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Monitoring of Quercus frainetto Ten. Stands from Maleshevska Mountain Using Dendrochronology and Climatic Data

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Abstract. The research relates to the topic "Monitoring forests to assess their performance under climate change" and provides some methodological updates and new results on the growth of *Quercus frainetto* Ten. forests in Bulgaria. An attempt was made to assess the state of oak ecosystems by using the growth index, the concept of eustress and climatic type of year. The objects of research were the communities of Hungarian oak, situated at an altitude of about 920–900 m in Maleshevska Mountain, Southwest Bulgaria (longitude 23.1; latitude 41.5-41.6). Dendrochronological samples and wooden patterns (26 from Sokolata Reserve and 20 from the village of Igralishte surroundings, Maleshevska Mountain with maximal age respectively 201 and 152 years) were processed by TSAPWin software, program COFECHA and SPPAM program, version 2.0. EPS was 84.5 and 92.4 for Sokolata Reserve and Igralishte, respectively. The approximating polynomials were with 6 to 8 degree and R^2 was between 0.45 and 0.84. The received eustress years and periods were 87 and 33 as well 49 and 23 respectively for Sokolata Reserve and Igralishte surroundings. In other words, the eustress was found for 43.28% and 32.24% from investigated years respectively for two objects. For the period of 201 and 152 years, the common stress years were 12 – 1908, 1909, 1913, 1928, 1929, 1934, 1935, 1936, 1951, 1995, 2012 and 2019. The obtained average functional types were respectively trees with very rare or rare eustress occurrence (F1 and F2) with normal duration (D3), small or very large depth (amplitude) – A2 and A5. Totally, 85 and 70 climatic types have been established, respectively for Sokolata Reserve and Igralishte, associated with the eustress – adverse climatic types. The examined climatic patterns, or three-year periods (eustress year and two years before) would provide an opportunity to understand how climatic factors impact growth. The overall patterns for both objects, i.e., those that were completely certain to be related to the climate, showed that extended hot and dry conditions as well as changes from cold to hot and wet, also cold and dry to hot and dry or hot and dry to hot and wet and vice versa reflected very unfavorable to the stem growth.

Key words: Maleshevska Mountain, *Quercus frainetto* Ten., growth index, eustress, plant functional type, climatic type of year.

Introduction

The International Cooperative Program on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) has developed into one of the world's largest forest monitoring networks over the last 30 years (Gessler et al., 2022; and others). The received results provide information on forest health, growth, diversity, effects of air pollution and climate change. The objectives of the program are: 1) to provide a periodic overview on the spatial and temporal variation of forest condition in relation to anthropogenic and natural stress factors on a systematic network by European-wide and national large-scale monitoring (Level I), and 2) through intensive monitoring on selected permanent monitoring sites spread across Europe, to gain a better understanding of the causal relationships between the state of forest ecosystems and anthropogenic and natural stressors (in particular air pollution) in Europe (level II). The research topic "Monitoring forests to assess their performance under air pollution and climate change" provides a number of updates such as new methodological developments and new results on the growth and vitality of European forests.

Scientific researches of oak forests and their monitoring plays an important role in understanding the state and ecosystem function of these forests. The numerous latest developments on this topic related to four directions:

1. Researches on climate change and oak forests decline. Numerous studies focus on the impact of climate change on the health and distribution of oak forests. This includes analyses of temperature and precipitations trends, changes in pest and disease distribution, and potential adaptation strategies (Lyubenova, 2014; Bölöni et al., 2021; Forest Europe, 2020; Gessler et al., 2022; and many others);

2. Monitoring the forest ecosystems through Remote sensing. Modern remote sensing techniques, such as satellite imagery and aerial drones, are used to observe and map oak forests. These data are essential for assessing the health and dynamics of forest ecosystems (Lyubenova et al., 2014; Adeline et al., 2024; Crocker et al., 2023; Kowsari &Karimi, 2023; and many others);

3. Studies on Biodiversity. Many studies focus on the diversity of plant and animal species in the oak forests. These studies not only help conserve the biodiversity, but also reveal important information about the ecosystem services provided by oak forests (Lyubenova et al., 2017; Pilotto et al., 2020; Storch et al., 2023; and many others);

4. Monitoring human activities and sustainable management. Research also focuses on understanding the impact of human activities on the oak forests, including deforestation, intensive forestry and pollution. This helps develop strategies for sustainable management and conservation of these valuable ecosystems (Lyubenova et al., 2015a; Lyubenova, 2019; Chikalanov et al., 2019; Lovett et al., 2000; and many others).

These studies are essential for the conservation and management of oak forests, which represent an important natural resource and are crucial for the biodiversity and environmental quality.

In the present study, an attempt was made to assess the state of the oak ecosystems in Maleshevska Mountain by using the growth index, the concept of eustress, plant functional type (PFT) and climatic type of year (CTY). Similar studies for other regions and tree species have already been published by the authors (Lyubenova, 2014; Lyubenova et al., 2014; Lyubenova & Chikalanov, 2023).

Materials and methods

The objects of research were the communities of Hungarian Oak, situated at an altitude of about 920–900 m in Maleshevska Mountain, Southwest Bulgaria (longitude 23.1; latitude 41.5-41.6). According to the phytogeographical zoning of Bondev (2002), these forests fall within the Middle Struma Area of the Mediterranean Sclerophyllous Forest Region. The investigated region is included in the Submediterranean climatic area, characterrized by warm and dry summer, mild winter and thin snow cover (Velev, 2002). The soils in the mountain are chromic cambisols, medium and highly eroded (Ninov, 2002). The detailed characteristics of the studied oak communities was published by Todorova & Lyubenova (2022).

Dendrochronological samples were taken by Presler's auger at a height of 1-1.5 m and they were mounted on wooden patterns with 4 grooves and sizes 50/5/2 cm. The disks cut from stems were also used. The samples and disks were polished with sanders and sandpaper before measurement. The measuring of annual ring widths of the samples was made by LINTAB 6 Tree ring station with an accuracy of 0,01 cm. Sampling and measurement were under methodological guidance (Mirchev et al., 2000; Payette & Filion, 2011; Speer, 2010). Data processing and dating were made according to the methodological requirements, using TSAPWin software, program COFECHA and the next processing and analysis - by SPPAM program version 2.0 (Lyubenova et al., 2015b; Lyubenova & Chikalanov, 2023). Data with implausible values (outliers) were eliminated. Climatic data were obtained from on-line data base – www.stringmeteo.com for 1901 – 2019, for which period the climatic analyze was done. In Table 1 could be seen the average geo-climatic characteristics and these of investigated series.

The dendrochronological rows from Maleshevska Mnt., the Sokolata Reserve – SR (26) were 201 years old (1818 – 2019), while those from the village of Igralishte surroundings (IS) (20) were 152 years old (1868 – 2019). The average DBH (diameter at breast height) was 37 cm and 32 cm, respectively. The resulting EPS (Expressed population signal) was better for the stands from the IS.

The eustress was considered as a repeating state of diminished radial growth of tree stems within a period of one or multiple years and caused by unfavorable factors in the environment (Lyubenova & Chikalanov, 2024). An assessment of stressful periods was made by a scale and based on three characteristics: the number of consecutive years with eustress in series; frequency (F) - the number of stress years for 100 years; amplitude (A) - the value of statistically proven negative deviation of I_t (growth index) for each year with eustress.

Table 1. Object characteristics.

SA	Long., °	Lat., °	Alt., m	$T_{av.}$, °C	$P_{av.}$, mm	Climatic Period, y	Age_{min}, y	Age_{max}, y	DBH*, cm	N	EPS**, %
SR	23.10	41.53	920	7.3	646	1901-2019	31	201	37.1	26	84.5
IS	23.09	41.57	900	7.3	646	1901-2019	41	152	32.2	20	92.4

Legend: *Diameter at breast height; **Expressed population signal *indicates good representation of the hypothetical population from the constructed tree ring width* chronology.

Results and Discussion

The tree ring width series from SR (n=26) were included in the analyses, 15 from them had the approximating polynomials with 6 to 8 degree and R^2 was between 0.45 and 0.84. The further analyses continued with these series. The other 11 series had polynomials with 5 to 8 degree and R^2 varied between 0.17-0.41. The tree ring width series from IS (17 in number) had polynomials with 6-8 degree and R^2 was 0.46 - 0.82. Three of the series were with R^2 between 0.31 and 0.43 (7-8 degree) and they were excluded from further analyses. The received average indexes were shown on Fig. 1. The variability of the mean index was more pronounced for the trees from SR. There were periods, where the direction of the index change differed from the index row of SR. The correlation coefficient between two indexed series was 0.102 – weak dependence (Mirchev et al., 2000). It is likely that the stands from Maleshevska Mountain have a better EPS given the context provided: the stands from the reserve are older but have a larger average diameter at breast height (DBH), yet the stands from the IS have a better EPS despite being younger and having a slightly smaller average DBH.

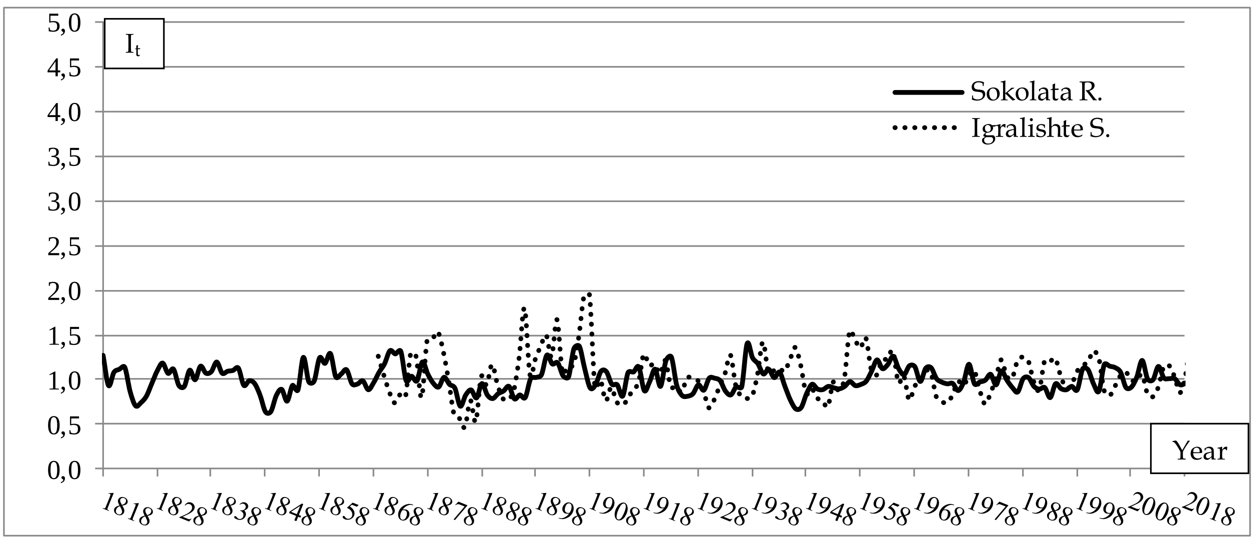

Fig. 1. Dynamics of average index (It_{av}) series by years (1818-2019) for Sokolata R. and Igralishte S.

The average index of the average row of indexes in Sokolata R. was 1.002±0.059, as its value was higher and with bigger variation in studied plots of IS – 1.073±0.127, which is probably connected with the differences in the length of series and the climate (respectively 201 and 152 years). For Sokolata R., 38 more eustress years were received. The other four coefficients were equal (Cov) or differed - from 1.2 to 2 times greater for Card and Ct, and 2.5 times smaller for K in IS compared to Sokolata R. (Table 2).

The received eustress years – respectively 33 periods and 87 years for Sokolata R. as well 23 periods and 49 stress years for Igralishte S., were presented in Table 3.

Table 2. Characteristics of average series of indexes.

Series of *Q. frainetto*	Period (P), y	It (av)	m_{av}	SY*, n	Card**	Cov***	Ct=Card/N	K=P/SY
SR	201	1.002	0.059	87	6.2	0.7	0.2	3.5
IS	116	1.073	0.127	45	7.5	0.7	0.4	2.8

Legend: *Eustress years – the years for which statistically proven decreasing of I_t under 1 was identified; ** cardinality – the number of sequences that had the same stress years; ***coverage - the ratio between Card and the number of investigated sequences, which included the same periods.

Table 3. Stress years and their characteristics.

Sokolata R.							**Igralishte S.**						
N	First year	Last year	N of years	$Card_{av}$	Cov_{av}	A_{av}	N	First year	Last year	N of years	$Card_{av}$	Cov_{av}	A_{av}
1	1823	1826	4	5	0.8	0.3	1	1870	1871	2	4	0.7	0.4
2	1832	1832	1	5	0.8	0.2	2	1873	1873	1	3	0.6	0.3
3	1834	1834	1	4	0.7	0.1	3	1876	1876	1	3	0.6	0.4
4	1847	1854	8	5	0.7	0.3	4	1882	1884	3	6	0.9	0.5
5	1856	1857	2	5	0.6	0.1	5	1886	1886	1	5	0.8	0.5
6	1861	1861	1	6	0.8	0.1	6	1891	1893	3	4	0.7	0.3
7	1866	1869	4	4	0.6	0.2	7	1908	1910	3	5	0.7	0.2
8	1875	1875	1	4	0.6	0.2	8	1912	1913	2	4	0.7	0.4
9	1879	1879	1	4	0.6	0.2	9	1916	1916	1	4	0.6	0.2
10	1882	1882	1	4	0.6	0.4	10	1923	1923	1	4	0.6	0.5
11	1884	1892	9	5	0.7	0.3	11	1928	1929	2	6	0.8	0.3
12	1894	1896	3	6	0.8	0.3	12	1934	1937	4	11	0.7	0.3
13	1903	1903	1	4	0.6	0.2	13	1950	1951	2	10	0.6	0.5
14	1908	1909	2	6	0.7	0.2	14	1953	1953	1	12	0.8	0.3
15	1913	1914	2	6	0.7	0.2	15	1960	1960	1	8	0.5	0.3
16	1918	1918	1	6	0.8	0.2	16	1966	1967	2	8	0.6	0.3
17	1921	1921	1	5	0.6	0.3	17	1970	1974	5	10	0.7	0.4
18	1924	1929	6	5	0.6	0.3	18	1978	1982	5	9	0.6	0.3
19	1933	1936	4	6	0.7	0.2	19	1995	1995	1	9	0.5	0.4
20	1944	1949	6	8	0.8	0.3	20	2003	2005	3	9	0.7	0.3
21	1951	1952	2	6	0.6	0.3	21	2010	2012	3	10	0.6	0.3
22	1954	1955	2	8	0.7	0.2	22	2016	2016	1	10	0.6	0.3
23	1959	1959	1	7	0.6	0.2	23	2019	2019	1	8	0.6	0.2
24	1969	1969	1	7	0.6	0.2	**S**	**-**	**-**	**49**	**162**	**15.1**	**7.8**
25	1975	1976	2	8	0.6	0.2	**Av**	**-**	**-**	**2.1**	**7.0**	**0.7**	**0.3**
26	1983	1983	1	8	0.7	0.2							
27	1986	1987	2	8	0.7	0.2							
28	1989	1998	10	8	0.6	0.2							
29	2001	2002	2	9	0.7	0.3							
30	2007	2008	2	8	0.6	0.2							
31	2012	2012	1	8	0.6	0.1							
32	2017	2017	1	8	0.6	0.2							
33	2019	2019	1	7	0.5	0.2							
S	**-**	**-**	**87**	**203**	**21.6**	**7.4**							
Av	**-**	**-**	**2.6**	**6.2**	**0.7**	**0.2**							

In other words, the eustress was found for 43.28% and 32.24% from the investigated years respectively for two objects. For the period of 201 and 152 years, the common stress years were 12 – 1908, 1909, 1913, 1928, 1929, 1934, 1935, 1936, 1951, 1995, 2012 and 2019. The average number of stressful years in one period was greater for Sokolata R, observing 7 periods with respective duration of 4 (2 periods), 6 (2 periods), 8, 9, and 10 years. In IS, there were 8 stressful periods with shorter duration– ranging from 3 (5 periods), 4, and 5 (2 periods) years; however, the average amplitude of eustress and $Card_{av}$ is slightly larger.

As defined in the methods, the stressful periods assessment was made by a scale presented in Table 4 on the base of frequency (F), duration (D), and amplitude (A). The amplitude of the stressful periods is higher for the trees from IS (respectively A_{av}, A_{max} - 0.34 and 0.67; A_{av}, A_{max} - 0.25 and 0.45), while for Sokolata R., their duration was longer - 3 and 10 years compared to 2.5 and 5 years, and the frequency of stress occurrence was higher (at 28 years) (Table 5). The obtained average functional types (PFT) was respectively trees with very rare or rare eustress occurrences (F1 and F2) with normal duration (D3), small or very large depth (amplitude) – A2 and A5 (see Table 4).

For the period 1901 - 1919 (118 years), for which we have climatic data, cold years predominated with different moisture regimes – dry, normal, or wet (CD, CN, and CW) - 46.61%, among them the highest percentage was of cold and wet years – 21.19% (CW). According to the temperature regime, hot years with different moisture regimes ranked second (HD, HN and HW - 30.51%), with predominance of dry ones – 14.41% (HD). Years with normal temperatures and different moisture regimes accounted for 22.88% (ND, NN and NW), among which wet years predominated, NW - 10.17%.

Table 4. *Q. frainetto Ten.* five-graded scale for assessment of eustress features.

Frequency			**Duration**			**Amplitude**		
N	Group	Value	N	Group	Value	N	Group	Value
1	Very rarely	≤31.79	1	Very short	≤1.73	1	Very small depth	≤0.23
2	Rarely	>31.79 - ≤36.06	2	Short	>1.73 - ≤2.20	2	Small depth	>0.23 - ≤0.26
3	Normal	>36.06 - ≤44.61	3	Normal	>2.20 - ≤3.14	3	Normal depth	>0.26 - ≤0.31
4	Offen	>44.61 - ≤48.88	4	Long	>3.14 - ≤3.61	4	Deep	>0.31 - ≤0.34
5	Very Offen	>48.88	5	Very Long	>3.61	5	Very Deep	>0.34

Table 5. Characteristics of eustress for investigated *Q. frainetto* Ten. serries and functional type.

Objects	A_{av}	A_{max}	Y, A_{max}	D_{av}	D_{max}	Y, D_{max}	F_{av} for 100 y	PFT
Sokolata R.	0.25	0.45	1825	3.0	10.0	1986 - 1998	28.0	F1D3A2
Igralishte S.	0.34	0.67	1882	2.5	5.0	1970 -1974, 1978 -1982	36.0	F2D3A5

According to the moisture regime, wet years predominated – 42.48%, among which the highest percentage was of wet and cold years (CW). Second, with 33.05%, were dry years with the highest percentage of hot and dry ones (HD). Years with a normal moisture regime accounted for 24.58% and had the highest percentage of cold years (CN) – 12.71%. Years with normal temperatures and precipitation (NN) were only 8 or 6.78% - Fig. 2 and Table 5. All climatic types were associated with the occurrence of eustress – adverse climatic types (ACT), only 15.25% (18 years) did not participate. They were indicated in Table 6.

Totally, 85 and 70 ACT have been established, respectively for SR and IS - Fig. 3, Table 6. In both objects, ACW predominated (21.18% and 18.57%), followed by AHD years - 16.47% and 17.14%. The percentage of ACN and ACD years was also high. Some ACT were observed in one or the other object. These were 34 and 19 years, respectively for SR and IS, with the highest percentage of ACW years (Table 6). For both objects, 51 common ACTs have been identified, with the adverse effects of hot and dry (AHD) and cold and wet (ACW) years being most strongly expressed, at 19.61% and 17.65% respectively. From the remaining climatic types, the influence of cold and dry (ACD) and cold with normal precipitation (ACN) years is expressed at 15.69% each.

It was not certain that the individual ACTs for both objects (non-matching years) were associated with the occurred climatic stress, which might be due to other factors as well. In the group of adverse climatic types for both objects, i.e., those associated with the occurrence of stress, years with normal temperatures and precipitation (NN) were included.

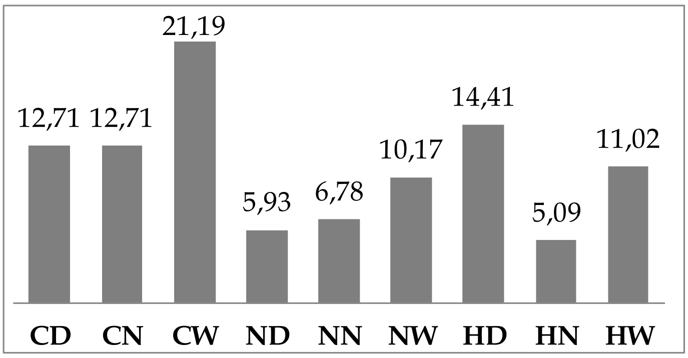

Fig. 2. Climatic types of years for 1901-1919 (%).

Legend: *Climatic type of year (CTY) - It is determined by the difference between the average temperature and the average precipitation for a given year, entering the period and the respective average values for 30-year periods starting from 1900. When the difference is greater than the confidence interval of the 30-year value, it is respectively hot and wet (H, W); when smaller, it is cold and dry (C, D); and when there is no difference, it is considered a normal (NN) year in terms of temperature and precipitation.
**Not associated with eustress climatic types.

Table 6. Years, associated with climatic types for the period 1901 – 2019 (118 y) – Climatic background.

CTY*	N	%	Years
CD	15	12.71	1902, 1904, 1905**, 1907, 1908, 1911, 1913, 1932, 1948, 1949, 1953, 1965, 1984, 1985, 2000
CN	15	12.71	1921, 1933, 1942, 1959, 1964, 1967, 1969, 1973, 1983, 1992, 1993, 1997, 2001, 2008, 2009
CW	25	21.19	1912, 1914, 1918, 1920, 1929, 1940, 1941, 1944, 1954, 1956, 1974, 1976, 1978, 1980, 1991, 1994, 1995, 1996, 1998, 1999, 2002, 2003, 2004, 2005, 2006
ND	7	5.93	1903, 1935, 1943, 1945, 1986, 2012, 2013
NN	8	6.78	1906, 1910, 1917, 1922, 1924, 1981, 1982, 2011
NW	12	10.17	1909, 1919, 1931, 1939, 1957, 1963, 1971, 1972, 1975, 1987, 2007, 2010
HD	17	14.41	1916, 1926, 1930, 1934, 1946, 1947, 1950, 1952, 1958, 1970, 1977, 1989, 1990, 2016, 2017, 2018, 2019
HN	6	5.08	1928, 1936, 1938, 1961, 1988, 2015
HW	13	11.02	1915, 1923, 1925, 1927, 1937, 1951, 1955, 1960, 1962, 1966, 1968, 1979, 2014

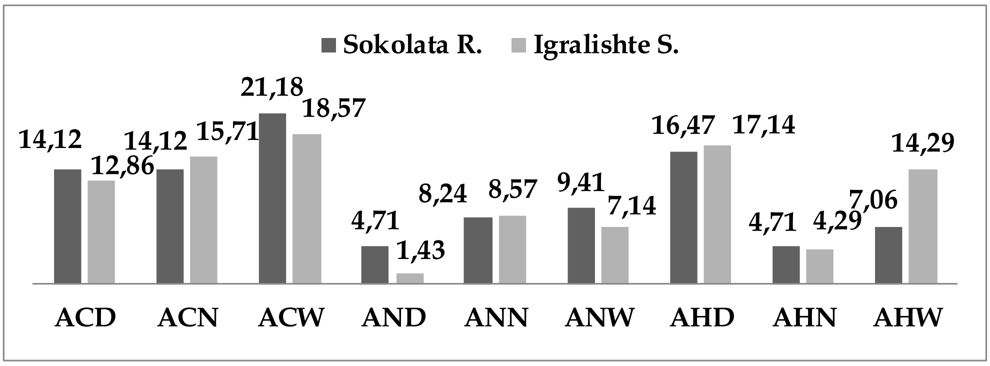

Fig. 3. Climatic types of years, associtae with eustress (ACT, %).

To understand whether the cause of this stress was the climate or not, we would need to analyze the climate of the neighboring years - a year and two years before the indicated NN year. These three-year periods were called climatic patterns. The climatic patterns would provide an opportunity to understand how climatic factors impact the growth. Table 7 showed the overall patterns for both objects, i.e., those that were completely certain to be related to the climate. Since there was a one-year delay or acceleration between the trees of two objects in the manifestation of eustress, it was possible to reconstruct the climatic types up to 4 years. The following common cases had been observed:

- Extended cold and dry years;
- Cold years, alternating in a year with hot and wet years. The highest amplitude was recorded - 0.453. It was possible that other unfavorable factors leading to stress may have been at play;
- Change from wet years to cold and dry, then to cold and finally to hot and dry years. Some of the high amplitudes were recorded - 0.246 and 0.283, along with a low growth index - 0.874;
- Change from wet to hot and dry, then switching to cold and finally to hot and wet years. A high amplitude was recorded - 0.264;
- Change from cold to hot and wet years, followed by another change to cold, and in the fourth year, a switch to hot and dry conditions;
- Hot years, with the sequence of changes being: hot and wet, hot and two years of hot and dry conditions. A high amplitude was recorded - 0.282 and a low growth index - 0.854.

For the *Q. frainetto* Ten. trees from both objects in Maleshevska Mountain, a three-year overall stressful period was observed, from 1934 to 1936, with the climatic types of years associated with eustress being: hot and dry/dry/hot. One of the high amplitudes and the lowest growth index were observed, respectively 0.399 and 0.789.

Table 7. Common climatic patterns for *Q. frainetto* Ten. from two objects in Maleshevska Mnt.

Object	Year	CT_{Y-2}*	CT_{Y-1}**	CT/ACT	ACT_{Y+1}***	A_Y	A_{Y-1}	A_{Y-2}	I_{tY}	I_{tY-1}	I_{tY-2}
IS******	1908	NN	CD	CDe	-	0.211	-	-	0.913	1.938	1.935
SR ********	1908	NN	CD	CDe	-	0.234	-	-	0.909	1.119	1.367
IS	1923	CN	NN	HWe	NNe ******	0.453	-	-	0.923	0.917	1.211
SR	1924	CN	NN	HW	NNe	0.171	-	-	0.937	1.249	1.207
IS	1934	NW	CD	CN	HDe	0.246	-	-	0.931	1.272	1.065
SR	1933	NW	CD	CNe	HDe	0.283	-	-	0.874	0.989	1.015
IS	1960	NW	HD	CN	HWe	0.264	-	-	1.050	1.110	1.461
SR	1959	NW	HD	CNe	HWe	0.204	-	-	0.982	0.947	0.934
IS	1970	CN	HW	CN	HDe	0.233	-	-	1.083	1.097	0.985
SR	1969	CN	HW	CNe	HDe	0.174	-	-	0.980	1.141	1.153
IS	2016	HW	HN	HDe	HDe	0.282	-	-	0.854	1.027	1.154
SR	2017	HW	HN	HD	HDe	0.173	-	-	0.944	1.011	1.011
Object	**Year**	**ACT_{Y-2}**	**ACT_{Y-1}**	**ACT_Y**	**-**	**A_Y**	**A_{Y-1}**	**A_{Y-2}**	**I_{tY}**	**I_{tY-1}**	**I_{tY-2}**
IS	1936	HDe	NDe	HNe	-	0.399	0.348	0.246	0.789	0.815	0.931
SR	1936	HDe	NDe	HNe	-	0.277	0.228	0.199	0.920	0.922	0.832

Legend: *CT_{Y-2} - climatic type before two years; **CT_{Y-1} - climatic type before a year; ***ACT_Y - adverse climatic type, connected with appeared eustress; **** Igralishte S.; *****Sokolata R.; ******Reconstructed by analogy climatic type.

Conclusions

The received eustress years (1901-2019) for oak trees in Sokolata Reserve were 87 entered into 33 periods and for the trees from Igralishte Surroundings - 49 stress years and 23 periods. The stressful periods in IS were with shorter duration. For the period of 201 and 152 years for two objects, the common eustress years were 12 - 1908, 1909, 1913, 1928, 1929, 1934, 1935, 1936, 1951, 1995, 2012 and 2019.

The amplitude of stress periods was higher for the trees from Igralishte S., while for Sokolata R. their duration was longer and the frequency of stress occurrence was higher. The obtained average functional types (PFTs) were respectively trees with very rare or rare eustress occurrences (F1 and F2) with normal duration (D3), small or very large depth (amplitude) – A2 and A5. Based on the analyses conducted, it can be concluded that for the *Quercus frainetto* Ten. trees in Sokolata R., there is no risk to their existence and the ecosystem services they provide. However, outside the reserve, there is a certain risk associated with the significant depth of the emerging stress.

For the period 1901 - 1919 (118 years), cold years predominated with different moisture regimes (CD, CN, and CW). According to the precipitation, the wet years predominated, among which the highest percentage was of cold and wet (CW) years. The second were dry years with the highest percentage of hot and dry ones (HD). Totally, 85 and 70 adverse climatic types have been established, respectively for Sokolata R. and Igralishte S. In both objects, ACW predominated.

The received seven common climatic patterns (including climatic types of eustress year and two years before it) showed that extended hot dry conditions as well as changes from cold to hot wet, also cold dry to hot dry or hot dry to hot wet, and vice versa, reflected very unfavorable to the stem growth.

The studied and identified stress periods for oak trees in the researched region depend on the existing climate during the considered period but are also influenced by factors such as soil, tree age, cohabitants and competition, diseases, and anthropogenic interference. Therefore, it is not accurate to compare data from different regions for the same or different species. The methodology used for assessing the state of forest ecosystems and the ecosystem services they provide is quite promising for continuous monitoring.

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