces installed in Transylvania, the Targu Mures oak stand will be the most severely affected in the future by the two climatic factors (precipitation and temperature). Various oak stands were also installed in the Moldova plateau at Traian (Bacau County), Ciurea (Iasi County) and Dorohoi (Botosani County).

The oak stand situated in Traian is characterized by lower values of annual precipitation under the tolerating threshold for both historical data and future simulations.

The average rainfall will be lower and lower, and even if there are extremely rainy years - they will not be able to compensate for the dry periods.

As such, the program's prediction for both climatic scenarios (rcp-4.5 and rcp-8.5) shows us that the oak stand from this area has low chances of survival in the future (Figure 6).

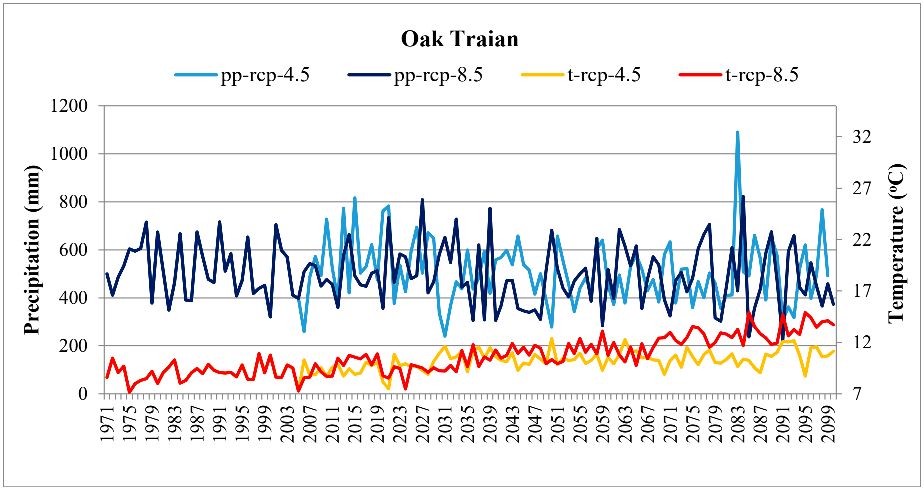

Figure 6. Climatic scenarios for the oak surface from Traian

The are no great difference between the oak stand from Ciurea and the one from Traian. When we apply the two climatic models, some major problems arise in relation to the temperature factor (Figure 7). In the second climatic scenario (rcp-8.5), the oak stand will be severely affected by temperature starting with the middle of 2050.

The HYPE software has calculated a number of years of low precipitations for both climatic scenarios, namely 31 and 35 years corresponding for rcp-4.5 and rcp-8.5.

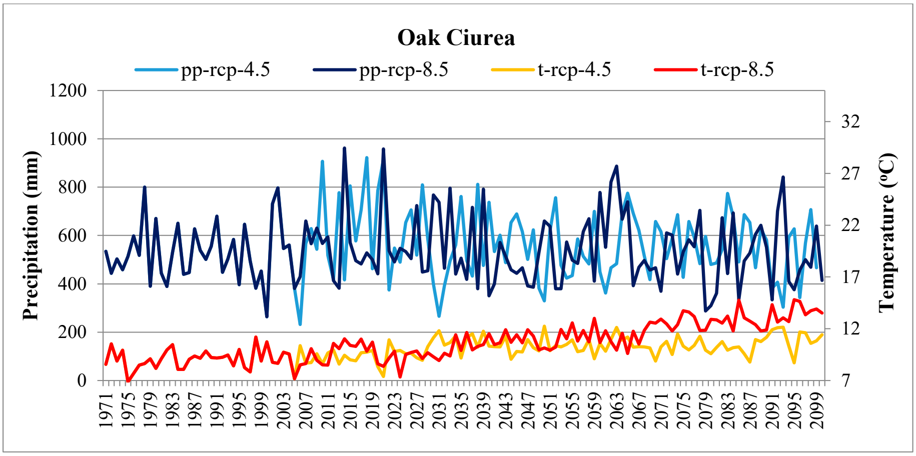

Figure 7. Climatic scenarios for the oak surface located at Ciurea

The Dorohoi oak stand is characterized by high annual average temperatures and low annual average precipitations in both climatic scenarios (rcp-4.5 and rcp-8.5). In this case, there will be 30 annual averages for rcp 4.5 and 29 for rcp 8.5 which will be lower than the limit (Table 1, less than 500 mm/year) of the species existence over the next 80 years (Figure 8). Starting with 2053, the temperature factor from the second scenario records annual exceedings of the 11°C limit (Table 1).

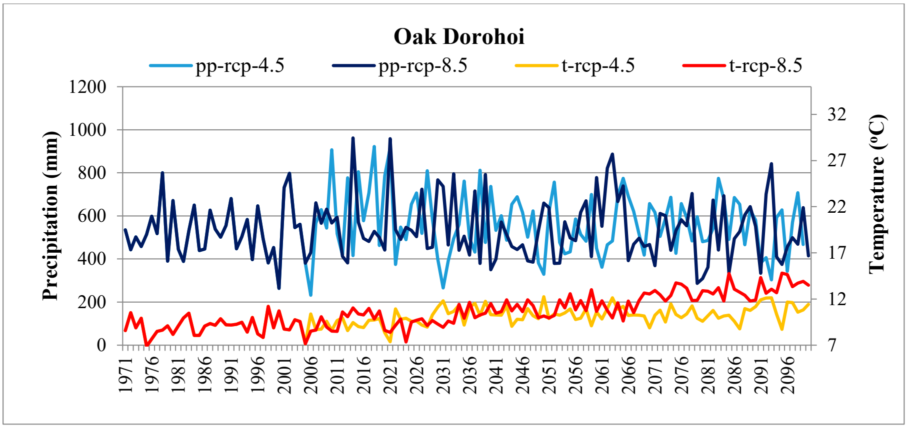

Figure 8. Climatic scenarios for the oak surface from Dorohoi

From all the oak surfaces installed in the Moldova plateau, the Traian oak stand will be the most severly affected in the following decades by the two climatic factors.

An important problem regarding the future climate conditions will be the productivity of the forest ecosystems, considering that, in the conditions of ecological optimum, the productivity of the oak forests is 7.5 m^3/year/ ha at the age of 100 years (Şofletea & Curtu, 2008).

CONCLUSIONS

The research study has focused on future climatic scenarios in order to analyze the increasing effects of greenhouse gas concentrations on the oak forest ecosystems from the plateaus of Transylvania and Moldova. Over the next 80 years, two climatic scenarios have been aknowledged as plausible in the context of moderate and significant changes.

The Targu Mures stand from the Transylvania plateau and the Traian stand from the Moldova plateau will be the most affected in the future by these two climatic factors within all the oak stands.

For both the rcp-4.5 and the rcp-8.5 climatic scenarios, oak stands will be medium to severe affected by annual average precipitations with one exception - Gherla. In the same scenarios, the impact of temperatures will affect medium to severe plots, with 2 exceptions - Gherla and Mociar from Transylvania plateau.

Both scenarios reveal the fact there will be time periods when the annual average temperature is higher than normal and the annual level of precipitation will be rather low. These conditions imply that the survival of oak species is under threat. Provided the species survive, there will be a severe impact on the stand productivity.

It is absolutely necessary to verify and use future climatic scenarios as well, from other areas of our country in order to observe how other forest ecosystems will be affected. The conclusions which result from these studies will lead to taking the best forest management measures.

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