RISCURI ŞI CATASTROFE, NR. XIII, VOL. 14, NR. 1/2014

THE RISK OF CLIMATE CHANGES ON ROMANIAN FORESTS UNDER THE IMPACT OF RAINFALLS

OCTAVIA BOGDAN[1], MARIA COŞCONEA[2]

Abstract. **- The risk of climate changes on romanian forests under the impact of rainfalls.** The risk of climate change on forests in Romania under the impact of precipitation. This paper is a continuation of studies published in the previous magazine Risks and Disasters, editor V. Sorocovschi, which treated the risk of climate change on forests induced by air temperature in Romania. This time, using the same methodology (Bogdan, Coşconea, 2013) demonstrated that rainfall-induced climate changes, due to global warming, exert a risk to vegetation in general and forests in particular, but of a regional nature (tablel 1) . This is due to a complex of geographical factors (position, orographic barrier role, topoclimatic discontinuity ─ alternating positive and negative forms of relief etc.) and meteorological factors (enhancing or reducing atmospheric air circulation). The decennial analysis by floors of vegetation during 1961-2010 (table 3a-3h) indicates that under conditions of increasing air temperature are likely to take place, both a decrease in precipitations (as in decades 3-4), as well as an increase, like in the last decade, 2001-2010, which was at the hottest. The cause lies in the intensification of heat stroke, the evaporation, thermal convection (especially in the hottest months of the year), which increases cloudiness and precipitation implicitly. The feedback reaction of forest ecosystems to climate change leads to the following conclusions: under the conditions of decreasing rainfall, the water storage in the soil lowers, the soil dryness increase weakens trees and increases resistance to wind-blown trees phenomenon, so that the forest loses its climate equilibrium role under increased rainfall, frequency of rain showers accompanied by hail and storms, there are foliaceous system destruction, intense erosion processes (leading to CO_2 release from soil to the atmosphere) and thunderstorms (which will generate increased forest fires and pollution), whereas global warming is more intense below 500m altitude, where pollution is higher, a surplus of water is assumed, but also with regional character. Expansion of forested areas under *the National Strategy for Sustainable Development* will create conditions for the climate system to be able to regenerate naturally.

Key words: climate changes, atmospheric precipitations, forest ecosystems, Carpathians, Romania, feed-back reaction

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[1] Institute of Geography, Romanian Academy, Bucharest, octaviabogdan@yahoo.com
[2] National Meteorology Administration, Bucharest, cosconea2006@yahoo.com

1. Introduction

In the latest issue of hazards and disasters, we published a similar material on ***the risk of climate change on forests in Romania***, where we aimed the impact of air temperature on them. This time we plan to study ***the impact of rainfall under climate changes impact***. We have analyzed these two climatic elements, as thermal and moisture resources are critical to the development of vegetation in general and forests in particular. On the other hand, the forests have a climate "rectifier" potential. Forests, like water, maintain a "natural balance" of the climate. Through their physiological to consume CO_2 in the chlorophyll asimiliation process and to cede O_2, the forest fulfills the role of purifying the air and thereby reduce pollution, the main cause of the greenhouse effect and global warming. Drying of the forests is due not only to temperature increase, but also to the reducion of the amount of moisture, a situation in which they no longer fulfill the role of "natural balance", as their vital functions diminish or disappear.

On the other hand, not only the ***green mass*** of the forest is the CO_2 processing laboratory, but also the soil in which their roots are fixed, as we have shown in the previous material. ***Soil drying*** caused by temperature increase and decrease or absence of rainfall has same results (Giurgiu, 2010).

Although temperature and precipitation are two dimensions that correlate by their reverse variation, the influence of these factors on the forest under the impact of climate change is not always expected. The climate system has great possibilities for natural recovery, not only anthropogenic. Thus, under ***global warming climate conditions, there are several options for precipitation***:

– to hold a ***positive feed-back reaction***, meaning that the absence or reduction of rainfall can trigger a cascading series of risks (eg, drying of the forest, cutting its CO_2 release from soil, air and noise pollution and further accelerate the pollution process);

– a ***negative feed-back reaction*** may take place, in the sense of trying to maintain the steady state, due to the increase in the quantity of water vapor in the atmosphere, under the influence of evaporation and thereby to increase the amount of precipitation by 5-15 % globally, as shown in the *Report of the Intergovernmental Panel on Climate Change*, and for Romania, by about 14% (Busuioc, Storch, 2003).

– can occur simultaneously ***both types of feed-back reaction***, but it will have a regional character, depending on the influence of local geography (terrain features, elevation, the orientation of big orographic chains, the slopes orientation, the topoclimatic discontinuity etc.).

– can exist a happier version, whereby the ***forest,*** as otherwise vegetation generally, adapts to new climate conditions;

– an alternative would be the horizontal or vertical "tanslation" of the forest looking for favorable ecological space to maintain the conditions of "climate equilibrium" (Bogdan, 2005, Bogdan, Marinică, 2007, Giurgiu, 2010, Bogdan, Coşconea, 2013 etc.).

It should be noted that, in Romania, with a great topography variety and the orographic barrier of the Carpathians, concentrically arranged, that separates different types of air movement, in all indicated variants, the climatic signal (i.e. positive or negative trend variation), as well as the amount of fallen water, will not be the same throughout the country, as a result of these regional climate characteristics.

So for example, Busuioc and colab., 2010, estimated that there is a relatively large uncertainty regarding climate signal of rainfall at the country level, which can be different depending on the model used for estimation. Thus, based on the A1B emissions scenario, for ***2021-2050 temporary horizon,*** the average annual rainfall is estimated to be 14% richer in the north and northeast and poorer, up to 12% in the southern half of the country.

At anotimpual level, a surplus will be produced in the north in winter and a surplus in the south and southeast, during summer and autumn. It will also be deficient in winter and spring in the south and south-east, south-east summer and autumn in the southwest (p.182 and p.184).

For the 2071-2100 temporary horizon, the average annual precipitation will increase in the north and isolated in the Carpathian regions up to 14% and will be deficient in the southern half of the country up to 12% (Busuioc şi colab., p.186).

Anotimpual, there will be be a slightly surplus in the north, in winter and in the north and east, during spring and autumn, while the southern and south-eastern regions will be deficient.

In general, in the prospect of the end of the XXI century, the precipitation surplus will be higher during the period 2021-2050, while in the second period will turn into a deficit, as a result of temperature increase in both periods, and especially in the latter.

2.Climate changes in precipitation *on vegetation tiers* in Romania

2.1. Methodology

Our research on ***climate change in precipitation on vegetation tiers*** were performed using the same methodology as in air temperature.

Thus, eight pluvial parameters were studied based on weather stations located on different floors of vegetation, ie average annual precipitation (Pm year), the average amount of rainfall in the first cold half (cold ΣPm), the average amount of precipitation in the warm semester (warm ΣPm), the average amount of precipitation in January (January Pm) February (Feb. Pm), June (June Pm) July

(July Pm) and August (August Pm) for the two major reference periods of 55, and respectively, 50 years, exceeding limits from the start of (1896-1955 ─ with a five years break during the period 1916- 1920, due to suspension of work during World War I) and end of the twentieth century (1961-2010).

The selection of two reference periods was meant to determine rain differences in vegetation tiers, given that the climate has undergone an obvious heating process, especially in the last two decades;

First ***were established the averages for each parameter*** in the two reference periods, for each weather station on existing floors of vegetation. For the beginning period, we used climate data from RSR, volume II (1966), in which we could identify 11 common stations with homogeneous string with the last period. And for the end period, we used the data from the NMA archive, calculated by us for the same weather stations (table 1).

The next stage of work was to ***calculate the differences between the two periods for all 8 pluvial parameters*** (table 1) and for each weather station (using the 11 stations with common period). This has helped us to establish whether during the twentieth century, precipitation increased or decreased, as the air temperature increased, according to the previous article (Bogdan, Coşconea, 2013).

Next, we followed ***the decennial evolution of each pluvial parameter in the second period, 1961-2010***, for which ***averages were calculated for a 50 years period*** from 22 meteorological stations and the ***averages on vegetation floors*** (table 2). Then, ***the standard deviation of each decade of the period*** compared to the average on vegetation tires (tables 3a-3h).

This helped us to determine whether the changes in precipitation in the second period, under the influence of global warming, has the same climate signal (positive or negative variation trend) for the whole country, or has a regional character.

2.2. The deviation of average pluvial parameters during 1961-2010 than during 1896-1955

- The comparative analysis of the 8 pluvial parameters analyzed on reference periods from 11 meteorological stations (table 1), located on different floors of vegetation, indicates that, in general, ***the rainfall recorded in the second period, 1961-2010***, when heating was felt better, ***are smaller than those of the first period, 1896-1955***, which highlighted their negative deviations from the first period, which is consistent with the heating process.
- Negative deviations were recorded in all floors of vegetation, but ***not in all pluvial parameters, with a strong regional character***.
- ***The largest negative deviations were recorded in the alpine level*** (Omu Peak) in all parameters and special the pluvial ***annual average quantities*** (-358.7 mm), the ***cold semester*** (-321.7 mm) and ***February*** (- 107.7 mm), and then

in January (-48.7 mm) (August is an exception with a positive deviation of +0.4 mm). It follows that for alpine, climate signal was negative, diminishing precipitation lately XXI century (table 1), although this story, according to the previous material, heating was greatest, but the oak floor (Bogdan, Coşconea, 2013). However, it states that warming was felt throughout the vertical of oak floor, to alpine.

● Vertically, ***the most common negative deviations*** were recorded by the ***annual average quantities, the cold half of the year and in January and February*** (with some exceptions ─ positive deviations─ in the coniferous and the beech), which is in accordance positive deviations highest air temperature in the same range

● We point out that in the ***coniferous and beech level***, although the annual average quantities registered positive deviations (see Parang, Predeal), rainfall and ***cold semester, respectively the coldest months, January and February registered negative deviations***, so a deficiency of precipitation over the first period, i.e. a climate signal that emphasizes warmer weather during winters with less rainfall in Romanian mountain regions.

● In general, there is a ***wide variety territorial positive and negative deviations of all climatic parameters*** in recent years of the twentieth century as a result of local geographical reasons.

● So, for example in ***Ciucuri Depression***, at Miercurea Ciuc weather station in ***the beech floor***, all ***recorded deviations*** by the 8 pluvial parameters ***are positive***, ranging from +0.9 mm rainfall in August and +38.8 mm for the annual quantities, so is a positive signal indicating a surplus of precipitation in the last period.

At the same time in the immediate vicinity of ***Braşov Depression***, Braşov station deviations of these parameters (except August rainfalls of +10.5 mm) ***are negative***, ranging from -4.5 mm in February and -142.2 mm for annual precipitation amounts, which means a shortage of rainfall for this latter time. We find thus two different signals for depressions in the Eastern Carpathians, both positive and negative, although very close, but with particular geographical features (Braşov Depression with many "gates" where hot air enters into it).

● Also in the ***oak floor***, on the west side of the Plateau of Transylvania in Cluj, near the Apuseni Mountains (but east of them), all analyzed parameters registered ***negative deviations*** in the second period (1961-2010), with values ranged between -0.1 mm in the cold semester and -25.9 mm for annual average; July is an exception when there was a positive deviation +7.9 mm (table 1).

● Instead, on the eastern side of the Plateau of Transylvania, near the Eastern Carpathians, in Bistrița, ***the deviations were positive*** for most of the parameters analyzed, with values ranging from +0.7 mm in summer and +20.3 mm

Table 1. The deviation (**ΔP**) of average pluviometricl parameters (**Pm**) during the period 1961-2010 (**P$_1$**) * compared to average during 1896-1915 ... 1921-1955 (**P$_2$****) from different weather stations located in each floor of vegetation.

Nr. crt	**Weather station**		**Pm year**	**ΣPm cold**	**ΣPm warm**	**Pm Jan**	**Pm Febr.**	**Pm June**	**Pm July**	**Pm August**
ALPINE FLOOR (>2000m)										
1	**Omu Peak**	**P$_1$**	987.3	353.5	633.7	59.5	63.2	132.6	141.3	110.8
		P$_2$	1346.0	675.2	670.8	108.2	170.9	173.0	145.7	106.8
		ΔP	**-358.7**	**-321.7**	**-37.1**	**-48.7**	**-107.7**	**-40.4**	**-4.4**	**+4.0**
CONIFERS FLOOR (1200…1750-1800m**)**										
2	**Parâng**	**P$_1$**	974.5	333.2	641.4	52.2	47.3	144.6	124.0	97.7
		P$_2$	951.5	376.6	574.9	61.9	49.9	124.2	118.9	64.6
		ΔP	**+23.0**	**-43.4**	**+66.5**	**-9.7**	**-2.6**	**+20.4**	**+5.1**	**+33.1**
BEECH FLOOR (500 - 1200m)										
3	**Predeal**	**P$_1$**	954.0	312.1	641.9	47.1	47.4	136.3	133.1	108.7
		P$_2$	945.0	329.6	615.4	52.6	53.7	141.8	118.8	101.6
		ΔP	**+9.0**	**-17.5**	**+26.5**	**-5.5**	**-6.3**	**-5.5**	**+14.3**	**+7.1**
4	**Miercurea Ciuc**	**P$_1$**	578.8	176.0	402.8	26.9	23.4	89.3	87.4	68.8
		P$_2$	540.0	155.4	384.6	22.4	17.8	87.9	80.7	67.9
		ΔP	**+38.8**	**+20.6**	**+18.2**	**+4.5**	**+5.6**	**+1.4**	**+6.7**	**+0.9**
5	**Târgu Secuiesc**	**P$_1$**	512.2	128.5	383.7	18.7	17.7	81.4	78.7	70.7
		P$_2$	543.0	141.0	402.0	15.8	13.9	75.6	90.7	77.5
		ΔP	**-30.8**	**-12.5**	**-18.3**	**+2.9**	**+3.8**	**+5.8**	**-12.0**	**-6.8**
6	**Braşov**	**P$_1$**	605.0	180.6	424.5	26.0	25.1	86.1	93.2	76.4
		P$_2$	747.2	224.1	523.1	34.7	29.6	124.8	101.2	86.9
		ΔP	**-142.2**	**-43.5**	**-98.6**	**-8.7**	**-4.5**	**-38.7**	**-8.0**	**+10.5**
OAK FLOOR (<500m)										
7	**Cluj**	**P$_1$**	587.1	179.5	407.6	26.2	23.8	87.6	89.3	67.6
		P$_2$	613.0	179.6	433.4	27.0	26.2	99.0	81.4	77.5
		ΔP	**-25.9**	**-0.1**	**-25.9**	**-0.8**	**-2.4**	**-11.4**	**+7.9**	**-9.9**
8	**Bistriţa**	**P$_1$**	700.3	263.9	436.4	44.6	33.7	91.8	89.2	70.9
		P$_2$	680.0	244.9	435.1	35.2	37.3	94.4	81.1	74.8
		ΔP	**+20.3**	**+19.0**	**+0.7**	**+9.4**	**-3.6**	**-2.6**	**+8.1**	**-3.9**
9	**Piatra Neamţ**	**P$_1$**	615.9	161.9	453.9	20.8	20.7	97.2	103.9	75.2
		P$_2$	649.0	180.3	468.7	22.6	24.0	114.9	93.8	70.5
		ΔP	**-33.1**	**-18.4**	**-14.8**	**-1.8**	**-4.7**	**-17.7**	**+10.1**	**+4.7**
10	**Tg. Jiu**	**P$_1$**	700.0	332.8	457.2	51.8	48.0	95.7	80.6	71.5
		P$_2$	753.0	342.8	410.2	58.8	48.9	88.4	91.1	59.8
		ΔP	**-53.0**	**-10.0**	**+47.0**	**-7.0**	**-0.9**	**+7.3**	**-10.5**	**+11.7**
11	**Bucureşti-Filaret**	**P$_1$**	616.9	256.3	380.6	40.0	37.1	76.4	61.7	54.8
		P$_2$	580.0	233.9	346.1	38.5	36.2	91.9	57.7	51.9
		ΔP	**+36.9**	**+22.4**	**+34.5**	**-1.5**	**-0.9**	**-15.5**	**+4.0**	**+2.9**

*) After *ANM Archive,* calculated data;**) After *RSR Climate*, vol II, 1966

Table 2. Average rainfall parameters (Pm) during 1961- 2010 at the weather stations in each floor of vegetation and average per floor (mm).

Nr. crt	Weather station	Pm year	ΣPm cold	ΣPm warm	Pm Jan	Pm Febr.	Pm June	Pm July	Pm August
ALPINE FLOOR (>2000m)									
1	Omu Peak	987.3	353.5	633.7	59.5	63.2	132.6	141.3	110.8
2	Țarcu	968.4	352.4	616.0	60.4	56.9	141.0	122.4	114.5
	Media	**977.9**	**353.0**	**624.9**	**60.0**	**60.1**	**136.8**	**131.8**	**112.7**
SUB-ALPINE FLOOR (1750-1800...2000m)									
3	Vlădeasa	1159.5	430.3	729.1	71.3	65.2	169.2	149.1	123.2
4	Iezer	1278.7	504.7	774.0	69.3	69.0	158.2	154.9	125.9
	Media	**1219.1**	**467.5**	**751.6**	**70.3**	**67.1**	**163.7**	**152.0**	**124.6**
CONIFERS FLOOR (1200...1750-1800m)									
5	Lăcăuți	829.9	242.6	587.4	37.4	41.1	125.2	127.7	110.5
6	Parâng	974.5	333.2	641.4	52.2	47.3	140.6	124.0	97.7
7	Sinaia	1055.4	399.2	656.2	59.1	60.1	141.9	131.5	102.2
8	Semenic	1177.3	416.8	760.5	68.4	65.8	167.5	142.9	121.7
9	Fundata	892.5	304.2	588.3	43.4	45.3	123.7	119.3	97.5
10	Băişoara	875.5	286.1	586.6	44.5	39.3	127.1	114.5	98.0
	Media	**967.5**	**330.4**	**636.7**	**50.8**	**49.8**	**137.7**	**126.7**	**104.6**
BEECH FLOOR (500...1200m)									
11	Predeal	954.0	312.1	641.9	47.1	47.4	136.3	133.1	108.7
12	Întors.Buzăului	649.8	189.7	460.1	29.7	27.1	99.1	97.0	81.0
13	Miercure Ciuc	578.8	176.0	402.8	26.9	23.4	89.3	87.4	68.8
14	Tg. Secuiesc	512.2	128.5	383.7	18.7	17.7	81.4	78.7	70.7
15	Braşov	605.0	180.6	424.5	26.0	25.1	86.1	93.2	76.4
16	Polovragi	871.1	338.9	532.3	48.2	48.5	108.4	97.1	90.8
	Media	**695.2**	**221.0**	**474.2**	**32.7**	**31.5**	**100.1**	**97.8**	**82.4**
OAK FLOOR (<500m)									
17	Cluj	587.1	179.5	407.6	26.2	23.8	87.6	89.3	67.6
18	Bistrița	700.3	263.9	436.4	44.6	33.7	91.8	89.2	70.9
19	Piatra Neamț	615.9	161.9	453.9	20.8	20.7	97.2	103.9	75.2
20	Oravița	844.7	329.3	515.5	53.5	51.6	107.0	98.0	78.1
21	Tg. Jiu	700.0	332.8	457.2	51.8	48.0	95.7	80.6	71.5
22	Bucureşti-Filaret	616.9	256.3	380.6	40.0	37.1	76.4	61.7	54.8
	Media	**692.5**	**254.0**	**438.5**	**39.5**	**35.8**	**92.6**	**87.1**	**69.7**

Source: Data processed by NMA Archives, Bucharest

Similar situations can be noticed in Subcarpații Moldovei and Subcarpații Olteniei in:

● ***In Subcarpații Moldovei***, in Piatra Neamț, deviations recorded by most parameters ***were negative***, so there was a rainfall deficit, with values between -1.8 mm in January and -33.1 mm for the annual quantities; exception summer months July (+ 10.1 mm) and August (+4.7 mm), with ***positive deviations***.

● In Subcarpații Olteniei, in Târgu Jiu there were also ***negative deviations*** for most parameters analyzed that ranged between -0.9 mm in February and -53.0 mm for annual quantities and ***positive deviations*** for precipitation durin the warm semester (+47.0 mm) of June (+7.3 mm) and August (+11.3 mm).

● We notice that positive or negative rainfall signal is not the same for all analyzed parameters and for all the stations. This high ***territorial variability is generated by increased or decreased air circulation in the troposphere, the role of orographic dams, topoclimatic discontinuity (alternation of positive to negative relief), and the geographical location of the weather stations***.

So for example, ***the negative signal*** (rainfall deficit) from Cluj, Piatra Neamț and Târgu Jiu stations, which occurs amid climate warming, is emphasized due to foehn effects that occur after air masses escalate the orographic dams, instead, the ***positive signal*** recorded by most parameters analyzed in Bistrița are the recovery effect of air masses over Transylvania.

● A particular situation can be seen in ***the oak floor plains in southern Romania*** where warm air was highest (Bogdan, Coşconea, 2013).

Here, contrary to expectations, most pluvial parameters registered ***positive deviations*** that ranged from +2.9 mm in August and +36.9 mm for annual rainfall quantities, except for the winter months (January, -1.5 mm, February -0.9 mm) and October (-15.5 mm), with ***negative deviations*** (table 1). If ***negative deviations*** correlate with global warming, the ***positives*** are an effect of a pluviometric excellent due to intense heating processes felt best under 500m altitude, processes which stimulated evaporation, air heating convection and tropospheric dynamics that led to increased rainfall. This phenomenon is true for the ***positive deviations*** from Târgu Jiu in the ***warm half*** of the year (+47.0 mm) and summer months (+7.3 mm +11.7 mm in June and August), plus the effect of higher insolation due to southern exposure of the orographic dam, and the southern movement of Mediterranean origin.

● In terms of the ***size of deviations*** recorded regardless of positive or negative signal, we find the following: in general, besides ***the alpine level*** where the annual amounts, from the cold semester and February had the highest deviations (which ranged from - 107.7 mm to -368.7 mm), in the other floors of vegetation, the deviations are relatively small (≤ 40 mm) with 1-2 higher exceptions (eg. Braşov, -142.2 mm annual quantities). This shows that although there has been a growing trend, especially for the reduction of rainfall in the last period (1961-2010), when heating was better felt, it seems that not low rainfall are the ones who contribute more to the drying of forests, as particularly high temperatures, extreme heat, at least until now.

2.3. Decennial evolution of pluvial parameters by floors of vegetation and their deviation from the multiannual average of the floor, during 1961-2010.

To determine the climatic signal (the evolution trend of positive or negative deviations from each decade from the average, during the last 50 years period, from 1961 to 2010) were prepared tables 3a-3h. A brief look at the distribution pattern of these deviations, highlights some conclusions as follows.

● Generally, from decade to decade, the climate signal is the same for all climatic and vegetation floors. So for example, for ***the decade 1961-1970, the deviations were positive for all floors of vegetation, but only for the following pluvial parameters***: cold semester (table 3b), January (table 3d), February (table 3e) for other parameters, the positive and negative alternate.

We deduce that, as this decade has been the coldest for all forest floors where negative deviations air temperature from January varied between -2.0 ° C in oak floor and -1.0 ° C in the alpine level (Bogdan, Coşconea, 2013), the positive signal climate for all pluvial parameters listed above, show that in the first decade of the 1961-2010 period, would be assumed that ***the situation from the previous reference period (1896-1955), with high rainfall, is mantained***. At the same time, the presence of negative deviations from the lower floors (oak and beech) of other pluvial parameters in the same decade (eg annual quantities of rainfall ─ table 3a warm semester ─ table 3c, June ─ table 3f, July ─ table 3g and August ─ table 3h), allows us to conclude that ***in this first decade climatic characteristics of the first reference period interfere with high rainfall and low temperatures to those of the last period, when the situation is reversed***.

● We reach the same conclusion in the case of ***the next decade, 1971-1980***, also characterized by ***positive deviations, but only for some the pluvial parameters***, eg., average annual precipitation (table 3a), the warm semester (table 3c) the summer months ─ June (table 3f), July (table 3g) and August (table 3h) ─ for all floors of vegetation, while for the other parameters, the ***deviations were positive***, as eg. cold semester (table 3b) and winter months ─ January (table 3d) and partly in February (table 3e), especially for the upper floors and negative for some lower floors, which ***confirms the interweaving of general climatic characteristics of the two great reference periods (1896-1955 and 1961-2010).***

● If we were to believe that global warming involves reducing rainfall, then we can accept that this has been possible in the ***decades 1981-1990 and 1991-2000***, the warming began to be felt more and ***pluvial parameter deviations were negative in all floors of vegetation***, with some exceptions, when they have been positive, but very small, as in the decade 1981-1990, in February, the lower floors (beech +0.2 mm and oak +3.1 mm ─ table 3e), and in the decade from 1991 to 2000, in July, in the oak floor (+4.6 mm ─ table 3g).

Table 3. Decennial evolution of pluvial parameters by floors of vegetation (P10) and their deviation (ΔP) from the multiannual average, during 1961-2010 (P50)

Table 3a. *Average annual precipitations*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=977.9		P50=1219.1		P50=967.5		P50=695.2		P50=692.5	
1961-1970	1227.5	**250.0**	1228.4	**9.3**	1033.3	**65.8**	691.8	**-3.4**	686.2	**-6.3**
1971-1980	1134.9	**157.0**	1366.9	**147.8**	1064.0	**96.5**	742.4	**47.2**	724.4	**31.9**
1981-1990	689.5	**-288.4**	1110.9	**-108.2**	810.1	**-157.4**	622.6	**-72.6**	624.1	**68.4**
1991-2000	825.8	**-152.1**	1091.1	**-128.0**	886.9	**-80.6**	669.2	**-26.0**	669.4	**-23.1**
2001-2010	1011.6	**33.7**	1308.4	**89.3**	1043.5	**76.0**	749.7	**54.5**	758.3	**65.8**

Table 3b. *Average precipitations during warm semester*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=353.0		P50=467.5		P50=330.4		P50=221.0		P50=254.0	
1961-1970	469.5	**116.5**	494.3	**26.8**	376.8	**46.4**	241.8	**20.8**	275.5	**21.5**
1971-1980	388.4	**35.4**	513.3	**45.8**	328.7	**-2.0**	206.7	**-14.3**	236.9	**-17.1**
1981-1990	230.5	**-122.5**	390.9	**-76.6**	282.9	**-47.5**	203.0	**-18.0**	233.9	**-20.1**
1991-2000	287.6	**-65.4**	399.6	**-67.9**	299.4	**-31.0**	205.1	**-15.9**	235.0	**-19.0**
2001-2010	389.1	**36.1**	539.6	**72.1**	363.9	**33.5**	248.3	**27.3**	288.5	**34.5**

Table 3c. *Average precipitations during cold semester*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=624.9		P50=751.6		P50=636.7		P50=474.2		P50=438.5	
1961-1970	758.1	**133.2**	734.1	**-17.5**	656.5	**19.8**	450.0	**-24.2**	410.8	**-27.7**
1971-1980	746.5	**121.6**	843.5	**91.9**	735.4	**98.7**	535.7	**61.5**	487.5	**49.0**
1981-1990	459.0	**-165.9**	720.0	**-31.6**	527.1	**-109.6**	419.6	**-54.6**	390.3	**-48.2**
1991-2000	538.8	**-86.1**	691.5	**-60.1**	587.4	**-49.3**	464.2	**-10.0**	434.4	**-4.1**
2001-2010	622.5	**-2.4**	768.8	**17.2**	677.2	**40.5**	501.4	**27.2**	469.8	**31.3**

Table 3d. *Average precipitations during January*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=60.0		P50=70.3		P50=50.8		P50=32.7		P50=39.5	
1961-1970	83.1	**23.1**	75.6	**5.3**	59.2	**8.4**	40.9	**8.2**	47.1	**7.6**
1971-1980	67.2	**7.2**	87.9	**17.6**	53.6	**2.8**	31.7	**-1.0**	37.0	**-2.5**
1981-1990	41.4	**-18.6**	72.7	**2.4**	44.6	**-6.2**	29.5	**-3.2**	38.6	**-0.9**
1991-2000	41.8	**-18.2**	44.0	**-26.3**	41.2	**-9.6**	24.6	**-8.1**	30.6	**-8.9**
2001-2010	66.4	**6.4**	71.5	**1.2**	55.7	**4.9**	37.1	**4.4**	44.2	**4.9**

Table 3e. *Average precipitations during February*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=60.1		P50=67.1		P50=49.8		P50=31.5		P50=35.8	
1961-1970	89.6	**29.5**	88.1	**21.0**	65.2	**15.4**	40.5	**9.0**	43.9	**8.1**
1971-1980	48.3	**-11.8**	68.2	**1.1**	42.4	**-7.4**	24.8	**-6.7**	31.4	**-4.4**
1981-1990	40.5	**-19.6**	51.4	**-15.7**	48.0	**-1.8**	34.6	**3.1**	36.0	**0.2**
1991-2000	43.6	**-16.3**	50.0	**-17.1**	43.0	**-6.8**	27.5	**-4.0**	28.3	**-7.5**
2001-2010	78.3	**18.2**	78.2	**11.1**	50.6	**0.8**	30.4	**-1.1**	39.6	**3.8**

Table 3f. *Average precipitations during June*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=136.8		P50=163.7		P50=137.7		P50=100.1		P50=92.6	
1961-1970	171.4	**34.6**	159.9	**-3.8**	146.1	**8.4**	96.8	**-3.3**	85.6	**-7.0**
1971-1980	162.3	**25.5**	210.8	**47.1**	154.3	**16.6**	107.3	**7.2**	105.5	**12.9**
1981-1990	118.6	**-18.2**	165.0	**2.1**	129.5	**-8.2**	101.8	**0.7**	93.5	**0.9**
1991-2000	109.2	**-27.6**	142.8	**-20.9**	125.4	**-12.3**	98.4	**-1.7**	84.7	**-7.9**
2001-2010	122.4	**-14.4**	140.1	**-23.6**	133.1	**-4.6**	96.3	**-3.6**	93.8	**1.2**

Table 3g. *Average precipitations during July*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=131.8		P50=152.0		P50=126.7		P50=97.8		P50=87.1	
1961-1970	153.4	**21.6**	144.0	**-8.0**	139.0	**12.3**	101.2	**3.4**	85.0	**-2.1**
1971-1980	156.3	**24.5**	171.4	**19.4**	147.4	**20.7**	111.0	**13.2**	92.7	**5.6**
1981-1990	91.4	**-40.4**	132.3	**-19.7**	95.2	**-31.5**	77.4	**-20.4**	66.8	**-20.3**
1991-2000	120.7	**-11.1**	142.1	**-10.0**	108.7	**-18.0**	90.1	**-7.7**	91.7	**4.6**
2001-2010	137.4	**5.6**	170.2	**-18.2**	143.1	**16.4**	109.2	**11.4**	99.4	**12.3**

Table 3h. *Average precipitations during August*

Reference period	**Alpine floor** (>2000m)		**Sub-alpine floor** (1800-2000m)		**Conifers floor** (1200-1800m)		**Beech floor** (500-1200m)		**Oak floor** (<500m)	
	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP	P10	ΔP
1961-2010	P50=112.7		P50=124.6		P50=104.6		P50=82.4		P50=69.7	
1961-1970	126.6	**13.9**	140.8	**16.2**	101.9	**-2.7**	73.3	**-9.1**	71.5	**1.8**
1971-1980	134.3	**21.6**	128.1	**3.5**	113.8	**9.2**	91.0	**8.6**	72.8	**3.1**
1981-1990	87.6	**-25.1**	123.8	**-0.8**	87.9	**-16.7**	69.3	**-13.1**	62.7	**-7.0**
1991-2000	93.8	**-18.9**	99.5	**-25.1**	97.9	**-6.7**	82.4	**0.0**	60.9	**-8.8**
2001-2010	121.2	**8.5**	130.7	**6.1**	121.6	**17.0**	96.2	**13.8**	80.5	**10.8**

Source: Data processed by NMA Archives, Bucharest

There are, however, situations in which ***global warming*** (as noted above) ***causes higher rainfall***. This is the case of the 2001-2010 decade, when this was the largest, with positive deviations of air temperature in the warmest months (July and August) of +1.1°C...+1.4°C (Bogdan, Coşconea, 2013). In this case, ***even the precipitations had positive deviations for all parameters and in all floors of vegetation***. The largest recorded annual values ranged from 33.7-89.3 mm ─ table 3a of the ***warm semester*** (27.3-72.1 mm ─ table 3b) and ***cold semester*** (17.2-40.5 mm ─ table 3c), with some exceptions: in ***February*** for beech floor where they were negative, and positive in the other floors, (table 3e) and in ***June*** where were positive for oak floor, whereas in other floors, in this month were negative (table 3f).

In this case, ***positive deviations of the decenial pluvial parameters*** of the reference period 1961-2010 compared to the average for this period ***are consistent with intense of heat stroke processes, thermal convection, evaporation due to***

global warming which lead inevitably to increased cloudiness, increased air dynamics troposphere and that increased rainfall.

The richest decade in terms of precipitations, thus the one with the largest positive deviation compared to the reference period 1961-2010, was the ***decade 1971-1980, on the annual quantities*** (which ranged between 31.9 mm in the oak floor and 157.0 mm in the alpine floor ─ table 3a) and the warm semester (which ranged between 49.0 mm in the oak floor and 121.6 mm in the alpine floor ─ table 3c). This is one of the coldest decades where negative deviations of air temperature prevailed.

The decade with the lowest amounts of precipitation in all floors of vegetation, so the ***largest negative deviations*** over the same reference period, 1961-2010, was the ***decade 1981-1990*** on the ***annual quantities*** (which ranged from -68.4 mm in the oak floor and -288.4 mm in the alpine level ─ table 3a), the ***warm season*** (which ranged from -31.6 mm in sub-alpine floor to -165.9 mm in the alpine level ─ table 3c) and the ***cold semester*** (which ranged from -18.0 mm beech floor and -122.5 mm the alpine level-table 3b), although this was the warmest decade on the contrary prevailed negative deviations of air temperature (Bogdan, Coşconea, 2013).

If we ***compare the largest positive deviations*** from the decade 1971-1980, ***with the largest negative deviations*** from the 1981-1990 decade (two decades characterized by the predominance of ***negative deviations*** of air temperature, being the coldest) and rainfall ***positive deviations*** in the last decade, 2001-2010 (when positive deviations of air temperature were the biggest), we find ***that the latter were lower, though this was the warmest decade***. It is not excluded, however, that in view of maintaining or enhancing the heating process, these deviations increase, or conversely, reduce puviometric contrasts are possible.

But it is difficult to determine the climate signal for the next period, given local geographical conditions and that they will generate regional features in the distribution of precipitations in Romania.

The rainfall increase with altitude will be maintained however, so that ***the most vulnerable*** to reducing rainfall under global warming impact will be the ***lower floors***, oak and beech in the ***warm summer months***, while rainfall deviations will be negative as well as the ***conifers in the winter months***, when possible, also negative deviation due to vertical propagation warming.

In terms of reducing rainfall, even if they will have a regional character, there are ***two alternatives***: possible ***degradation of forest ecosystems***, as well as other vegetal ecosystems due to global warming, or on the contrary, their ***adaptation to new climatic conditions created***.

Also as a form of adaptation should be seen the possible "translation" of vegetation floors vertically and hence overall forest ecosystems, which will seek to maintain required environmental conditions of temperature and humidity (Bogdan, 1995, Bogdan, Marinică, 2007), Giurgiu, 2010, Bogdan, Coşconea, 2013 etc.).

3. The feedback reaction of the forest ecosystems to climate changes induced by precipitations

According to the IPCC, global warming, through the feedback reaction leading to general increased atmospheric circulation, increased pluviometric and thermal contrasts (hot weather characterized by alternating periods of heat waves with other periods characterized by waves of cold, rainy periods alternating with droughty periods), and to increase rainfall, increased frequency of rain showers accompanied by hail and storms, the thunderstorms etc. and the consequences do not stop there. All these risk phenomena may affect both directly and indirectly the forest ecosystems.

First there can be a negative influence exerted by ***reducing soil water reserve*** that ensures the conditions of existence. Then ***the mechanical action exerted by downpour of rain accompanied by hail and storms*** that destroy the canopy cover of foliaceous, and ***lightning*** can cause fires (especially in dry forests, in terms of heat).

On the other hand, the lack of rainfall or poor rainfall, together with higher temperatures will lead to ***drying of soil and will facilitate blown-down trees*** under storm conditions, storms, blizzards (Bogdan, Coşconea, 2010).

Given the fact that pollution is highest in the lower regions under 500m altitude, where global warming is the greatest, it is assumed that ***in perspective, precipitation may increase if warming will continue, or will be intensified,*** so that, ***at these altitudes, forests may suffer less moisture and more heat*** (having though a regional character) that may ***exert its climatic balance role, although it will not be to its normal ability.***

At the same time remains valid the adaptation ***of forest and forestry in general, to temperature climate changes and precipitation induced by the global warming,*** through resistant varieties, through ecological restoration of deconstructed forests that will ***increase forest productivity by 30-40% in Romania and hence their potential to capture*** CO_2 from the atmosphere and store it in forest biomass and soil (Giurgiu, 2010, p. 13).

Other measures aims to ***increase forest resilience of ecosystems to adversity*** (storms, fires, pathogens, insect attacks that will become more aggressive with the persistence of global warming etc.), reducing CO_2 sequestration potential of the forest. To these are added ***ecological reconstruction*** of broken trees in relation to hydrological and anti-erosion, as well as torrential hydrographic basins, which will help reduce slope processes (Giurgiu, 2010, p.14)

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