Characteristics concerning the radial growth of mountain pine (*Pinus mugo*) from the subalpine ecotone area of Călimani National Park, Romania

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Abstract. This present research mainly analyzed the radial growth of mountain pine (*Pinus mugo* Turra) in relationship with the climate factors from two different exposures (shaded and sunny slopes) in Călimani Mts., North of the Eastern Carpathians (Romania). In total, 40 samples from both exposures were collected and used to measure annual growth on four radial directions of the stem discs. Dendrochronological series were elaborated for *P. mugo* that covers the period of 1886-2018 for the sunny slope, and 1894-2018 for the shaded slope. The average tree ring width varied individually between 0.20 mm year^{-1} and 1.1 mm year^{-1}. The individual growth series have been standardized in order to eliminate the age-induced trend. Dendroclimatic models were calculated from monthly climatic temperature and precipitation for different time periods of the year, between March of the previous year and September of the current year. On the sunny slope the dendroclimatic model reveals a positive response to temperatures of the current vegetation season, respectively a negative response to the precipitation regime. On the shaded slope, the dendroclimatic model was characterized by a positive response to the temperatures from the previous and current year of the annual ring formation. The precipitations from the year preceding the formation of the annual ring also has a positive and statistically significant influence.

Key Words: dendrology, dendroclimatology, tree ring, temperature, precipitation.

Introduction. In order to know how shrub species specific to habitats in subalpine ecotone areas adapt to the increasingly pronounced climate changes of recent decades, comprehensive research is needed on the structure and functions of ecosystems, and upon the relationship between climatic and biotic factors. According to the literature (Camarero et al 2017), subalpine ecotone areas represents early warning check instruments of the climate change effects on the terrestrial ecosystems. However, the accuracy with which the dynamic of the limit forest vegetation can exactly register the expected temperature rise, is still unclear. The locally existing specific abiotic constraints, such as topography and demographic trends, could cause the limit forest vegetation to be less receptive regarding the climate changes.

In his study of Tibetan treeline vegetation, namely of the annual growth of juniper, Liang et al (2012), has demonstrated that the main restrictive factor of its growth is the water stress. This statement was proven by the variation in the increment of the ring-width during the heating/cooling periods from May-June (evapotranspiration), in contrast to the shrubs and dwarf shrubs from the circumpolar tundra for which the restrictive factor was the low temperature during the vegetation seasons. The precipitation during the summer, its range, duration and the rhythm of the melting of snow have also proven to be key factors concerning the growth of shrubs (Myers-Smith et al 2015).

Variations of climatic factors in relation to different abiotic conditions were recorded in the growth rings of mountain pine (*Pinus mugo* Turra) at the tree line ecotone. Thus, Pelfini et al (2006) in Central Italian Alps, found that May and July temperatures and June precipitations positively influence tree-ring growth. In Apennines, Palombo et al (2014) also found significant correlations with spring temperatures and summer precipitation, *P. mugo* being showed as a sensitive species, in terms of climate–growth relationships. As in the Western Carpathians (Parobekova et al 2018) *P. mugo* lays like a subalpine belt that dominates high-elevation plant communities, which was also affected in the past by deforestation in order to create alpine meadows suitable for grazing.

The present study aimed to determine the radial growth in *P. mugo* and the correlation of radial growth indices with climatic factors, on two opposite exposures in the Călimani Mountains.

Material and Method. The study has been conducted in Călimani National Park, located in the upper area of Călimani Mountains, in the west side of the Eastern Carpathians, Romania, between 47°15'-47°23' northern latitude and 25°11'-25°14' eastern longitude, and 1,300-2,100 m altitude respectively (Figure 1).

P. mugo is the dominant tree species of the subalpine area of Călimani Mountains, extending like a compact layer. The composition of the woody vegetation in this area sporadically includes the species such as green alder *Alnus alnobetula* (Ehrh.) K.Koch, mountain-ash *Sorbus aucuparia* L., spruce *Picea abies* (L.) H.Karst and Swiss stone pine *Pinus cembra* L.

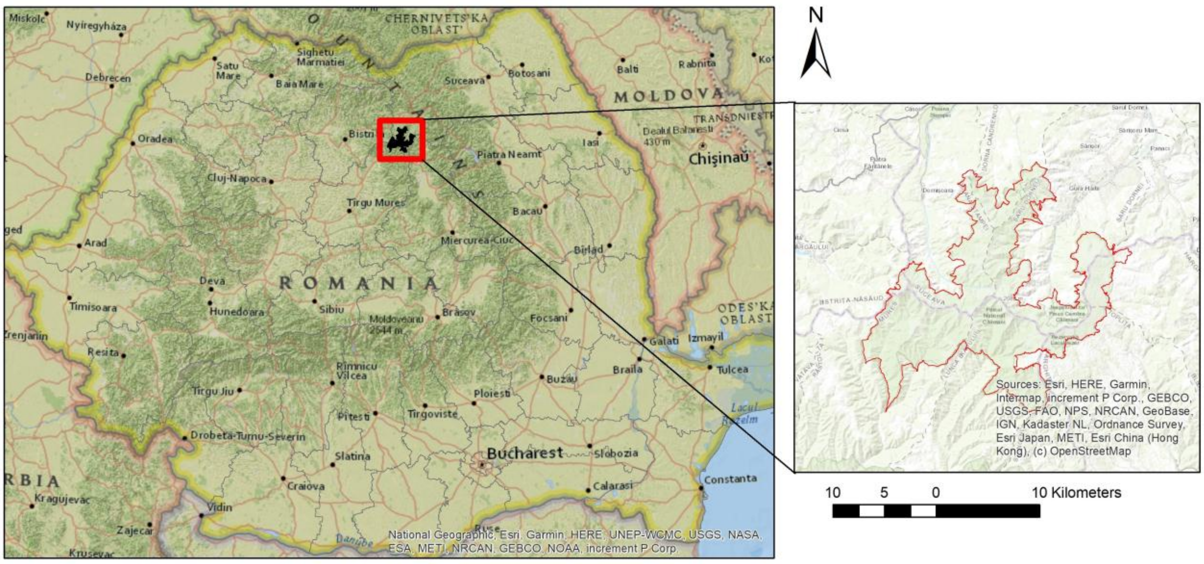

Figure 1. Location map of Calimani National Park, Romania. Map source: http: //geo-spatial.org/ and NFA-Romsilva, Călimani National Park.

Data collection and analysis. In order to determine the multiannual radial growth of the *P. mugo*, a series of samples have been collected from 40 *P. mugo* trees located in two different exposures: a sunny slope (CALS) and a shaded slope (CALN). The altitude where these specimens could be found is between 1,750-1,800 m, in the subalpine area of the Călimani National Park (Figure 2).

In order to emphasize the annual rings, a series of wood samples were studied. The measurements have been generated on high resolution images (2400 DPI) with the help of the CooRecorder software (Larsson 2014), having a precision of 1/100 mm and individual series of radial growth have been elaborated through the CDendro software (Larsson 2014).

The individual growth chronology concerning the annual ring-width has been standardized afterwards by applying a theoretical cubic spline function of 67% of the length of the individual chronology in order to exclude the variation influenced by the age trend. The growth indices were obtained by reporting the measured values to the values estimated by the standardizing function. The average growth index series were obtained by weighted average (Semeniuc Fecioru et al 2019).

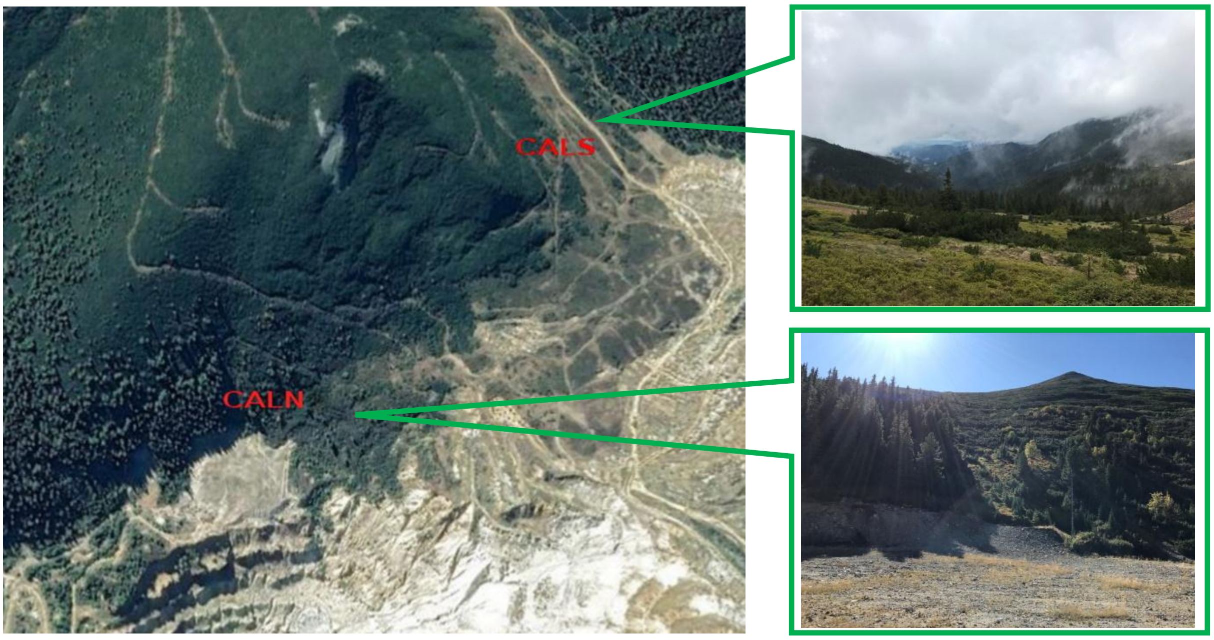

Figure 2. Area location in the Călimani National Park – shaded slope (CALN) and sunny slope (CALS) (original).

The monthly analysis of the climatic factors for different time periods of a year, between March from previous year and September current year, represented the basis on which the dendroclimatic models for determining the manner of response of the *P. mugo* concerning their variation have been established. DENDROCLIM2002, an informatic program (Biondi & Waikul 2004), was used to statistically calibrate the climate signals in tree-ring chronologies, the climatic data set used in the dendroclimatic modeling is represented by the daily data exported automatically from the database grid with a spatial resolution of 0.25° x0.25° - 1950-now: E-OBS v20.0e Tg (Europe), of the KNMI Climate Explorer web application.

Results and Discussion. The radial growth chronology of *P. mugo* corresponding to the sunny slope has taken place during 1886-2018, reaching the max value of 133 years, respectively an average of 67 years. The average width of the annual tree-ring varied individually from 0.24 mm year^{-1} to 1.1 mm year^{-1}, the average value being 0.60 mm year^{-1}. The radial growth chronology corresponding to the shaded slope has taken place during 1894-2018, reaching a maximum length of 125 years, with an average of 63 years, respectively. The average width of the annual tree-ring varies at an individual level, starting from 0.20 mm year^{-1}, reaching 1.06 mm year^{-1}, with an average value of 0.62 mm year^{-1} (Figure 3). The average sensitivity is higher compared to the sunny slope, being of 0.19 and the order I correlation, lower (0.743).

The correlation between the climatic factors and the radial growth parameters of the mountain pine tree unveiled a reduced influence. The shape and the relatively high presence of the compression wood lead not only to a high variability of the annual ring-width, but also to a high level of noise in the dendrochronological signal.

The dendroclimatic model for the sunny slope displays a positive influence of the temperature from the current vegetation season, mainly focused in January, thus being also relevant from a statistic point of view. Regarding the precipitation regime, one can identify negative correlations centered in the month of May, respectively August of the current year of the annual ring formation (Figure 4).

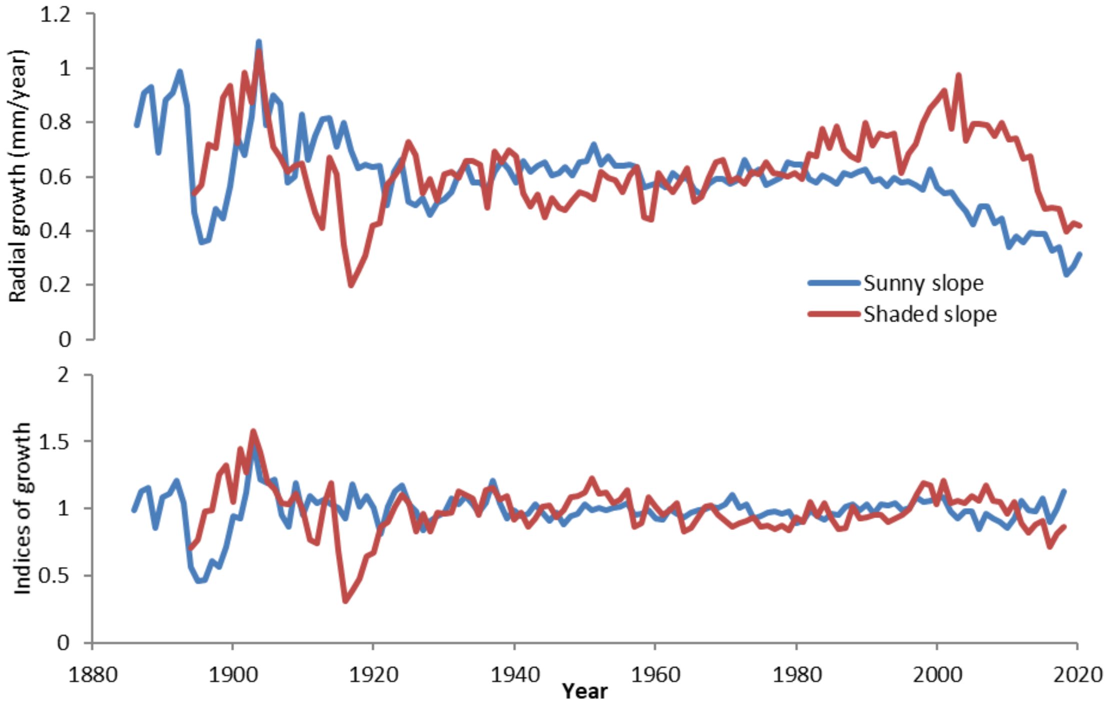

Figure 3. The average radial growth chronology and the indices of growth of the *Pinus mugo*.

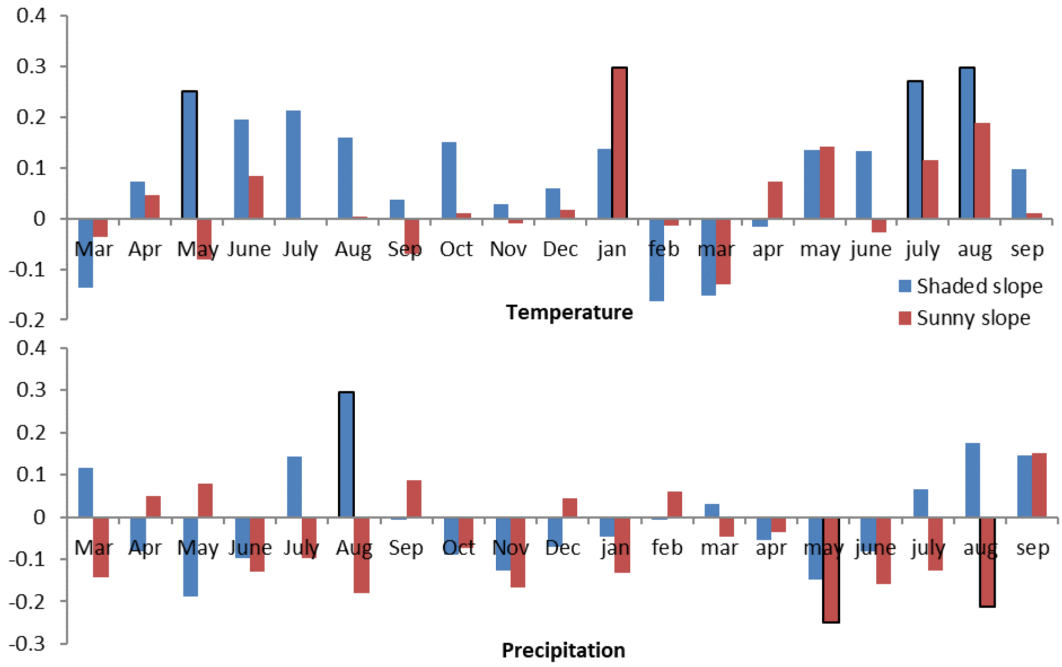

Figure 4. The correlation between the radial growth parameters and the climatic factors of *Pinus mugo*.

Studying the shaded slope, the dendroclimatic model highlighted a positive outcome concerning the May temperatures from the previous year, respectively the July and August temperatures from the current year. Moreover, a positive and statistically important influence could be defined by the August precipitation from the year previous of the annual ring formation. Coppola et al (2013), Pelfini et al (2006), Frank & Esper (2005) who conducted studies for numerous species in the Alps, Švajda et al (2011), Büntgen et al (2007) in Tatra Mountains, and Calderaro et al (2020) and Dai et al (2017) in the Apennines, found similar positive and significant correlations with summer temperatures in tree growth.

Conclusions. The results of the correlation analysis between the parameters of radial growth and climatic factors have emphasized a significant influence concerning the regime of temperatures and precipitations. These have also drawn the conclusion that *P. mugo* could be depicted as a sensitive species. Therefore, the temperature from the previous year of the formation of the annual ring had a positive influence upon the growth in the late spring (May) of *P. mugo* located on the sunny slope. Moreover, in the previous year of the formation of the annual ring, the precipitations have positively influenced the mountain pine located on the shaded slope during the late summer (August).

The temperature during the winter months, January respectively, of the current year of the formation of the annual ring has positively influenced the radial growth of the *P. mugo* located on the sunny slope. Furthermore, the *P. mugo* located on the shaded slope has proven to be positively influenced by the summer temperatures (July-August).

No compelling positive correlations concerning the precipitations from the current year have been identified. One could emphasize that the precipitation registered in spring (May) and summer (August) had a negative impact towards the *P. mugo* located on the sunny slope.

In the present research paper, the impact of the climatic factor on the radial growth of *P. mugo* in Călimani Mts. has been emphasized which could be henceforth considered an important subject of further study in the context of climate change.

References

Biondi F., Waikul K., 2004 DENDROCLIM2002: A C++ program for statistical calibration of climate signals in tree-ring chronologies. Computers & Geosciences 30(3):303-311.

Büntgen U., Frank D. C., Kaczka R. J., Verstege A., Zwijacz-Kozica T., Esper J., 2007 Growth responses to climate in a multi-species tree-ring network in the Western Carpathian Tatra Mountains, Poland and Slovakia. Tree Physiology 27(5):689-702.

Calderaro C., Cocozza C., Palombo C., Lasserre B., Marchetti M., Tognetti R., 2020 Climate–growth relationships at the transition between *Fagus sylvatica* and *Pinus mugo* forest communities in a Mediterranean mountain. Annals of Forest Science 77(3):1-15.

Camarero J. J., Linares J. C., García-Cervigón A. I., Batllori E., Martínez I., Gutiérrez E., 2017 Back to the future: the responses of alpine treelines to climate warming are constrained by the current ecotone structure. Ecosystems 20(4):683-700.

Coppola A., Leonelli G., Salvatore M. C., Pelfini M., Baroni C., 2013 Tree-ring-based summer mean temperature variations in the Adamello-Presanella Group (Italian Central Alps), 1610-2008 AD. Climate of the Past 9:211-221.

Dai L., Palombo C., Van Gils H., Rossiter D. G., Tognetti R., Luo G., 2017 *Pinus mugo* krummholz dynamics during concomitant change in pastoralism and climate in the Central Apennines. Mountain Research and Development 37(1):75-86.

Frank D., Esper J., 2005 Characterization and climate response patterns of a high-elevation, multi-species tree-ring network in the European Alps. Dendrochronologia 22(2):107-121.

Larsson L. A., 2014 CooRecorder and Cdendro programs of the CooRecorder/Cdendro package. Cybis Elektronik, Saltsjöbaden, Sweden.

Liang E., Lu X., Ren P., Li X., Zhu L., Eckstein D., 2012 Annual increments of juniper dwarf shrubs above the tree line on the central Tibetan Plateau: a useful climatic proxy. Annals of Botany 109(4):721-728.

Myers-Smith I. H., Elmendorf S. C., Beck P. S., Wilmking M., Hallinger M., Blok D., Tape K. D., Rayback S. A., Macias-Fauria M., Forbes B., Speed J. D. M., Boulanger-Lapointe N., Rixen C., Lévesque E., Schmidt N. M., Baittinger C., Trant A. J., Hermanutz L., Collier L. S., Dawes M. A., Lantz T., Weijers S., Jørgensen R. H., Buchwal A., Buras A., Naito A. T., Ravolainen V., Schaepman-Strub G., Wheeler J. A., Wipf S., Guay K. C., Hik D., Vellend M., 2015 Climate sensitivity of shrub growth across the tundra biome. Nature Climate Change 5(9):887-891.

Palombo C., Battipaglia G., Cherubini P., Chirici G., Garfì V., Lasserre B., Lombardi F., Marchetti M., Tognetti R., 2014 Warming-related growth responses at the southern limit distribution of mountain pine (*Pinus mugo* Turra subsp. *mugo*). Journal of Vegetation Science 25(2):571-583.

Parobeková Z., Bugala M., Kardoš M., Dovciak M., Lukáčik I., Saniga M., 2018 Long-term changes in dwarf pine (*Pinus mugo* Turra) cover and growth in the Orava Beskid Mountains, Slovakia. Mountain Research and Development 38(4):342-352.

Pelfini M., Leonelli G., Santilli M., 2006 Climatic and environmental influences on mountain pine (*Pinus montana* Miller) growth in the Central Italian Alps. Arctic, Antarctic, and Alpine Research 38(4):614-623.

Semeniuc Fecioru A., Balabașciuc M., Rogojan C., Popa I., 2019 Modele dendroclimatice pentru smirdarul din zona de limită superioară a Munților Călimani. Revista de Silvicultură și Cinegetică 45:22-26.

Švajda J., Solár J., Janiga M., Buliak M., 2011 Dwarf pine (*Pinus mugo*) and selected abiotic habitat conditions in the western Tatra Mountains. Mountain Research and Development 31(3):220-228.

Trouet V., Van Oldenborgh G. J., 2013 KNMI Climate Explorer: a web-based research tool for high-resolution paleoclimatology. Tree-Ring Research 69(1):3-13.

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