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Comparative Assessment of European Black PineTree Ring Width Series for Eustress and Risk Identification in Different Locations

KEYWORDS: black pine, eustress model, risk assessment, SPPAM application.

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ABSTRACT *Communities of black pine offer a variety of ecosystem services and are important edaphic and hydrological factors in the regions of distribution. Black pine is not demanding to the richness and depth of soil horizon, has a large vertical range of distribution, resistant to drought and high temperatures, which reveals its prospects inrelation with forecasted climate warming. Black pine forests are characterized by a great diversity of species, the participation of endemic, rare and protected plants, some habitats are a priority for protection to sustainable existence in the landscape. The occupied territories of black pine communities are greatly reduced by human activity. The aim of the study isto demonstrate a comparative analysis of black pine tree ring widthseries from different locations in Europe for eustress identification and eustress featuresby using a new holistic approach anddeveloped SPPAM application. The analisis of growth index series shows that the radial growth is with little differences in studied locations. The number of identified stress years also slightly varies depending on the local conditions (reflected in the value of K - coefficient), but the differences in the eustress features are significant. The mean values for K- coefficient, the depth of eustress periods, the duration and frequency of eustress years are closed to the published values for QuercusfrainettoTen. that has similar ecological requirements.Applying scale-evaluation of eustress features, an attempt for the black pine functional behaviour and the level of risk for forests existence in studied locations was implemented. For the majority of investigated locations - 48.3% the risk is weak and moderate and for only 10.3% - the risk is significant.The research findings can be used for rapid assessment of black pine communities' state and support the management of forest areas.*

Introduction

The European black pine is a native species to Central and Southern Mediterranean Europe and Southwest Asia. The area extends from Spain and Morocco to eastern Turkey - on Anatolian peninsula on east, south to Cypress, and north to northeastern Austria and the Crimea, Russia, and in the high mountains of theMaghreb in North Africa. European black pine is widely planted in its native areas and also in the United States - in northern states in New England, around the Great Lakes, and in the Northwest. It has naturalized in New England and the Great Lakes States [1].Associations of black pine are included in class Erico-Pinetea, order Erico-Pinetalia, unionErico-Pinion with sub-union Orno-Pinenionpallasianae[2]. In the Balkans, including the territory of Bulgaria,Pinusnigra subsp. pallasiana is growing and one of the associations isSesleriolatifoliae-Pinetumnigrae.Habitat 9530 * Sub-Mediterranean pine forests with endemic subspecies pine [3] in Bulgaria includes relict phytocenoses with participation of rare and protected vascular plants.The black pine forests are commonbetween 400 and 1800 m a.s.l. in the mountains - Slavianka, Pirin, Rhodopes, Rila, Ossogovo, Vlahina and some low hills in Western Bulgaria, Western and Central Balkans and ForeBalkans.Part of the plant communities of Pinusnigra subsp. Pallasianaisin protected areas: reserves "BajoviDupki - Dzhindzhiritsa", "Red Wall", "Ali boot"; managed reserves "Gabra", "Boraka", "Borovo"; National parks - "Pirin" and "Central Balkan" and protected areas of the European ecological network "Natura 2000" [3].

Communities of black pine offer a variety of ecosystem services. From an economic perspective, the black pine is used in the construction, furniture manufacturing, for the extraction of resin and for heating.The wood of black pine is valued less than that of the white pine, as it is heavier, with a high content of resin and more difficult for treatment [4].The soot from burnt black pine wood is used in the painting technique.Two-year cones are a source for the preparation of a yellow-gray dye, containing tannins bark is used in leather manufacture.The pollen can be used for the preparation of baby powder and young tipped, collected in the spring - in folk medicine as a bronchodilatory tea, to treat rheumatism, gout and others. The leaves contain a large amount of essential oil used in perfumery [5].The essential oil has a pronounced anti-inflammatory and bactericidal action and it is very useful in respiratory tract infections, acute bronchitis, sinusitis and more. It is an excellent means of reducing airborne infections, also forstrengthening the immune system. Another effect of the oil is the regeneration of skin tissue, as amplified cell activation and growth. Pine essential oil calms the nervous system, reduces stress, anxiety and mental tension. The oil is successfully applied in cardiac neurosis, general hyperactivity and migraine headaches [6]. Black pine has good decorative qualities and prices in landscaping and afforestation.Black pine is not demanding to the richness and depth of soil horizon, has a large vertical range of distribution, resistant to drought and high temperatures, which reveals its prospects in warming. Black pine forests are characterized by a great diversity of species and are important edaphic and hydrological factors in the regions of distribution. The occupied territories of communities of black pine are greatly reduced -destroyed by human activity or replaced in natural succession processes of other species.The black pine forestsare a priority for conservation and sustainable existence in the landscape.

The aims of the study areto demonstrate a comparative analyze of black pine dendrochronologyseries from different locations in Europe for eustress identification and to assess eustress featuresby using a new holistic approach andSPPAM application developed under author's supervision.The research findings can meet the needs for rapid assessment of the black pine communities' state and support the management of the forest area.

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Object and Methods

Analyses were conducted with 682 series from 29 locations in Europe (from 36.55^{0}lat. and 22.21^0 long.to48.07^{0}and16.15^0) on the altitude ranged from 350 to 1800 m, taken from on-line data base [7], except of the series from Bulgaria – Table 1.

Table1. Object characteristics

№	Sampling area (SA)	Lat. , ^{0}	Long., ^{0}	Alt., m	T_{aveg}., ^0C	P_{aveg}., mm	Period from 1901 to:	N	Serieslength		Age_{min}, y	Age_{max}., y	DBH, cm	EPS
1	Taygetos Forest (GR)*	36.60	22.21	1400	13.7	680	1999	31	1657	1999	76	341	49.2	0.90
2	Langada (Sparta) (GR)	37.05	22.20	1450	13.4	651	1981	24	1825	1981	100	157	37.1	0.86
3	Puertollano (ES)	37.49	-2.57	1800	12.6	371	1985	26	1585	1985	171	401	62.6	0.93
4	Canada de la Fuente (ES)	37.50	-2.65	1450	12.6	371	1985	34	1698	1985	92	288	52.7	0.94
5	Las Banas (ES)	37.57	-2.56	1405	12.5	376	1985	26	1745	1985	113	241	56.8	0.94
6	Cuenca - buenavhe (ES)	40.09	-1.54	1385	9.4	462	1983	12	1711	1983	169	257	49.1	0.87
7	Torreton (ES)	40.11	-2.05	1500	9.0	501	1988	17	1485	1988	359	504	57.2	0.90
8	Cuenca - una (Site 1) (ES)	40.15	-1.56	1385	9.5	462	1985	30	1638	1985	78	329	29.3	0.90
9	Cuenca - una (Site 2) (ES)	40.16	-1.56	1440	9.5	462	1985	35	1644	1985	65	338	28.9	0.91
10	Gudar los Roquetas (ES)	40.17	-0.42	1475	14.0	444	1985	26	1681	1985	97	198	28.2	0.90
11	TierraMuerta (ES)	40.18	-2.08	1350	9.0	501	1988	17	1615	1988	160	362	51.4	0.91
12	Scotida Forest Kastoria (GR)	40.18	20.54	1500	8.9	670	2003	42	1751	2003	66	228	33.5	0.94
13	Cercelas (ES)	40.26	-4.47	1350	10.6	523	1991	14	1754	1991	133	238	49.2	0.85
14	Penahorcada (ES)	40.29	-4.47	1450	10.5	525	1988	17	1667	1988	114	321	59.8	0.92
15	Gudar-villarluengo (ES)	40.38	-0.29	1500	14.0	444	1985	20	1829	1985	80	157	37.6	0.94
16	Gaudarrama (ES)	40.40	-4.10	1350	10.8	521	2008	49	1625	2008	151	384	37.0	0.86
17	Riscopol (ES)	40.47	-4.00	1600	10.5	525	1988	24	1523	1988	64	437	48.2	0.94
18	Tajo (ES)	40.52	-2.08	1750	9.9	495	1988	16	1610	1988	126	379	46.5	0.89
19	Zagradeniye Forest (GR)	41.40	24.63	1320	10.6	617	1979	10	1706	1979	174	273	53.4	0.84
20	CamosciaraeM.Teamaro (IT)	41.46	13.49	1550	14.4	777	1987	16	1750	1987	118	238	33.4	0.84
21	Monte Mattone (IT)	41.47	14.02	1500	13.1	655	1980	22	1844	1980	92	137	39.4	0.93
22	Col de SorbaMt. Renoso (FR)	42.04	-9.12	1400	12.9	1456	1980	18	1700	1980	113	259	57.7	0.84
23	Gabra R., Vlachina Mt. (BG)	42.58	23.63	1000	11.2	517	2002	28	1826	2002	41	177	36.0	0.91
24	Vitosha Mt. (BG)	42.72	23.33	920	10.6	533	2000	22	1894	2000	41	107	35.5	0.89
25	t.Berkovitza, W. Balkans (BG)	43.24	23.12	500	11.8	501	2009	10	1932	2010	70	146	48.1	0.84
26	Ennenda GL Sitenwald (CH)	47.02	9.05	620	8.6	1043	2007	17	1893	2007	80	115	23.0	0.85
27	Bierhaeuslberg (AT)	48.07	16.15	350	9.0	530	1995	38	1840	1995	78	156	33.8	0.96
28	Parapluiberg (AT)	48.07	16.15	450	9.0	530	1995	21	1766	1995	130	217	26.2	0.94
29	Kammersteinhuette (AT)	48.07	16.15	582	9.0	530	1995	20	1804	1995	122	191	29.1	0.95

***AT - Austria, BG - Bulgaria, CH - Switzerland, ES - Spain, FR - France, GR - Greece.**

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The average annual temperature ($T_{avg.}$) of selected locations varies from 8.6 to 14.4^0 C and average annual sum of precipitation ($P_{avg.}$) is from 371 to 1456 mm. The average climatic parameters were calculated from 1901 to the latest year of studied series. The age of used series is from 41 to 504 years (as 1485 is the earlier and 2007 – the latest year) and DBH of sampled trees varies from 23.0 to 62.6 cm. The series are from different age classes - from 6th to 22thand 24th.

SPPAM, version 1.2 is applied for the analysis of data; its functionality encompasses classical analyses in dendrochronology [8, 9, 10, 11]and new developments [12, 13]. Sequences with R^2> 0.45 and locations with EPS (Expressed Population Signal) >83% are included in the analysis. The studies on the expression of eustress and its assessment are conducted by analysis of the average growth index sequences (It = MW/AW, where MW is measured width and AW – computed width only for the sequences with trusted approximations). The eustress is characterized by: duration (D), frequency (F) and negative deviation (A), described reduction in growth. The coefficients: "K","Ct", Card. and Cov.ware calculated for black pine series characteristics (Lyubenova et al. 2014).

The climatic database CRU – TS [14] was used as a source of data on temperature and precipitation for 1901-2009. The average annual temperature (T_{avg}.) and precipitation ($P_{avg.}$) and their confidence intervals (μ_{ti} and μ_{pi} at the level of significance - α = 0.05) for every 30 years were calculated, starting from 1901. [13].

Results

The average growth index of the analyzed P. nigra Arnold.seriesis 1.015±0.102 and varies from0.997 ±0.061to 1.306±0.523 insample areas, SAs (calculated for the period of115-504 years) - Fig. 1. The radial stem growth of analyzed series is approximated with polynomials of 6th to 11thdegree and R^2 varies from 0.453 to 0.958.

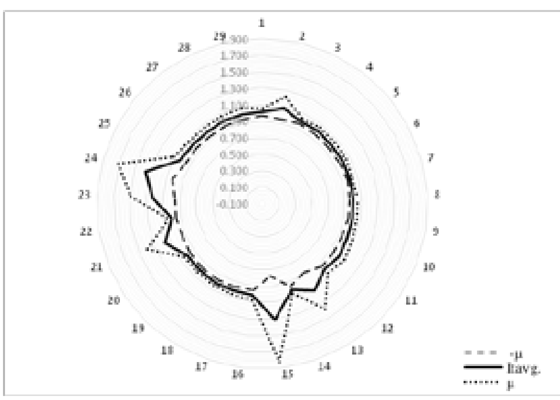

Fig. 1. Variation in average growth index - It_{avg}. and its confidence interval (μ) in studied locations

The average index of series from 1 to 6 SAs (group 1) have moderate correlation (r = 0.3 - 0.4)for 32.61% of cases and week correlation (0.1 - 0.2) for 46.38% of cases according to the published scale [11] – Fig. 1.1.The variation in the radial growth of the series is with well-defined synchronization with a

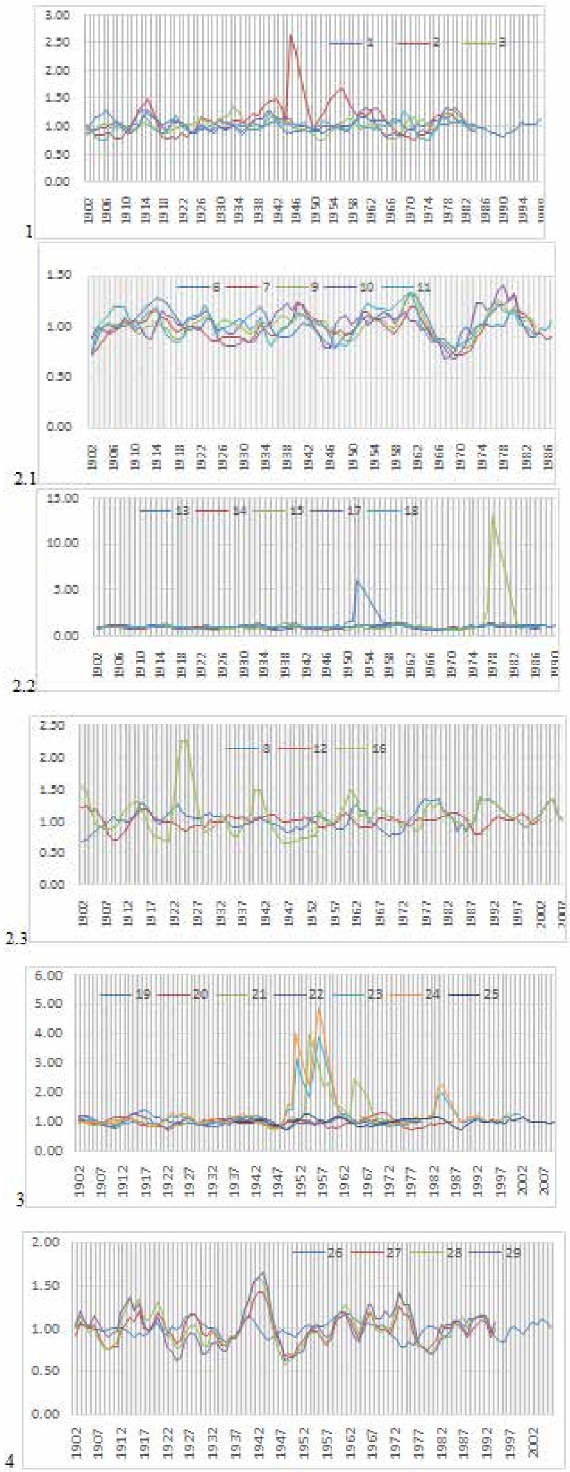

Fig. 2. Variation of average growth index (It) of P. nigraArnold.byyears and locations with altitude in the rages: 1) 36.55^0 - 37.57^0; 2) 40.09^0 – 40.52^0; 3) 41.40 – 43.24; 4) 47.02 – 48.07

few exceptions in separate years. The differences in growth tendency of average index series of location 2 are more visible according to the others.The correlation between the series from 6 to 18 SAs (group 2) is mainly moderate(61.31%) and weak (29.46%). In 1.19% of cases the correlation is high –between index series of locations 11, 17, 18 and 25.The variation of It avg. for locations of group

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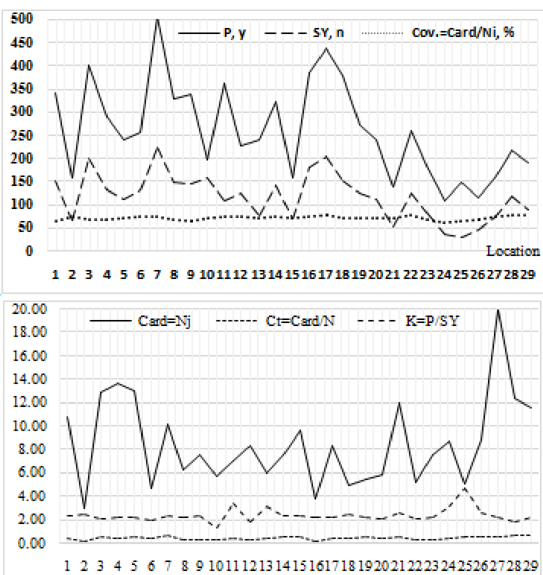
2 in years is with well-defined synchronization (Fig. 1.2.1) with a few exceptions in separate periods and locations – 13 and 15 for 2 periods(Fig. 1.2.2). The average index series of locations 8, 12 and 16 are the longones and they are separately shown on Fig.1.2.3. The discrepancy in the direction of changes in the index by years is clearly visible, especially for 16 location.The correlation between $It_{avg.}$ series of group 3 (19 - 25) is mainly weak (48.98%) as cases of moderate and high correlation are respectively 30.61 and 2.04% (between series of 23 and 24 location).The variation of $It_{avg.}$ for locations of group 3 in years is with well-defined synchronization (Fig. 1.3) with exceptions – for example in 1945 to 1969 and 1982 - 1988 for locations 21, 23 and 24. The correlation between $It_{avg.}$ series of group 4 (26 - 29) is mainly high for 50% of the cases (between 27, 28 and 29 locations) and weak – for 33.33% of the cases. The variation of $It_{avg.}$ of location 26 has frequent gaps in the direction of changes of indexes by yearscomparedto-the other locations (Fig. 1.4).

The established stress years for the black pine locations vary from31 to204forthe period of 204 to 504 years of different series (Fig. 3.1). Theaverage Cov.is 71% and varies by locations from 64 to 78%. The average number of series that have the same SYs (Card.) is 8.44. The lowest Card. is obtained for locations 29 and 2 (2.00 and 2.91) and the highest – for location 27 (19.89), following by locations: 4, 5, 3 and 28(respectively: 13.61, 12.95, 12.91 and 12.37) -

1.
2.


Location

Fig. 3.Average characteristics of investigated series by locations:1)Period (P), number of stress years (SY), coverage (Cov.); 2) cardinality (Card.), Ct and K: N – total number of investigated series; Nj–number of series with the same SY; Ni – number of series having measurements for obtained SYs

- Fig. 3.2.The average Ct – coefficient is 0.39 and 5 groups of locations can be formed according to the variation of Ct: 1) 0.08 – 0.2 (3 locations - 16, 2 and 12); 0.21 – 0.29 (5 locations - 8, 9, 10, 23 and 22); 3) 0.31 – 0.40 (7 locations – 18, 1, 17, 20, 6, 24 and 4) 0.41 – 0.50 (7 locations – 11, 13, 14, 15, 3, 5 and 25) and 5) 0.52 – 0.59 (7 locations – 26, 27, 21, 19, 29, 28 and 7). The number of the same SYs is decreased from first to five groups.

The average value of K – coefficient is 2.36. For the most of studied locations (20 in number) it varies from 2.09 to 3.32. Minimal values are reported for 5 locations: 10, 12, 28, 6, 3 (K=1.27 to 2.00) and maximal ones – for 4 locations: 24, 13, 11 and 25 (K=3.06 – 4.71).

The average frequency of occurrence of eustress years (F) is 43 at locations varying from 29 (11) to 50 and 51 (3, 10 and 28 location) – Fig. 4.

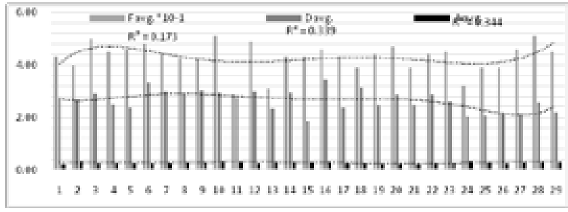


Fig.4. Variation of average eustress characteristics according tolatitude of studied locations

The variation of average F according to the variation of locations characteristics can be described by a polynomial of sixth degree and low R^2 - 0.2 to 0.3 (the last - only for the amendment of altitude) – Fig. 4.

The average duration of eustress (D) is 2.6 yearsand varying atsampledlocations from 1.9 (15) to 3.3 and 3.4 (6 and 16 location) – Fig. 4. The variation of average D according to the variation of locations characteristics can be described by a polynomial of sixth degree and low R^2 - 0.2, 0.3 and 0.4 (latitude) – Fig. 4. The absolute maximums of D for studied locations are seen in the last centuries -Table 2.

The average depth of eustress (A) is 0.28and varying at locations from 0.23 (19 and 20) to 0.36 (10 location) – Fig. 4. The variation of average D according to the variation of locations characteristics can be described by a polynomial of sixth degree and low R^2 - 0.2, 0.3 (to latitude and altitude) and 0.4 ($P_{avg.}$) – Fig. 4. The absolute maximums of A for studied locations are seen in the last centuries, except location 25, where the absolute max was in 2003 - 0.49 (Table 2).

Table 2.Maximum values of eustress characteristics for black pine series and functional type

SA	Amax	Amax, Y	Dmax	Dmax, Y	PFT	SA	Risk degree
1	0.59	1896	9	1752 - 1760	F3D3A2	7	Slight Risk
2	0.76	1832	5	1878 - 1882	F3D3A2	23	
3	0.58	1806	17	1774 - 1790	F3D3A1	1	
4	0.46	1821	11	1737 - 1747	F3D3A1	22	
5	0.64	1751	6	1970 - 1975	F3D2A3	5	
6	0.63	1737	17	1767 - 1783	F3D2A2	4	
7	0.69	1562	15	1893 - 1907	F3D2A2	17	
8	0.55	1806	11	1725 - 1735 1803 - 1813	F3D2A1	19	
9	0.60	1753	15	1800 - 1814	F1D3A1	18	
10	0.74	1718	11	1751 - 1761	F1D2A1	21	
11	0.62	1853	12	1742 - 1753	F1D1A1	26	
12	0.56	1769	13	1823 - 1835	F1D1A3	25	

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13	0.56	1935	8	1826 - 1833 1847 - 1854	F3D3A5	14	Moderate Risk
14	0.75	1713	8	1965 - 1972	F3D3A4	8	
15	0.51	1950	7	1944 - 1950	F3D3A4	9	
16	0.95	1704	15	1870 - 1884	F3D2A5	29	
17	0.59	1582	12	1745 - 756	F3D1A4	15	
18	0.72	1771	15	1766 - 1780	F3D1A4	27	
19	0.47	1892	12	1886 - 1897	F1D3A5	11	
20	0.51	1823	11	1798 - 1808	F1D2A4	13	
21	0.39	1922	6	1942 - 1947	F1D1A5	24	
22	0.53	1824	10	1767 - 1776	F4D3A1	20	
23	0.47	1875	8	1866 - 1873 1968 - 1975	F4D4A2	6	Moderate Risk
24	0.88	1901	4	1985 - 1988	F5D3A1	12	
25	0.49	2003	6	1945 - 1950 1984 - 1989	F5D3A2	3	
26	0.39	1934	5	1970 - 1974	F2D3A5	2	
27	0.52	1993	7	1944 - 1950	F3D4A5	16	Significant Risk
28	0.65	1945	8	1945 - 1952	F5D3A5	28	
29	0.67	1922	8	1945 - 1952	F5D3A5	10	

The five-graded scale for assessment of Pinusnigra Arnold. eustress features is composed by statistical analysis of obtained values for studied locations – Table 3.

Table 3. The five-graded scale for assessment of Pinusnigra Arnold. eustress features

Characteristics	F		D		A	
Group	name	value	name	value	name	value
1	Very rarely	≤39.55	Very short	≤2.176	Very small	≤0.2611
2	Rarely	>39.55- ≤41.71	Short	>2.176- ≤2.507	Small	>0.2611- ≤0.2729
3	Normal	>41.71- ≤46.01	Normal	>2.507- ≤3.17	Normal	>0.2729- ≤0.2965
4	Often	>46.01- ≤48.16	Long	>3.17 - ≤3.501	Deep	>0.2965- ≤0.3083
5	Very Often	>48.16	Very Long	>3.501	Very Deep	>0.3083

DISCUSSION

The average growth index varies slightly in different locations - the difference between the maximum and the minimum value is only 0.018. The correlation between the studied index series is mainly moderate to weak. With a few exceptions only, the It_{avg}.defferences in years are with the same direction in studied locations, i. e.expressesthe similar trends.

The average correlation coefficient (r) between It_{avg}.and-T_{avg}., $P_{avg..}$, dT,dP is positive for all locations. The dependences are week, but the average r - values with $P_{avg.}$ anddP (r=0.05) are 2.5 times higher than those with T_{avg}. and dT indicating the greater importance of precipitation for the black pine growth.

There is a big difference in the number of eustress years at sampled locations, which is associated with different lengths of the studied index series and with differences in local conditions. The maximal number of eustress yearsrelative to the length of the studied period is obtained for location 27 and the minimal number is seen at location 10. Correlation analysis also shows that the number of SYs is highly dependent from theinvestigated period – r = 0.91. Likewise K - factor that eliminates the influence of the size of the analyzed period, varies comparatively slightly between locations.

The average Cov.is relatively high and slightly varies by locations, the same goes for K - coefficient. The locations with a higher value of K have a fewer in number stress years. The average Card. is relatively low and varies greatly by locations, the same valid for Ct – coefficient, that probably reflecting the differences in local conditions. The values of coefficients K and Ct less depend of the investigated period (r=- 0.19; r=0.3), that is very important for the comparative analysis of a large number of dendrochronology series. The values of coefficients primarily depend of Cov. and Card., respectively for K and Ct (r=0.45 and r=0.44,), also – of the number of investigated series (r=0.54 for Ct and r=- 0.39 for K) as the mentioned Cov. and Card. are dependent of the number of studied series, too.

The variability of F - values for studied locationsis significant (the difference between maximal and minimal obtained values is about 49% from the average value). F - valuesweakly correlate with T_{avg}. (r=0.16), and with other characteristics of locations (latitude, longitude, altitude, P_{avg}.) r<0.043. The differences in D - values are significant (58% from the average value), too. D – valueshave a significant positive correlation with the altitude (r=0.55) and negative moderate – with the latitude (r=-0.40), as with the other characteristics of locations almost there is no any correlation. The differences in A - values at locations studied are 46% from the average A- value. A- valueshave a weak positive correlation with the latitude (r=0.17), negative moderate – with the altitude (r=-0.31) and P_{avg}. (r=-0.35) and with the other characteristics of locations almost there is no suchcorrelation.

The absolute maximums of D and A for studied locations are seen in the last centuries,except one location. This fact may be used as an argument that the growth conditions are relatively favorable for black pine in considered locations in this century.

The evaluation of F, using a scalein Table 3, shows that at the most of locations appearance of eustress for black pine is with normal frequency (51.72%) or very rarely and rarely (27.59%). Often and very often frequency of eustress is obtained only for 20.69% of locations studied – Fig. 5. The evaluation of D shows that only at 6.9% of black pine locations have eustress with a long duration and at the most of studied locations it is normal – 51.72%, very short or short (41.38%). The depth of eustress evaluated for the

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black pine is very small, small or normal for the most of locations – 55.17%, but the eustress is deep or very deep for a large number of locations, too – 44.83%.

Combined assessment of eustress characteristics allowsthe assessment of black pine functional behavior in the locations-sampled for the studied period(PFT) -Tab. 2.

F	F1							F2		F3														F4		F5			
SA	11	13	24	18	21	25	26	2	8	9	1	14	15	17	7	19	22	4	23	29	5	16	27	20	6	12	3	10	28
D	D1					D2							D3																D4
SA	15	24	25	26	27	29	13	5	17	21	19	4	28	23	2	1	11	8	22	20	3	14	10	7	12	9	18	6	16
A	A1									A2						A3		A4				A5							
SA	19	20	1	21	22	18	12	26	6	3	4	23	17	7	5	25	27	8	9	13	15	14	16	29	11	28	24	2	10

Fig.5.Histogram of qualitative evaluation of F, D and Aforblack pine locations

The risk locations with varying degrees of risk for black pine forests existence can be identifiedby obtained functional types of black pine trees – Table 2.The locations where the eustress of black pine has: normal frequency and duration, very small or small depth (F3D3A1/2); normal frequency, short in duration with a very small or small depth (F3D2A1/2); rarely occurring, normal, short or very short duration and with normal or very small depth (F1D3/1/2A3/1) can be assessed as locations with low risk. The locations where eustress has the following characteristics: F3D3/1/2A4/5; F1D3/2/1/A5/4; F2D3A5; F4D3/4A1/2 and F5D3A1/2 are at moderate risk. The long or very frequently occurring and very deep eustress places forests in locations at significant risk.

Conclusion

The comparative characteristics of growth indices series show that the radial growth of black pine has small variation in studied locations. The number of identified stress years also slightly varies depending on the local conditions (reflected bythe value of K - coefficient), but the differences in the characteristics of eustress are significant. The calculated correlations between the studied factors and eustress characteristics express dependencies, whichneed of further examination and consideration.

The mean values for K- coefficient and the depth of eustress periods are close to the published values for Quercusfrainetto Ten, while those for the duration and frequency of eustress years are the same with them (respectively: K = 2.36, A = 0.280, D = 2.6 and F = 43), which species has thesimilar ecological requirements as the black pine does [15].

The absolute maximums of D and A for studied locations are seen in the last centuries, except one location only. This fact may be used as an argument that the growth conditions are relatively favorable for black pine in locations considered in this century.

The differences in the values of eustress characteristics: frequency by the altitude, duration by the longitude and depth according to the average annual precipitation in the locations is described by a polynomial of sixth degree with R^2= 0.3 – 0.4.

By combining scale-evaluation of frequency, duration and depth of eustress, an attempt for characterization of the functional behaviour of black pine in locations and the level of risk for the forests existencein studied locations was implemented. For the majority of the investigated locations - 48.3%, the moderate risk is established. For about 41.4% of locations the risk is weak and for only 10.3% - the risk is significant.

In relation with the environmental characteristics of black pine, also the importance of forests as a source of a variety of ecosystem services in the areas of species distribution and not least to the conservation value of the communities, the proposed approach of analysis and the obtained results could be useful for the management and protection of black pine forests in the occupied territories of species.

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