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Оригинални научни рад

EFFECT OF GLOBAL SOLAR RADIATION THREATS TO FOREST FIREIN THE AREA OF NATURE PARK „GOLIJA“ SERBIA

STANIMIR ŽIVANOVIĆ[1]
MARINA VUKIN[2]

Abstract: Solar energy has a strong impact on the vegetation and on creating conditions suitable for the occurrence of fire. This study presents a model which allows determination of the intensity of the global solar radiation at the specified location in the certain period of time. The aim of the study was the evaluation of the forests fire risk factors, depending on the topographic elements. The object of the research was the protected natural area of the Nature Park "Golija", in southwestern Serbia. Since 2001, Golija mountain has been under state protection as the **Golija Nature Park**, which was placed in category I as a natural resource of great importance for Serbia. Because of the exceptionally well-preserved natural environment, but also because of its cultural resources, the committee of the MAB/UNESCO Man and the Biosphere Reserve Programme set up the **Golija – Studenica Biosphere Reserve** within the Golija Nature Park. Changes in global radiation were determined using the method PVGIS-CMSAF considering variability dependant on the side of the world and angle of the surface. The analysis was based on the average monthly and annual values of global solar radiation in the study area. The calculations obtained by PVGIS program showed that in the Golija mountain area there is a significant radiation intensity dependant on the orientation and inclination of the surface. For an area with an inclination of 10°, maximum measured radiation was in July, when the surface was oriented towards the south. Annual values of solar radiation on a surface oriented towards the south, are approximately 60,7% higher than the inflow of energy on the surface oriented toward the north. Some practical information and arguments presented in this study can be used by the competent services in the assessment of forests fire risk factors.

Keywords: global solar radiation, Protected natural area of the Nature Park "Golija", orograph*y*, forest fire

ЕФЕКАТ ГЛОБАЛНОГ СУНЧЕВОГ ЗРАЧЕЊА НА УГРОЖЕНОСТ ШУМА ОД ПОЖАРА НА ПОДРУЧЈУ ПАРКА ПРИРОДЕ "ГОЛИЈА" У СРБИЈИ

Извод: Сунчева енергија има велики утицај на стање вегетације и стварање услова погодних за настанак пожара. У раду је представљен модел који омогућава израчунавање интензитета глобалног сунчевог зрачења, на одређеној локацији и у одређеном временском периоду. Циљ рада био је вредновање фактора угрожености шума од пожара зависно од орографских елемената. Објекат истраживања представљало је Заштићено природно подручје Парк природе "Голија", у југозападној Србији. Од 2001. године подручје планине Голије стављено је под заштиту државе као Парк природе „Голија", који је сврстан у I категорију заштите као природно добро од изузетног значаја. Због очуваности изворних природних вредности, али и културних вредности, MAB/UNESCO комитет у оквиру овог парка природе прогласио је Резерват биосфере Голија – Студеница. Промене глобалног зрачења одређене

1 *PhD Stanimir Živanović, ex Emergency Management Sector of Serbia, Belgrade*
2 *PhD Marina Vukin,expert Associate, University of Belgrade Faculty of Forestry, Belgrade*

су применом метода PVGIS-CMSAF, са сагледавањем промењљивости зрачења у зависности од стране света и угла (нагиба) површине. Анализа је вршена на основу средње месечне и годишње вредности глобалног сунчевог зрачења на истраживаном подручју. Прорачуни добијени од стране PVGIS програма показали су да за подручје Голије постоји изражена разлика интензитета зрачења, у зависности од оријентације и нагиба површине. За површину са нагибом од 10^{o}, максимално измерено зрачење је у јулу уколико је површина са оријентацијом према југу. Годишње вредности енергије сунчевог зрачења на површину која је оријентисана према југу су за око 60,7% веће од прилива енергије на површину оријентисану према северу. Практични подаци и аргументи приказани у овом раду могу да се користе од стране надлежних служби у процени угрожености шума од пожара.

Кључне речи: глобално сунчево зрачење, Природно заштићено подручје Парк природе "Голија", орографија, шумски пожар

1. INTRODUCTION

The duration of sunshine has a great influence on vegetation. Schedule, type and weight gain, as well as the condition of vegetation depends on the amount of solar radiation received. The total potential energy radiation that reaches the surface, changes considerably during the day and those changes depend on the time of the year and the position of the illumination in the area (Markvart, T. *et al.*, 2003; Živanović, S., 2011). All this shows the great variability of the radiation power. Continuity changes can be predicted with greater or lesser accuracy, because the rhythm of phenomenon is known (sunrise and sunset).

The largest quantity of solar radiation in the northern hemisphere is recorded during the period from April to September, which coincides with the vegetation period (Gburčik, P. *et al.*, 2004). In Serbia, it is an average of 3.5 kWhm^{-2} per day (Dragićević, M. S. *et al.*,2007; Gburčik, P. *et al.*, 2006; Radičević, B. *et al.*, 2009). The energy potential of solar radiation in Serbia is about 30% higher than in Central Europe (Radičević, B. *et al.*, 2009; Stamenić, Lj., 2009). Due to the geometry, the inclination and the rotation of the Earth, which therefore comes in different positions relative to the Sun, solar radiation is unevenly distributed on the surface of the Earth (Milanković, M., 1997). In the areas with different exposures and different slopes, duration and intensity of solar radiation is different, as well as the conditions for drying of combustible materials. The intensity of direct solar radiation increases with increasing altitude (Kolić, B., 1988) which is caused by the reduction of air density and the reduction of air adjoins (water vapor, dust particles, etc.). As the sun rays pass the shorter path through the thinner and cleaner air to the mountain peaks than to the plains on small altitudes, their intensity is stronger in the mountains than in the plains. The slope of the terrain affects on the formation of the local climate, soil and plant covers, as well as on the amount of solar radiation received (Xavier, P. *et al.*, 2008) believes that calculating the value of solar radiation on the Earth's surface, considering the relief, is of the great importance for the environment study. Data about the intensity of solar radiation can be calculated based on satellite measurements of extraterrestrial radiation at the edge of the Earth's atmosphere. The intensity of radiation on the earth's surface can be determined by different models. PVGIS

(*Photovoltaic Geographical Information System*) is a model that is widely used for various calculating of the solar radiation intensity (Ramachandra, T.V., 2007; Lalit, K. *et al*., 1997).

The aim of this study is to analyze the impact of solar radiation on the fire vulnerability of forests dependant on the exposure time and the inclination of the vegetation surface.

2. MATERIALS AND METHODS

"Golija" Nature Park is located in the southwestern part of Serbia between 18° 06 'and 23° 01' east longitude and 41° 52' and 46° 11' North longitude. It is 751,83 km^2 wide and covers the territory of the municipalities Ivanjica, Kraljevo, Raska, Novi Pazar and Sjenica. The highest peaks are Jankov Kamen (1.833 m a.s.l.), Radulovac (1.785 m a.s.l.), Bojovo mountain (1.748 m a.s.l.) and Black top (1.725 m a.s.l.). The lowest point in the area is located at the mouth of the river Ibar in Studenica (329 m a.s.l.). Relief has a mountainous character, because over 90% of the territory is on 500 m above the sea level.

Golija belongs to the inner zone of Dinara mountain system. It stretches in the direction west-east in a distance of about 32 km. In the western part, it is curved toward the south and in the eastern part, it is curved to the north. The characteristics of the climate are long and harsh winters, rich in precipitation and short, cool summers. The forest coverage is about 48% of the territory, dominated by broadleaf and mixed forests with sylvan character at some parts. The most widespread are beech forests (63,3% of the total volume), spruce forests (19,5% of total volume) and the forest with mountain maple (Acer heldreichii). The area is dominated by pure stands in 60,5% and by mixed stands on 39,5% of the territory. Since 2001, Golija mountain has been under state protection as the **„Golija" Nature Park**, which was placed in category I as a natural resource of great importance for Serbia. Because of the exceptionally well-preserved natural environment, but also because of its cultural resources, the committee of the MAB/UNESCO Man and the Biosphere Reserve Programme set up the **Golija – Studenica Biosphere Reserve** within the Golija Nature Park.

For the analysis of climatic and meteorological parameters, data from the meteorological station Sjenica (φ 43° 17N 20° 00E λ altitude 1.038 m a.s.l.) had been used. Series of solar radiation data from the area of Nature Park "Golija" (Serbia) had been used for analyze of forests fire risk factors, dependant on the topographic elements. Determination of the intensity of solar radiation was analyzed for the areas with a different slope and deferent orientation towards different parts of the world. The intensity of this radiation was determined by applying the model PVGIS (Photovoltaic Geographical Information System). After processing the data of solar radiation, it is possible to define the forest fires risk dependant on topographic conditions.

3. RESULTS AND DISCUSSION

3.1 Location and climate

"Golija" Nature Park is located in the southwestern part of Serbia. The geographical location is determined with 18° 06' and 23° 01' east longitude and 41° 52' and 46° 11' North longitude. Its altitude and position in relation to the neighboring mountains and valleys have influence on the specific climate of the area (http: /www.hidmet.gov.rs /) with the average annual air temperature of 6,7°C and precipitation of 749,5 mm (period 1981-2010.). In the Golija area there are three main climatic regions:

- Valley with mountain, covers areas up to 700-750 m above the sea level (a.s.l.) and it is characterized by a moderate continental climate modified by the influence of the surrounding mountains;

- Transitional-continental, includes the areas of 700-750 to 1300 m a.s.l., with short and fresh summers, warm days, cool nights and long, cold winters with plenty of snowfall;

- Mountainous, covers an area of more than 1.300 m above sea level, and it is characterized by sharp, cold winters and short chilly summer (*Уредба о утврђивању Просторног плана подручја посебне намене Парка природе Голија, 2009*).

Živanović, S. *et al.* (2013) indicates that this area has the characteristics of humid climate with Bioclimatic area of high forest. The area of this park, where the forests are positioned, was predominately composed by ultramafic, acidic silica and limestone rocks. Plots are preserved, the most common type of brown, rarely rankers, except where the limestone, due to the erosion process, created barren land. Due to the impermeable geological substrate and the abundance of rainfall, Nature Park Golija is rich in water. Golija is a mountain with a well-preserved forests of beech, spruce and maple.

Warmest month on Golija is July on the average daily temperature of 16,5 °C, while the coldest month is January with an average daily temperature of -3,6 °C. Summers are fresh and winters are cold with a with lots of snow that retains for a long time. Annual maximum average precipitation on Golija is in June (79,1 mm) and minimum (46,3 mm) is in January. Based on RHMZ Serbia data, in the period from 1981 to 2010, the average duration of insolation on Golija was 1936,8 hours with a maximum in July of 264,4 hours or with an average insolation of 8,5 hours a day. The minimum duration of sunshine is in December with 72,6 hours or with an average of 2,3 hours a day.

Average values of meteorological data, for Meteorological station Sjenica, in the period 1981 to 2010 are shown in Table 1.

Table 1 Average values of the meteorological data of Sjenica in the period from 1981 to 2010 (Source: http: /www.hidmet.gov.rs/)

Табела 1. Средње вредности метеоролошких података за подручје Сјенице за период 1981-2010. године (извор: http: /www.hidmet.gov.rs/)

Month	Average air temperature (°C)	Precipitation (mm)	Monthly Sunshine duration (hour)
January	-3.6	46.3	87.0
February	-2.7	47.4	101.3
March	1.8	46.4	145.6
April	6.5	55.7	162.3
May	11.5	71.5	206.2
June	14.7	79.1	229.5
July	16.5	66.9	264.4
August	16.2	62.0	246.1
September	11.9	75.6	179.6
October	7.8	62.4	145.7
November	2.2	74.1	96.6
December	-2.1	62.2	72.6

3.2 Geomorphologic characteristics of "Golija" Nature Park

Exposure relief modifies the effect of light and heat in a series of inter-related phenomena and processes (temperature, air and soil and the state of combustible material). The speed of surface water runoff, soil moisture saturation and intensity of geomorphologic processes depends on, inter alia, from the slope of the ground. GIS analysis shows that the aspect of relief on northeast (15,9%), Western (14,4%) and Eastern (14,3%) aspects occupy the largest part of the park (Table 2).

Table 2 Orientation with respect to the compass of "Golija" Nature Park

Табела 2. Оријентација с обзиром на стране света у Парку природе "Голија"

Side of the world	North	South	East	West	Northeast	Southeast	Northwest	Southwest
Share in total area (%)	8.6	9.0	14.3	14.4	15.9	12.3	12.6	12.9

The analysis of inclination angles of the "Golija" Nature Park relief, show that the angles of inclination between 20-30% distributed to 31.6%, on the largest part of the territory (Živanović, S., 2015). It is very important data that only 1.9% of the territory of the park is on the slope greater than 40° (Figure 1,Table 3).

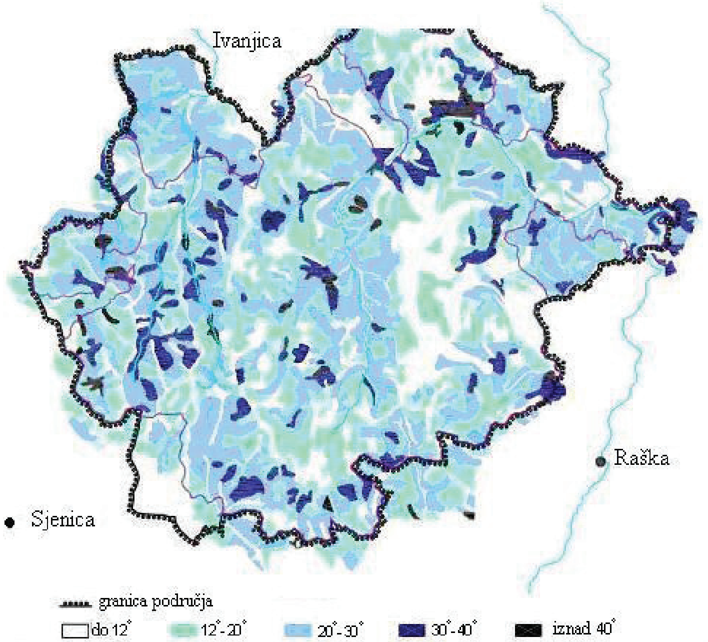

Figure 1 Slope of the terrain "Golija" Nature Park
(Source: CEP 2004)
Слика 1. Нагиб терена у Парку природе "Голија"
(извор: CEP 2004)

Table 3 The values of the angles of inclination of relief "Golija" Nature Park
Табела 3. Вредности углова нагиба рељефа у Парку природе "Голија"

Type field depending on the size of the angle of inclination	Slope (°)	Share in total area (%)
Flat and very gently sloping terrain	0-3	3.6
Gently sloping terrain	3-5	5.1
Pretty sloping terrain	5-8	5.4
Skew field	8-12	8.2
Highly skewed field	12-16	13.4
Moderately steep terrain	16-20	22.9
Moderate steep terrain	20-30	31.6
Very steep terrain	30-40	7.8
	above 40	1.9

Regarding the altitude zone (CEP 2004), this analysis shows that predominantly, the park areas are located at altitudes above 500 m above the sea level (Figure 2).

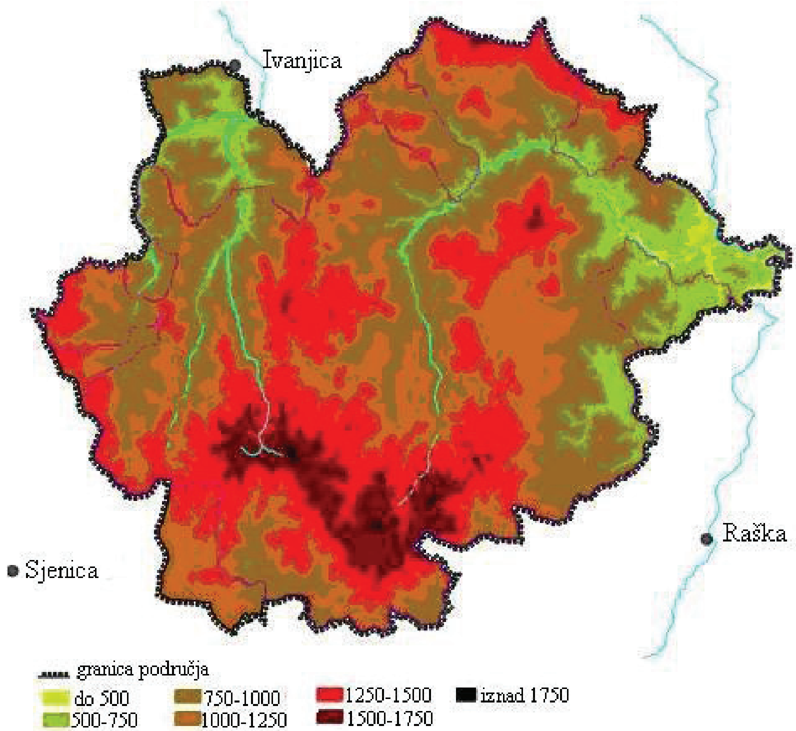

Figure 2 Altitude zone “Golija” Nature Park
(Source: CEP 2004)
Слика 2. Висинске зоне у Парку природе “Голија”
(извор: CEP 2004)

3.3 The energy of solar radiation

A. extraterrestrial radiation

The radiation spectrum of the sun, without the influence of the atmosphere (extraterrestrial radiation, irradiance), is changing during the year proportionally with the distance between the Earth and the Sun, with a value from 1321 Wm^{-2} to the largest 1412 Wm^{-2}. It should be noted that the optimal slope surface for receiving solar energy changes from month to month. The optimum slope of surface is being reduced from the beginning of the year till June, and it increases again towards the end of the year. The lowest values of the optimal relief slope (Figure 3) for the influx of solar radiation on Golija (Location: 43° 19’59” North, 20° 16’54” East, Elevation: 1766 m a.s.l.) are in June (8°) and the highest values are in December and January (61°).

Calculations shows that the optimal angle for the influx of solar energy throughout the year is 33° to the horizontal surface.

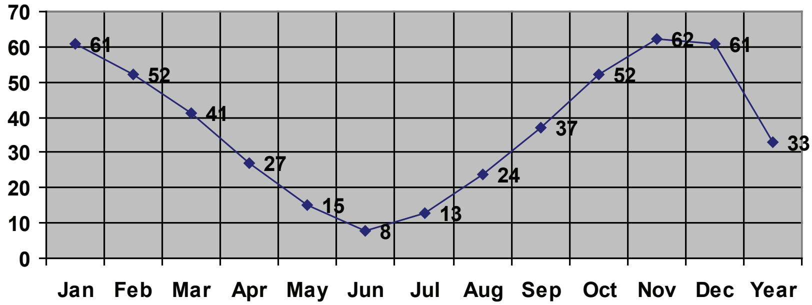

Figure 3 Optimal slope surface inflow of solar radiation on "Golija" Nature Park (°)
Adapted for Serbia from PVGIS © European Communities, 2001–2012
Слика 3. Оптималан нагиб површине за прилив енергије сунчевог зрачења у Парку природе "Голија" (°)
Прилагођено за подручје Србије помоћу PVGIS © European Communities, 2001–2012.

Changes in the intensity of solar radiation at the Golija surface, depending on the exposure time and the inclination of the surface, are shown in the Figure 4, on which shows that the largest influx of solar radiation that comes to the surface is oriented toward the south if the surface is inclined 33°. The lowest values of the radiation are on the north side of the vertical surface. The difference in the intensity of radiation exposure is greatest between the north and south sides, about 60,7% for the surface inclined at an optimal angle for the influx of solar radiation. The figure shows that the intensity of annual radiation is approximately identical on the surface oriented toward the southwest and southeast, the east and the west, and northeast and northwest.

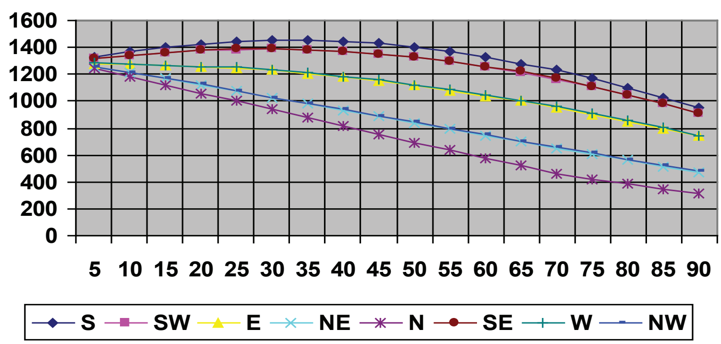

Figure 4 Average annual sum of global solar radiation energy to Nature Park "Golija" the surface oriented toward opposite sides of the world at different angles (kWh/m²/day)
Adapted for Serbia from PVGIS © European Communities, 2001–2012
Слика 4. Средње годишње суме енергије глобалног сунчевог зрачења на подручју Парка природе "Голија" на површинама оријентисаним према различитим странама света под различитим углом (kWh/m²/дан)
Прилагођено за подручје Србије помоћу PVGIS © European Communities, 2001–2012.

According to the geomorphologic characteristics of the Nature Park "Golija", it is necessary to determine the flow of energy according the inclination of the surface and its orientation towards different sides of the world.

For the practical determination of the influx of solar energy per month, the analyze of surfaces with the slope up to 45° and with the orientation to the different sides of the world is being done. Table 3 shows that the percentage of relief inclination above 40° does not exceed 2%.

Statistical analysis of solar radiation for the reference station Golija, is prepared by methods PVGIS Figure 5 to Figure 12 (http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php).

Figures 5 to Figure 12 show that the greatest potential values of solar radiation are in the summer on the surface of the lower slope. The largest influx of solar radiation is on the surface which is oriented towards the south, where the conditions for the emergence of fire are suitable. The minimum flow of energy is in area oriented toward the north, where the probability of fire occurrence and the uncontrolled spread of fire is lower. Maximum radiation measured on a monthly basis is on the surfaces oriented towards the south during the period of July to the slope from 10° to 15°, when the fire risk is the highest .

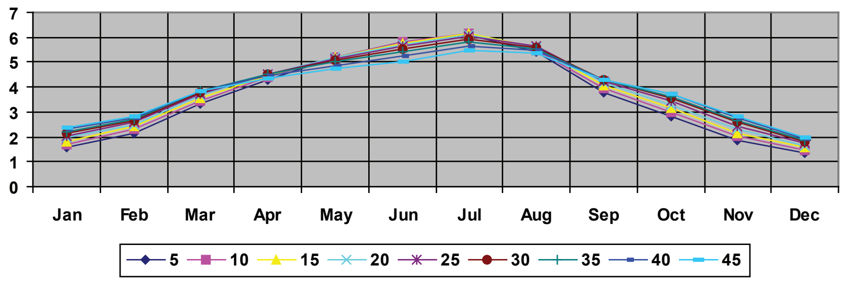

Figure 5 The intensity of solar radiation on Nature Park "Golija" that comes to the surface with different inclination and orientation to the south (kWh/m^2/day)
Adapted for Serbia from PVGIS © European Communities, 2001–2012
Слика 5. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према југу (kWh/m^2/дан)
Прилагођено за подручје Србије помоћу PVGIS © European Communities, 2001–2012.

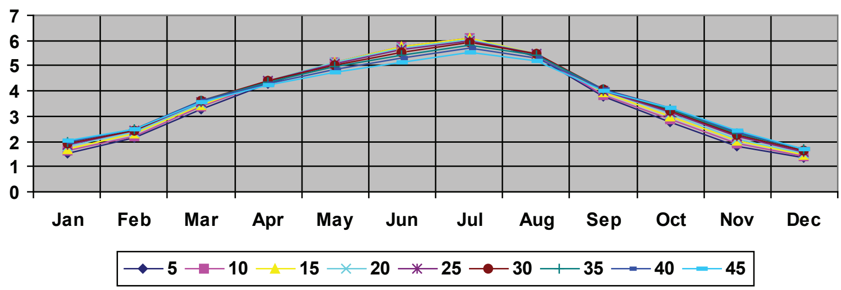

Figure 6 The intensity of solar radiation on Nature Park "Golija"that comes to the surface with different inclination and orientation to the southeast (kWh/m^2/day)
Adapted for Serbia from PVGIS © European Communities, 2001–2012
Слика 6. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према југоистоку (kWh/m^2/дан)
Прилагођено за подручје Србије помоћу PVGIS © European Communities, 2001–2012.

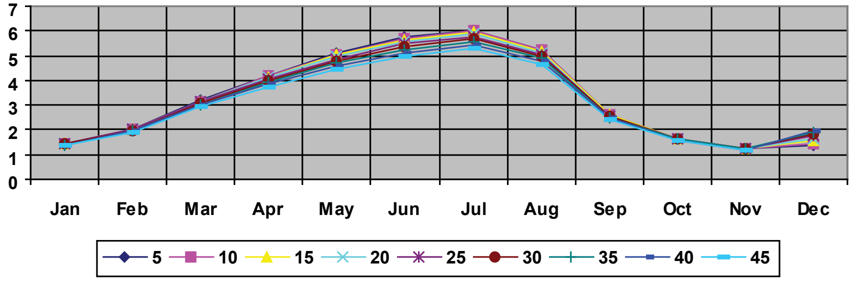

Figure 7 The intensity of solar radiation on Nature Park "Golija" that comes to the surface with different inclination and orientation to the east (kWh/m²/day)
Adapted for Serbia from PVGIS © European Communities, 2001–2012
Слика 7. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према истоку (kWh/m²/дан)
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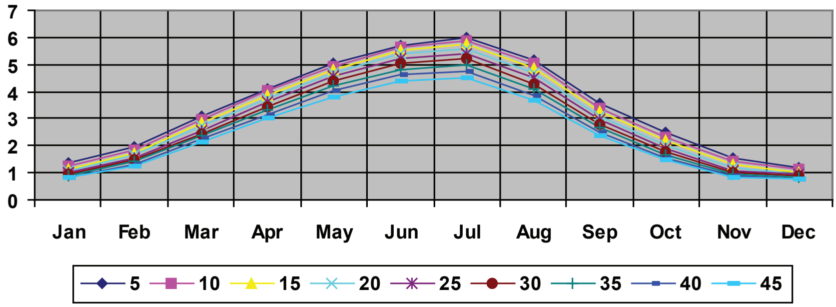

Figure 8 The intensity of solar radiation on Nature Park "Golija" that comes to the surface with different inclination and orientation to the northeast (kWh/m²/day)
Adapted for Serbia from PVGIS © European Communities, 2001–2012
Слика 8. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према североистоку (kWh/m²/дан)
Прилагођено за подручје Србије помоћу PVGIS © European Communities, 2001–2012.

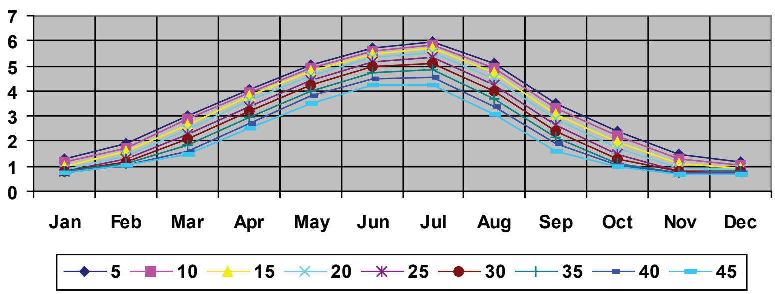

Figure 9 The intensity of solar radiation on Nature Park "Golija" that comes to the surface with different inclination and orientation to the north (kWh/m²/day)
Adapted for Serbia from PVGIS © European Communities, 2001–2012
Слика 9. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према северу (kWh/m²/дан)

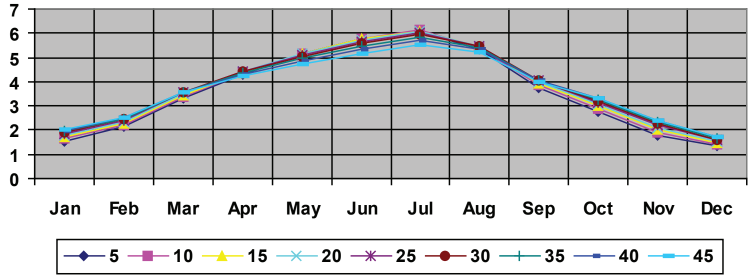

Figure 10 The intensity of solar radiation on Nature Park "Golija" that comes to the surface with different inclination and orientation to the southwest (kWh/m^2/day)
Слика 10. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према југозападу (kWh/m^2/дан)
Прилагођено за подручје Србије помоћу PVGIS © European Communities, 2001–2012.

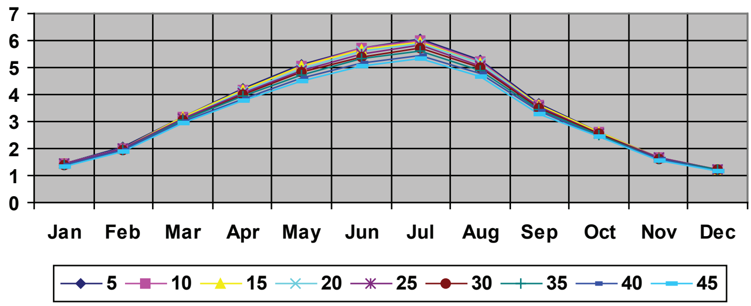

Figure 11 The intensity of solar radiation on Nature Park "Golija" that comes to the surface with different inclination and orientation to the west (kWh/m^2/day)
Слика 11. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према западу (kWh/m^2/дан)
Прилагођено за подручје Србије помоћу PVGIS © European Communities, 2001–2012.

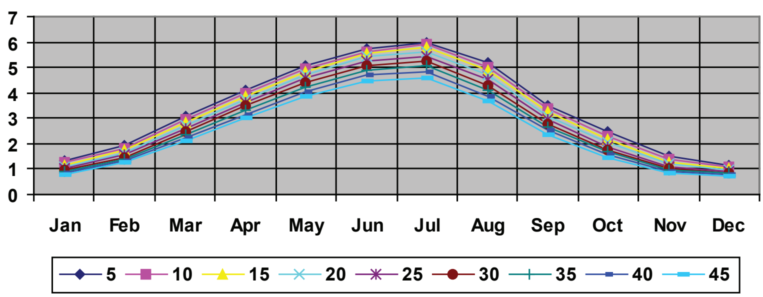

Figure 12 The intensity of solar radiation on Nature Park "Golija" that comes to the surface with different inclination and orientation toward the northwest (kWh/m^2/day)
Слика 12. Интензитет сунчевог зрачења у Парку природе "Голија" који долази на површину са различтим нагибом и оријентацијом према северозападу (kWh/m^2/дан)

The dynamics of fire

The fire occurrence on Golija varies from period to period. Figure 13 shows the number of fires in the open air by months (Tabaković-Tošić, M., 2009). The figure shows that the largest number of fires occurred in an open area in July, when the largest influx of solar radiation occurs. It is important to notice that numerous fires occur during the spring, what can be related with increased human activities (agricultural work) and inadequate training of inhabitants about the fire protection in rural areas.

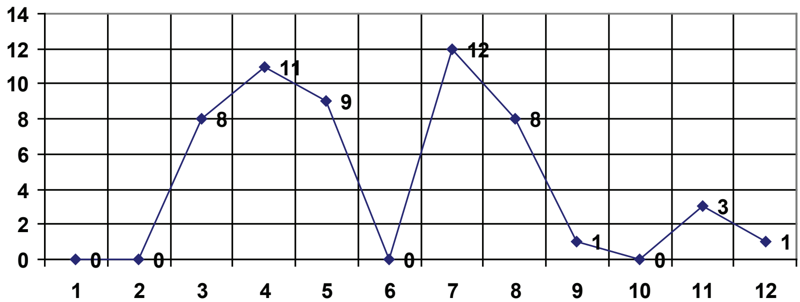

Figure 13 Number of fires in "Golija" Nature Park per month in the period from 2003 to 2007 year
Слика 13. Број пожара у Парку природе "Голија" по месецима у периоду 2003-2007. године

The largest number of fires was initiated in the period from 10 to 18h (Table 4), during the daily sun's radiation.

Table 4 The dynamics of fire during the day in the period from 2003 to 2007 year
Табела 4. Динамика појаве пожара током дана у периоду 2003-2007. године

Time of Day	10-18h	18-04h	04-06h	06-10h	unknown time
Number of fires	33	2	0	0	18

Selection criteria and methods for evaluating the impact of orography on the forest fires risk

After identifying aspects of orography is done, it is necessary to define the criteria for evaluating the significance of their impact on the risk of forest fires. Assessment of orography significance is the process of determining the significance of aspects of orography based on the probability of fire occurrence and expected speed of development and uncontrolled fire expansion. For orography criteria levels (values) of significance have been defined. In this case, the method of ranking significance in calculation of the risk of forest fires, was applied (Table 5).

Table 5 Factor incidence of fire
Табела 5. Фактор учесталости појаве пожара

Elements of orography		Assessment of the incidence of fire	Rating
Exposure	South	expected to be extremely high rate of fire	5
	Southwest, Southeast	expected high rate of fire	4
	West, East	expected mean frequency of fire	3
	Northeast, Northwest	low expected frequency of occurrence of fire	2
	North	expected frequency of occurrence of fire negligible	1
The slope (inclination) (°)	>45	expected to be extremely high rate of fire	5
	30	expected high rate of fire	4
	15	expected mean frequency of fire	3
	10	low expected frequency of occurrence of fire	2
	to 5	expected frequency of occurrence of fire negligible	1
Elevation (m)	1500	expected to be extremely high rate of fire	5
	1000	expected high rate of fire	4
	500	expected mean frequency of fire	3
	250	low expected frequency of occurrence of fire	2
	100	expected frequency of occurrence of fire negligible	1

From the orographic point of view, the overall risk factor is being evaluated on the basis of the elements such as the altitude, elevation, slope and the exposure, ranking from the smallest to the biggest impact. The risk of forest fires from the aspect of orography is calculated as the sum of the significance probabilities of terrain exposure (ZE), the slope of the relief (UN) and altitude (ZNV), as follows:

$$R = ZE + ZN + ZNV.$$

Based on this classification of risk (R) can be determined from negligible over the small and medium-sized to large and very large, as follows:

$R=3$	negligible
$4 \leq R \leq 6$	small
$7 \leq R \leq 9$	middle
$10 \leq R \leq 12$	large
$13 \leq R \leq 15$	extremely large.

According to this model, the risk of forest fires in terms of orography is the smallest on surfaces oriented toward the north side. The greatest fire risk and rapid uncontrolled fire expansion should be expected on the southern exposures and at higher altitudes and greater inclination of relief. The same results have been achieved in their works by Hutchison, B.A., Matt, D.R., 1976, 1977.

4. CONCLUSION

In the areas with different exposures and slope, duration and intensity of solar radiation is different, as well as the drying conditions for combustible materials. The trend of solar radiation on surfaces under plant cover is a very important factor in the development of vegetation and creating conditions conducive for the fire occurrence. If the effects of solar radiation on plant vegetation are implemented in the forest fires risk assessment, adverse effects can be minimized.

Forest fire risk factors as well as tactics of fighting forest fires has to be evaluated on the basis of this impact. The data obtained about the intensity of solar radiation on different surfaces, can be used for defining areas with an increased risk of forest fires. In the analyzed site, the characteristics of the solar energy inflow indicate that the highest annual inflow comes on energy surfaces oriented to the south at an inclination of 33 degrees. The greatest amount of solar radiation energy are available for the period from April to September, during the vegetation period.

The data obtained from the PVGIS models indicate that there is a correspondence between periods of maximum radiation measured with a period of forest fires. On analyzed area, by application of this method, the monthly sums of radiation were measured – the highest in June-July which coincides with the period when the fire season is indicated. The lowest values measured are during the period from December to January, which coincides with the period when there is no forest fires. During the fire season, fire incidence may be expected in areas oriented towards the south, southwest and the southeast.

By applying different models, the possibility for quantitative analysis of the fire risk in given area is created. This type of analysis provides a good basis for a complex analysis of space. The analysis results have broad utility value and they are unavoidable in determining the fire risk and the basis for the space mapping.

REFERENCES

CEP-Centar za planiranje urbanog razvoja: Prostorni plan područja posebne namene Parka prirode Golija-strategija zaštite, uređenja i razvoja, Beograd, 2004

Dragićević, M. S., Vučković, M. N. (2007): Evaluation of distributional solar radiation parameters of Čačak using long-term measured global solar radiation data, Thermal science: Vol. 11, No. 4, pp. 125-134

Gburčik, P., Gburčik, V., Vučinić, Ž. (2004): Study of potential of Serbia for explcitation of wind and solar energy, MNZŽS, National energy eficiency programm, EE704-1052A, Beograd

Gburčik, P., Gburčik, V., Gavrilov, V., Srdanović, S., Mastilović, S. (2006): Complementary Regimes of Solar and Wind Energy in Serbia *Geographica Pannonica*, 10, pp. 22-25,

Hutchison ,B. A., Matt, D.R. (1976): Beam enrichment of diffuse radiation in a deciduous forest, Agricultural Meteorology, Volume 17, Issue 2, pp. 93–110

Hutchison, B.A., Matt, D.R. (1977): The annual cycle of solar radiation in a deciduous forest , Agricultural Meteorology, Volume 18, Issue 4, pp. 255–265

Kolić, B. (1988): Šumarska ekoklimatologija sa osnovama fizike atmosfere, Naučna knjiga, Beograd

Lalit, K., Andrew, K. S. , Edmund, K. (1997): Modelling topographic variation in solar radia-

tion in a GIS environment, International Journal of Geographical Information Science, Volume 11, Issue 5, pp. 475-497
Markvart, T., Castaner, L. (2003): Practical Handbook of Photovoltaics - Fundamentals and Applacations, Oxford: Elsevier Science Ltd.., p 984
Milanković, M. (1997): Kanon osunčavanja Zemlje, Zavod za udžbenike i nastavna sredstva u Beogradu. Beograd
Radičević, B., Mikičić, D., Vukić, Đ. (2009): Energetski potencijal sunca u Srbiji i primena energije sunca u poljoprivredi, Poljoprivredna tehnika, vol 34. broj 4. (str. 53-62)
Ramachandra, T.V. (2007): Solar energy potential assessment using GIS, Energy Education Science and Tehnology, Vol . 18(2), pp. 101-114,
Stamenić, Lj. (2009): Korišćenje solarne fotonaponske energije u Srbiji, Jefferson institute, Beograd
Tabaković Tošić, M., Marković, M., Rajković, S., Veselinović, M. (2009): Wildfires in Serbia: Chance or frequentphenomenon, Sustainable Forestry: Collection, iss. 59-60, pp. 97-127
Xavier, P., Miquel, N. (2008): Mapping a topographic global solar radiation model implemented in a GIS and refined with ground data, Int. J. Climatol.28, Issue 13: pp.1821–1834
Živanović, S. (2011): Procena potencijala sunčevog zračenja za proizvodnju električne energije u Negotinu, ELEKTROPRIVREDA, br. 4, str. 395–401
Živanović, S., Zigar, D., Zdravković, M. (2013): Meteorological monitoring for wildfire protection, Ecologica 20 Vol. 69, pp. 63-66
Živanović, S. (2015): Утицај морфометријских параметара рељефа на ризик од шумских пожара, Шумарство 4. УШИТС, Београд. стр. 127-138
(2009): *Уредба о утврђивању Просторног плана подручја посебне намене Парка природе Голија.* Службени Гласник РС, бр. 16, 2009.
http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php
http:/www.hidmet.gov.rs/

ЕФЕКАТ ГЛОБАЛНОГ СУНЧЕВОГ ЗРАЧЕЊА НА УГРОЖЕНОСТ ШУМА ОД ПОЖАРА НА ПОДРУЧЈУ ПАРКА ПРИРОДЕ "ГОЛИЈА" У СРБИЈИ

Станимир Живановић
Марина Вукин

Резиме

Трајање сијања Сунца има велики значај и утицај на вегетацију. Распоред, врста и прираст, као и стање вегетације зависи од количине примљеног Сунчевог зрачења. Укупни енергетски потенцијал зрачења који дође на површину, знатно се мења током дана, а његове промене зависе од годишњег доба и положаја обасјане површине. Све ово показује велику промењивост снаге зрачења. Континуитет промена може се с већом или мањом тачношћу предвидети, јер је познат ритам појава (излазак и залазак Сунца). На теренима са различитом експозицијом и нагибом терена различито је трајање и интензитет сунчева зрачења, а самим тим и услови сушења горивог материјала. Уколико се утицаји сунчевог зрачења на биљну вегетацију имплементирају у процене угрожености шума од пожара, штетне последице могу да се минимизирају. Фактори ризика шума од пожара као и тактика гашења шумских пожара морају да се сагледају на основу утицаја орографских елемената. Добијени подаци интензитета сунчевог зрачења на различитим површинама могу се искористити за дефинисање зона са повећаним ризиком шума од пожара. У раду су спроведена истраживања утицаја Сунчевог зрачења на учесталост шумских пожара, у зависности од орографских фактора, на подрчју

Парка природе “Голија” у југозападној Србији. Карактеристике прилива Сунчеве енергије указују да су највећи годишњи приходи енергије на површинама оријентисаним према југу на нагибу од 33 степени. Највеће количине енергије Сунчевог зрачења су на располагању у периоду од априла до септембра, односно током вегетационог периода. Добијени резултати истраждвиања, применом PVGIS модела, показују да постоји подударност периода максимума измереног зрачења са периодом шумских пожара. На истраживаном подручју, месечне суме зрачења највеће су у периоду јуни-јули, када је изражена и сезона пожара. Најмање вредности су у периоду децембар-јануар, што се подудара и са периодом када нема шумских пожара. У току сезоне пожара, може се очекивати учесталост појаве пожара на површинама оријентисаним ка југу, југозападу и југоистоку. Резултати истраживања указали су на могућност квантитативне анализе ризика од пожара на одређеном подручју применом различитих модела. Оваква врста анализа даје добру основу за комплексна истраживања конкретног простора. Резултати анализе имају широку употребну вредност и незаобилазни су у утврђивању ризика од пожара те представљају основу за израду мапа простора.