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IDENTIFICATION OF RECENT FACTORS THAT AFFECT THE FORMATION OF THE UPPER TREE LINE IN EASTERN SERBIA

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Abstract - The recent climate changes, among others, have contributed to the change in elevation of the upper tree line in high mountainous areas. At the same time, direct anthropogenic impact on the fragile ecosystems of high mountains has also been significant. The aim of this paper is to determine the actual dynamics of the formation of upper tree line in eastern Serbia and to identify the recent factors which condition it. The results obtained show that preconditions have been accomplished for the upper tree line increase, but this has not completely been confirmed by previous field researches.

Key words: Upper tree line, climate changes, temperature gradient, Mt. Stara Planina, anthropogenic influence, depopulation.

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INTRODUCTION

In conditions when changes in abiotic and biotic environment are intense and diverse, the question arises as to the origin and magnitude of potential factors that influence the location, i.e. changes in elevation of the upper tree line. The upper tree line is defined as a zone of transition from the belt of sub-alpine forests to the highest rarely distributed and stunted individual trees (Holtmeier and Broll, 2005). Elevation at which this limit stretches depends on the geographical position of the mountain mass, local orographic and climate conditions, as well as on the response of biocenoses to anthropogenic pressures (formation of settlements, land use, etc.). The best-studied relationship is the one between air temperature and limiting values of high-altitude distribution of vegetation. W. Koppen (1936) stated that the air temperature of the warmest month of 10˚C influences the elevation of the upper tree line.

The aim of the research presented in this paper is to determine the actual dynamics of the formation of the upper tree line in eastern Serbia and to identify some of the recent factors by which it is conditioned. The Stara Planina mountain, as the most prominent high-altitude zone of the region, was examined. The study assumes that changes in the high-altitude limits of forest spreading occurs in response to changes in climatic, orographic and anthropogenic conditions of the environment. Since orographic changes take place in long time periods, they have not been considered.

MATERIALS AND METHODS

Study area

The Balkan part of Eastern Serbia is marked by the Stara Planina mountain range which mostly covers the northwest-southeast direction at a length of 100 km, extending to the Balkan Mountain in Bulgaria. Owing to the geographical position and morphology of the massif, specific climate zonality was created which influences the occurrence of extreme high-altitude vegetation zones. The mountainous part of the Stara Planina massif is hypsometrically and morphologically divided in a belt of 692 m to 2169 m (43° 00'-44° 00' N and 22° 16'-23° 00' E).

In the area of the Stara Planina, transitional or sub-mountain climate region at altitudes between 600 m and 1 250 m above the sea level, mountain climate region at altitudes between 1 250 m and 1 900 m and high mountain climate region at altitudes above 1 900 m were singled out within a group of mountain climate regions (Milovanović, 2010).

It has been established that the lowest forest belt in the Stara Planina mountain is comprised of communities of Hungarian oak and Turkey oak, with big-leaf pubescent oak (*Quercetum frainetto-cerris-virgilianae* Jov. et Vuk. 1977.). A variety of relict, poly-dominant mesophilic communities of mountain beech and other species (*Fagetum submontanum mixtum*) appear in a wide high-altitude range (Mišić et al., 1978). In the belt between 1 200 m and 1 500 m above sea level, covering mainly sunny exposures, thermophilic forest phytocoenoses *Luzulo-Fagetum festucetosum drymeiae* have developed on acid-reaction soil. In the same altitude belt, but on the northern slopes of the massif, the sub-range of mixed beech and fir forests is well distributed (*Abieti-Fagenion moesiacae* B. Jov. 1976). Forest of spruce, fir and beech (*Piceo-Fago-Abietetum* Col. 1965) appear at elevations above 1 400 m and extend to 1 600 m (Mišić et al., 1978; Jovanović et al., 1997). The lowest limit of the sub-alpine belt is determined by altitudes at which spruce forms the upper tree line (1 750 m–1 800 m); above these altitudes it is accompanied by juniper and blueberry (*Vaccinio-Junipero-Piceetum subalpinum*). Due to highly developed animal husbandry in the past, large areas under forest vegetation have been cleared (by cutting and burning), so that in mountain pastures *Nardetum* appears at about 1 400 m, while at altitudes above 1 600 m they are in the pasture community *Foetum violaceae serbicum*, and the remains of mountain pine community are found on the locations of Tri kladenca and Tri čuke (1 920 m) (Belij et al., 2007).

Data and methodology

Two meteorological stations in eastern Serbia (Dimitrovgrad at 450 m and Crni vrh at 1 037 m) and Kopaonik, as the highest station in Serbia (at 1 710 m), were selected for defining changes in air temperature at different altitude zones. Given that the location of the station in Crni vrh changed in September 1981, data series were used for the period 1982-2009 for trend analysis of air temperature. In an effort to check air temperature changes over a longer period of time, we analyzed the data from the station in Dimitrovgrad in the period 1949-2009. Trends in air temperature were analyzed at a monthly, seasonal and annual basis. The Mann-Kendall test was used for testing the significance of the trends, and Sen's method for evaluating the slope trend lines (Milovanović, 2005). The data used for the concluding remarks on the influence of anthropogenic factors were obtained from official census statistics of the Statistical Office of the Republic of Serbia.

RESULTS AND DISCUSSION

There are many studies describing the mutual influence of climate change and the formation of the upper tree line (Sveinbjörnsson, 2000; Subedi, 2009; Whitesides and Butler, 2010; Elliott, 2011). If climate directly affects the formation of upper tree line, then the temperature increase during the 20th century must be related to the rapid increase in areas under forest cover (Elliott, 2011).

However, a rise in temperature is not the only climatic element that can influence the change in elevation of the upper tree line, but also changes in CO_2 concentrations (Sveinbjörnsson, 2000). On the other hand, the dominant influence of precipitation (on the width of annual rings at trees in Durmitor Mountain, Montenegro, 300 m below the actual upper tree line (Ducić et al., 2010)) was established. Also, Crimmins et al. (2011) assumed that temperature is a dominant factor that affects the upper limit of vegetation spread, while ignoring the influence of the water regime (more specifically, the climatic water deficit, defined as the difference between potential evaporation/transpiration and precipitation).

Studies of the correlation between temperature changes and annual ring width in *Abies alba* Mill. species in the Jura Massive in Switzerland revealed that the temperature maximum trends during the vegetation season exhibited a slight decreasing trend throughout the 20th century while their mean annual values increased (Rebetez et al., 2003). A strong link has been established between global climate phenomena (e.g. the North Atlantic Oscillation or NAO) and variability of vegetation periods, which is has not just been the consequence of global warming, but also of changes in land-use (Linderholm, 2006).

Vertical temperature gradients obtained for the Stara Planina mountain have shown clear variations throughout the year. The lowest value is observed in December, ranging from 0.28˚C-0.42˚C, while the vertical temperature gradient is 0.65˚C-0.72˚C in the period April-June, with the highest mean value 0.68˚C observed in April and 0.67˚C in May (Milovanović, 2010). The cause of such variation of the gradients is due to longer periods of snow-cover in higher regions when heat is consumed on melting the snow melting. According to the obtained data, the upper tree line in the Stara Planina mountain is in the belt between 1 900 m and 2 000 m.

According to data presented on Table 1, it can be concluded that there is a statistically significant increase in mean annual air temperature, mean summer temperature and mean monthly temperature (in June and July) at all stations. It is important to note the negative trend in air temperature in September at all stations.

If the upper tree line on Stara Planina is around 1 900 m to 2 000 m and since the cumulative air temperature increase varies from 1.7˚C-1.8˚ C in July and from 1.4˚C-1.8˚ C in August (according to the trend observed in the period 1982-2009), and since the temperature gradient value is about 0.6, then

Table 1. Results of trend analysis of mean monthly, mean seasonal and mean annual air temperatures in the period 1982-2009.

Station	Dimitrovgrad		Crni vrh		Kopaonik	
	Z statistic	Slope of trend line (°C/year)	Z statistic	Slope of trend line (°C/year)	Z statistic	Slope of trend line (°C/year)
I	0,277	0,023	0,040	0,000	0,554	0,028
II	1,008	0,073	1,483	0,129	0,771	0,062
III	0,910	0,037	1,403	0,092	0,613	0,038
IV	1,029	0,054	1,502	0,085	1,622	0,074
V	1,168	0,032	1,106	0,050	1,840	0,051
VI	**2,870**	0,090	**2,591**	0,100	**3,029**	0,113
VII	**2,434**	0,068	**2,535**	0,067	**2,577**	0,064
VIII	1,760	0,053	1,701	0,070	1,701	0,066
IX	-0,831	-0,026	-1,001	-0,045	-1,129	-0,038
X	1,367	0,039	1,048	0,050	0,337	0,017
XI	1,799	0,082	1,740	0,102	1,127	0,049
XII	0,593	0,036	0,198	0,016	0,316	0,017
Annual	**2,786**	0,038	**2,793**	0,062	**2,509**	0,041
Spring	1,304	0,039	1,719	0,068	1,383	0,042
Summer	**2,530**	0,061	**2,629**	0,074	**2,926**	0,072
Autumn	0,970	0,023	1,245	0,040	0,237	0,015
Winter	0,292	0,014	0,417	0,029	0,334	0,010

[1] The bold ones are statistically significant on p=0,05.

Table 2. Results of trend analysis of mean monthly, mean seasonal and mean annual air temperatures in the period 1949-2009 at the station Dimitrovgrad

Station	Dimitrovgrad	
	Z statistic	Slope of trend line (°C/year)
I	0.187	0.002
II	0.075	0.000
III	1.345	0.023
IV	-0.206	-0.002
V	0.922	0.010
VI	0.567	0.005
VII	0.380	0.004
VIII	0.336	0.005
IX	**-2.428**	-0.027
X	-0.031	0.000
XI	-1.388	-0.022
XII	-0.610	-0.011
Annual	-0.398	-0.002
Spring	1.201	0.011
Summer	0.492	0.005
Autumn	-1.917	-0.017
Winter	-0.485	-0.005

conditions for the movement of the upper tree line to the highest peaks of the Stara Planina mountain were acquired in the observed period. However, it should be noted that the annual air temperatures decreased in southeastern Serbia in the period 1951-2000 (Ducić et al., 2005). Still, in the period 1949-2009 for the station Dimitrovgrad (Table 2), the mean annual temperature exhibited a slight downward trend, spring and summer temperatures showed a slight increase, while winter and autumn temperatures decreased. Except in November, December, April and September when statistically significant temperature decreases were measured, this trend was absent in February and October, while there was a slight increase in temperature in January, March, May, June, July and August.

Based on the published results of field research carried out by Mišić et al. (1978) and Belij et al. (2007), degradation stages of deciduous-coniferous forest *Abieti-Fagetum* have been registered, together with traces of intensive exploitation of fir trees so that the beech forest at altitudes of 800 m-1 600 m can be considered as a arising as the consequence of anthropogenic activity. In communities of spruce, fir and beech that can be found up to 1 600 m, spruce trees have mostly been exploited.

Nevertheless, the high mountain area of the Stara Planina mountain has been marked by pronounced demographic depopulation in the last decades and indirectly, reduced anthropogenic pressures on the environment. Namely, according to the results of the research carried out by Miloševic et al., (2010), the area of the Stara Planina higher than 600 m above the sea level represents an emigration zone. The process has been the most intensive in the area of Knjaževac and Dimitrovgrad where some villages have completely disappeared, while in others the population has declined to less than 10. Based on the statistical data for the period 1971-2002, Pavlović and Jančić (2009) have underlined in their research that was carried out in the area of the Zaječar municipality, that the population is ageing faster in higher settlements (above 350 m). Even though agricultural activity remains the primary activity, due to small population numbers and an unfavorable age structure for intensive agriculture, this form of land use has had less impact on the quality and size of the forest communities than decades before that. Poor and moderate grazing has even had a positive impact on the formation of the coniferous canopy, whereas intense pressure due to animal husbandry has a negative effect (Whitesides and Butler, 2010).

The Stara Planina mountain acquired the status of a Nature Park and has been under protection since 1997 as a natural resource of great importance. The areas of the Stara Planina that correspond to the elevation zones of the upper range of forests are subjected to protective regimes which strictly prohibit the use of natural resources and changes of the autochthonous vegetation cover. Among other things, favorable conditions are expected to be created for spontaneous restoration of vegetation at the highest limits of the forests due to controlled anthropogenic pressure.

Fig. 1. *Tri čuke*: - the upper tree line at an altitude of 1900 m (S. Belij, 2003).

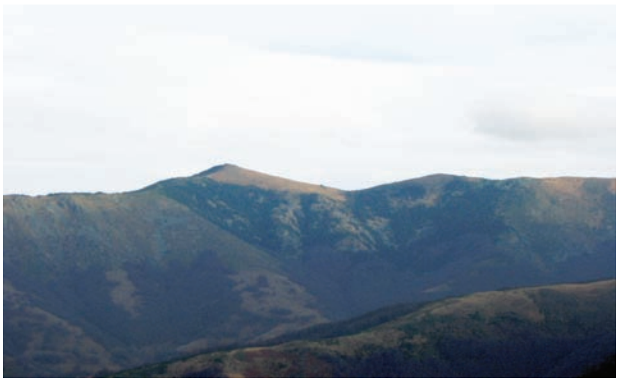

Fig. 2. *Golemi kamen* – a rare example of an upper tree line above the altitude of 1900 m (B. Milovanović, 2004).

At which time period positive changes in vegetation cover are possible to be concluded? The greatest number of taxa show relatively short periods of stagnation in growth after the appearance of shoots; they usually follow the growth of pioneering communities with almost exponential speed (Moore, 2003). There is no doubt that both climatic and anthropogenic factors have affected the recent dynamics of the upper tree line in the Stara Planina mountain, by acting in the same direction - favoring its increase. However, during the field research that was carried out in 2003 and 2004 we did not observe any substantial changes in elevation of the upper tree line when compared to the data of Mišić et al. (1978) (Figures 1 and 2). Further research will attempt to identify the reasons for the slower responses of these taxa to the current climate change.

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