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Dendroecological research in beech (*Fagus sylvatica* L.) stands affected by abnormal decline phenomena from Dragomirna plateau, Suceava county, Romania

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Abstract. This paper approaches the subject thought evolution of radial growth of the trees in the studied stand. We also discuss about the influence of climatic parameters (temperature and precipitations) on the physiological regress. The study was conducted in the Dragomirna plateau, a part of Suceava Plateau (Băcăuanu 1980) in beech stands affected by phenomena of abnormal dying. In order to asses growth loss, obtained datas was compared with a control tree stand with normal gowth. In order to obtain dendrocronological series and to assess climat-tree conections were used COFECHA (Holmes 1983; Cook & Peters 1997) TSAPwin v.3.0 (Rinn 2005), ARSTAN (Grissino-Mayer et al 1996), DendroClim 2002 (Biondi & Waikul 2004) software.
Key words: growth, growth ring, beech stand, climate, the dying phenomenon.

Rezumat. Acest articol abordează problema evoluției creșterilor radiale la exemplare de fag afectate de fenomene de uscare anomală localizate în Podișul Dragomirnei. Studiul se referă și influența parametrilor climatice (temperatură și precipitații) asupra declinului creșterilor. Cercetările au fost localizate în Podişul Dragomirnei, unitate a Podişului Sucevei (Băcăuanu 1980) în arborete de fag afectate de fenomene de uscare anormală. Încă de la începutul cercetărilor, pentru cuantificarea pierderilor de creştere a fost stabilit un arboret martor, în care fagul vegetează normal. Obţinerea seriilor dendrocronologice şi stabilirea legăturii climat-arbore a necesitat utilizarea programelor COFECHA (Holmes 1983; Cook şi Peters 1997) TSAPwin v.3.0 (Rinn 2005), ARSTAN (Grissino-Mayer et al 1996), DendroClim 2002 (Biondi şi Waikul 2004).
Cuvinte cheie: creştere, inel anual, arboret de fag, climat, fenomen de uscare.

Introduction. Climate change of the last two decades constitutes a threat to the human society, as to the forestry ecosystems (IPCC 2001, 2007; Giurgiu 2010; Oroian 2011; Şimonca et al 2011).

Beech (*Fagus sylvatica* L.) is the predominant species in European forests. Any major climatic change can make a huge impact of the Europeean forests landscape because of the abnormal death incidence of beech. Mainly in the last last decade of the past century this fact was object of study on forestry research in Europe. Some of these studies were conducted in the area of the major climate changes on beech population dynamics of Europe (Jump et al 2006, 2007; Jung 2009).

Even if beech has a very high ecological plasticity, extreme climate conditions, mainly in the eastern limit of the European areal (this case), subdue this species to be vulnerable to the various pests. This phytopathological approach was studied also in Romania by various specialists. In Romania well known studies are the ones of Chira (2004). He shows that the degeneracy phenomena occur mainly in old stans (more than 100 years), (almost) pure of very high productivity. Most affected are the tree stands situated in sites with clayey soils or on the slopes with surface sandy soils. Most of the studies carried on this subject, associate beech dying with various pests as insects and xylophagous fungi (Perrin 1977, 1980, 1981, 1983; Perrin & Garbaye 1984; Perrin & Van Gerwen 1984; Chira et al 2004; Roibu & Grudnicki 2006).

A different approach of this subject was given trough dendroecologycal studies, which showed an auxological decline (Dittmar & Elling 2007).

This paper approaches the subject thought evolution of radial growth of the trees in the studied stand. We also discuss about the influence of climatic components (temperature and precipitations) on the physiological regress.

The purpose of the present study is to show the evolution of beech trees affected by drying trought radial growth. The main objectives were:

- to analyze the evolution of drying phenomena and the moment when this occurs based on dendrocronologycal series;
- study of dynamics and growth tendences of the annual ring;
- to analyze the climate evolution in the area of Dragomirna plateau;
- to make an climat-tree study in order to estimate volumetrical growth in the future.

Material and Method. The study was conducted in the Dragomirna plateau, a part of Suceava plateau (Băcăuanu 1980) in beech stands affected by phenomena of abnormal dying. In order to asses growth loss, obtained datas was compared with a control tree stand with normal gowth. The first sample plot (PATRA) was put in an area affected by the dying phenomena (with average values of crown defoliation degree ranging 52.3-58.4%)(Chira et al 2004). In order to make the comparative study, was put a second sample plot in a control stand, in the compartment 16a, situated in the rezerve Fagetum Dragomirna (DGR), (Roibu 2010) (Figure 1). Both stands are composed exclusively by beech trees with an average age ranging 120-140 years and almost constant diameter of the basal area (dg).

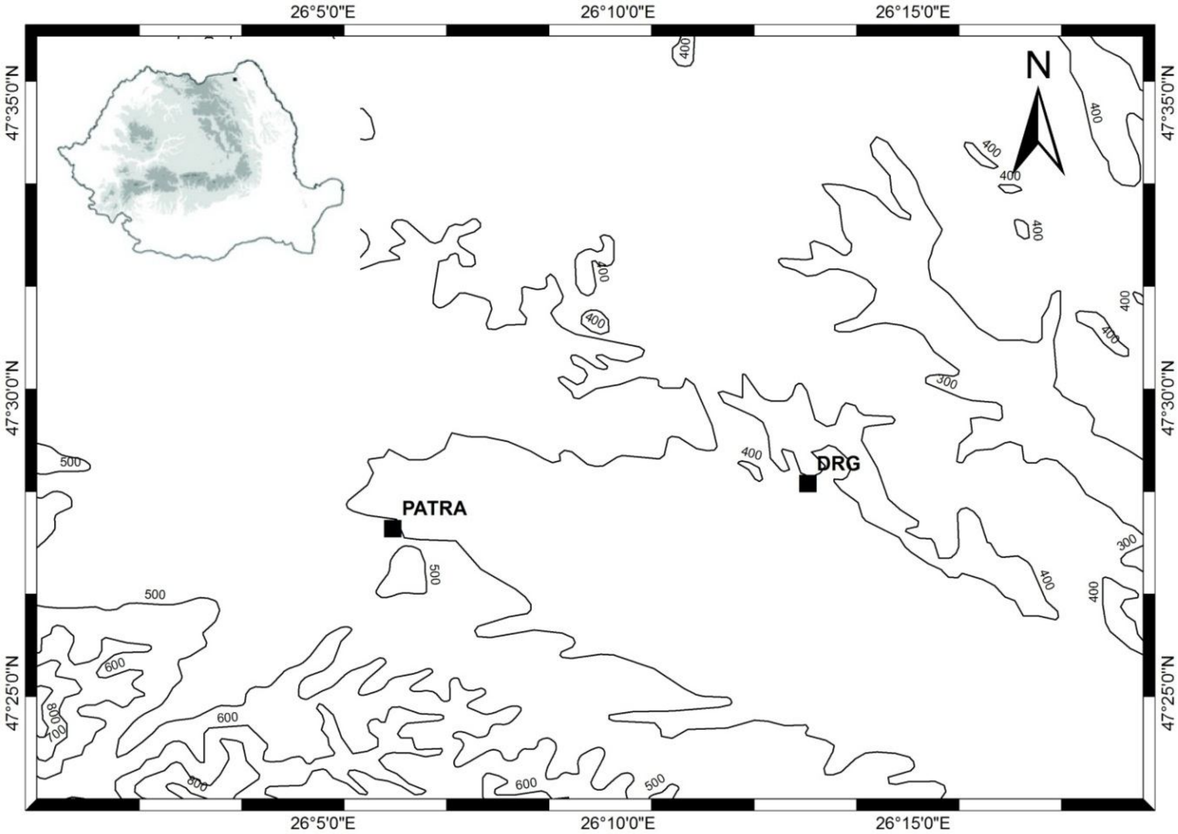

Figure 1. Research location.

The tree stand affected by abnormal dying is situated on a plot slightly inclined on luvosol bicstagnic type of soil, characterized trought moderate stagnogleyzation phenomena, strongly textural differentiated (Idt=1.83). The major type of site in the Hilly oak type

(FD_2), Pm (i), luvosoil±stagnic, midlle edaphic with *Poa pratensis* and some others hydrophilic species.

Methodology of the study compared the dynamics of the growth and the growth indices. 30 Increment core samples were collected from trees in different drying stages in both sample plots. The increment cores were dried, and polished with 200-800 grid sandling belts to highlight the annual rings.

Width measurements of annual rings were made with digital positiometer LINTAB 6 and TSAP software, with an accuracy of 0.001 mm.

Growth series were crossdating trought graphic comparison method with TSAPwin and COFECHA software (Holmes 1983; Cook & Peters 1997). For each growth series were calculated statistical specific parameters. To assess the influence of climatic parameters on beech stands from Dragomirna plateau was applied a standard of growth series with a lenght spline function of 67% (67% cutoff) (Cook & Kairiukstis 1990).

In order to obtain dendrocronological series and to assess climat-tree conections were used COFECHA (Holmes 1983; Cook & Peters 1997) TSAPwin v.3.0 (Rinn 2005), ARSTAN (Grissino-Mayer et al 1996), DendroClim 2002 (Biondi & Waikul 2004) software.

Results and Discussion

Climate characterization of the studied area in the context of global climate change. Future world climate changes in short time periods impose study of climatic parameters (average annual temperature, and annual amount of precipitation). We've studied this also in the case of Dragomirna plateau, because the studied species, beech is here at the eastern limit of his European areal.

The main limitation of beech ecological niche in this area is of pluviometric, and the short amount of precipitations in some years under 550 mm have a negative effect on the growth of annual ring.

When average annual temperature was analyzed for the last 50 years, their tendencies trough a spline cubic smoothing spline of 10 or 30 years allowed us to identify a clear tendency of rising annual average temperature in the last 30 years (about 0.5 °C) (Figure 2).

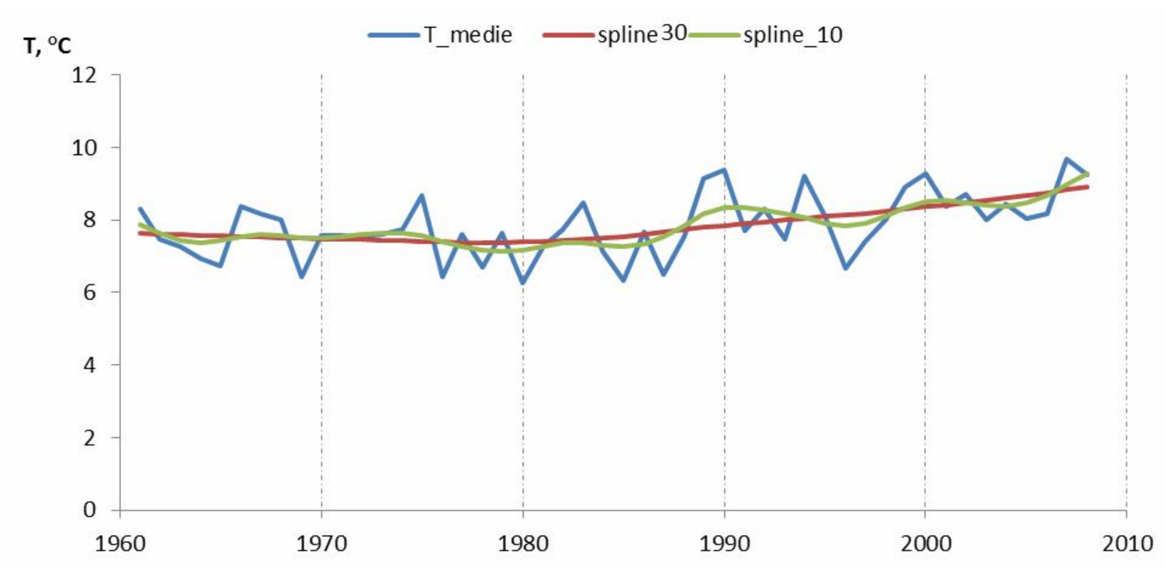

Figure 2. Dynamic evolution during the 1960-2008 of annual average temperature.

The average annual temperature of the area is not a limitative factor; beech is here in optimal thermal conditions. Interesting to study is the future evolution of these stands under the current climate changes. If scenarios developed so far are true (IPCC 2001, 2007), then the annual average temperature can be a future limitative factor for the presence of beech stands in Dragomirna plateau.

Evolution of the annual precipitations is fluctuant in the last 50 years (Figure 3). It can be seen that the mean of annual precipitation amount exceeded the annual average of the 70's, then for the next two decades to drop a lot under the average. The years (2000, 1994, 1990, 1986) were extremely warm and dry (Nistor 2007).

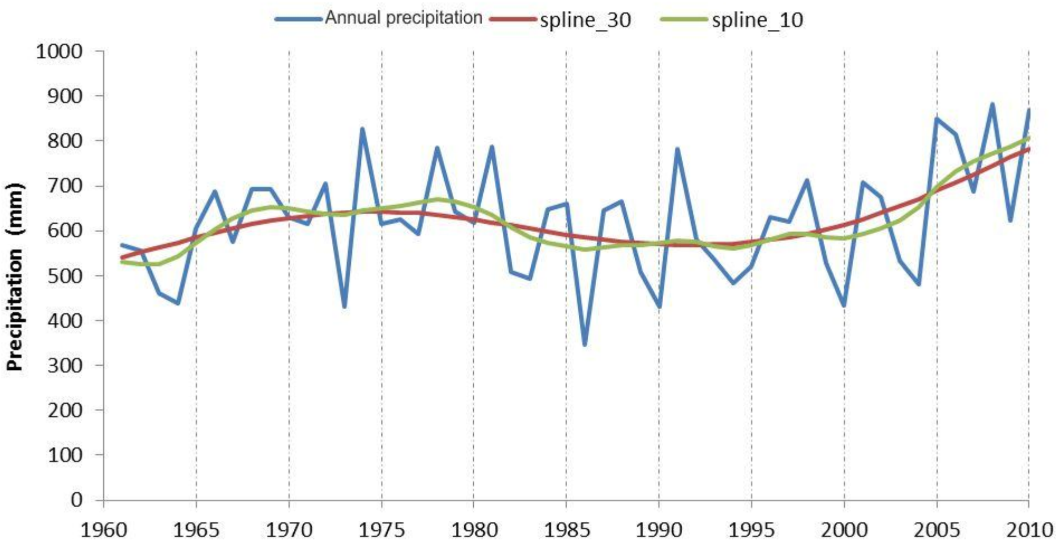

Figure 3. Dynamics of annual precipitation during the 1960-2010.

After 2000 A.D., especially after 2005 A.D., it can be observed a growth of annual precipitation. The years 2008 and 2010 were considered extremely rainy, amount of annual precipitation exceeded 800 mm. According to climate scenarios generated on global scale, in some areas growth in annual average temperature will rise the quantity of precipitation and in others can increase the incidence of aridity and desertification (IPCC 2001, 2007). In these conditions, mainly in the beech stands of the eastern limit of the European areal (in the case of the investigated area), these phenomena can alter the natural range of the species.

Dynamics of radial growth. In the case of control stand, the curve of radial growth has a clear maximum along the year 1910, and then takes a descending trend, as a result of increased cambial age (Figure 4A).

Also it can be seen a decline in growth around years 1945-1950, because of the massive drought of this interval, afterwards is recorded a diminution of growth. For the stand affected by abnormal tree dying it can be observed (Figure 4A) the descending trend of the last two decades (1990-2010). When referred to statistical parameters of dendrochronological series analyzed, (1884-2007), it was observed a certain difference between average growth of control stand and the one of the stand affected by abnormal tree dying (Table 1).

Table 1

Statistical parameters of tree-ring series

Series	ML (years)	Common interval	Mean (mm)	Std (mm)	SNR	PC1 (%)	AC1	MS
DRG	133	1884-2007	1.85	0.82	2.60	35.3	0.64	0.32
PATRA	107	1884-2010	1.68	0.88	15.03	47.20	0.63	0.33

* ML – mean length, std – standard deviation; SNR – signal to noise ration; PC1- first principal component; AC1- first order autocorrelation; MS – mean sensitivity.

The signal to noise ratio was identified as a clear difference between the two tree stands on the values of 2.60 (DRG) and 15.03 (PATRA). This difference is explained by the interventions made in the tree stand with dying phenomena, the remaining trees feeling much stronger the influence of climatic factors.

In terms of average sensitivity and first order autocorrelation the two tree series are almost identical.

The observations mentioned above are also confirmed by graph representations of the average series for the two stands. There is a clear descending trend of the annual radial growth in the last two decades (1990-2010). The trend is for both stands (the one with and the one without dying phenomena) and is very well reflected by the spline curves for a 20 year period (Figure 4B).

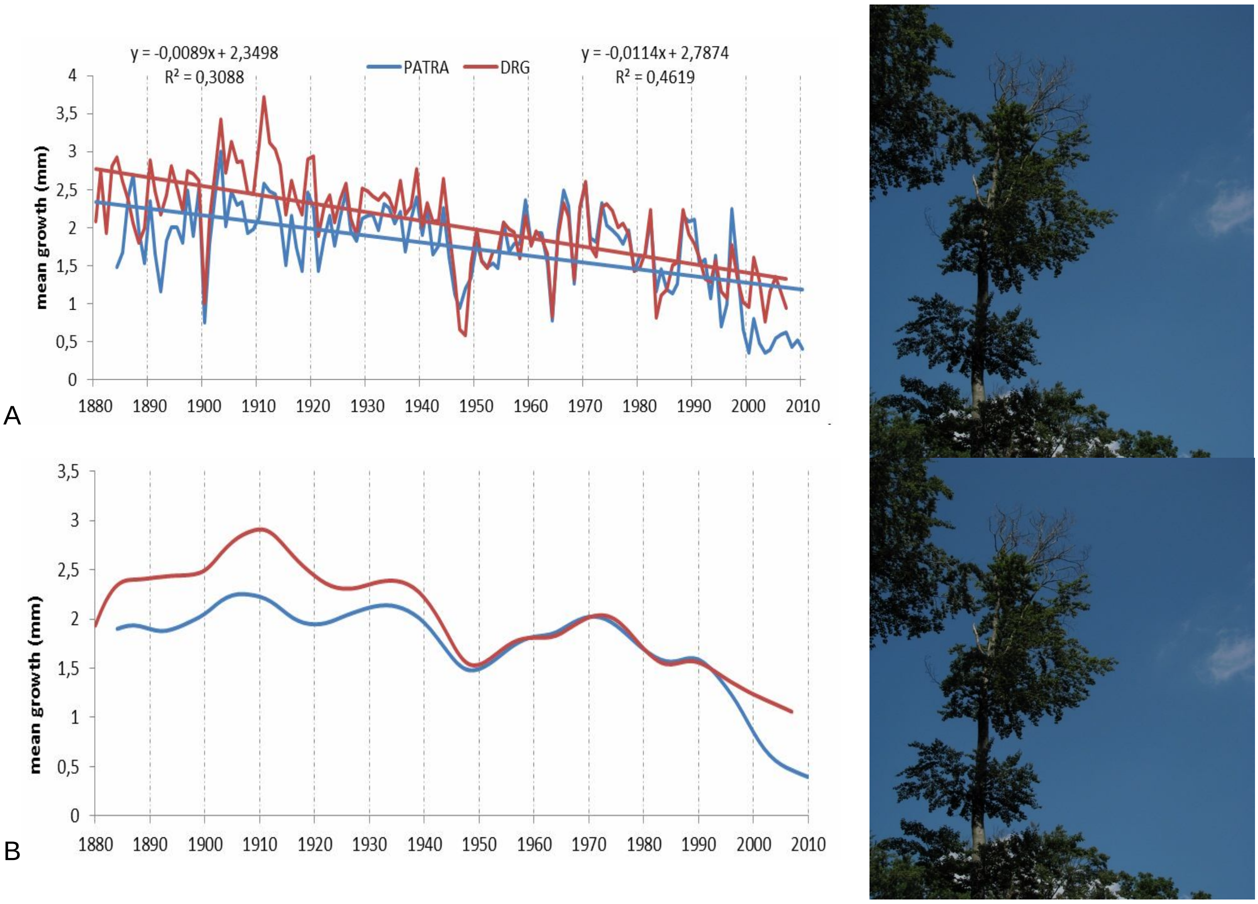

Figure 4. A-Radial growth dynamic in relation to cambial age for beech (annual values) from PATRA plot and DRG, the control plot; B- Radial growth dynamic in relation to cambial age for beech (20 year spline values) in PATRA plot- blue colour and in DRG, control plot – in red colour.

For the control plot (DRG) the descending trend is natural, due to the average stand age of 140 years. In the case of the PATRA plot, which is affected by dying phenomena, the descending trend for the last 20 years is more evident. An explanation for this fact is also the stand's age (120) and at least one more factor, of a presumptuous nature, the phytopathologic attacks from the beginning of years 2000 (Chira et al 2004).

Another potential factor that must be taken into consideration is a 2004, high intensity, stand intervention (a gap opening cut, specific to progressive cuttings). The high intensity intervention caused the so called tree *isolation crisis,* which determined, alongside with a drop in general stand health, a sudden, radial growth descending trend (Figure 4). For average radial growth comparison, between the two plot series, the "t" test has been used (Horodnic 2004, 2008) (Table 2).

Table 2

"T" test significance for the two sample plots (affected by drying and control)

Statistics	*Growth series*	
	PATRA	DRG
Mean	1.776847	2.0388387
Variance	0.313011	0.393322
Observations	124	124
Pearson Correlation	0.822704	
Df	123	
t Stat	-8.12281	
P(T<=t) one-tail	2.03E-13	
t Criticalone-tail	1.657336	
P(T<=t) two-tail	4.05E-13	
t Criticaltwo-tail	1.979439	

The "t" test shows a significant difference between the two stands. So we can conclude that a beech production loss exists in "Dragomirna" plateau, due to abnormal dying phenomena.

Growth indexes dynamics. Concerning the growth indexes, obtained through the standardization of individual growth series (Figure 5), a tight connection between index values, can be noticed, up to the year 1980, the 1990-2010 period showing value shifts and fluctuant trends (first negative and then positive- after the year 2005) (Figure 6). This fact is due to high precipitation values in the 2005-2010 interval. Annual precipitation level, for the 2005-2010 interval, was over 600 mm (a maximum of 883.2 mm was reached in 2008) determining a growth increase.

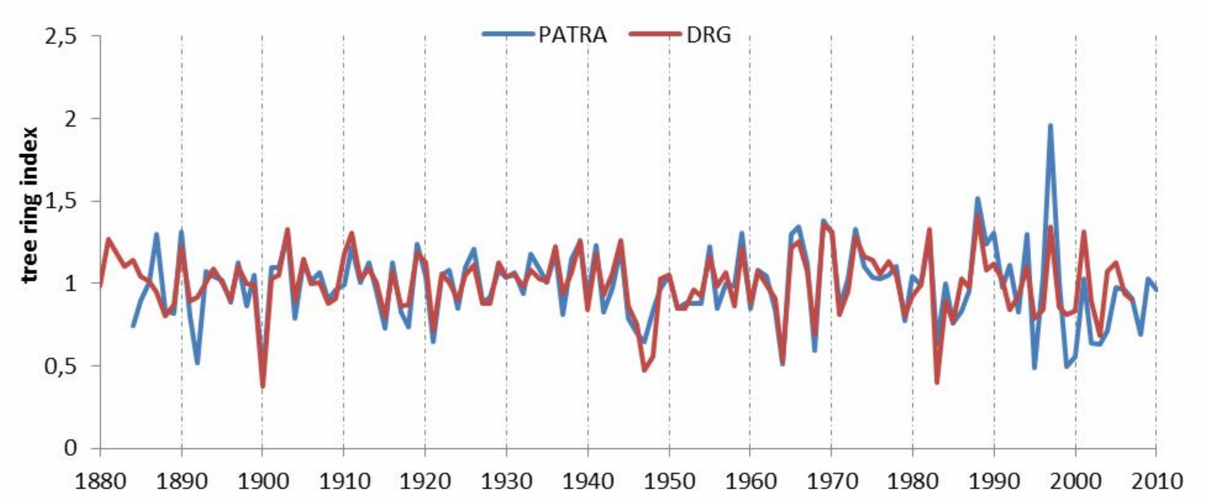

Figure 5. Beech growth indexes dynamic for PATRA and control (DRG) plots.

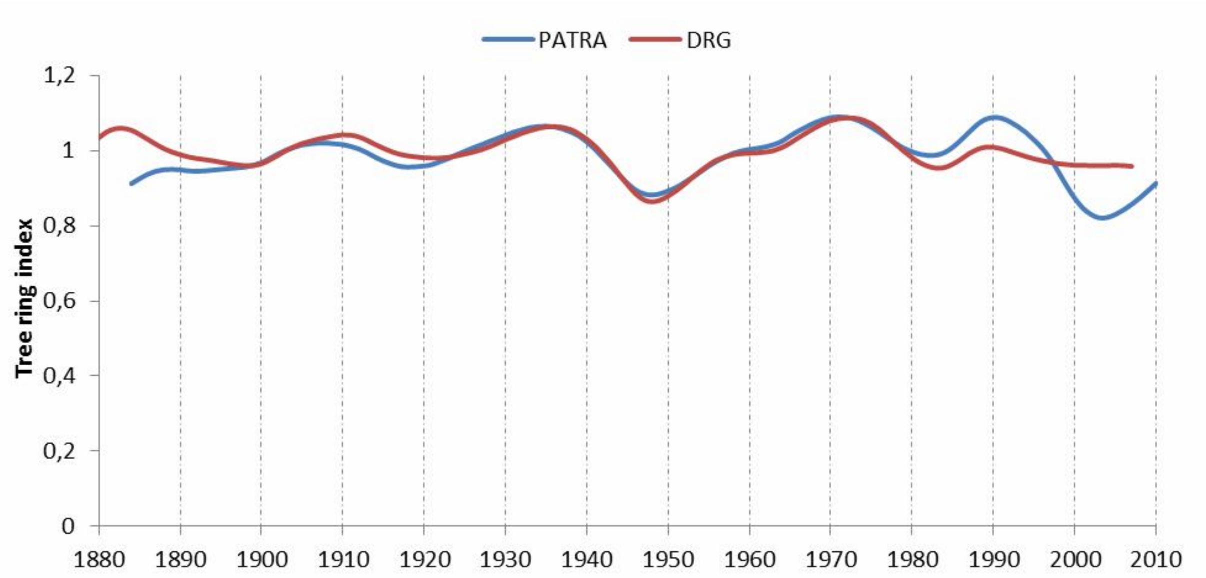

Figure 6. Beech growth index dynamics (spline values 20 years) in plots with dying phenomena (PATRA) and the control plot (DRG).

Another method used in dendrochronological research is the growth rates method (Figure 7). This method implies the identification of decline or auxological bounce periods.

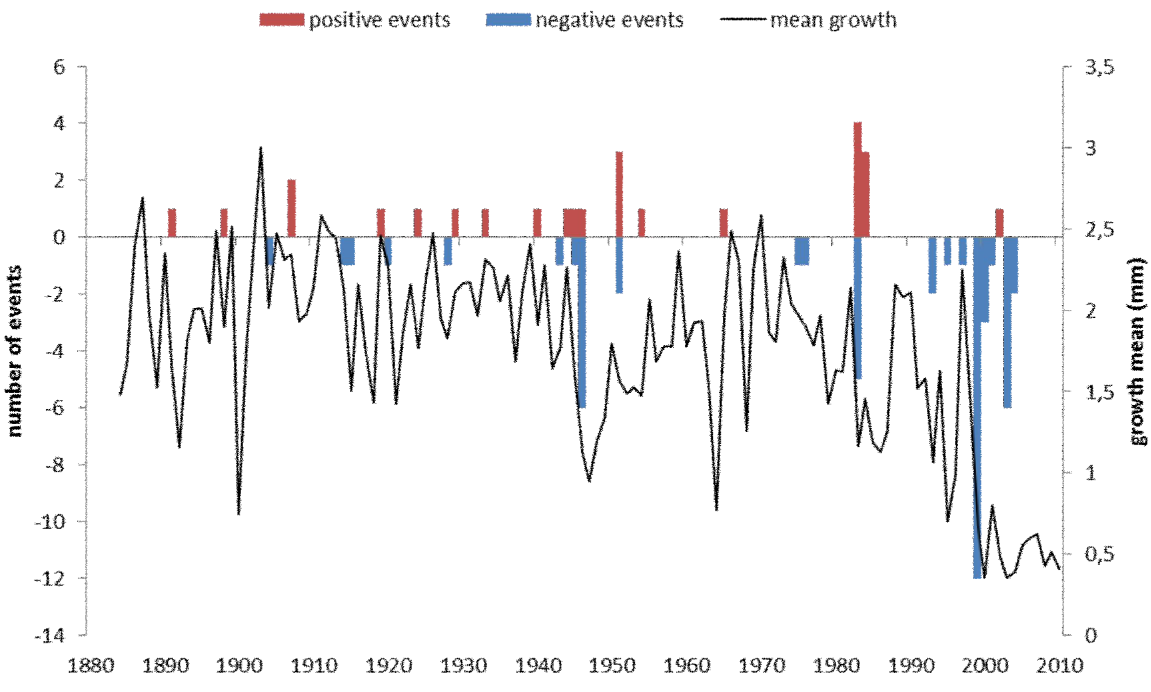

Figure 7. Disturbance events for PATRA beech series.

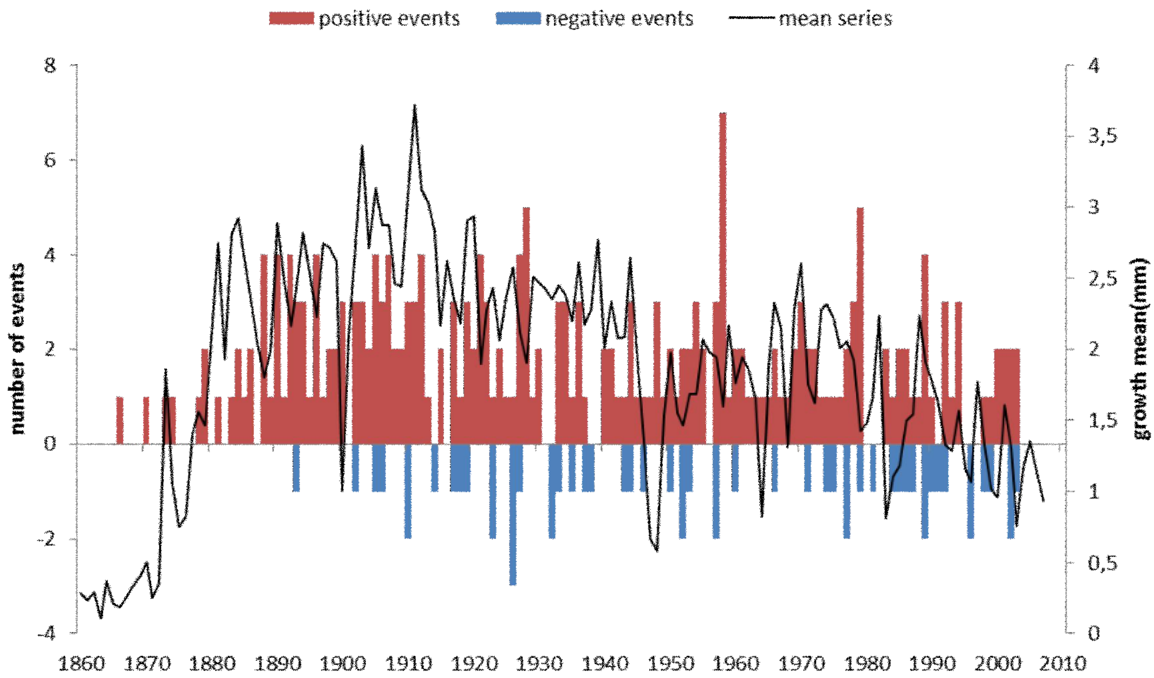

Figure 8. Disturbance events for DRG beech series.

Disturbances dynamics are random in the 1890-1990 period, with the exception of the year 1946, for which 30% of the analyzed series show a severe growth decrease, due to extreme drought (Figure 8). It's very important to point out the auxological decline following the year 1990, which coincides with a beech's dying period in the analyzed area. Climate chance can be a main cause for auxological decline of beech, the years 2000, 2003 and 2007 being among the hottest ever (IPCC 2001, 2007), added with the fact that beech is at its European eastern limit (Roibu 2010) in this area. For the natural stand (DRG) decline periods are registred for a limited number of trees, having a much lower intensity. These results back the above conclusions, clearly showing the auxological decline determined by abnormal drying phenomena.

Climate-tree relation for the analyzed series. Correlation between the elaborated dendrochronological series and meteorological parameters was conducted for individual values (from june, the previous year, to august, the ring formation year). Using the response functions analysis implies the reduction of the autocorrelation between climatic parameters and confirms the positive and significant influence of precipitation registred in May, the current year (Figure 9). The graph representation shows that response function is a much more precise indicator than the correlation coefficient. Conditions specific for the month a May, have a real influence on annual ring growth, and an explanation would be, that in drought years, in May, beech is more vulnerable to the attack of xylophagous fungi. Also this period of the year has a significant influence on hilly beech stands, increasing temperatures from the beginning of the vegetation season favouring early foliage development, which causes hidric stress all hot season (Di Filippo et al 2007).

The influence of annual and May precipitations on growth indexes. A comparison between growth indexes (obtained through standardization) and annual and May precipitation values, has been made, using graph representations. The purpose was to show the connection between precipitation and growth index values. Results shown by graph representations (Figure 10) point out that in PATRA plots (affected by dying phenomena) growth index values are closely connected to May precipitation values, and especially annual precipitation values. The end of the analyzed period (2005-2010) marks trend offsets for the above mentioned characteristics.

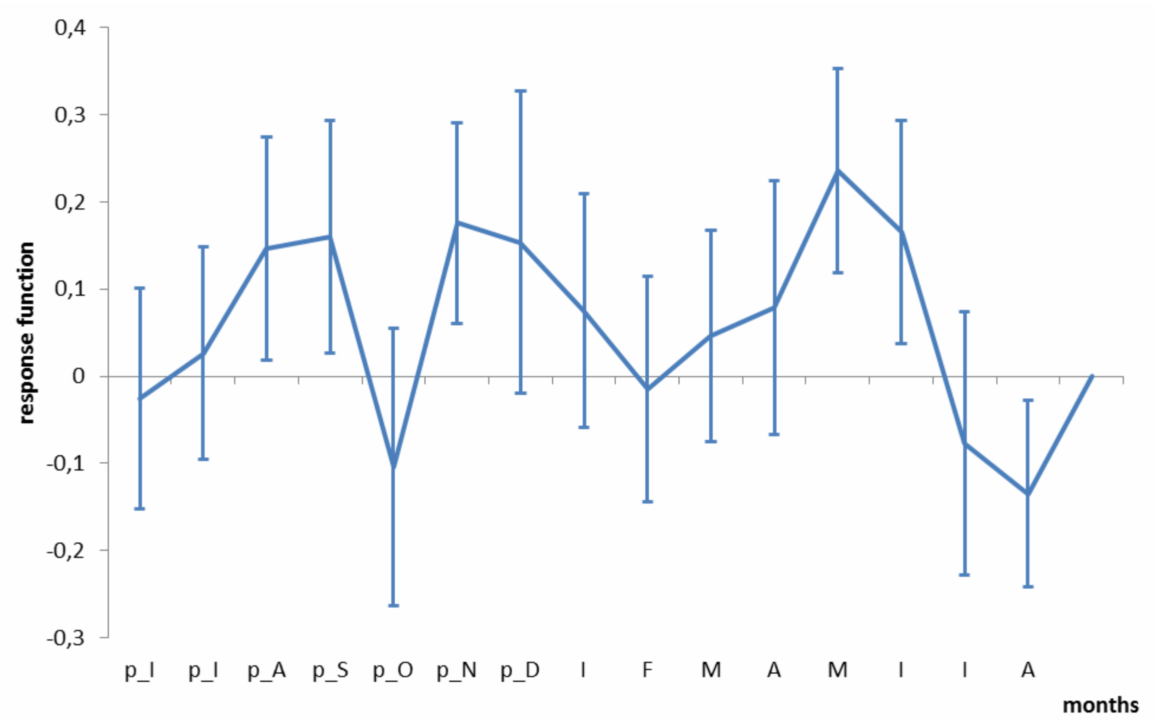

Figure 9. Response function for beech from "Dragomirna" plateau (for annual precipitation).

Conclusions. As a result of the conducted dendrochronological studies the following conclusions have been reached:

There is indeed an important role of the *climatic-precipitations* factor in the sudden growth drop of the annual ring.

For the two analyzed plots (Pătrăuți - with tree dying phenomena and "Dragomirna" - control plot) it has been shown, in the case of drying trees, a strongger decrease in radial growth. Age can be one of the factors responsible for the growth decrease, but there is at least another factor implicated, like intense phytophatologic attacks from the beginning of 2000. Gaps created in the stand as a result of 2004's progressive cuttings, causing the so called tree *isolation crisis,* can also influence growth decrease.

The analysis of growth indexes dynamics in relation to age showed that after 2005, *spline* curve has an ascendant trend for the plot affected by drying Phenomena, due to growth increase, a result of high values of average annual precipitations in the 2006-2010 period. (a maximum of 883.2 mm was registered in 2008).

The analysis of average annual temperature evolution showed a clear increasing trend for the last 30 years (by approximately 0.5^{0}C). For the 2000-2010 period, a increase of average annual precipitations values, is noticed.

Using the *response function* method it has been determined that May precipitations have a positive and significant influence on annual ring growth, May drought making beech more vulnerable to xylophagous fungi.

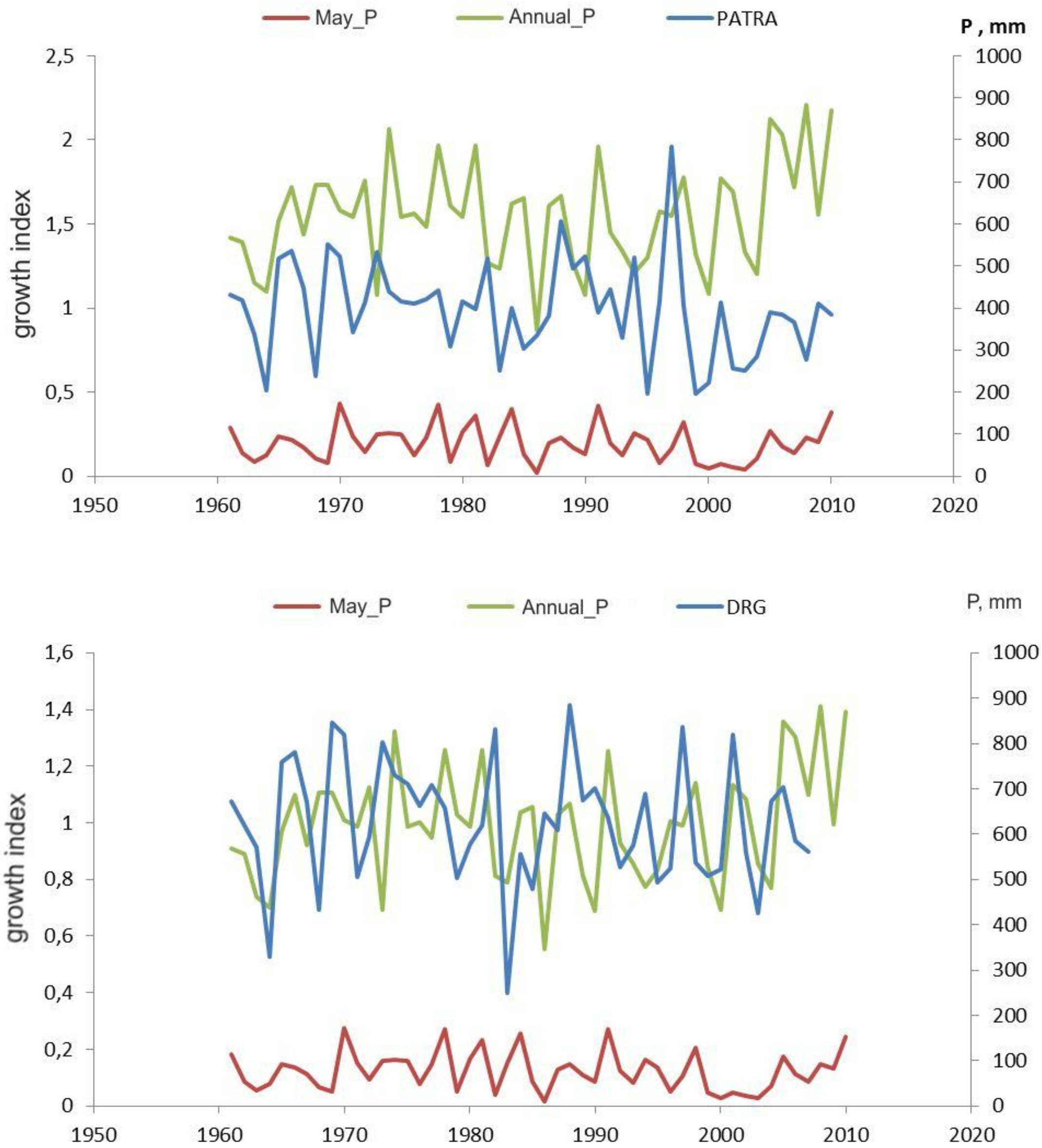

Figure 10. Graphical comparison between May and annual precipitations dynamics and growth indexes for PATRA and the control plots.

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