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CLIMATE-VEGETATION CHARACTERISTICS OF KOPAONIK MOUNTAIN IN SERBIA

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Abstract: The values of basic climate elements for the definite altitude (from 750 to 1,950 m) were obtained, by the application of the calculated altitudinal linear gradients characterized by the altitudinal distribution of the certain forest zones in the Kopaonik mountain massif in central Serbia. At the lower limit of the zone the average annual temperature ranges from 6.8°C at the south exposure to 7.1°C at the north exposure (in the vegetation period it is about 13°C), and at the upper limit it is 1.8°C. The average annual quantity of precipitation at the lower limit of the zone is below 776 mm at the south exposure, and it is 861 mm at the north exposure, whereas at the upper limit of the zone it is above 955 mm. The climate classification by Thornthwaite's method shows that in the analyzed altitudinal forest zone in Kopaonik the following climate types occur: midly humid (B_1) at the lower limit, extremely humid (B_4) at the altitudes ranging from 1,500 to 1,700, and perhumid (A), at the altitudes above 1,700 m. The interdependence of the occurrence and survival of the forest vegetation in this area, its distribution and altitudinal differentiation, and the climate characteristics, is proved in this research as well. Each altitudinal forest zone is characterized by the specific microclimate conditions.

Key words: Kopaonik, Serbia, climate conditions of Kopaonik, vegetation characteristics of Kopaonik, climate-vegetation classification

1. INTRODUCTION

The occurrence and survival of the vegetation in a certain area, its distribution and altitudinal differentiation, as well as zoning, in addition to the other ecological conditions, mainly depends on the climate characteristics of the area and their change due to the altitude**.** The authors such as Leibundgut (1951), Bunuševac (1951), Kolić & Gajić (1975), Jovanović & Kolić (1980), Fang & Yoda (1988), Cogbill & White (1991), Krstić (1998, 2005, 2008), Krstić et al., (2001), Krstić & Stojanović (2002), Krstić & Ćirković (2005), Krstić & Govedar (2006), Pendry & Proctor (1996), Smailagic et al., (2002), Kimmins (2004), Körner & Paulsen (2004), Beniston et al., (1997), Richardson et al., (2004), Wang et al., (2004), Tang & Fang (2006), Hayes et al., (2007), etc, particularly emphasizes the importance of the climate factors and undoubted connection between them, as well as the alternations of the certain types of vegetation, and the occurrence of the upper limit of the forests and vegetations.

The terrain exposure and geographical position are the important determiners of the local temperature conditions (Kimmins, 2004). According to Ohsawa (1990), the altitude and temperature conditions are limiting factors for the forest, whereas the change of the temperature limit for the forest is in the accordance with the longitude - the change of the zoning of the mountain vegetation along longitude. According to Beniston et al., (1997), the changes of the climate on the sites located at the great altitudes are very "sensitive" indicators of the environmental conditions. Based on the values of the temperature extremes and temperature sums, the global forecasting of the upper limit of trees can be made (Körner & Paulsen, 2004).

This paper describes the climate-vegetation characteristics, their interdependence, and conditions of the mountain massif Kopaonik located in the

Balkans Penninsula - in Southeast Europe (Fig. 1). Because of the impressive nature characteristics, which represent the specific sites and range of the numerous forest and grass phytocoenosis, Kopaonik was declared the National Park of the Year, in 1981. The relief of Kopaonik is very favourable for the development of the winter sports, and it represents the most significant mountain winter tourist center in Serbia.

According to Rakićević (1980), this area belongs to the Kopaonik climate region, the global climate of which is characterized by the coldest and longest winter in central Serbia, with low temperatures from December to April, frequent early autumn and late spring frosts, high and long-lasting snow drifts. The vegetation of Kopaonik is almost ideally differentiated into the altitudinal zones (Mišić & Popović, 1954).

In addition to the above facts, the researches are significant because this mountain is the center of biodiversity and contains many ecosystems with rather low anthropogenic influence, particularly at higher altitudes (Grunewald et al., 2009), whereas high mountains and their ecosystems are often significant for the studies of the influence on the climate changes (Scheithaeuer et al., 2009).

According to the above facts, this paper is aimed at a more detailed determination of the influence of the orographic and climate factors on the occurrence and distribution of the certain types of the forest vegetation in the mountain massif Kopaonik in Serbia along the with the other ecological conditions, i.e. at more detailed definition of their interdependence.

2. THE OBJECT OF THE RESEARCH AND METHOD OF WORK

Kopaonik stretches from 43°28 to 42°44 of the north latitude, i.e. from 20°37' to 21°24' of east longitude. It is 83 km long, and 63 km wide. The main ridge spreads in the direction northwest-southeast. The greatest part of the mountain is located at the altitudes from 500 to 1,000 meters. In addition to the highest summit, located at 2,017 meters above the sea level (Pančićev vrh), there are several outstanding summits, located at the altitudes above 1,900 meters above the sea level. The occurrence of the steep or gently-inclined slopes, saddles, deep and steep brooks, as well as gorges, reflects the well-expressed relief characteristics.

The vegetation characteristics of Kopaonik were determined based on the literary sources, in which the altitudinal classification of the vegetation, as well as its altitudinal zonation are described: Mišić & Popović (1954), Mišić (1964), Jović & Tomić (1990).

The climate characteristics were determined based on the data of the multi-annual measuring of the climate (from 1961 to 2005) performed by the meteorological stations, typical for this area. In the aim of the increasing of the accuracy and more realistic assessment of the micro-climate characteristics, the method of the altitudinal gradients of the climate elements, obtained by using the data of the lowland meteorological stations (Kraljevo - located at 215 meters above the sea level and Prishtina - located at 573 meters above the sea level), and the data of one mountain meteorological station (Kopaonik - located at 1,710 meters above the level) in the investigated area, was applied.

Figure 1. The geographical position of Serbia and "Kopaonik" locality.

Table 1. Vertical classification of the forest vegetation of Kopaonik (Misic & Popovic, 1954)

Exposition and height above sea level (m)		Forest belt		Existing forest communities	Dominant phytocoenosis
Northern	Southern				
< 750	< 1050	I Hilly	a) lower	Austrian Pine, Oaks, Beech	*Quercetum montanum s.lat.*
750-1000	1050-1150		b) upper	Beech, Sessile oak	*Fagetum montanum*
1000-1100	1150-1250	II Mountain	a) lower	Beach	
1100-1500	1250-1550		b) upper	Beech-Fir, Spruce-Fir	*Abieti-Fagetum*
1500-1600	1550-1650	III High mountain	a) lower	Beech-Spruce, Spruce, Pre-Alpine Beech	*Piceetum excelsae*
1600-1700	1650-1750		b) upper	Pre-Alpine Beech-Spruce, Spruce, Beech	
1700-1850	1750-1850	IV Subalpine	a) lower	Pre-Alpine Spruce with Blueberry and Dwarf Juniper	*Vaccinio-Juniperetum sibiricae*
1850-1950	1850-1950		b) upper	Bluebery and Dwarf Juniper shrub	
> 1950	> 1950	V Alpine belt		Highland pastures	*Poetum violaceae*

By the use of the calculated gradients, the linear changes of the values of the climate elements for the certain altitude (from 750 to 1,950 m), characterized by the altitudinal distribution of the certain forest cover, were obtained. The annual and seasonal values (for the growth season) of the most important climate elements, significant for the development of the vegetation: temperature and precipitation, as well as climate-geographical characteristics (Lang's rain factor, serving as a base for the climate-vegetation classification of the climate), are presented. In addition, the belonging to a certain climate type was determined by using the methods by Thornthwaite and Lang.

3. RESULTS

3.1. Vegetation characteristics of Kopaonik

Although the vegetation of Kopaonik Mountain is almost ideally differentiated into altitudinal forest zones, there is a difference between the north and south sides the massif (Mišić & Popović, 1954), which is presented in the table 1. The map of vertical distribution forest vegetation on Kopaonik is presented in figure 2.

I. Hilly area, in the lower part of which the oak phytocoenosis are dominant on all aspects, whereas Austrian pine (*Pinus nigra* Arn.) forests occur fragmentary within oak zone. In the upper part of this area hilly beech forest are dominant on northern, and oaks on southern aspects. Characteristic species are: *Quercus petraea* (Matt.) Liebl, *Quercus cerris* L, *Quercus pubescens* Willd, *Quercus frainetto* Ten, *Fagus sylvatica* subsp. *moesiaca* (Malý) Szafer, *Fraxinus excelsior* L, *Fraxinus ornus* L, *Carpinus orientalis* Mill, *Carpinus betulus* L, *Corylus avellana* L, *Corylus colurna* L, *Acer campestre* L, *Acer tataricum* L, *Cornus mas* L, *Cornus sanguinea* L, *Sorbus torminalis* (L.) Crantz, *Prunus avium* L, *Pyrus communis* subsp. *pyraster* (L.) Ehrh, *Juniperus oxycedrus* L, *Clematis vitalba* L, *Salvia glutinosa* L, *Genista tinctoria* var. *ovata* (Walds.&Kit.) Schultz, *Melica uniflora* Retz, *Stellaria holostea* L, *Scrophularia nodosa* L, *Circaea lutetiana* L, *Astragalus glycyphyllos* L, *Clinopodium nepeta* subsp. *glandulosum* (L.) Govaerts, *Lathyrus niger* (L.) Bernh, *Lathyrus vernus* (L.) Bernh, *Asplenium septentrionale* L. etc.

II. Mountain zone, which is clearly divided into two parts: the lower part is dominated by pure beech forests, while beech-fir forests occurr solely on northern aspects. The upper part is dominated by mixed beech-fir forests, with occurence of mixed beech-fir-spruce, spruce-fir and pure spruce forests on northern aspects.

Characteristic species are: *Picea abies* (L)Karst, *Abies alba* Mill, *Fagus sylvatica* subsp. *moesiaca* (Malý) Szafer, *Sorbus aucuparia* L, *Sambucus racemosa* L, *Lonicera alpigena* L, *Ribes petraeum* Wulfen, *Vaccinium myrtyllus* L, *Erica spiculifolia* Salisb, *Daphne* spp, *Cardamine enneaphyllos* (L.) Crantz, *Pyrola* spp, *Senecio nemorensis* L, *Doronicum austriacum* Jacq, *Gentiana asclepiadea* L, *Aegopodium podagraria* L, *Actaea spicata* L, *Bartramia pomiformis* Hedw. etc.

III. High mountain zone, which is characterized by the spruce forests (*Piceetum excelsae montanum serbicum*). In the lower part of the zone, on southern aspects, subalpine beech forests (*Fagetum moesiacae subalpinum inferiorum*)

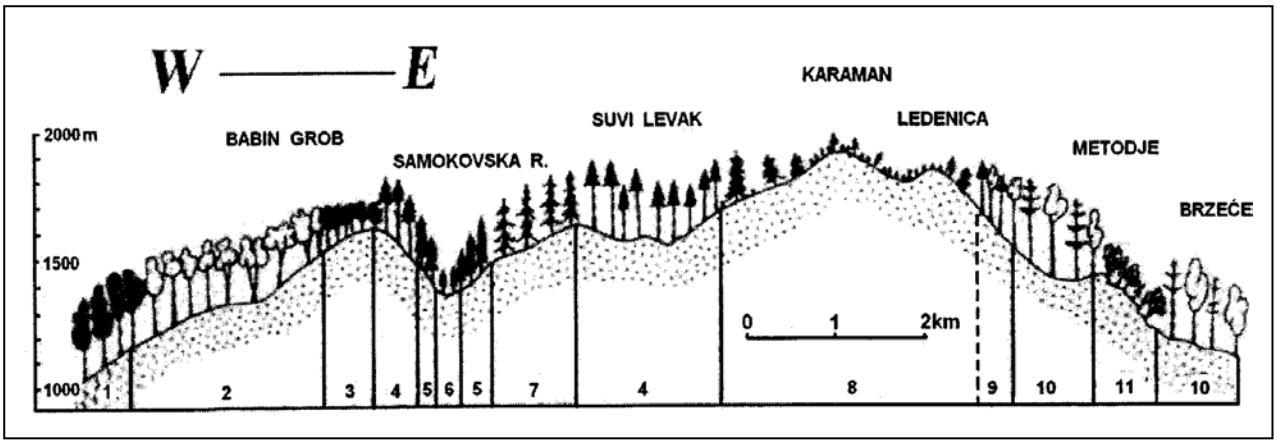

Figure 2. Vertical distribution of the forest vegetation on Kopaonik Mt. (according to Mišić & Popović 1954): 1. *Fagetum montanum*; 2. *Luzulo-Fagetum montanum*; 3. *Fagetum subalpinum*; 4. *Piceetum excelsae oxalidetosum*; 5. *Piceetum excelsae hylocomietosum*; 6. Bogs; 7. *Piceetum excelsae subalpinum*; 8. *Vaccinio-Junipero-Piceetum subalpinum*; 9. *Fago-Piceetum*; 10. *Abieti-Fagetum*; 11. *Seslerio-Fagetum.*

occur, while on colder aspects, apart from monodominant spruce forests, mixed beech-spruce and beech-fir-spruce forests occur also. In the upper High mountain zone spruce predominates on all aspects, whereas on southern aspects beech stands occur locally, which is at the upper limit of its occurrence, and it obtains the form of the bushy trees (*Fagetum moesiacae subalpinum superiorum*). Fir is not present in this zone.

Characteristic species are: *Picea abies* (L.) Karst, *Fagus sylvatica* subsp. *moesiaca* (Malý) Szafer, *Juniperus communis* var. *saxatillis* Pall, *Vaccinium myrtyllus* L, *Acer heldreichii* Orph, *Ranunculus platanifolius* L, *Ribes* spp, *Lonicera* spp, *Adoxa moschatellina* L. etc.

IV. Subalpine zone is in its lower part comprised of shrubby formations of Dwarf Juniper and Blueberry with occurence of shruby spruce foms. The upper zone is composed od Dwarf Juniper and Blueberry without spruce.

Characteristic species are: *Juniperus communis* var. *saxatillis* Pall, *Vaccinium myrtyllus* L, *Picea abies* (L.) Karst. etc.

V. Alpine zone is above the treeline, where the high mountain pastures occur. The most common plant community is *Poetum violaceae* Pavl 55, whereas *Nardetum strictae* Greb 50 and *Sileneto-Festucetum fallacis* R.Jov 55 also occur (Jović & Tomić 1990).

3.2. Climate characteristics of Kopaonik

3.2.1. Air temperature

The main characteristics of the temperature regime for the above altitudes in the analyzed altitudinal zone are the following (Table 2):

- at the lower limit of the zone (located at 750 m above the sea level at the north side of Kopaonik) the average annual temperature is 8.5°C, i.e. 7.5°C on the south side (located at 1,050 meters above the sea level), and at the upper limit (located at 1,950 meters above the sea level) it ranges from 1.8° to 1.9°C;

- at about 1,500 meters above the sea level (boundary zone between the broadleaf and conifer trees), the average annual temperature is balanced (4.3°C);

Table 2. The change of the average air temperature (^{o}C) – annual (An), in the growing season (GS) and amplitudes (A) due to the increase of the altitude (Al) in the period from 1961 to 2005.

Altitudinal belt	Northern aspect				Southern aspect			
	Al.(m)	An.	GS	A	Al. (m)	An.	GS	A
I a	750	8.5	14.6	19.9	1050	7.5	13.5	19.8
I b	1000	7.1	13.0	19.1	1150	6.8	12.8	19.4
II a	1100	6.6	12.3	18.8	1250	6.2	12.0	18.9
II b	1500	4.3	9.7	17.5	1550	4.3	9.8	17.9
III a	1600	3.7	9.0	17.2	1650	3.7	9.1	17.5
III b	1700	3.2	8.3	16.9	1750	3.1	8.4	17.1
IV a	1850	2.3	7.4	16.5	1850	2.5	7.6	16.7
IV b	1950	1.8	6.7	16.2	1950	1.9	6.9	16.3
V	> 1950	< 1.8	< 6.7	< 16.2	> 1950	< 1.9	< 6.9	< 16.3

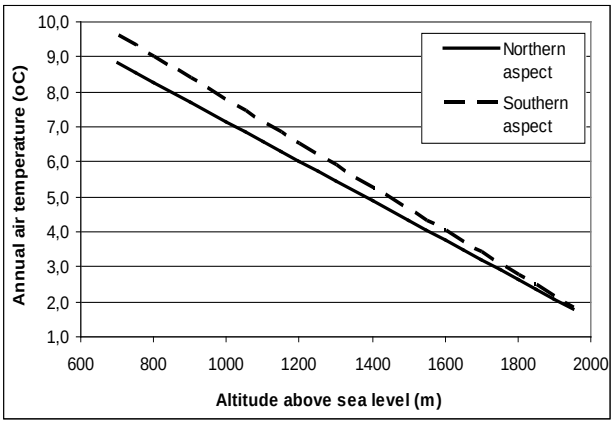

Figure 3. Change of the annual average air temperature

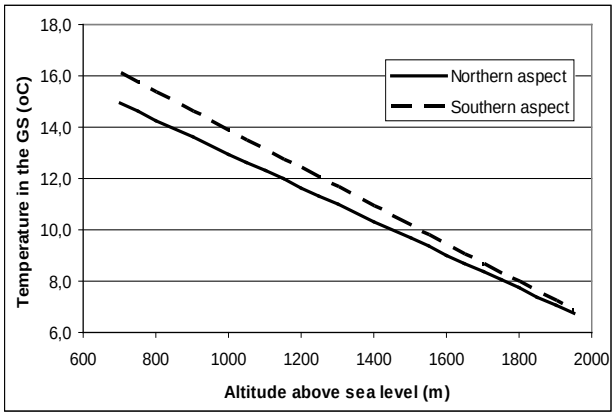

Figure 4. Change of air temperature in the growing season

- the annual gradient of the change of the air temperature due to increase of the altitude is 0.56°C/100 m on the north side of Kopaonik it is 0.6°C/100 on the south side, and in the vegetation period it is 0.7 °C/100 m. Change of the annual average air temperature and air temperature in growing season, are presented in figures 3 and 4;
- air temperature in the growing season (April-September) at the lower limit ranges from 13.5° and 14.6° C, and at the upper limit it ranges from 6.7° to 6.9° C;
- the annual temperature amplitude changes and is about 20°C at the lower limit of the zone, whereas it is about 16°C at the upper limit.

3.2.2. Precipitation regime

The average annual quantity of precipitation (P) at the lower limit of the analyzed forest zone ranges from 743 mm (on the south side) to 827 mm on the north side, whereas at the upper limit it is about 1,000 mm (Table 3). During the vegetation period from 57 to 61% of the annual quantity of the water sediment is distributed.

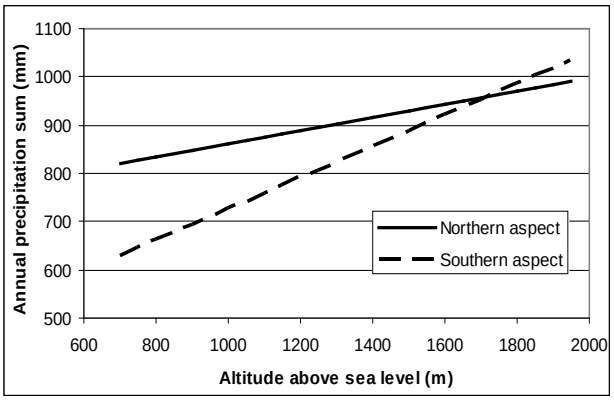

Figure 5. Change of the annual precipitation sum

Due to the increase of the altitude by 100 m, the annual quantity of precipitation increases by about 20 mm on the south, and by about 9 mm on the north side of Kopaonik (Fig. 5).

Change ratio of the precipitation sum in growing season and annual sum is presented in table 3 and figure 6.

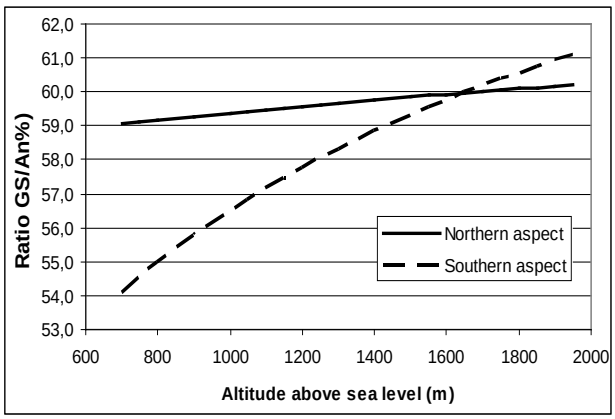

Figure 6. Change ratio GS/An (%)

3.2.3.Hydric balance by Thornthwaite

The calculated elements of the hydric balance (the ratio of deficit to surplus of water in the soil, for the analyzed altitudes show the following (Table 4):

- the potential evapotranspiration (PE) decreases by the increase of the altitude - at the lower limit of the analyzed zone it ranges from 582 to 614 mm, which accounts for about 75% of the annual quantity of precipitation, whereas at the upper limit it is 420 mm, i.e. only about 40% of the annual quantity of precipitation;
- actual evapotranspiration (AE) at all altitudes is equal to potential evapotranspiration,
- there is no deficit, i.e. lack of water in the soil;
- the surplus of water in the soil (WS) occurs in the colder part of the year and accounts for 25% of the annual quantity of precipitation at the lower limit of the analyzed zone (WS/P), whereas it accounts from 60 to 64% at the upper limit. At

altitudes above 1,600 meters the surplus of water accounts for more than 50% of the annual quantity of the precipitation. In the zone of the oak forests the water surplus occurs from November to June at the altitudes above 1,500 m on the north side of Kopaonik, whereas at the altitudes above 1,600 m on the south side the surplus of water does not occur only in the summer months (in July and August).

3.2.4. Climate classification

The climate classification using the method of Thornthwaite was conducted based on the values of the calculated hydric balance. In the analyzed altitudinal forest zone, based on the climate index of Thornthwaite (Im), the climate ranges from mild to extremely humid (B_1-B_4) up to about 1,700 meters above the sea level, whereas at greater altitudes the climate is perhumid (A), i.e. very wet (Table 5).

Table 3. The change of the precipitation sum (P mm) - annual (An), in the growing season (GS), and their ratio (GS/An%) due to the increase of the altitude (Al) in the period from 1961 to 2005.

Altitudinal belt	Northern aspect				Southern aspect			
	Al. (m)	An.	GS	GS/An %	Al. (m)	An.	GS	GS/An %
I a	750	827	489	59.1	1050	743	422	56.8
I b	1000	861	511	59.4	1150	776	446	57.5
II a	1100	874	520	59.5	1250	808	469	58.1
II b	1500	928	556	59.8	1550	906	539	59.6
III a	1600	942	564	59.8	1650	938	563	60.0
III b	1700	955	573	60.0	1750	971	586	60.4
IV a	1850	976	587	60.1	1850	1003	610	60.8
IV b	1950	989	596	60.2	1950	1036	633	61.1
V	> 1950	>989	>596	>60.2	> 1950	>1036	>633	>61.1

Table 4. The changes of the annual values of the elements of the hydric balance calculated by the use of Thornthwaite's method due to the increase of the altitude (Al) in the period from 1961 to 2005.

Altitud. belt	Northern aspect					Southern aspect				
	Al. (m)	PE mm	AE mm	WS mm	WS/P %	Al. (m)	PE mm	AE mm	WS mm	WS/P %
I a	750	614	614	213	25.8	1050	582	582	183	24.6
I b	1000	570	570	290	33.6	1150	562	562	213	27.4
II a	1100	553	553	321	36.7	1250	542	542	266	32.9
II b	1500	486	486	442	47.6	1550	489	489	417	46.0
III a	1600	470	470	472	50.1	1650	471	471	467	49.8
III b	1700	455	455	501	52.5	1750	453	453	517	53.2
IV a	1850	431	431	544	55.7	1850	436	436	567	56.5
IV b	1950	418	418	571	63.6	1950	420	420	616	59.5
V	> 1950	<418	<418	>571	>63.6	> 1950	<420	<420	>616	>59.5

Table 5. The change of the climate characteristics and climate classification of Thornthwaite due to the increase of the altitude in the period from 1961 to 2005.

Altitud. belt	Northern aspect				Southern aspect			
	Al (m)	Im	Symb.	Climate type	Al. (m)	Im	Symb.	Climate type
I a	750	34.7	B_1	Mildly humid	1050	29.2	B_1	Mildly humid
I b	1000	50.8	B_2	Moderately humid	1150	38.0	B_1	Mildly humid
II a	1100	58.0	B_2	Moderately humid	1250	49.0	B_2	Moderately humid
II b	1500	91.0	B_4	Extremely humid	1550	85.3	B_4	Extremely humid
III a	1600	100.0	B_4	Extremely humid	1650	99.1	B_4	Extremely humid
III b	1700	110.1	A	Perhumid	1750	114.2	A	Perhumid
IV a	1850	126.1	A	Perhumid	1850	129.9	A	Perhumid
IV b	1950	136,6	A	Perhumid	1950	146.8	A	Perhumid
V	>1950	>136.6	A	Perhumid	> 1950	>146.8	A	Perhumid

Im – climate index by using Thornthwaite's method (Kolić, 1988);
A, B_1-B_4 – the symbol of the climate type by using the Thornthwaite method

Table 6. The change of the climate characteristics and climate classification by using Lang's method due to the change of the altitude in the period from 1961 to 2005.

Altitud. belt	Northern aspect			Southern aspect		
	Alt. (m)	RF	Climate type	Alt. (m)	RF	Climate type
I a	750	97	Climate of the weak forests – not in the optimal level	1050	100	Climate of the weak forests – not in the optimal level
I b	1000	118	Climate of the high forests – reached the optimum level	1150	113	Climate of the high forests – reached the optimum level
II a	1100	128	Climate of the high forests – reached the optimum level	1250	130	Climate of the high forests – reached the optimum level
II b	1500	189	Perhumid	1550	208	Perhumid
III a	1600	212	Perhumid	1650	252	Perhumid
III b	1700	242	Perhumid	1750	313	Perhumid
IV a	1850	302	Perhumid	1850	404	Perhumid
IV b	1950	359	Perhumid	1950	557	Perhumid
V	>1950	>359	Perhumid	> 1950	>557	Perhumid

RF- rain factor (climate index) by Lang (Kolić, 1988)

Based on the climate classification by using Lang's method (Table 6), which is defined based on the rain factor (RF), it can be observed that in the forest zone of Kopaonik, up to 800 m above the sea level on the north side, and about 1,100 m above the sea level on the south side of Kopaonik the forests do not reach their climate-physiological-biological optimal level, in contrast to the greater altitudes. The perhumid climate occurs at the altitudes above 1,500 m.

3.3. Climate-vegetation characteristics of the area

By comparing the obtained climate data with the altitudinal zonation of the vegetation in Kopaonik, the following characteristics are noticed:

1. In the hilly area of Kopaonik, in the zone of the oak and beech forests (*Quercetum montanum s.lat.* i *Fagetum monatanum s. lat.*), which occurs up to 1,000 meters at the north exposure, and up to 1,1150 m above the sea level, at the south exposure, the climate characteristics are the following: the average annual air temperature ranged from 6.8 at the south exposure, to 7.1°C at the north exposure (in the vegetation period it is about 13°C), the annual quantity of the precipitation is below 776 mm at the south aspect, and 861 mm at the north aspect.

The drainage is abundant, and the surplus of water in the soil is not present only in the summer months, when there is a period of the moderate drought. In this zone the climate ranges from the moderately to the midly continental. According to Lang's bioclimate classification the forests in the lower part of the zone have not reached the optimal climate-physiological value, whereas they reached it in the upper part of the zone. The limit is located at about 800 meters above the sea level on the north side of Kopaonik, and at 1,100 meters above the sea level on the south side of it. By Thornthwaite's climate classification, the climate ranges from midly to moderately humid.

2. Climate-regional zone of the mountain beech forest (*Fagetum moesiacae montanum* Jov.) and beech-fir forest (*Abieti-Fagetum s.lat.*), located at the altitudes from 1,000 to 1,500 m, is characterized by the average annual temperature from 4.3 to 7.1°C (in the vegetation period it ranges from 9.7 to 3.0°C), and the annual quantity of precipitation ranges from 806 to 928 mm. The drainage is abundant, and the surplus of water in the soil is not present only in the summer months. In this altitudinal zone the climate ranges from mildly continental (mountain) at the lower limit of the zone, to the maritime at the upper limit. According to Lang's bioclimate classification the climate ranges from humid to perhumid, and the forests have reached their biological optimal level. According to Thornthwaite's classification the climate ranges from humid to extremely humid.

3. High mountain vegetation zone (located at the altitudes ranging from 1,500 to 1,750 m), in which spruce forests are dominant (*Piceetum excelsae s.lat.*), is characterized by the average annual air temperature which ranges from 3.1 to 4.3°C (in the vegetation period it ranges from 8.3 to 9.8°), and annual quantity of precipitation ranging from 906 to 971 mm. The surplus of water is not present in the soil only in July and August. The climate in this altitudinal zone is maritime.

According to Lang's bioclimate classification the climate is perhumid, and the forests have reached their optimal biological value, whereas according to Thornthwaite's classification the climate is extremely humid at the lower limit of the zone, and perhumid at the upper limit.

4. In the Subalpine vegetation zone (located at the altitudes from 1,700 to 1,950 m, depending on the terrain exposure), which represents the upper zone of the forest vegetation (*Vaccineto-Junipereto–Piceeto subalpinum*), the average annual air temperature ranges from 1.8 to 3.2°C (in the vegetation period it ranges from 6.7-8.4°C), and the annual quantity of precipitation ranges from 955 to 1,036 mm. The drainage is also abundant. According to Lang's and Thornwhaite's classification the climate is perhumid.

5. In the Alpine zone (located at the altitudes above 1,950 m), where the high mountain grass vegetation is present, the average annual air temperature is below 1.8°C (in the vegetation period it is below 6.7°C), and the annual quantity of precipitation is above 955 mm. The climate is perhumid.

4. DISCUSSIONS

According to Smailagić (1995), the occurrence of the specific factors, which determine the climate characteristics of the mountain massif of Kopaonik, is conditioned by the geographical position of it. Since it is 150-200 km away from the Adriatic Sea, and it is about 300 km away from the Aegean Sea, there is a strong impact of the circulation of the air masses. By the direction and altitude, it represents the climate boundary between the Mediterranean climate in the southwest and the continental climate in the north and northeast, since it hinders the migration of the warmer air masses from the south parts to the north. The vegetation cover, except for the highest summits, influences the climate by the increase of the air humidity, decrease of the velocity of the wind and the temperature amplitude. Due to all the above characteristics Kopaonik is located in the zone of the moderate continental climate, but by the increase of the altitude the local mountain climate becomes dominant, owning to which the highest summits of Kopaonik have the characteristics of the Alpine climate.

The vegetation of Kopaonik is almost ideally differentiated into the altitudinal zones. The distribution of some forest communities, along with the altitude and geological substratum, is conditioned by a number of other ecological factors, such as the configuration of the terrain, exposure, and inclination, which caused the occurrence of the micro and mesoclimate conditions. Since these conditions determine the type of the forest and limit the spread of it, there is a difference between the north and south sides of the massif - the lower and upper limits of the distribution of some phytocoenosis descend lower than the south limits, which mainly occurs on the north sides (Mišić & Popović, 1954; Mišić, 1964). Jović & Tomić (1990) present the ecologically-biological (typological) classification of the forest and forest sites of the National Park "Kopaonik". The authors singled out three forest complexes: Complex of the mesophilic beech and beech-conifer forest types, the complex of frigophillic conifer forest types, and the complex of the subalpine bushy conifers and broadleaves. In the mountain massif of Pirin in neighbouring Bulgaria the zone located at the altitudes from 1,900 to 2,250 meters, is characterized by two subendemic tree species - *Pinus peuce* Grisebach and *Pinus heldreichii* (Grunewald et al., 2009).

The above main characteristics of the temperature regime for the altitudes in the analyzed altitudinal zones are in the accord with the claims by Tang & Fang (2006) that the changes of the temperature due to the altitude greatly influences the occurrence and the distribution of the plants and vegetation by the change of the altitude in the mountain area. In Serbia the continental regime of the precipitation is dominant, which is characterized by two maximum and two minimum quantity of precipitation during the year. The primary maximum most usually occurs in the early summer (June), and in some places in the late spring (May), whereas the secondary maximum most often occurs in October, and in some areas in November as well. The primary minimum occurs in the late winter (in February), or in early March, whereas the secondary minimum mostly occurs in the early autumn – in September (Kolić, 1986). In Kopaonik, in the analyzed altitudinal zone, the continental regime of the precipitation is dominant, but the primary miminum occurs in January, and the secondary minimum in October.

In the comparison with the widespread forest communities in Kopaonik, in southeast Serbia the zone of the communities of the hilly beech forests (*Fagetum submontanum s. lat.*) is present, at the altitudes up to 800 m, mainly at the colder – north, northeast and northwest exposures. At the altitudes ranging from 800 to 1,300 m the beech forms climate-regional zone of the mountain forest (*Fagetum moesiacae montanum s.lat.).* Above the zone of the mountain beech, the zone of the

Subalpine beech forest is located (*Fagetum moesiacae subalpinum s.lat.*), which occurs in the oustanding ridges at greater altitudes, up to 1,530 m (Jovanovic & Kolic, 1980). In the altitudinal zone the community of the hilly beech forests, the air temperature does not exceed 7.2°C (in the vegetation period it is up to 12.9°C), and the annual quantity of precipitation is up to 811 mm; the zone of the mountain beech forest is characterized by the average annual temperature which ranges from 7.2 to 4.8°C (in the vegetation period it ranges from 12.9 to 10.2°C), the annual quantity of precipitation ranges from 811 to 843 mm; in the altitudinal range of the zone of the Subalpine beech forest the average annual air temperature ranges from 4.8 to 3.8°C (in the vegetation period it ranges from 10.2 to 9.2°C), the annual quantity of precipitation ranges from 843 to 856 mm (Krstić & Ćirković, 2005). According to Smailagić *et al*., (2002), in east Serbia the beech forms the climate-regional zone of the mountain beech forest (*Fagetum moesiacae montanum* Jov.) at the altitudes ranging from 600 to 900 (1,100) m. Above the mountain zone of the beech, at the summits of Deli Jovan Mountain and the oustanding ridges at the greater altitudes, the zone of the subalpine beech forest occurs (*Fagetum altimontanum moesiacum* Jov). The main characteristics of the temperature regime of the analyzed altitudinal zone are the following: at the lower limit of the zone the average annual temperature is 8.6°C, and at the upper limit it is 6.1°C, whereas in the vegetation period it ranges from 15.5°C to 12.6°C. The annual quantity of precipitation ranges from 666 mm at the lower limit, to 700 mm at the upper limit of the zone.

The methods of the climate classification by Thornthwaite and Lang, which are of great importance for the needs of forestry, and particularly for the selection of the methods of forest management and reforestation, are most frequently used (Kolić, 1988).

The climate classification by Thornthwaite shows that in the analyzed altitudinal forest zone in Kopaonik the following climate types occur: midly humid (B_1) at the lower limit, extremely humid (B_4) at the altitudes ranging from 1,500 to 1,700, and perhumid (A), at the altitudes above 1,700 m. In east Serbia the following climate types are present: subhumid dry climate (C_1), subhumid wet climate (C2), at the altitudes up to 800 m, and midly humid climate, at the altitudes above 800 m (Smailagić *et al*., 2002), whereas in southeast Serbia the following climate types occur: midly humid, increasingly humid (B3) at 800 m above the sea level, and perhumid climate, at the altitudes above 1,400 m (Krstić & Ćirković, 2005).

The bio-climate classification of climate by Lang shows that at the lower limit of its altitudinal range the forests of Kopaonik have not reached their climate-physiological (biological) optimal value, in the contrast to the forests at the upper limit. This limit is located at the 800 m above the sea level on the north side and at the 1,110 m on the south side. According to Smailagić et al., (2002) in east Serbia the limit is located at about 900 m above the sea level, whereas in southeast Serbia it is also located at 800 m above the sea level (Krstić & Ćirkovic, 2005).

5. CONCLUSIONS

This paper presents the climate-vegetation characteristics of the altitudinal zone ranging from 750 to 1,950 meters above the sea level in Kopaonik. Each altitudinal zone of a certain type of forest have specific climate characteristics. The general characteristics of the temperature regime of the analyzed altitudinal zone are the following: at the lower limit of the zone the average annual temperature ranges from 6.8°C at the south exposure to 7.1°C at the north exposure (in the vegetation period it is about 13°C), and at the upper limit it is 1.8°C. The average annual quantity of precipitation at the lower limit of the zone is below 776 mm at the south exposure, and it is 861 mm at the north exposure, whereas at the upper limit of the zone it is above 955 mm.

The bio-climate classification of the climate by Lang, defined according to the rain factor, shows that in the analyzed altitudinal zone the climate ranges from humid to perhumid. The forests have not reached their climate-physiological (biological) optimal level at the lower limit of its altitudinal zone, in contrast to the forest on the upper limit. This limit is located at about 800 m above the sea level on the north side of Kopaonik, and at 1,100 m above the sea level on the south side of it.

The climate classification by Thornthwaite shows that in the analyzed altitudinal forest zone in Kopaonik the following climate types occur: midly humid (B_1) at the lower limit, extremely humid (B_4) at the altitudes ranging from 1,500 to 1,700, and perhumid (A), at the altitudes above 1,700 m.

The interdepence of the occurrence and survival of the forest vegetation in this area, its distribution and altitudinal differentiation, and the climate characteristics, is proved in this reseach as well. Each altitudinal forest zone are characterized by the specific microclimate conditions.

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