THE INFLUENCE OF CLIMATE CHANGE ON THE DRYING OF FIR TREE IN THE ROZNOV AREA (NEAMȚ COUNTY, ROMANIA)

INFLUENȚA MODIFICĂRILOR CLIMATICE ASUPRA USCĂRII BRADULUI DIN ZONA ROZNOV- NEAMȚ

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Abstract.
Due the climate change, an alarming increase of the phenomenon of drying of coniferous trees, has been observed. The attack of ipides found in fir stands is a secondary attack that occurs following the physiological weakening of the trees and their drying as a result of the lack of precipitation and high temperatures. The entire Eastern range of the Eastern Carpathians is vulnerable to drought, especially the stands located at altitudes below 800-1000 m and with S, S-E or S-W exposure, where the precipitation level is low and the temperatures are quite high, the mountains themselves constituting a barrier for the precipitation coming from the West. An urgent measure to stop the phenomenon, is the urgent valorization of the already affected wood mass and its exploitation. Trees that are lanceolate, attacked by mistletoe, fungi, etc. should also be extracted. For regeneration, deciduous or other species with higher resistance to drought and heat stress should be used.
Key words: fir, drying, infestation, resinous, ipidae.

Rezumat.
Din cauza schimbărilor climatice, s-a observat o creștere alarmantă a fenomenului de uscare a coniferelor. Atacul ipidelor care apare la brad, este un atac secundar, ce apare în urma slăbirii fiziologice a arborilor și a uscării acestora datorită lipsei de precipitații și a temperaturilor ridicate. Întregul lanț estic al Carpaților Orientali este vulnerabil la fenomenul de uscare a brazilor, în special a arboretelor situate la altitudini sub 800-1000 m și cu expoziții S, S-E sau S-V, unde nivelul precipitațiilor este scăzut, iar temperaturile destul de ridicate, munții înșiși constituind o barieră pentru precipitațiile provenite din zona vestică. Ca măsură urgentă de stopare a fenomenului, se va acorda o atenție sporită alegerii arborilor care vor fi extrași, fiind necesar să se extragă și arborii care au formă lanceolată, atacați de vâsc, ciuperci etc.

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Pentru regenerare, trebuie folosite specii de foioase sau altele rezistență mai mare la condiții de secetă și stres termic.
Cuvinte cheie: brad, uscare, infestare, rășinoase, ipide.

INTRODUCTION

According to the 2014 Forest Management Plan, the Roznov Forest District has an area of 4712 ha of coniferous forests (state forest fund), of which 3388 ha are fir, 1244 ha are spruce and approximately 100 ha are other coniferous stands (pine, larch, Douglas fir). It should be noted that out of the 1244 ha of spruce, 115 ha are spruce outside the species range. Pure coniferous stands are in very small areas, forming mixtures of coniferous trees with beech and other deciduous species.

In recent years, because of the climate change at a global and national level, there has been an alarming increase in the phenomenon of drying of coniferous trees, especially fir trees. The main causes are increasing temperatures and lack of precipitation, the combination of the two, leads to the phenomenon of dryness and then drought. In addition, there are a number of factors that amplify this phenomenon.

The major factor that most influences the drying phenomenon is drought, in its various forms. In order for drought to occur, a period of pluviometric deficit is needed, and recent years (2019-2023) are notable for the low level of meteoric precipitation as well as the high multiannual average temperature. In fact, the year 2023 was declared the warmest year from 1960 to the present. Taking into account that the drying phenomenon in the fir tree has gained since 2023, we will refer to the statistical data and the climatological parameters of this year.

Fir tree (*Abies alba*) is an economically important species that forms valuable mixed stands together with spruce and beech. In recent decades, however, a decline of this species has been observed, with phytopathological, entomological and climatic causes [Barbu *et. al.,* 1991].

The problems recorded by fir both in pure and mixed stands have extended even into the natural range of this species, manifesting themselves both at advanced ages (by drying) and at the level of regeneration of the respective stands.

MATERIAL AND METHOD

This study aimed to analyze the structure of fir stands affected by the drying phenomenon, especially in order to determine the degree of pest infestation of the stands.and method.

The research method used was observation, both direct (with reference to tree morphology, presence of defects, etc.), and instrumental (consisting of measuring lengths/heights, diameters/thicknesses, etc.). As data processing methods, mathematical statistics methods were used: correlation analysis as well as methods related to spatial analysis of phenomena (precipitation maps, with pluviometric severity classes, etc.).

RESULTS AND DISCUSSIONS

The cumulative precipitation level for the year 2023, at the Piatra-Neamt weather station, was approximately 531.55 mm. The data from this weather station are also of reference for the area where the Roznov Forest District is located.

Table 1

Monthly level of precipitation, 2023

Mth	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	mm/ yr.
Qty	21.5	49.4	16.9	135.7	33	80.3	35.8	6.85	24.1	12.5	108.2	7.3	531.6

Table 1 shows that the seasonal precipitation levels are:

- Spring - 185.6 mm;
- Summer - 122.95 mm;
- Autumn - 144.8 mm;
- Winter - 78.2 mm.
- Vegetation period (April - September) - 315.75 mm.

A major deficit of precipitation is observed both during the vegetation period and during the vegetative rest period (fig. 1 and fig. 2, www.meteoromania.ro/clim/caracterizare-anuala/cc_2023.html).

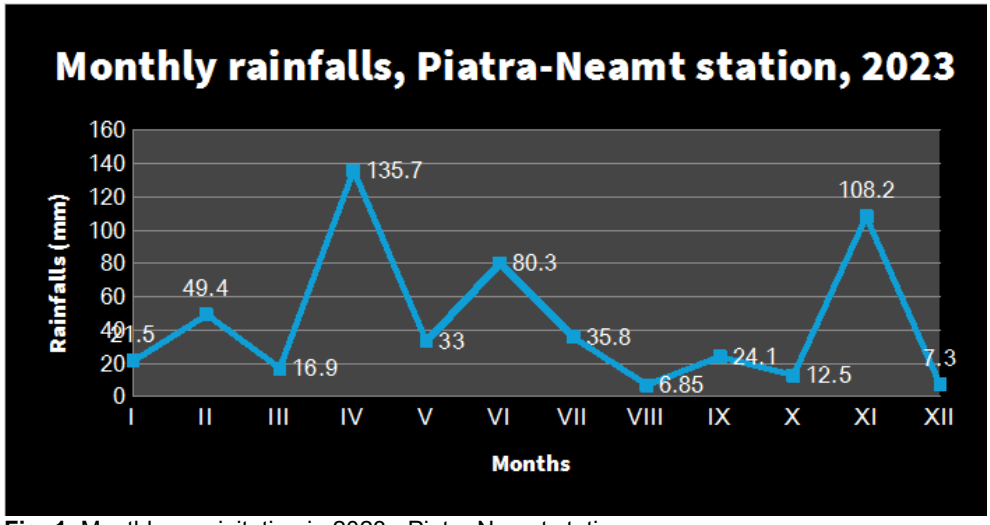

Fig. 1. Monthly precipitation in 2023 - Piatra Neamț station

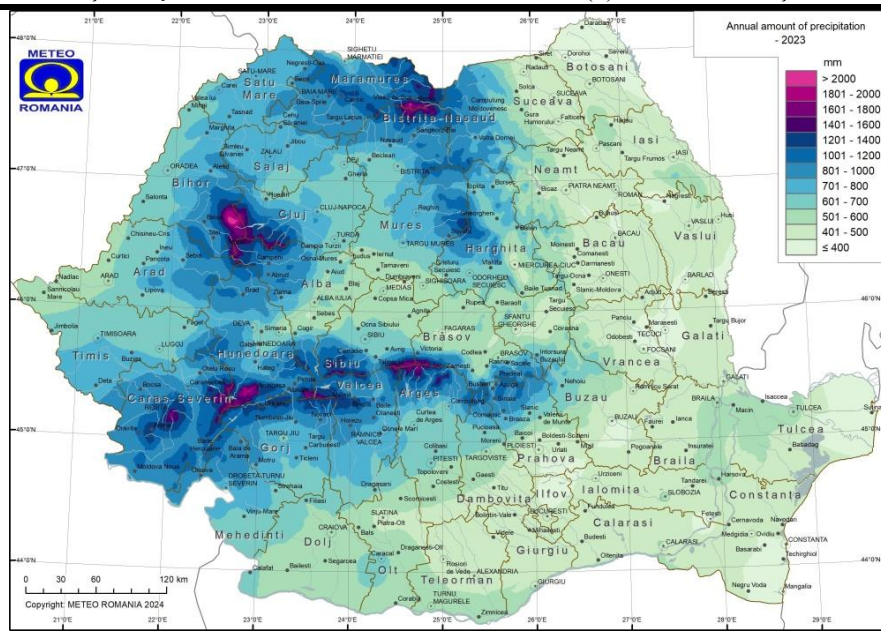

Fig. 2. Precipitation map, year of 2023

From the two maps provided by the National Institute of Meteorology and Hydrology Romania, we can see the low level of precipitation in our area and also the classification of the area in the maximum severity class = very deficient (fig. 3, www.meteoromania.ro/clim/caracterizare-anuala/cc_2023.html).

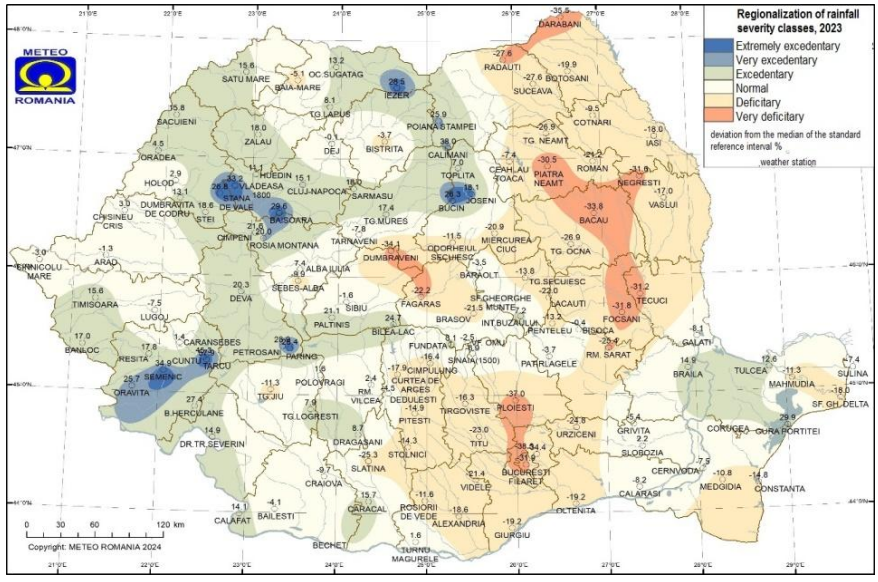

Fig. 3. Regional map with rainfall severity classes in 2023

The rainfall deficit is based on two components:

• Dry period - when there has been no precipitation for at least 5 consecutive days or it is much below the multiannual daily average. During 2023, several drought sequences were observed in the Roznov Forest District area;

• Drought period - when at least 10 consecutive days (between April and September) have not had precipitation or those that have fallen have a value lower than 0.1 mm and 14 consecutive days in the cold period. Such a sequence was in September.

The drought manifested in 2023 is based on 3 components:

• Absence of precipitation/humidity;

• Abnormal deficit, manifested in relation to statistical reference values;

• Prolonged duration of the deficit.

Drought was classified by Lambert (1990) into several categories, and of these, the following were manifested within the Roznov Forest District:

► Atmospheric drought - which manifested itself through a significant deficit of precipitation compared to the usual average conditions (table 2).

Table 2

Monthly level of precipitation deficit, 2023

Mth	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
max	6.6	6.1	13.0	13.4	22.0	27.1	30.7	31.7	26.4	22.0	11.6	7.3	18.2
min	-0.2	-2.7	0.2	3.8	9.2	13.4	16.2	16.1	12.7	6.0	1.9	-2.4	6.2
mthly	3.2	1.7	6.6	8.6	15.6	20.3	23.4	23.9	19.5	14.0	6.7	2.4	12.2

This is also correlated with the high temperature in 2023 (12.2ºC), compared to the annual average of 8.4º C (according to the 2014 Forest Management), with high wind speed and the periods in which it manifested itself (fig. 4):

Fig. 4. Temperature variation, Piatra-Neamț meteorological station, 2023

It has been noted in the last three years there has been a greater number of days in which wind was present (generally winds from the West and North-West direction) and a decrease in the number of days with atmospheric calm. The constant presence of winds together with high temperature leads to an increase in evapotranspiration (ETP) and an increase in the humidity deficit.

The average temperature by season was:

◦ Spring +10.3°C;

◦ Summer +22.5°C;

◦ Autumn +13.4°C;

◦ Winter +2.4°C.

► Meteorological drought – when the level of precipitation falls below a certain threshold P<ETP<ETR;

► Pedological drought – appeared and manifested itself with the extension of the atmospheric drought. Under these conditions, the useful water reserve in the soil for forest formations decreases, RU→0. The soil water deficit as well as the edaphic characteristics of the soil, exposure, slope, also contribute to the exacerbation of this drought;

► Phreatic drought – which leads to the decrease in groundwater and the drying up of springs, QS→0. Many springs existing in the forest fund of Roznov Forest Dostrict dried up in 2023. This is the result of the water deficit;

► Hydrological drought – is manifested by the drying up / drastic decrease of water courses, these tending →0. In 2023, the Calu stream completely dried up on a section of approx. 1 km before the spillway, and in the U.P. IV Cut area, the streams have completely dried up. The flow of the Iapa stream has been reduced by 2/3 of its volume.

In addition to this classification of Lambert, which also lacks the drought of hydraulic reservoirs, we must also mention physiological drought, which occurs in cold periods, when the air temperature increases (up to 10ºC) and the soil is frozen or suffers from phreatic drought. The affected forest species are conifers, which are evergreen, and at positive temperatures photosynthesis and the transpiration process begin. Becoming bioactive, evapotranspiration increases (accentuated by the constant presence of wind), they do not have access to the water resource in the soil, which is frozen or devoid of useful water resources. In this sense, they consume their reserves, which leads to their irreversible "withering". In the first phase, the foliage (conifers) turns purple, after which it soon turns completely red and falls.

The most vulnerable species is fir, being affected stands/specimens that are located at low altitudes, on sunny slopes (South, South-East and South-West), those located on steep slopes (where drainage is rapid), with skeletal soil/rock on the surface, with a short bioactive soil horizon. Also affected are lanced/weakened fir stands, affected by anthophytoses and cryptogamic factors (rot), those of advanced age or where have been efectuated regeneration cuts and where the consistency has dropped below 0.6, being affected that favorable climate, existing in stands with

full consistency where the temperature inside is lower in summer and higher in winter by 1-2 degrees compared to the outside and where the humidity is higher and the air currents are weaker. It is observed that young resinous stands are not affected by the drying phenomenon, the phenomenon appearing after the age of 100 years.

In order to highlight the climatic changes in recent years that have contributed to the increase of the phenomenon of drying of fir trees and the infestation of resinous stands with ipides, we calculated a series of ecometric indices that highlight the favorability or otherwise of certain forest formations in the current climatic context for the area of the Piatra-Neamt weather station. These indices were calculated for the year 2023 and were compared with those calculated/existing in the 2014 Forest Management Plan (table 3, fig. 5).

Table 3

Monthly temperatures and precipitation level, 2014/2023

mth	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yr
t.avg 2023	3.2	1.7	6.6	8.6	15.6	20.3	23.4	23.9	19.5	14.0	6.7	2.4	12.2
t.avg 2014	-3.3	-2.5	2.4	8.8	14.2	17.5	19.5	18.9	14.8	8.9	3.1	-1.1	8.4
P. 2023	21.5	49.4	16.9	135.7	33	80.3	35.8	6.85	24.1	12.5	108.2	7.3	531.6
P. 2014	31.3	29.4	39	60.5	95.1	120.8	101.8	74.9	56.2	53.7	35.3	33.9	731.9

Mth – month; t.avg – average temperature; P. – precipitations; yr – year

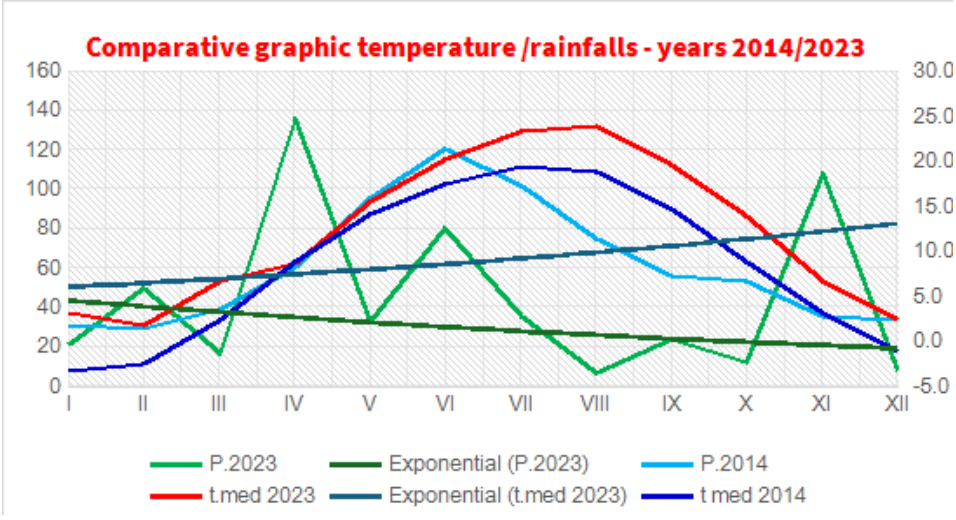

Fig. 5. Comparative graph of temperatures/precipitation in the years 2014/2023

From table 3 and figure 5 we can observe that:

• The year 2023 was the year with all positive monthly average temperatures;

• The annual average temperature in 2023 is 3.8ºC higher than in 2014;

• The total annual precipitation in 2023 is 200.3 mm lower than in 2014;

• The temperature trend is increasing compared to 2014;

• The annual precipitation trend in 2023 is decreasing compared to 2014.

• In the graph, a correlation was made between the thermal regime and the precipitation regime (Chiriță diagram [Chiriță, 1997]), valid for each year studied, in which it is observed for 2023 that during the period of maximum biological activity the precipitation level is very low (15.04-15.09).

The temperature range for 2023 is 22.2 ºC.

Evapotranspiration ETP =584-for 2014.

Relative humidity =68%.

Climate indices are calculation formulas that highlight the favorability of a climate and are based on the values of some main climate factors. In this regard, the following indices have been calculated:

► Martonne aridity index - allows determining the degree of aridity of a region over a given period (year, month, season) It is calculated with the formula:

• Ia=P/T+10 (annual) =23.99 for the Piatra Neamt/2023 station and corresponds to a semi-humid climate with a value range of 20-25 and a steppe subtype with tall grasses.

• Ia= 35.5 (since 1977 and taken over in the 2014 arrangement) - according to Chiriță, 1977, it corresponds to a humid climate with a value range of 35-40 and a beech forest subtype.

• In conclusion, we observe a decrease in this index from humid climate to semi-humid climate, characteristic of steppe and forest-steppe.

►The Gams continentalism index - shows the climatic influence in establishing favorable areas for some forest formations, and is calculated with the formula Icont=P/alt, where P = annual precipitation, alt = altitude of the nearest weather station.

Icont=1.046, for the Piatra Neamt station/2023. When its value is <1 the area is favorable for conifers, when the value is between 1-2 the area is favorable for beech, and when its value is > 2 the area is favorable for thermophilic species.

►Tetraterma Mayr (TM) - this index highlights the climatic restrictiveness of an area for certain forest formations through continentality, altitude, exposure, etc. It is calculated as an arithmetic mean of the warmest consecutive months, overlapping periods of maximum biological activity.

◦ TM=(tv+tVI+tVII+tVIII)/4 = 21.78, for the Piatra Neamt station/2023. Values between 18-22 represent the optimum, however, for thermophilic species.

►Precipitation amounts:

◦ ΣPIX-III = 203.3 mm, for the Piatra Neamt station/2023 and represents the period of water accumulation in the soil. For the year 2014, Σ =278.8 mm, 75.5 mm more than in 2023;

◦ ΣPVII-VII =4 2.65 mm/year 2023 - represents the sum of precipitation during the period of maximum biological activity. For the year 2014- ΣPVII-VII = 176.7mm, 134 mm more than in 2023.

►The conventional moisture balance (K) - represents the degree of climatic favourability for forest vegetation. K=ΣPtc≥10ºC/ΣT≥10ºC =1.651/ for the year 2023. When the value of this index is sub-unit, the favourability is for steppe formations, and when K>1 it is favourable for forest-steppe and forest species.

►Rain index Lang - this index is the result of the ratio between precipitation and temperature. R=T/P =43.721, for the Piatra Neamț station/2023, corresponding to a semi-arid climate with values between 40-60. For 2014, this index had a value of 87.13 - corresponding to a warm temperate climate (100-60).

►Fao-Unep index - bioclimatic index of aridity and desertification, Iα=P/ET=0.91, value calculated for the year 2023. For the year 2014 the value of this index was Iα=P/ET=1.25. The trend of aridification of the climate is observed.

►Forest aridity index FAI – (100*(TVII+TVIII)/2)/(PV+PVI+2*PVII +PVIII) = 11.91.

As can be seen from the above presented and calculated indices, there is a dramatic climate change trend, a warming and aridification trend of the territory. It is also observed that the climates are becoming unfavourable for certain forest stands currently existing in the field.

It is observed that the distribution of precipitation is subject to some distribution laws, which consist of:

• Progressive decrease of precipitation from West to East, the dominant circulation of air masses is the Western one;

• Atmospheric precipitation increases constantly in altitude in accordance with the vertical pluviometric gradient (fig. 2).

Climate change through changes in air temperature and precipitation amounts has an impact on trees and plants by influencing their productivity, distribution and area of spread, as well as on the soil [Belyazid *et. al.*, 2019; McNulty and Boggs, 2010]. High temperatures can also have an impact on tree phenology, by increasing the growing season, but can also contribute to the migration of species to higher altitudes [Parmesan, 2006]. At the same time, increasing temperatures can intensify the evapotranspiration process and in combination with reduced precipitation lead to increased water stress. Air pollution and climate change are two strongly correlated factors. Most of the time, their impact on forest ecosystems, especially on tree growth and the relationship between climatic factors and auxological processes, have been analysed separately [Bytnerowicz *et. al.*, 2007]. The annual tree ring is a source of information, providing details about both tree growth and environmental conditions. It also represents an objective monitor of climate change, but also of other disturbing factors such as air pollution [Juknys *et al*, 2014].

CONCLUSIONS

The phenomenon of drying of fir trees has its origin in the climate changes that manifest themselves locally /zonally / globally and constitute a main factor.

The attack of ipides (Insecta: Coleoptera: Ipidae) that is observed in fir stands, is a secondary attack that occurs following the physiological weakening of the trees and their drying as a result of the lack of precipitation and high temperatures;

The entire eastern range of the Eastern Carpathians is vulnerable to the phenomenon of drying of fir trees and especially, the stands located at altitudes below 800-1000 m and with Southern, South-Eastern or South-Western exposures, where the level of precipitation is low and the temperatures are quite high, the mountains themselves constituting a barrier for precipitation coming from the western area.

As an urgent measure to stop the drying phenomenon is the urgent valorisation of the already affected wood mass and its exploitation. Also, greater attention will be paid to the choice of trees to be removed, and trees that are weak, attacked by mistletoe, fungi, insects, etc. will also need to be removed.

In regeneration compositions in low-altitude mountainous areas or with sunny exposures, deciduous species or species with greater resistance to drought conditions and thermal stress should be promoted.

Continuous monitoring of the evolution of the pest population (ipides), application of appropriate cultural treatments and operations and maintenance of perfect forest hygiene.

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REFERENCES

1. **Barbu I., 1991 -** *Stabilirea măsurilor de prevenire şi combatere a fenomenului de uscare a bradului şi molidului-restabilirea echilibrului ecologic al pădurilor de brad,* ICAS, (Establishing measures to prevent and combat the phenomenon of drying out fir and spruce - restoring the ecological balance of fir forests), (manuscript).
2. **Belyazid S., Phelan J., Nihlgård B., Sverdrup H. U., Driscoll C., Fernandez I., Aherne J., Teeling-Adams L. M., Bailey S., Arsenault M., Cleavitt N., Engstrom B., Dennis R., Sperduto D., Werier D., Clark C., 2019** - *Assessing the Effects of Climate Change and Air Pollution on Soil Properties and Plant Diversity in Northeastern U.S. Hardwood Forests: Model Setup and Evaluation*, Water Air Soil Pollut (2019) 230:106, https://doi.org/10.1007/ s11270-019-4145-6.
3. **Bytnerowicz A., Omasa K., Paoletti E., 2007** - *Integrated effects of air pollution and climate change on forests: A Northern hemisphere perspective.* Environmental pollution, 147(3): 438-445.
4. **Chirită, C.,1977** - *Ecologia formatiilor forestiere din Romania*, https: // op. europa. eu/special - reports/ desertification-33-2018/ro/
5. **McNulty S.G., Boggs J.L., 2010** - *A conceptual framework: redefining forest soil's critical acid loads under a changing climate*, Environ Pollut., 158(6):2053-8, doi: 10.1016/j.envpol.2009.11.028.

6. Parmesan C., 2003 – *Ecological and Evolutionary Responses to Rcent Climate Change*, Annual Review of Ecology Evolution and Systematics, 37(1):637-669.

7. Yuknys R., Liobikienė G., Dagiliūtė R., 2014 - *Sustainability of catch-up growth in the extended European Union*, Journal of Cleaner Production, 63:54-63.

8. INCDS, 2014 - *Amenajamentul Silvic a Ocolului silvic Roznov - Forest Management of the Roznov Forest District.*

9. *, 2023** – https://www.meteoromania.ro/clim/caracterizare-anuala/cc_2023.html