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DETERMINATION OF FOREST DECLINE DUE TO THE ACTION OF DOMINANT STRESS FACTOR THROUGH MONITORING OF DEFOLIATION - CASE STUDY OF MALJEN, SERBIA

SUMMARY

The paper presents the results of research on the influence of climatic factors on the occurrence of defoliation and decline of forests as a final outcome. The research was conducted in a mixed beech and fir forest, in the period from 2004 to 2019 at sample plot 415 - Maljen, as a representative example of forest decline, which is part of regular monitoring conducted on the territory of the Republic of Serbia. Due to the fact that defoliation may be due to the influence of various factors, research, analysis and results are focused on long-term trends. Special attention is paid to the analysis of the degree of influence of climatic parameters on the occurrence of defoliation. Data on temperatures and precipitation in the period 2004-2019 were processed and analyzed on a monthly and annual basis, as well as in the vegetation period, for the main meteorological station Valjevo, which is closest to sample plot 415. Also, drought assessment was performed during this research period based on Lang's rain factor, de Martonne aridity index and climate diagram by Walter. In order to confirm these methods, the Standardized Precipitation Index was calculated as one of the method that has been mostly used in drought identification lately. It was stated that the defoliation of trees was initiated by extreme climatic events during three consecutive drought years (2011-2013), after which there was the largest decline of forests in the researched area.

Keywords: defoliation, abiotic factors, drought, forest decline, sample plots, Maljen.

INTRODUCTION

Forest decline is a natural process due to which old and physiologically weakened trees are more susceptible to decay. However, when a large number of

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trees in one stand or in a wider area begin to decline, and their number increases from year to year, it is clear that there has been some disturbance at the site or in the entire environment. Decline is not a consequence of a sudden event, but a process that progressively increases from year to year until it reaches proportions noticeable to the naked eye. When it comes to individual trees, it is usually easy to determine the cause of death, although it can be very diverse (physiological age limit, damage from biotic or abiotic factors, the struggle for light or other living conditions, etc.). However, when it comes to the decline of trees of one or more species, especially in wide territories, the causes of tree decay change successively.

The ICP Forests program represents an international cooperative program for monitoring the impact of air pollution on forests while monitoring of forest is performed within this program as one of the most diverse approaches to researching the impact of various environmental factors on forest ecosystems. Defoliation was adopted by ICP Forests in many European countries in the 1980s as the main indicator of the forest condition. It represents a visual assessment of the crown of a tree and is an indicator of the missing amount of leaves/needles in relation to the reference tree in the immediate vicinity and is the main parameter when assessing the condition of individual trees (ICP Forests Manual and Criteria).

There are discourses of many researchers who deal with this issue, which is the dominant factor (abiotic, biotic or anthropogenic), which negatively affects forest ecosystems and leads to defoliation. Sometimes the same factor can be predisposing, stimulating and contributing to defoliation. On the one hand, the primary factor of defoliation and decline of forests is considered to be climate change, because they cause constant stress in the environment that strongly affects forests (Aber, J. *et al.*, 2001; Dale, H.V., *et al.*, 2001; Seidling, W 2007; Kadović, R. and Medarević M. 2007; Brašanac-Bosanac, Lj. *et al.*, 2011, 2014, 2015; Češljar, G. *et al.,* 2013, 2014; Ćirković-Mitrović, T. *et al.*, 2013; De la Cruz, A. *et al.,* 2014; Sánchez-Salguero, R. *et al.* 2017). The mentioned authors find a connection between the increase in defoliation and climatic conditions, emphasizing, above all, the frequent droughts followed by high air temperatures. Schuldt B. *et al.* (2020) state that even species that are considered drought-resistant, including beech, suffer long-term damage, while increased mortality is also recorded on fir.

Beech and fir forests, mainly on smaller areas on several lower mountains in Serbia, among them on Maljen, were described by Gajić, M. *et al.* (1954). According to these authors, these are mountain beech-fir forests, which occur at lower altitudes (descending to about 700 m).

A high degree of defoliation on beech trees, as a consequence of severe drought, was stated by Seletković, I. *et al.* (2009) on beech trees on the Medvednica mountain massif in Croatia. Popa, I. *et al.* (2017) state that, in the network of Level I sample plots in Romania, there are significant negative correlation between defoliation of beech trees and mean temperature from 1997 onwards, in the monitoring period 1992-2013. The widespread occurrence of crown defoliation on beech trees after drought and heat waves in the beech forests of Tuscany in central Italy was also noted by Pollastrini, M. *et al.* (2019).

Also, it is known that fir has a very narrow ecological valence and that it is difficult to tolerate the extremes of various factors of abiotic nature, and that in the previous period it was affected by more intensive decline processes in the entire area. Androic and Klepac (1969) also stated that an extremely wet or dry year is unfavorable for fir, when the trees lose the ability of normal assimilation, so decline occurs in the still partially green canopy. According to the annual reports of the ICP of the Republic of Croatia, fir is the most damaged species of forest trees in this country, with a very high percentage of significant damage (Seletković, I. and Potočić, N., 2004). Research has established that decline is a consequence of the synergistic action of several unfavorable habitat factors, such as drought, frost, large changes in air temperature, etc. (Potočić, N. *et al.*, 2008; Tikvić, I., 2008; Anić, I. *et al.*, 2009).

Based on all the above, defoliation can be influenced by various biotic, abiotic and anthropogenic factors that can act individually or in interaction. One-sided interpretation of these very complex phenomena and support for the decisive role of only one factor does not answer many questions. Therefore, the aim of this paper is to describe in detail the conditions that prevailed during the research period at the selected site in order to provide answers to the forest decline in this area, which was also found in the entire territory of the Republic of Serbia.

MATERIAL AND METHODS

Data collection was conducted as part of monitoring the condition of forests at the sample plot of Level I during the vegetation period when the leaf was fully formed (June-August), in the period from 2004-2019. As a good indicator of the impact of drought, i.e. abiotic factor on forest ecosystems during the research period (2004-2019), an example of sample plot 415 - Maljen I (Figure 1), in the state forest, on the mountain Maljen (coordinate network 4x4 km, coordinates: Y7431000 and X4886959) was singled out. This sample plot is located at 630 m above sea level, on the northern exposure, on eutric cambisol on serpentinite , with sufficient water availability. The average age of the stand is 61-80 years. In terms of phytocenological affiliation, the investigated locality is located in a beech and fir forest (A*bieti-Fagetum serpentinicum* Beus 1980).

According to the ICP Forests methodology (ICP Forests Manual and Criteria), during sampling of tress for monitor their condition in 2004, 24 trees were sampled, of which 15 beech trees and 9 fir trees, which were without mechanical or any other damage that could affect their vitality in the coming period.

The method of work is based on the criteria of the International Forest Program (ICP Forests Manual and Criteria), where, as the main parameter of the forest condition, visually assessment of defoliation is conducted, by classes 0-4, degrees and percentage of leaf/needle loss (Table 1).

Figure 1. Position of sample plot 415 on the map of the Republic of Serbia

Table 1: Categorization of defoliation according to *ICP Forest Manual and Criteria*

Classes of defoliation	Leaf /needle loss (%)	Degree of defoliation
0	0-10	None
1	> 10-25	slight (warning phase)
2	>25-60	moderate
3	>60<100	Severe
4	100	Dead

From climatic factors, the average annual air temperatures, the average annual air temperatures in the vegetation period (April-September), the sum of precipitation at the annual level and the sum of precipitation at the annual level in the vegetation period (April-September) were analyzed for the main meteorological station (MS) Valjevo for the period 2004-2019.The data were taken from the website of the Republic Hydrometeorological Service of Serbia (RHSS). The non-reactive method was used as a special scientific method for collecting data on climatic and meteorological conditions (Neuman W.L. 2006). This method includes research that does not involve direct data collection and in that sense is the opposite of research techniques such as interviews, surveys and experiments. Its basic techniques, such as content analysis or observation of documents and the use of existing statistics, documents and their secondary analysis, were used to assess the impact of temperature extremes (high and low temperatures) on forest ecosystems and identify possible changes over the years.

For the purpose of analyzing the height of the water layer in mm (if there were no evaporation, surface runoff and sinking into the soil), the Lang (1920) rain factor (IL) was calculated, which represents the ratio between the annual sum of precipitation and the average annual air temperature. According to the size of the IL, Lang characterized the following bioclimatic types of areas: 0-20 deserts, 20-40 semi-deserts, 40-60 steppes and savannas, 60-100 weak forests, 100-160 high forests, > 160 perhumid types.

Also, the annual aridity index according to De Martonne (1926) was calculated, which is used to determine the type of water runoff and the need for irrigation. The classification of drought according to the aridity index according to De Martonne (DMI) was performed as follows (Hrnjak, I. *et al.*, 2014): <10 - arid climate; 10-20 – semi-arid, 20-24 - mediterranean, 24-28 – semi-humid, 28-35 - humid, 35-55 - very humid and > 55 - extremely humid climate.

In order to consider the relationship between the movement of annual temperatures and precipitation as the most important factors of the climate of a region, climate diagrams were calculated and presented by Walter H. *et al.* (1975).To confirm the previously described methods for drought detection, the Standardized Precipitation Index (SPI) was calculated by McKee *et al.* (1993) as one of the methods most recently used in drought identification. SPI was calculated at intervals of 6 and 12 months (SPI-6 and SPI-12) and the assessment of the dry period was performed based on the categorization shown in Table 2.

Table 2. Categorization of moisture condition by SPI – Source: RHSS

Category of moisture conditions	**SPI values**
Exceptional drought	SPI ≤ -2.326
Extreme drought	-2.326 < SPI ≤ -1.645
Severe drought	-1.645 < SPI ≤ -1.282
Moderate drought	-1.282 < SPI ≤ -0.935
Minor drought	-0.935 < SPI ≤ -0.524
Near normal	-0.524 < SPI< +0.524
Slightly increased moisture	+0.524 ≤SPI< +0.935
Moderately increased moisture	+0.935 ≤SPI< +1.282
Considerably increased moisture	+1.282 ≤SPI< +1.645
Extremely wet	+1.645 ≤SPI< +2.326
Exceptionally wet	SPI ≥ +2.326

RESULTS AND DISCUSSION

Sample plot 415 at the Maljen locality was chosen as a good indicator of the primary cause of drought-induced decline, because during the research period at this locality gipsy moth (*Lymantria dispar* L.) was not found as the primary cause of damage, nor any other insect (eg. bark beetles), or a fungus that could affect the normal functioning of the plant organism and cause a stressful situation. Also, not a single tree was replaced at this site during the entire research period, which could have happened due to numerous other reasons such as regular felling, windbreaks, snowdrifts, forest theft, fire, etc. This means, that the same trees that go through identical favorable or unfavorable environmental conditions (microclimatic conditions), were monitored throughout the period. There are no industrial facilities or any other sources of pollution in the vicinity of the investigated site. For these reasons, as the only parameter, we can compare defoliation during the entire research period, which is shown in Table3.

From the presented data it can be concluded that all trees during the research period had defoliation within class 0 (0-10%) and no class 1 (> 10-25%) weak, which indicates the fact that it is a stable and healthy stand (2004-2010). However, the first symptoms of the beginning of decline were observed during 2011, when defoliations were observed on some trees, which significantly deviate from those observed until then. In the following 2012, this trend continued, and in 2013 the first decline was observed, which continued in 2014 and 2015. Table 3 shows that 30% of the trees that were continuously monitored in 2014 had symptoms of gradual to complete decline. In addition to the trees that have been isolated and monitored for many years, the researchers noted in their field records, that the same symptoms appear in the entire stand with the final outcome of decline. Also, in this period, very small leaves were noticed on the beach, which was a consequence of many years of drought, which the trees tried to fight against in that way, because less water is lost over a smaller leaf area, so it was the first line of defense against drought. As a consequence of a long period without precipitation with high temperatures, there was a premature leaf fall, which occurred well before the usual autumn leaf fall, which was observed in a large number of other investigated localities.

The beginning of intensive defoliation of beech trees in the research area, with a defoliation class of as much as 80%, was observed two years after the first extremely warm and dry year (2012). At the end of the research period, there were 20% of dead beech trees, while the most decline were in the period 2013-2015.

Concerning fir trees, the sensitivity to climatic extremes was higher in relation to beech. In the driest year of 2011, defoliation of 80% was found on one tree, and in the following years there was a sudden decline, so that in 2015, more than 2/3 of fir trees were dead. In the literature, a significant number of authors estimate that the occurrence of forest decline is largely conditioned by high temperatures and precipitation (Martinez-Vilalta J. *et al.* 2011; Fan Z. *et al.*, 2012; Zhang Q. *et al.*, 2017; Romagnoli M. *et al.*, 2018; Brèteau-Amores S. *et al.*, 2019). In addition to the amount of precipitation and their distribution during the vegetation period, the process of forest decline is greatly influenced by the deficit of soil moisture (Speich M.J.R., 2019). Fighting severe drought, forest trees slow down transpiration, and thus absorb less nutrients from the soil and slow down all other physiological processes. In such conditions, if the drought lasts for a long time, the trees are physiologically weak and become less resistant to other anthropogenic, abiotic and biotic causes of forest decline.

Air temperature is one of the most important climatic factors that affect vegetation. Analysis of average values of annual temperatures for MS Valjevo for the period 2004-2019, indicates that the warmest two periods stand out, namely 2012-2015 and 2017-2019 (Table 4). When it comes to positive temperature deviations from normal, 2018 was the year of climate records in Serbia: the warmest in the history of meteorological measurements; the warmest spring; the warmest April and the warmest summer according to the minimum temperature. According to the obtained data on the average annual temperature, in the research period, the highest average value was registered in 2019 (13.4°C).

During the vegetation period (April-September), the highest average annual values of air temperature in the area of Valjevo were registered in 2012 and 2018 (Table5). According to Kolić, B. (1988) with the increase of air temperature in the beginning, the intensity of photosynthesis increases sharply. However, the greater the increase in temperature, the intensity of photosynthesis does not follow the increase in air temperature, because with the increase in temperature begins the process of respiration, which is by its energy characteristics opposite to photosynthesis. The maximum intensity of photosynthesis in the vegetation period occurs at air temperatures of 15.5°C". Taking into account the above, it can be concluded that the air temperature in the investigated locality in the vegetation period during the entire research period was higher than necessary.

Based on the obtained data for the research period (2004-2019) and data for the reference period (1961-1990), their comparison was performed both on an annual level (Figure 2) and during the vegetation period (Figure 3). On both previously mentioned figures, a deviation of the mean monthly temperatures during the research period in relation to the normal 1961-1990 is noticeable. This trend is especially pronounced in the vegetation period, and the largest deviations were recorded during 2012. According to the data shown in Tables 6 and 7, the lowest average amounts of precipitation in the area of MS Valjevo were registered in the period 2011-2013. During the summer of 2011, longer periods without precipitation were recorded, which make this year one of the driest in the entire territory of Serbia since the measurements began. This year can be considered extremely dry because the average amount of precipitation was below 500 mm, which according to Rakićević T. (1980) is the limit for declaring drought. The deficit of moisture in the soil was intensified by the long-term high air temperature, which was about 3 degrees higher during the summer months compared to the several year average.

Table3: State of defoliation at sample plot 415 in the period 2004-2019.

SP Level I	**No. and label trees**	**Tree Species**	**Defoliation in percentages (%) per year**															
			2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
415	1N	Beech	30	30	10	10	0	10	10	5	0	10	**100**	0	0	0	0	0
415	2N	Fir	20	10	0	20	20	10	10	**30**	**80**	**90**	**100**					
415	3N	Beech	20	20	0	10	0	10	0	0	0	20	10	10	10	10	10	0
415	4N	Beech	10	10	0	10	10	0	0	0	0	0	10	0	10	0	0	0
415	5N	Beech	0	20	10	10	0	0	10	0	0	10	0	0	0	0	0	0
415	6N	Beech	10	20	10	10	0	10	0	0	0	10	0	0	0	0	0	0
415	1E	Beech	0	0	10	10	0	0	0	20	0	10	10	10	10	10	0	0
415	2E	Beech	10	0	0	10	10	10	0	10	10	20	10	10	10	10	0	0
415	3E	Beech	10	0	10	10	0	10	0	0	10	0	10	0	0	10	15	10
415	4E	Fir	0	10	0	10	25	10	0	5	0	0	10	15	10	15	0	0
415	5E	Fir	20	10	10	10	20	0	0	5	0	0	**100**					
415	6E	Beech	0	20	10	20	0	10	0	20	10	10	10	10	0	10	0	0
415	1W	Beech	10	10	0	10	10	10	0	0	10	10	10	0	0	0	10	10
415	2W	Beech	10	30	10	10	0	10	0	10	0	10	10	20	15	0	15	10
415	3W	Beech	0	10	10	10	10	20	0	5	0	0	0	0	0	0	15	0
415	4W	Fir	0	0	0	20	10	10	10	0	0	0	0	15	10	0	0	0
415	5W	Beech	0	20	0	10	10	10	5	10	0	10	0	0	0	0	0	0
415	6W	Beech	10	30	10	10	0	10	5	0	0	10	0	40	75	80	**100**	
415	1S	Fir	0	10	10	10	10	10	0	0	0	10	0	10	10	10	0	0
415	2S	Fir	0	10	0	10	20	10	10	10	0	**30**	**70**	**100**				
415	3S	Fir	0	20	10	20	30	10	0	**80**	**80**	**100**						
415	4S	Fir	0	10	10	0	10	0	5	0	0	20	**60**	**100**				
415	5S	Beech	20	20	20	10	10	10	5	0	0	**80**	**100**					
415	6S	Fir	0	10	0	10	10	20	0	10	10	**40**	**80**	**100**				

Table 4: Average values of annual air temperature (°C) for MS Valjevo in the period 2004-2019.

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
C sr.	11,5	10,7	11,5	12,7	12,8	12,5	11,9	11,9	**12,7**	**12,7**	**12,8**	**12,9**	12,5	**12,7**	**13,0**	**13,4**

Table5: Average values of annual air temperatures (°C) for MS Valjevo in the vegetation period (2004-2019)

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
C sr.	17,7	17,7	18,3	19,3	18,9	19,4	18,5	19,5	**20,4**	19,2	18,1	19,8	18,9	19,6	**20,2**	19,5

Table 6: Average precipitation amounts (mm) for MS Valjevo in the period 2004-2019

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Σ	846,4	843,9	821,7	843,3	656,1	916,3	1062,1	**601,0**	**611,0**	**681,7**	**1332,4**	765,9	980,4	737,7	791,9	741,1

Table 7: Average precipitation amounts (mm) for MS Valjevo in the vegetation period (2004-2019)

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Σ	497,2	533,4	465,5	393,2	360,1	427,0	677,7	**378,1**	**276,1**	**344,7**	**1066,6**	378,7	547,4	377,8	465,5	460,3

After the dry period, 2014 came with an extremely large amount of precipitation (1332.4 mm). In the period from April 14 to May 5, 2014, between 120 and 170 l/m² of precipitation was measured in most places in Serbia, while in some places in the vicinity of Valjevo, the amount of precipitation exceeded 300 l/m².

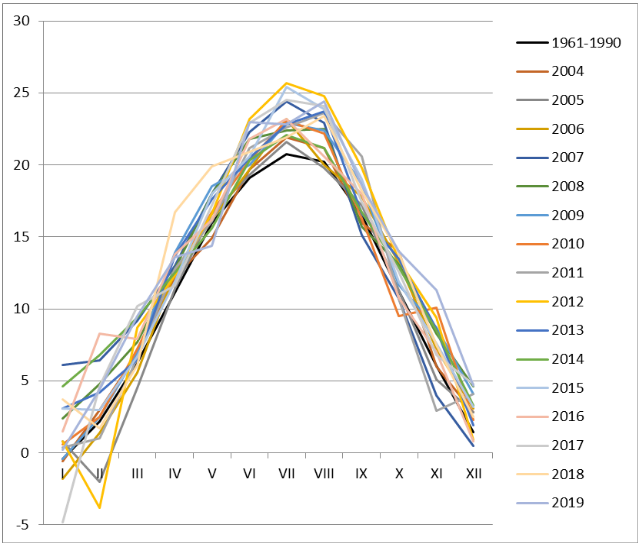

Figure 2. Mean monthly air temperature values (2004-2019) in relation to the normal for the MS Valjevo

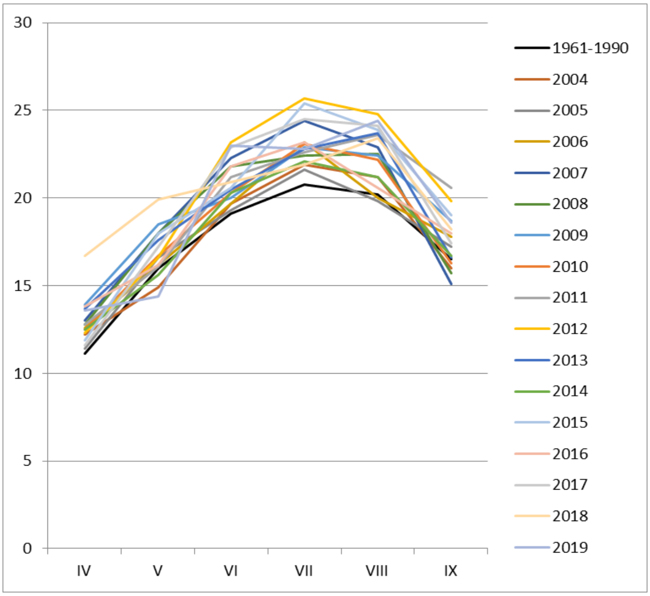

Figure 3. Mean monthly values of air temperature in the vegetation period (2004-2019) in relation to the normal for the MS Valjevo

To confirm the impact of the several year drought registered in the period 2011-2013 in the entire territory of Serbia, Figure 4 shows climate diagram by H.

Walter *et al.* (1975) for the main MS Valjevo, which is closest to the sample plot 415 locality.

These diagrams represent the ratios of annual temperatures and precipitation as the most important factors of the climate of a locality and give a visual representation of the monthly movement of drought, i.e. the distribution of the humid and arid periods during the year. On the climate diagram for 2011 (Figure 4a) it can be seen that some months (June, August) were dry and extremely dry (November). In summary, 2011 had the lowest amount of precipitation in relation to the next two observed years, but also for the entire research period. Climatologically, 2012 (Figure 4b) is also characterized by the lowest recorded temperatures at the beginning of the year, absolute maximums, absolute minimums of air temperatures and strong spring frost. The month of February 2012 was the coldest month since the beginning of meteorological measurements and the summer of 2012 was the warmest since meteorological measurements in Serbia is conducted. Also, for 2012, it can be said that the summer was extremely dry, because the precipitation was significantly below normal for several consecutive months. Extremely hot was also 2013 (Figure 4c), the seventh warmest in the period from 1951 to 2013. Six heat waves were registered, and according to the data of RHSS (2013), the strongest intensity of heat waves registered during 2013 was recorded in the area of Valjevo. In 2013, higher amounts of precipitation were recorded, compared to the previous two years, but this year stands out due to the length of the heat waves that characterized it.

Based on the analysed data for the MS Valjevo for the period 2004-2019, I_L is calculated according to Lang and aridity index (DMI) by de Martonne (1926) (Tables 8 and 9).

Table 8: I_L according to Lang for MS Valjevo

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
I_L	73.6	78.9	71.3	66.3	51.1	73.4	88.9	50.6	48.3	53.6	103.9	59.6	78.5	58.3	60.8	55.3

By analyzing the values of the rain factor according to Lang's bioclimatic classification, it can be concluded that the investigated area is at the transition from semi-arid bioclimatic type of area to semi-humid type. Stands out the period from 2011-2013, which is in the arid bioclimatic type. The exception is 2014 (I_L 103.9), when the humid bioclimatic type (climatic type of high forest area) prevailed.

Table 9: DMI according to de Martonne for MS Valjevo

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
DMI	39.4	40.8	38.2	37.1	28.7	40.7	48.4	27.5	27.0	30.0	58.4	33.5	43.6	32.6	34.4	31.7

By analyzing the values of the DMI according to de Martonne's classification of climate and area, it can be concluded that the research area is characterized by humid and very humid climate (DMI 35-55). With the characteristics of the semihumid climate (DMI 24-28), 2008, 2011 and 2012 stand out, while 2014 is characterized by an extremely humid climate (DMI 58.4).

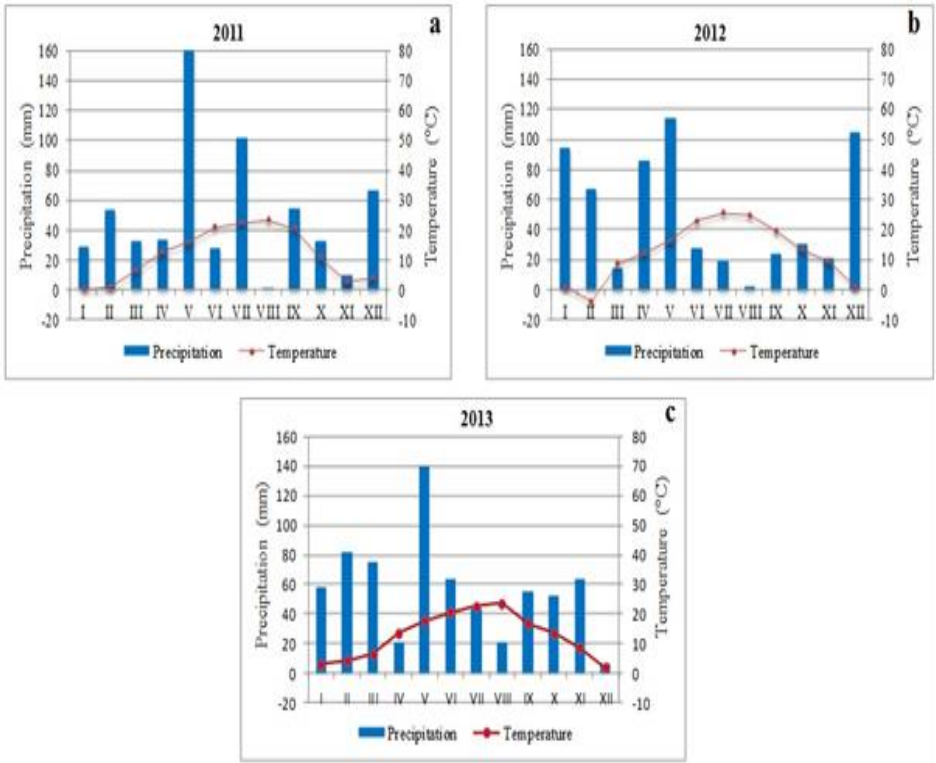

Figure 4. Ratio of annual temperatures and precipitation change during the driest several year period for MS Valjevo. (a) 2011, (b) 2012 and (c) 2013.

In order to confirm the impact of the drought period and its impact on individual trees and forests in general, the state of drought intensity is given based on the SPI during the growing season (SPI-6, Figure 5) and annually (SPI-12, Figure 6).

It can be noticed that this index in the vegetation period shows three consecutive years of intense drought, where 2011 is the driest year. However, considering the humidity conditions on an annual level, it can be noticed that 2011 was by far the driest during the entire research period and goes to the level of extreme drought. Which means that the trees reacted to such a long-lasting drought, which not only affected the vegetation period, when moisture is essential for plants for undisturbed growth and development, but also throughout the year

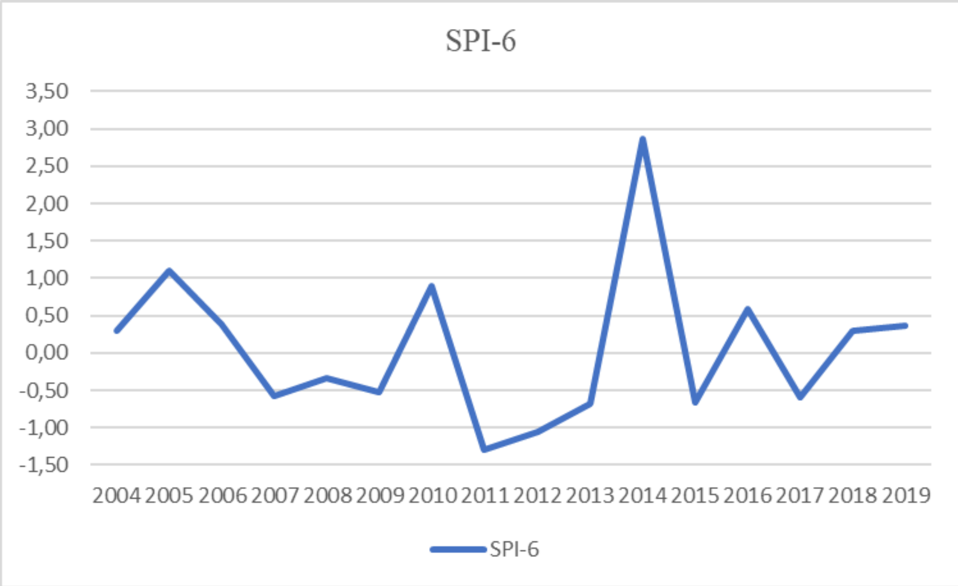

Figure 5. Humidity conditions in the vegetation period

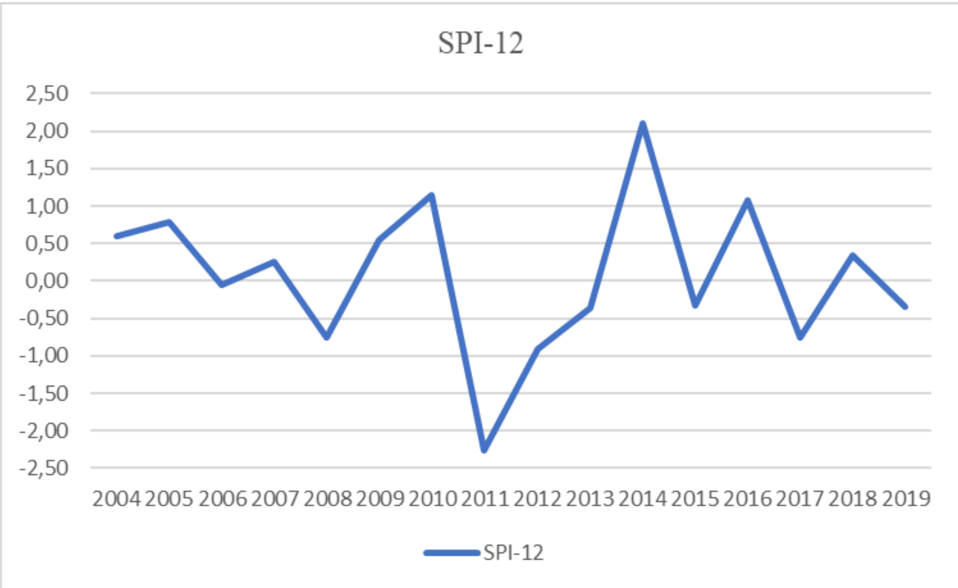

Figure 6. Humidity conditions on an annual basis

CONCLUSIONS

The phenomenon of forest decline exceeds the boundaries of a narrow professional, forestry issue, represents a problem of the broadest social interest and makes it one of the most significant social problems. Solving the problem of forest decline has specifics due to the diversity of climate, orographic conditions, habitat types, vulnerability by defoliators, tree species and forest ecosystems, as well as inequalities in the degree of industrialization of individual regions, the degree of measures and actions to protect the environment.

Although the research is defined as a case study, after three consecutive drought years (2011-2013), forest decline was found on the entire territory of the Republic of Serbia, so it can be concluded that they are unfavorable climatic conditions were the primary and dominant stress factor. In fir trees, the sensitivity to climatic extremes was higher in relation to beech. More than 65% of the trees of this species were dead at the end of the research period. In the case of beech, the percentage of dead trees was 20%. Also, the drought assessment based on the Lang rain factor (I_L), the de Martonne Drought Index (DMI) and the Walter climate diagram clearly distinguishes the years of drought (2011-2013). These observations were confirmed by the application of SPI both in the vegetation period and throughout the year, after which the drying of individual trees in a researched area begins to be recorded.

By continuous monitoring for a longer period of time, it is possible to determine the cause of decline of a certain tree and bring it into connection with a certain ecological factor. Intensive decline of trees occurs in the dry year, or in the year immediately after the drought, so it is possible to predict this phenomenon based on monitoring climatic parameters, if there is no action of other biotic and abiotic factors that would negatively affect the forest. If the symptoms that appeared on the isolated trees can be diagnosed in the immediate environment, then it is even easier to draw a conclusion about the cause.

The advantage of this research, in relation to other researches that are performed only after the appearance of decline as the final cause of the influence of a this factor, can be seen when these researches find decline of individual trees or larger forest areas in a locality, the cause is that moment is very difficult to determine, because it can be initiated by various factors that have occurred in the past to which some other factors have been added. Therefore, this type of continuous monitoring can accurately determine the initial stages of the impact of a specific factor.

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