

Assessment of Oak Dendrochronological Series in Protected Zone (Bulgaria) for Eustress Identification in Forest Stands

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Abstract – The paper presents results of *Quercus cerris* L. and *Q. frainetto* Ten. eustress investigations in SCI “Zapadna Stara Planina i Predbalkan” following a new holistic approach by applying an original software - SPPAM for the identification and assessment of eustress. The tree ring width sequences are approximated with polynomials with $R^2 > 0.45$. It indexes as a ratio between measured and approximated values are computed. Years, where It is lower than a threshold value, are categorized as eustressed ones. Specified in the investigation climatic type of years are studied as adverse years according to the obtained eustress. A five grade scale for assessment of frequency, duration and negative deviation of It as eustress characteristics and their comparative analysis is proposed. The predominance of hot and dry adverse years on the growth is established. The eustress characteristics were scaled and compared. The potential risk for studied forest vegetation is estimated. The proposed holistic approach is convenient for the fast diagnosis of forest state. This approach allows also the expression of reactive functional types, which may support the vegetation modelling.

Keywords – Dendrochronology, Eustress, SPPAM, Oak, Tree Stands Assessment, SCI¹.

I. INTRODUCTION

The presented new holistic concept for studying eustress of trees is based on computation of the following main eustress characterizing indicators – frequency, eustress duration and negative deviation of growth (It) which are defined in a rigorous way. Eustress modeling is implemented in an application called SPPAM. The application implements the classical dendrochronological analysis, which is backed by a powerful mathematical apparatus, for modeling of the periods with low growth called “eustress”.

Stress syndrome is considered as all nonspecific reactions or deviations from the functional norms under the influence of complex environmental impact [1]. In contrast to the destructive stress (distress), eustress is reversible, recurring state of reduced radial growth for a set of years caused by adverse environmental factors for the biological system exposed.

The background of this involvement is that the annual growth of stem is an important source of information about the environment, the tree vitality and state of its community. This information can be obtained by

measuring the following characteristics of annual tree rings - width, density, early-late wood ratio, diameter of the vessels, size of the cells, thickness of the cell walls, degree of lignification, chemical content etc. The change of growth for the sufficiently long period of time uncovers “the behaviour” of tree species and/or its community in the corresponding habitat that can support tree functional type’s classification [2, 3].

The application of holistic ecological approach to explore eustress (study the final total result of stress situations - impaired growth and production) rather than a metrological one gives the possibility for fast assessment of forest ecosystems.

The main aim of investigation is to analyze the eustress of *Q. cerris* L. and *Q. frainetto* Ten. in SCI “Zapadna Stara Planina i Predbalkan” following a new holistic approach and using an original software application. The present results of oak stands in the protected zone may support the management of forest area in the region and demonstrate the proposed methods.

II. OBJECTS AND METHODS

The objects of this research are *Q. cerris* L. and *Q. frainetto* Ten. stands dominated in xerothermic oak ecosystems in SCI “Zapadna Stara Planina and Predbalkan”, Bulgaria. The xerothermic oak ecosystems as a part of potential xerothermic forest vegetation of Bulgaria and South-eastern Europe [4] have expressed environmental, economic and social importance for the region of distribution. These forests have been destroyed in ancient times over a large part of their territory. Occupying altitudinal belt of rolling plains and foothills, i.e. near the settlements, the oak forests are subjected to intensive exploitation that continues to these days. The xerothermic oak forests in Bulgaria are mainly coppices and with degraded ecological and economic functions. The main task that was standing in front of forestry guild back in the last century was the gradual transformation of these sprouts forests in seeds ones. Parts of still preserved xerothermic oak forests in Bulgaria are included in protected areas of “Natura 2000” to ensure their protection and improvement of the future perspective. The national evaluation of habitat area of 91M0 Pannonian-Balkan turkey oak-sessile oak forests in the protected zone is 7.5. 105 ha, but for the past 5 years this area has decreased by 20.9% (D-30-38/21.03.2011-2013 “Mapping and determining the conservation status of habitats and species - Phase I”).

¹ Site of Community Importance (SCI) - accepted abbreviation to indicate protected zone (site) announced in European countries.

The analyses were conducted with 48 and 60 series, respectively of *Q. cerris* L. (with age from 42 to 108 years) and *Q. frainetto* Ten. (with age from 42 to 77 years) in five locations, respectively per each species – Table 1.

Table I: Objects characteristics

№	Sampling area(SA)	Long.	Lat.	Alt., m	Soil	Age _{min} , y	Age _{max} , y	DBH, cm	H, m	N
<i>c</i>	<i>Q.cerris</i> L.									
1	t. Montana	23.22	43.41	150	Luvisols	42	54	30.5	11	8
2	v. Gavril Genova	23.08	43.38	209	Luvisols	53	68	21.2	13	18
3	v. Protopopinci	22.57	43.56	276	Luvisols	51	59	26.1	13	6
4	v. Pomezhdin	22.99	43.38	357	Rendzic	53	108	21.5	11	8
5	v. Govezhda	23.00	43.30	371	Luvisols	67	70	20.5	13	8
<i>f</i>	<i>Q.frainetto</i> Ten.									
1	t. Montana	23.22	43.41	150	Luvisols	42	54	30.0	11	10
2	v. Gavril Genova	23.08	43.38	209	Luvisols	55	68	17.5	13	18
3	v. Protopopinci	22.57	43.56	276	Luvisols	50	73	15.0	13	16
4	v. Dolni Lom	22.92	43.75	342	Cambisols	61	65	16.0	11	8
5	v. Govegda	23.06	43.34	370	Luvisols	58	77	18.0	16	8

SPPAM, version 1.2 is applied for data analysis; its functionality encompasses classical analyses in dendrochronology and new developments [5]. Sequences with $R^2 > 0.45$ and locations with EPS (Expressed Population Signal) $> 80\%$ are included in the analysis. The studies on the expression of eustress, its assessment and determination of adverse climatic types are conducted by analysis of the average growth index sequences ($I_t = MW/AW$, where MW is measured width and AW – computed width only for the sequences with trusted approximations). This index allows the elimination of influence of trees' age on the growth and also facilitates clearing the climatic signal in dendrochronological series [6, 7, 8]. The eustress is characterized by: duration (D), i.e. the number of consecutive eustress years in the series; frequency (F) – the number of eustress years for 100 years period and negative deviation (A) described reduction in

the growth - $A = \frac{1}{s} \sum_{i=1}^s (1 - I_{t_i}) \sqrt{a^2 + b^2}$, where I_{t_i} are the

growth indexes for which the eustress has been found. The following coefficients were calculated also for the oak series characteristics: “K” - coefficient as the ratio between the number of years for which the analysis was performed (Period) and the number of stress years (SY); “Ct”- coefficient – the ratio between the number of series with the same stress year (cardinality, Card.) and the total number of analysed sequences from one location (Total n) and coverage (Cov.) – the ratio between the number of series with the same stress year (Card.) and the number of analysed sequences, which have the same periods.

The climatic database CRU – TS [9] was used as a source of data on temperature and precipitation for 1901-2009. The climatic type of year is described by the deviation of average annual temperature (dT) and annual sum of precipitation (dP) from the respective climatic norm. The average annual temperature ($T_{avg.}$) and precipitation ($P_{avg.}$) and their confidence intervals (μ_{ti} and μ_{pi} at the level of significance - $\alpha = 0.05$) for every 30 years were calculated, starting from 1901. The confidence interval, μ , is calculated from the formula - $\mu = 1.96 \sigma / (\sqrt{n})$,

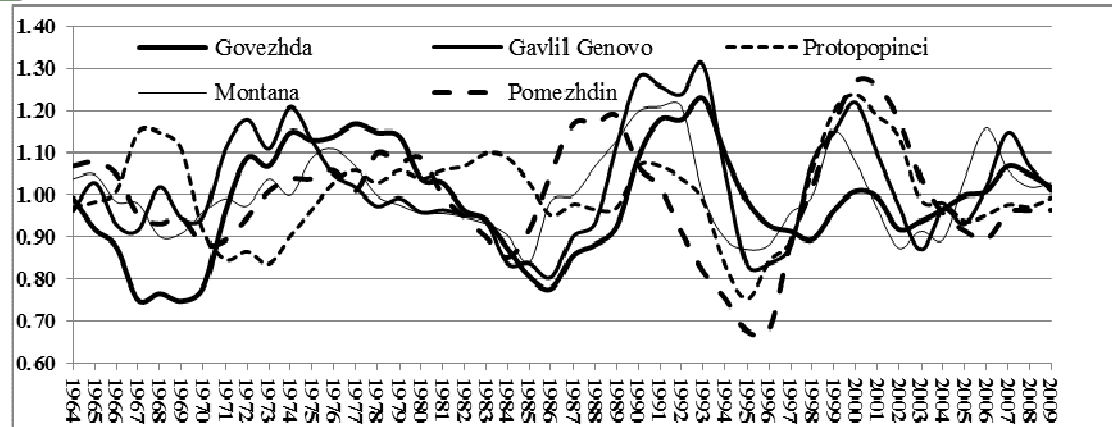
where σ is the standard deviation of average values of I_t , T and P. Values inside the intervals: $T_{avg.} \pm \mu_{ti}$ and $P_{avg.} \pm \mu_{pi}$ respectively are considered as climatic norms for temperature and precipitation [10]. The used climatic types of years are: hot (H) – $dT > \mu_{ti}$, cold (C) – $dT < -\mu_{ti}$, wet (W) – $dP > \mu_{pi}$ and dry (D) – $dP < -\mu_{pi}$. The year is with normal (N) average temperature, when $-\mu_{ti} \leq dT \leq \mu_{ti}$, and with normal sum of precipitation, when $-\mu_{pi} \leq dP \leq \mu_{pi}$ [3, 5].

III. RESULTS

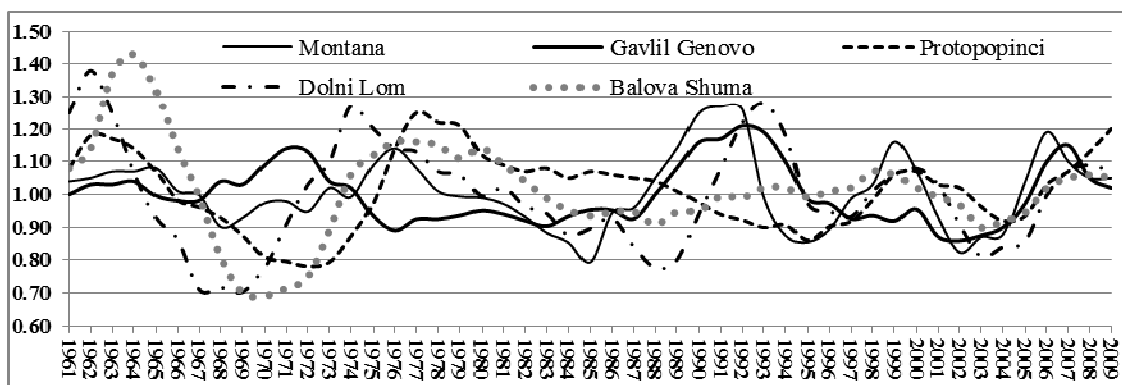
The average index for the analyzed *Q. cerris* L. series varies from 1.00 ± 0.06 to 1.02 ± 0.09 in SAs (for the period 54 - 70 years), and this for *Q. frainetto* Ten. series - from 1.00 ± 0.07 to 1.01 ± 0.09 (for 54 to 77 years period) - Table 2. The radial stem growth is described with polynomials from 6th degree for 92% of the analyzed series, R^2 varies from 0.781 to 0.955 Fig. 1 (a) and (b).

The *Q. cerris* L. series of indexes from sampling areas (SAs) as follows: t. Montana, v. G. Genova and v. Govejda, as well as these from v. Protopopinci and v. Pomezhdin have significant correlation ($0.5 \leq r \leq 0.7$) according to the published scale [11] – Table 3. The correlation between the series from t. Montana, v. Govezhda and v. Pomezhdin is moderate ($0.3 \leq r \leq 0.5$). The rest of the correlations are weak. The variation in the radial growth of series studied is with good synchronization on the whole. Only the average indexes of series from v. Protopopinci and v. Pomezhdin indicate a different direction of change for some years, with a few exceptions (Fig. 1(a)).

There is a moderate correlation between the *Q. frainetto* Ten. series of indices from t. Montana, v. G. Genova and v. D. Lom, also between these for v. B. Shuma, v. Protopopinci and v. D. Lom. The rest of the correlations are weak. Generally the synchronization in the variation of *Q. frainetto* Ten. indices is weaker in comparison to this of *Q. cerris* L. in the studied locations. There are periods in which the directions of changes are different for the part of series. (Table 3, Fig. 1(b)).



(a)



(b)

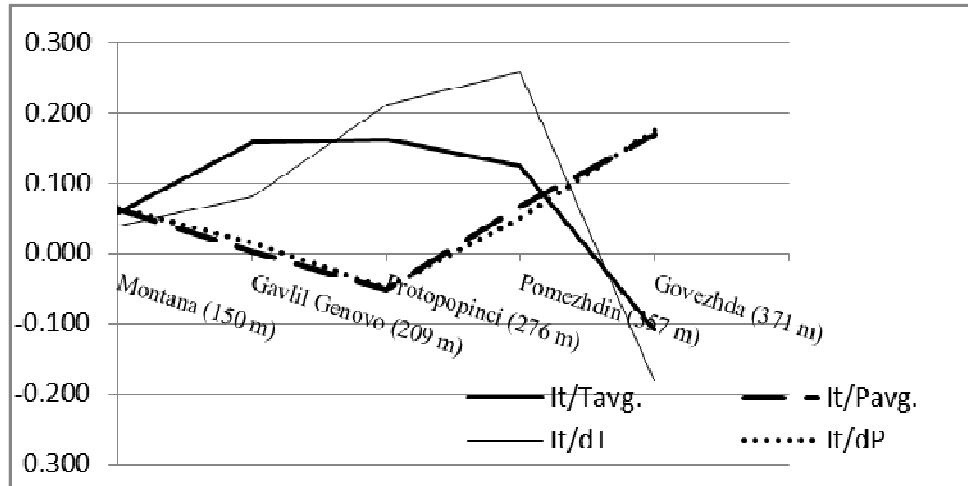
Fig.1. Variation of average growth index (It) of *Q. cerris* L. (a) and *Q. frainetto* Ten. (b)

Table II: Characteristics of the investigated oak series

Species/SA	Period (P), y	It (avg.)	μ (avg.)	SY, n	K= P/SY	Car.	Cov.	Ct= Card/N
<i>Q. cerris</i> L.								
t. Montana	54	1.02	0.09	18	2.94	4.11	0.69	0.51
v. G. Genova	68	1.02	0.08	30	2.27	9.6	0.72	0.53
v. Protopopinci	59	1.01	0.07	21	2.81	3.48	0.78	0.58
v. Pomezhdin	55	1.00	0.08	27	4.00	3.7	0.76	0.46
v. Govezhda	70	1.00	0.06	30	2.33	5.3	0.79	0.66
X	61	1.01	0.08	25	2.87	5.24	0.75	0.55
STDEV	7	0.01	0.01	5	0.70	2.54	0.04	0.08
<i>Q. frainetto</i> Ten.								
t. Montana	54	1.00	0.09	21	2.57	5.67	0.71	0.57
v. G. Genova	68	1.00	0.07	32	2.13	4.50	0.64	0.25
v. Protopopinci	73	1.01	0.09	32	2.28	7.28	0.64	0.46
v. D. Lom	65	1.00	0.08	27	2.41	4.89	0.74	0.61
l. B. Shuma	77	1.01	0.09	38	2.03	3.21	0.63	0.40
X	67	1.00	0.08	30	2.28	5.11	0.67	0.46
STDEV	9	0.01	0.01	6	0.22	1.50	0.05	0.14

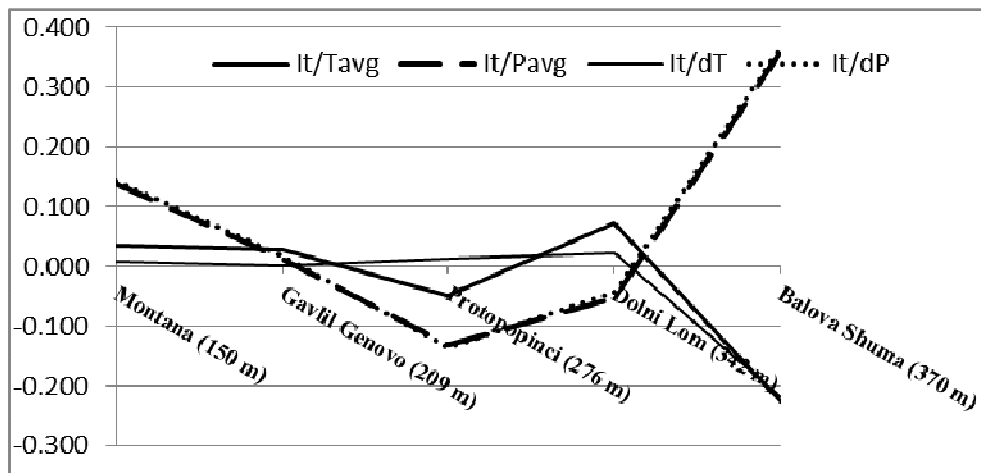
For the *Q. cerris* L. series of indexes the calculated correlation coefficients are positive. The correlation coefficient of It with average temperatures is higher compared to this with average precipitation. Both coefficients are from 1.02 to 1.04 times lower than the correlation coefficients between the growth index, dT and

dP (Fig. 2(a)). The correlation coefficients vary in the studied locations and the highest values of r_A with temperature parameters are for v. Protopopinci and Pomezhdin, and with precipitation parameters - for v. Govezhda.



(a)

r_A	$It/T_{avg.}$	$It/P_{avg.}$	It/dT	It/dP
Average	0.079	0.049	0.081	0.051



(b)

r_B	$It/T_{avg.}$	$It/P_{avg.}$	It/dT	It/dP
Average	-0.028	0.065	-0.035	0.070

Fig.2. Correlation coefficient variation by SAs for *Q. cerris* L. (A, r_A) and *Q. frainetto* Ten. (B, r_B)

For the *Q. frainetto* series of indexes the negative correlation between the growth index, T_{avg} and dT is established, and the positive one – with P_{avg} and dP (Fig. 2(b)). The correlation coefficient between It and P_{avg} is greater than this with the average temperatures, which differs the two studied species. Both coefficients are about 2 times lower than the correlation coefficients between the growth index, dT and dP . This determines the species as more sensitive to deviations from climatic norms. The correlation coefficients vary in locations and the highest values for r_B with temperature parameters are for v. D. Lom, and with precipitation parameters - for v. B. Shuma. The established stress years for *Q. frainetto* Ten. vary in number for locations as follows: from 18 to 30 for *Q. cerris* L. and from 21 to 38 for *Q. frainetto* Ten. Calculating the ratio between the number of stress years to the periods for which they are defined (K) shows, that most number of stress years are established for *Q. cerris*

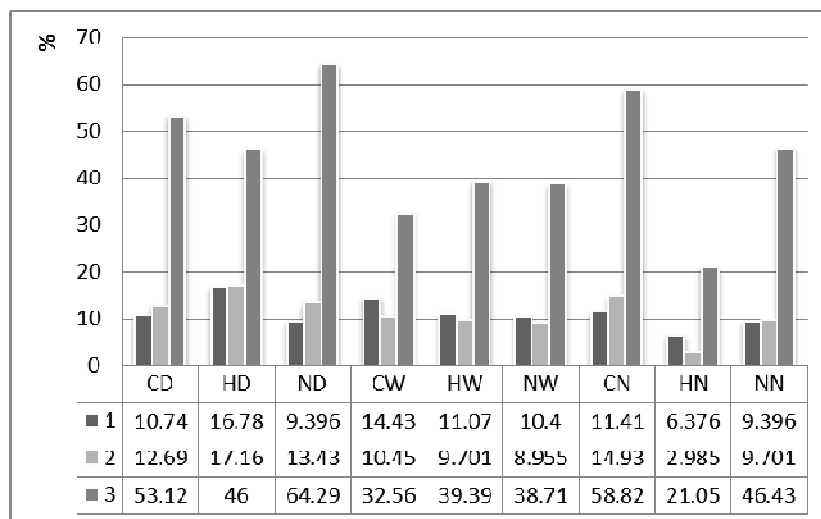
L. series from v. Pomezhdin – 4.00, and for the remaining locations coefficients vary between 2.27 (v. G. Genova) and 2.94 (t. Montana). For *Q. frainetto* Ten. series K -coefficient varies from 2.03 (v. B. Shuma) to 2.57 (t. Montana) - Table 2. The statistical indicators of identified stress years – Car., Cov. and Ct-coefficient are also listed in Table 2. The number of series having the same stress years (Card.), varies from 3.48 to 9.60 and from 3.21 to 7.28, respectively for *Q. cerris* L. and *Q. frainetto* Ten. The range of variation of Cov. for the studied oak series is similar, respectively 10 (0.69-0.79) and 11 (0.63 - 0.74) for *Q. cerris* L. and *Q. frainetto* Ten., while the range of variation of Ct-coefficient is higher for *Q. cerris* L. – 30 (0.46 – 0.76), i.e. the variation of ratio between the series with similar stress years and the total number of studied series is greater in comparison to *Q. frainetto* Ten. series of indexes - the diapason of Ct-coefficient is 21 (0.40 – 0.61).

Table III: Correlation coefficients between growth indexes (It) of *Q. cerris* L. and *Q. frainetto* Ten.

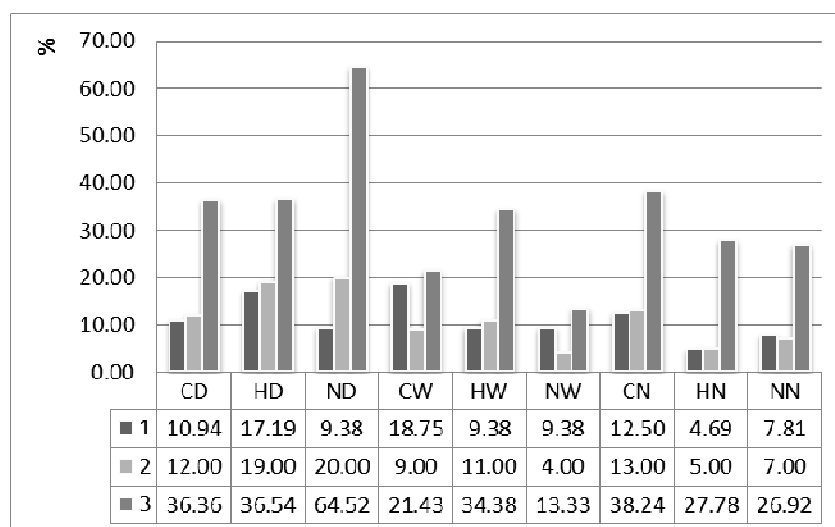
SA/<i>Q. cerris</i> L.	t. Montana	v.G. Genova	v. Protopopinci	v. Pomezhdin	v. Govezhda
t. Montana	-	0.62	0.15	0.38	0.47
v. G. Genova	0.62	-	0.19	0.24	0.53
v. Protopopinci	0.15	0.19	-	0.56	-0.1
v. Pomezhdin	0.38	0.24	0.56	-	0.01
v. Govezhda	0.47	0.53	-0.1	0.01	-
SA/<i>Q. frainetto</i> Ten.	t. Montana	v. G. Genova	v. Protopopinci	v. D. Lom	v. B. Shuma
t. Montana	-	0.48	0.18	0.36	0.31
v. G. Genova	0.48	-	-0.21	0.17	-0.07
v. Protopopinci	0.18	-0.21	-	0.28	0.42
v. D. Lom	0.36	0.17	0.28	-	0.49
l. B. Shuma	0.31	-0.07	0.42	0.49	-

The ratio between dry and wet years (D:W) in percentages is 36.10:36.89, and the ratio of cold to hot years (C:H) – 34.81:33.76 for the *Q. cerris* L. studied period. HD and CW are the most common climate types of years, respectively 15.84% and 13.77% (Fig. 3 (a)). In the

total number of eustress years the dry years (CD+HD+ND) bring the biggest part – 47%, followed by cold and hot years – 36% and 34%. Stress years are respectively from 52% and 55% to 60% of HD, ND and CD climate types stated.



(a)



(b)

Fig.3. Percentage of: (1) Climate type in the total number of years; (2) Climate type in the total number of stress years; (3) Adverse climate type in the total number of years with relevant climate type for *Q. cerris* L. (a) and *Q. frainetto* Ten.

(b)

The climate background of *Q. frainetto* Ten. period of study is determined by the cold and wet years. Respectively D:W:C:H in percentage is 36.91:37.51:42.19:31.26. HD and CW are the most common climatic types, respectively 17.19% and 18.75% (Fig.3 B). The dry

years (CD+HD+ND are also the main stress years in their total number) – 51%, followed by warm and cold years – 35% and 34%. A large part of ND and CN climatic types are stress years also, respectively 64.52% and 38.24%.

Table IV: Characteristics of eustress for investigated oak series and functional type

Species/SA	A	Amax	Y, Amax	Davg.	Dmax	Y, Dmax	F, 100 y	PFT
<i>Q. cerris</i> L.								
t. Montana	0.269	0.469	1993	1.6	3.0	2000-2002	33	F1D1A4
v. G. Genova	0.271	0.518	1995	2.1	5.0	1982-1986	44	F3D3A4
v. Protopopinci	0.268	0.700	1957	1.9	4.0	1956-1959	35	F2D2A4
v. Pomezhdin	0.244	0.399	1995	2.7	7.0	1990-1996	50	F5D4A3
v. Govezhda	0.242	0.612	1950	2.5	8.0	1963-1970	42	F3D4A3
X	0.259	0.540	-	2.2	5.4	-	41	-
STDEV	0.014	0.119	-	0.4	2.1	-	7	-
Istanbul-Belgrade Forest	0.188	0.378	1851	2.3	7.0	1819- 1825	43	F3D3A2
Bursa-Mustafakemalpassa-Devecikonak-Gurgendag	0.190	0.327	1797	2.6	9.0	1801-1809	46	F4D4A2
Around Pinarbasi	0.195	0.403	1634	1.8	6.0	1656-1661 1745-1750 1947- 1952	43	F3D2A2
X	0.191	0.369	-	2.2	7.3	-	44	-
STDEV	0.004	0.039	-	0.4	1.5	-	2	-
<i>Q. frainetto</i> Ten.								
t. Montana	0.346	0.623	1957	1.75	4.0	1982-985	38	F2D1A5
v. G. Genova	0.280	0.425	1959	2.29	6.0	1973-1978	47	F4D2A3
v. Protopopinci	0.306	0.608	1949	3.2	9.0	1965-1973	43	F3D4A3
v. D. Lom	0.275	0.519	1967	2.7	7.0	1963-1969	41	F3D3A3
I. B. Shuma	0.317	0.647	1949	2.9	7.0	1966-1972	47	F4D3A4
X	0.305	0.564	-	2.6	6.6	-	43	-
STDEV	0.029	0.092	-	0.6	1.8	-	4	-

The average depth of eustress is higher for *Q. frainetto* Ten. (A = 0.305) and varies for SAs from 0.275 to 0.346. For *Q. cerris* L. it is 0.259 and varies by SAs in the range 0.242 – 0.271. The maximum depth for the studied periods is 0.700 in 1957 for *Q. cerris* L.; 0.643 and 0.623 for *Q. frainetto* Ten., identified in 1949 and 1957. The average eustress duration for *Q. cerris* L. and *Q. frainetto* Ten. is respectively from 2.2 years (from 1.6 to 2.7) and 2.6 years (1.8 – 3.2). The maximum duration of eustress established is 8 years (1963 - 1970) for *Q. cerris* L. and 9 years (1965 - 1973) for *Q. frainetto* Ten. for the studied periods. The average frequency of eustress for 100 years is 41 and 43, respectively for *Q. cerris* L. and *Q. frainetto* Ten., where

the varying of average frequency by locations is lower for *Q. frainetto* Ten. The studied dendrochronological series are not at the same age and length, cover different periods, that is the reason for the seen variability of frequency.

Based on the analysis of variation in the values of A, D and F for the analyzed *Q. cerris* L. series from the protected area studied and data on Turkish series, taken from the international dendrochronological database [9], a five-graded scale for comparative assessment of eustress is drafted (Table 4). The scale for comparative evaluation of the eustress characteristics for *Q. frainetto* Ten. is a result of the analysis only of data used in this study.

Table V: The five-graded scale for assessment of *Q. cerris* L. and *Q. frainetto* Ten. eustress indicators

F		D			A		
<i>Q. cerris</i> L.							
Group	Value	Group	Value	Group	Value	Group	Value
1	Very rarely ≤ 34.3	1	Very short ≤ 1.67	1	VerySmall depth ≤ 0.182	1	VerySmall depth ≤ 0.182
2	Rarely >34.3 - ≤ 38.15	2	Short >1.67 - ≤ 1.936	2	Small depth >0.182 - ≤ 0.208	2	Small depth >0.182 - ≤ 0.208

3	Normal	>38.15 - ≤ 45.85	3	Normal	>1.936 - ≤2.469	3	Normal depth	>0.208 - ≤0.259
4	Often	>45.85 - ≤ 49.7	4	Long	>2.469 - ≤2.736	4	deep	>0.259 - ≤0.284
5	Very Often	>49.7	5	Very Long	>2.736	5	Very deep	>0.284
<i>Q. frainetto</i> Ten.								
1	Very rarely	≤ 37.39	1	Very short	≤1.862	1	Very small depth	≤0.29
2	Rarely	>37.39 - ≤ 40.05	2	Short	>1.862 - ≤2.293	2	Small depth	>0.229 - ≤0.258
3	Normal	>40.05 - ≤ 45.38	3	Normal	>2.293 - ≤3.157	3	Normal depth	>0.258 - ≤0.315
4	Often	>45.38 - ≤ 48.04	4	Long	>3.157 - ≤3.589	4	Deep	>0.315 - ≤0.344
5	Very Often	>48.04	5	Very Long	>3.589	5	Very Deep	>0.344

The combining of average eustress indicators estimates allows the expression of functional types of trees in locations listed in Table. 3. For three of the studied locations of *Q. cerris* L. - t. Montana, v. G. Genova and v. Protopopinci the growth takes place on the background of deep, short or very short eustress that occur very rarely or rarely (F1D1A4, F3D3A4, F2D2A4). For two locations of *Q. frainetto* Ten. - t. Montana and I. B. Shuma, the types F2D1A5 (rarely occurring very short and very deep eustress) and F4D3A4 (frequently occurring and deep eustress) were obtained respectively.

IV. DISCUSSION

The correlation dependence of It of *Q. cerris* L. and *Q. frainetto* Ten. with climatic parameters is weak according to the cited scale [11], although the use of the parameters dP and dT leads to a slight increase of the correlation coefficient (it is twice as pronounced for *Q. frainetto* Ten. series). More clear dependencies can be seen in the analysis of climatic types of years influence on the growth and manifestation of adverse or eustress years. The computed correlation coefficients of index series are positive for *Q. cerris* L., while for *Q. frainetto* Ten. a negative correlation dependency is determined between the growth index and the used parameters for temperature. The correlation coefficient of It with average temperatures is higher than that with average precipitation for *Q. cerris* L. and reverse dependency is shown for *Q. frainetto* Ten. series.

For the period of study the climatic background for *Q. cerris* L. and *Q. frainetto* Ten. growth is determined by dry and cold years. The percentage share of HD and CW - hot and dry and cold and wet years is prevailed. The greatest share in the total number of eustress years for two oaks are dry years (CD+HD+ND), respectively 43% and 51% for *Q. cerris* L. and *Q. frainetto* Ten.

The number of established eustress years, the average and the maximum established depth, the duration and the frequency of eustress for *Q. frainetto* Ten. are with higher values compared to the same indicators for *Q. cerris* L. (respectively in average: 30 to 25; 0.305 to 0.259; 9 to 8, and 43 to 41). The received data for the of *Q. cerris* L. locations is compared to the analysed data for three

locations in Turkey (Table 3). It is obvious that the eustress is having up to 1.4 times less depth compared to studied locations in Bulgaria, and the absolute maximum of A is up to 1.5 times lower in value but average duration of eustress is the same.

For the explored locations in the protected zone, there are 11 common eustress years for *Q. cerris* L. series, two of which (1983 and 1986) are eustress years in 71.43% of the locations, and 9 (1948, 1950, 1958, 1963, 1968, 1969, 1970, 1984 and 1985) - in 57.14% of the locations. Among the common eustress years the climatic types of dry years (HD, CD, and ND) - 78.26% are prevailed. The climatic types CW and CN are also established. The analysis reveals that the cold and wet climatic type is eustressed for the *Q. cerris* L. locations, as in the previous two years a sharp change of the thermal regime is observed: HW with CN climatic type. The cold climatic type in this case is prominent eustressed for the locations of *Q. cerris* L., as in the preceding two years a sharp change from wet to dry year (NW with HD climatic type) could be observed. There are 12 common eustress years for the locations of *Q. frainetto* Ten., five of them - 1967, 1969, 1983, 1985, and 2001 are eustressed for 80% of the locations, and seven - 1951, 1959, 1966, 1968, 1972, 1986 and 1987 are eustressed for 60% of the locations. Among the common eustress years climatic types of dry years (HD, CD and ND) are prevailed with 58.54% participation in the total number. The climatic types HW and CW, CN and NN also have been established. The listed climatic types are eustressed as a result of the sharp change in the regimes, started 2 years before the observed eustressed year. For example, before eustressed HW year the change of climatic type for a two year period is either CN/HD or CN/ND; before stressed CW year ND changed with HD; before stressed CN - HW with HD or HW with ND, and before stressed NN - the previous climatic types are either CD and ND or ND and HD, i.e. there are two consecutive dry years, as one of them might be at the same time either cold or hot regarding the average temperatures.

For three of the explored locations of *Q. cerris* L. the types of manifestation of eustress which would have negative but not critical significance for the existence of the forest have been received. For two of the *Q. frainetto* L. locations there have been established the types of manifestation of eustress which carry some risk for the

existence of forest as the very deep or frequent occurring eustress will result in the discharging of trees and decline in their immunity to diseases and pests, and also a decline in their reproductive and productive potential. During research of beech forests from the same area a different “behaviour” has been observed for analogical time period. The predominant functional type with recurrent continuous eustress with little depth is observed [5]. Only some of the established eustress years for *Q. cerris* L. and *Q. frainetto* Ten. locations have been notes as eustressful for the beech as well (i.e. 1948, 1966 etc.) which can be explained with the different altitude of the species distribution and their different ecological futures. The acquired functional types for the locations in Turkey are with little depth of the eustress compared to those in the protected zone, where 50% of the types are with deep and very deep eustress.

V. CONCLUSION

The correlation dependence between the growth index of studied oak series and the used climatic parameters is weak, even though the correlation coefficient with dP and dT as used climatic parameters increases. These results occur also when the index series of other species [3,5] were analyzed. Even though *Q. cerris* L. and *Q. frainetto* Ten. form mixed forests in the protected zone, they have some differences in their ecological characteristics – the growth index of *Q. frainetto* Ten. shows highest correlation coefficient value with the precipitation parameters and lower negative correlation - with temperature parameters compared to *Q. cerris* L. (lower coefficient with precipitation parameters and higher positive correlation – with temperature parameters). *Q. frainetto* Ten. seems to be more sensitive species compared to *Q. cerris* L., especially to deviations of T and P from climate norms and it has greater values for eustress and its characteristics. This confirms the cited characteristic obtained for oak series of other locations in Bulgaria [12].

The introduction of climatic types of years helps to study better the impact of climate change on tree growth than usage of average climatic parameters or temperature and precipitation. The conducted study with two oak species from the protected zone “Zapadna Stara Planina i Predbalkan” shows the influence of mainly dry years on stem growth (It) – over 40% and 50% of the dry years caused eustress. The stress influence of the other climatic types is often due to sudden changes in CT in previous two years, leading to tree depletion. There are 11 and 12 common stress years established for the studied locations of *Q. cerris* L. and *Q. frainetto* Ten. as 5 of them are common for the both species: 1968, 1969, 1983, 1985 and 1986, despite the mentioned ecological differences between the two oaks.

For about 50% of the surveyed locations the type of eustress is still not a risk for the forest existence, but the studied forests are with more pronounced eustress compared to the studied beech forests from the same region and *Q. cerris* L. forests from three Turkish

locations. The frequency and duration of eustress vary for the foregoing species and locations, but in about 50% of the oak locations in the protected zone the eustress are large and very deep, while the eustress is with very little depth for the beech and for Turkish locations of *Q. cerris* L.

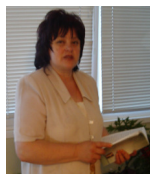
The presented results of studied oak stands in protected zone may support the forest monitoring and management and also they demonstrate the applied holistic approach. The assessment of forests state in protected zone (where it is assumed that the main impact on the growth is variation of climatic parameters) may be used as the basis data for comparison and analysis of forests areas in and out protected areas.

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AUTHOR'S PROFILE

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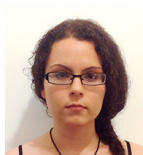
She is an author of over 150 scientific works published in national and international journals for the period of 2000-2014. Dr Lyubenova has published 10 books and scientific monographs: *Plant Ecology* (Sofia: M. Drinov Academic Publisher, 2004), *Functional Biocoenology* (Sofia: An-Di Publisher, 2009), *Role of underground plant mass in the annual fixation of CO2 from representative forest ecosystems in Bulgaria* (Sofia: University of Forestry Publisher, 2014) and others. Focus of her scientific research is in the field of structural and functional plant ecology, forest ecology and dendrochronology. Problems affecting allelopathy, primary production, net assimilation, biological cycle, energy flux and energy use, the use and accumulation of chemical elements and toxicants in plant biomass. Researches also affect issues such as: plant diversity, ecosystem health and risk assessment, rational use, conservation and regeneration of plants and their communities, and the use of data for monitoring (dendrochronology) and protection of the environment and vegetation. She is a leader or member of 25 international and national research projects.

Dr Lyubenova is a member of Balkan Academy of Science and Culture, Union of Scientists in Bulgaria, International Association of Plant Sciences, Balkan Environmental Federation, Association of Innovative Economy, Journal of Balkan Ecology Editorial Board, Annual of Sofia University Editorial Board (book Botany), Member Comity of four COST Actions (ES0805/2009-2014 “Terrestrial Biosphere in the Earth System, ES1101/2012-2016 “Harmonizing Global Biodiversity Modelling”, FP1106/2013-2017 “Studying Tree Responses to Extreme Events: a Synthesis” and FP1304/2014-2018 “Towards robust projections of European forests under climate change”). She is a president of NGO “Europe for all of us“. Dr M. Lyubenova was nominated as the “scientist of 2013” of Bulgaria through the competition of Bulgarian Academy of Science.


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The science interests of N. Georgieva are in the area of forest ecology and functional researches. Her PhD thesis is “Functional studies of xerothermic oak forest in SCI “Zapadna Stara Planina i Predbalkan” under the supervision of assoc. prof. Dr M. Lyubenova. The professional experience of the author includes studies of dense forest in Bulgaria, habitat diversity and protection and now dendrochronology in aspect of biomass and tree production. N. Georgieva has a few papers with the results of these researches in specialized journals in Bulgaria.


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