FORUM GEOGRAFIC

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XV**, Issue **2** (**December** 2016), pp. **126-132***
*http://dx.doi.org/**10.5775/fg.2067-4635.2016.022.d***

The Mediterranean Oscillation (MOI) and the Forest Fires in Romania in the Period 1986–2014

Milan MILENKOVIĆ[1], Vladan DUCIĆ[2], Violeta BABIĆ[3]

[1] Geographical Institute "Jovan Cvijić", Serbian Academy of Sciences and Arts, Djure Jakšića 9, 11000 Belgrade, Serbia
[2] University of Belgrade, Faculty of Geography, Studentski trg 3/III, 11000 Belgrade, Serbia
[3] University of Belgrade, Faculty of Forestry, Kneza Višeslava 1, 11030 Belgrade, Serbia
* *Corresponding author*, m.milenkovic@gi.sanu.ac.rs

Received on <09-10-2016>, reviewed on <23-11-2016>, accepted on <05-12-2016>

Abstract

The study examines the connection between the Mediterranean Oscillation (MOI) and the forest fires (the annual number of fires, the annual burned area and the average burned area per fire) in Romania in the period 1986–2014. Pearson's correlation coefficient (R) was used for determination of the correlation connection. Two MOI datasets were used: MOI-1 (Algiers and Cairo) and MOI-2 (Israel and Gibraltar). Monthly, seasonal and annual values of MOI were used in the calculations. Results for the number of fires and MOI-1: the highest values of R (statistically significant at the level of $p \leq 0.05$) were obtained for April (–0.446) and June (0.423), and for summer (0.432). The annual burned area and MOI-1: the highest values of R (statistically significant at the level of $p \leq 0.05$) were obtained for April (–0.459), and for winter (0.406). The number of fires and MOI-2: the highest values of R (statistically significant at the level of $p \leq 0.01$) were obtained for June (0.556) and February (0.475), and for summer (0.507). The annual burned area and MOI-2: the highest values of R (statistically significant at the level of $p \leq 0.05$) were obtained for June (0.449) and February (0.439), and for summer (0.439). Results of the research could be used for the long-term forecast of forest fires in Romania. However, further investigations of the connection between forest fires and other climate indices are necessary.

Keywords: *Mediterranean Oscillation, forest fires, burned area, Romania*

Rezumat. Indicele oscilaţiei mediteraneene (IOM) şi incendiile de pădure din România în perioada 1986-2014

Articolul examinează conexiunile dintre Indicele Oscilației Mediteraneene (IOM) și incendiile de pădure (numărul anual de incendii, suprafața arsă anual și suprafața medie afectată de un incendiu) din România în perioada 1986-2014. În acest scop, a fost utilizat coeficientul de corelație Pearson (R) pentru a determina corelațiile. Au fost folosite două seturi de date privind IOM : IOM-1 (Algiers și Cairo) și IOM-2 (Israel și Gibraltar), pentur calcule bazându-ne pe valorile lunare, sezoniere și anuale ale IOM. Rezultatele pentru numărul de incendii și IOM-1: cele mai mari valori ale lui R (semnificative statistic la nivel de $p \leq 0{,}05$) au fost obținute pentru luna aprilie (-0,446) și iunie (0,423), și pentru vară (0,432). Suprafața arsă anuală și IOM-1: cele mai mari valori ale lui R (semnificative statistic la nivel de $p \leq 0{,}05$) au fost obținute pentru luna aprilie (-0,459) și pentru iarnă (0,406). Numărul de incendii și IOM-2: cele mai mari valori ale lui R (semnificative statistic la nivel de $p \leq 0{,}01$) au fost obținute pentru luna iunie (0,449) și februarie (0,475), precum și pentru sezonul de vară (0,507). Suprafață arsă annual și IOM-2: cele mai mari valori ale lui R (semnificative statistic la nivel de $p \leq 0{,}05$) au fost obținute pentru luna iunie (0,449) și februarie (0,439), precum și pentru vară (0,439). Rezultatele cercetării ar putea fi folosite și pentru previziunile pe termen lung asupra incendiilor de pădure din România. Totuși, sunt necesare și alte investigații în ceea ce privește legătura dintre incendiile de pădure și alți indici climatici.

Cuvinte-cheie: *Indicele Oscilaţiei Mediteraneene, incendiile de pădure, suprafaţă arsă, România*

Introduction

Forest fires are among the greatest ecological threats in European countries. One of the countries seriously affected by forest fires is Romania. During last three decades the most extreme forest fire season in Romania was 2012 (911 fires, total burned area 6624 ha). Extreme fire seasons were also in 2000, 2002 and 2007 (http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/).

The connection between climate and forest fires is a subject of numerous researches. The influences of teleconnections on forest fires are especially interesting. Teleconnections are impacts of distant climate phenomena to the climate of some region. These impacts have been mostly investigated for North America (Norman & Taylor, 2003; Schoennagel et al, 2005; Sibold & Veblen, 2006; Schoennagel et al., 2007; Morgan et al., 2008; Milenković et al., 2016a). The authors mostly emphasize the importance of Atlantic Multidecedal Oscillation (AMO), Pacific Decadal Oscillation (PDO) and El Niño-Southern Oscillation (ENSO). There is also the impact of AMO on forest fires in Europe. Milenković et al. (2016b) established the connection between AMO and the forest fires in France (number of fires, total burned area and average burned area per fire). However, due to distance, the impact of AMO is weaker in East and Southeast Europe. Thus, the aim of this paper was to examine the connection between MOI and the forest fires in Romania.

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XV, Issue 2 (December 2016), pp. 126-132
http://dx.doi.org/10.5775/fg.2067-4635.2016.022.d

There are two versions of MOI. The first one (MOI-1) is defined as the normalized pressure difference between Algiers and Cairo (Conte et al., 1989; Palutikof et.al., 1996) and the second one (MOI-2) is calculated from Gibraltar's Northern Frontier and Lod Airport in Israel (Palutikof, 2003). The influence of MOI on climate, primarily air temperature and precipitation, has been confirmed in the researches (Maheras & Kutiel, 1999; Supić et al., 2004; Burić et al., 2014, Schmuck et.al. 2015).

Material and methods

The study used monthly, seasonal and annual values of Mediterranean Oscillation Index (MOI). Both MOI-1 (Algiers and Cairo) and MOI-2 (Israel and Gibraltar) datasets were used. The data were taken from Climatic Research Unit, University of East Anglia, Norwich, UK:

- https://crudata.uea.ac.uk/cru/data/moi/moi1.output.dat
- https://crudata.uea.ac.uk/cru/data/moi/moi2.output.dat

The data on the forest fires in Romania in the period 1986–2014 covered:

- Total annual number of forest fires (N)
- Total annual burned area (P)
- The average burned area per fire (*P/N*)

The data were taken from the European Commission Report – Forest Fires in Europe, Middle East and North Africa 2014, Joint Report of JRC and Directorate-General Environment (2015):

- http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

Pearson correlation coefficient (R) on the basis of linear trend was used for the calculation of correlation, and statistical significance was tested on p≤0.05 and p≤0.01. Monthly, seasonal and annual MOI-1 and MOI-2 values were used in the calculations, and one year phase shift was also performed (values from previous year were used). Calculation for the same year didn't use data for the period September to December, since the main fire season in Romania ends in September.

Statistical significance of linear trend was determined for *n–2* and on the basis of the coefficient of determination (R^2, attached to the charts). For the testing of the significance of linear trend t test was used:

$$t = R\sqrt{\frac{n-2}{1-R^2}}$$

wherein R^2 - the coefficient of determination; n – the length of the series.

Results and discussions

In Romania in the period 1986–2014 an increasing trend of the annual number of forest fires was recorded (Fig. 1). On the basis of table values it was determined that the trend is not statistically significant at p≤0.05.

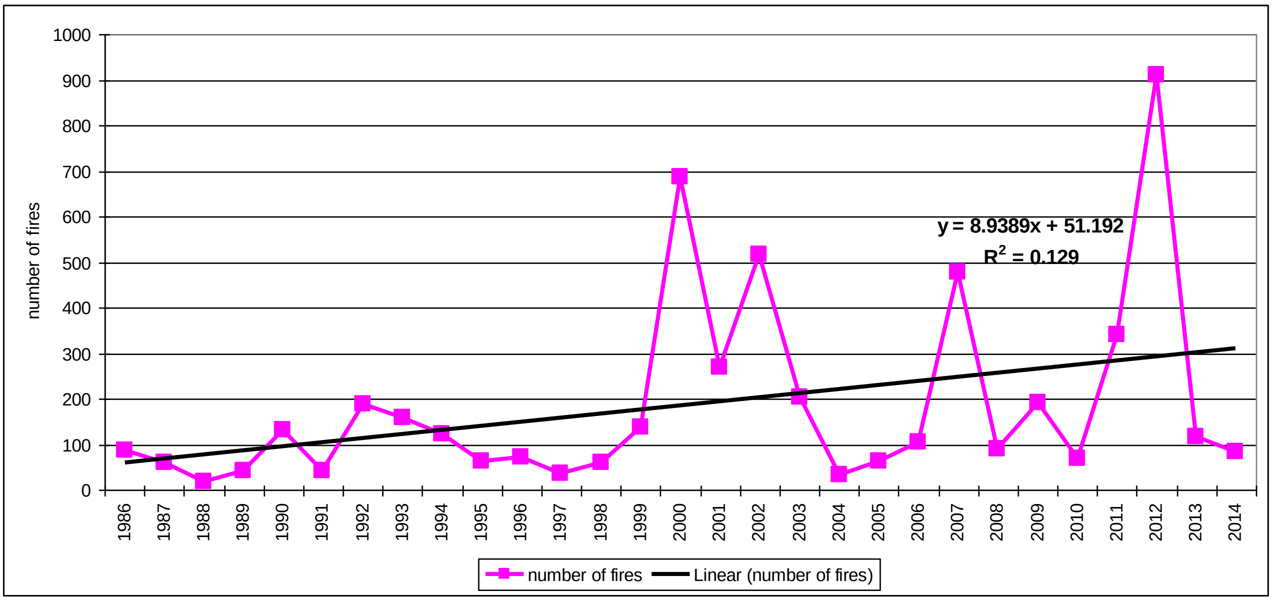

Fig. 1: The annual number of forest fires in Romania (1986–2014) with the trend line
Source of data: http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

In the same period an increasing trend of the total annual burned area was also noted (Fig. 2). On the basis of table values it was determined that the trend is statistically significant at p≤0.05.

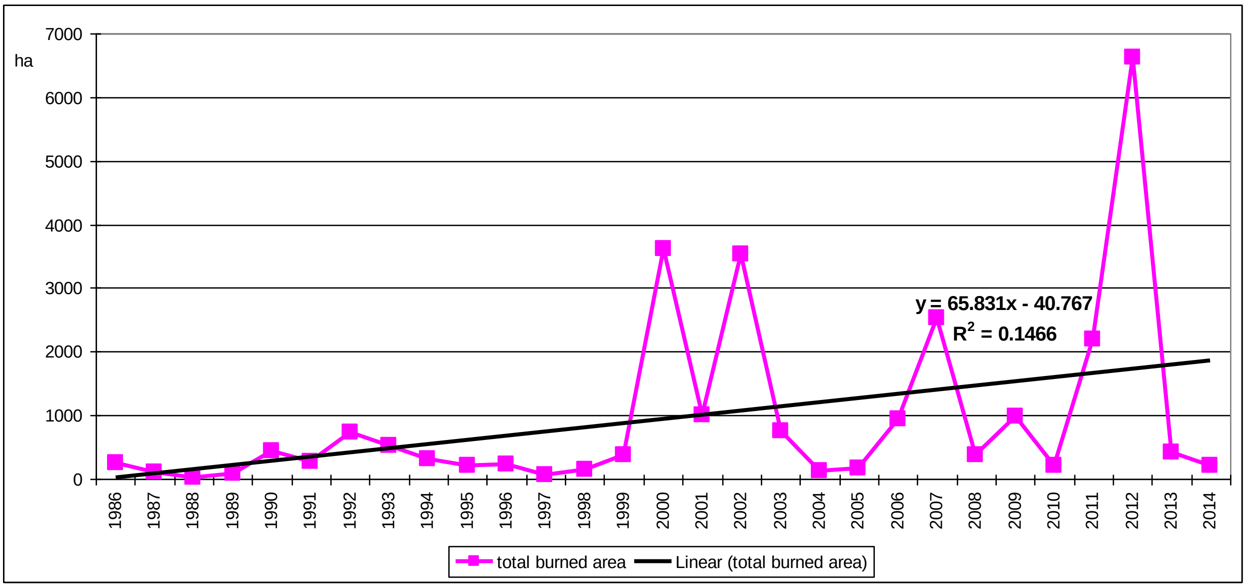

Fig. 2: The annual burned area in Romania (1986–2014) with the trend line
Source of data: http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

The average burned area per fire has also increasing trend in the period 1986–2014 (Fig. 3). On the basis of table values it was determined that the trend is statistically significant at p≤0.05.

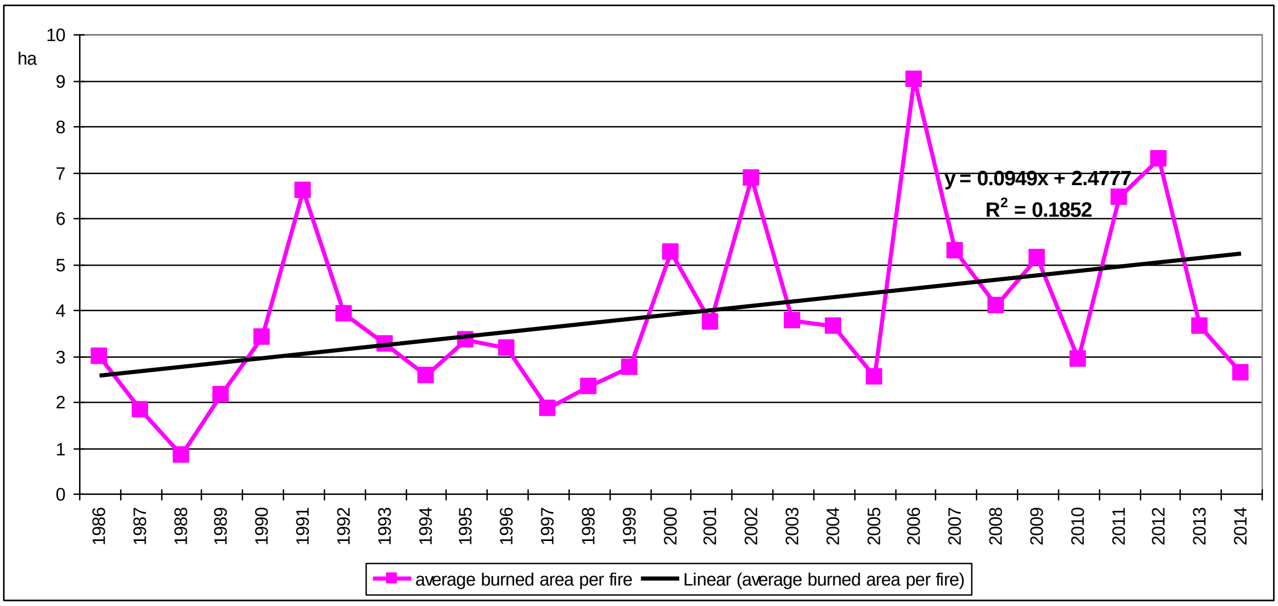

Fig. 3: The average burned area per fire in Romania (1986–2014) with the trend line
Source of data: http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

Table 1 shows the results of the research of the correlation between MOI-1 and the forest fires in Romania (1986–2014).

In the calculation with the forest fire data and MOI-1 there weren't any values of R statistically significant at p≤0.01. With the number of fires the highest values of R (statistically significant at p≤0.05) were obtained for April (–0.446) and June (0.423) at monthly level, and at seasonal level for summer (0.432). In the calculation with the annual burned area the highest values of R were obtained for April (–0.459), and for winter (0.406). In the calculation with the average annual burned area per fire in only one case the value of R was statistically significant at p≤0.05. It was for June MOI-1 (0.375). With the 1 year phase shift the values of R were lower.

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XV**, Issue **2** (**December 2016**), pp. **126-132***
*http://dx.doi.org/**10.5775/fg.2067-4635.2016.022.d***

Table 1: Pearson correlation coefficient (R): MOI-1 – forest fires in Romania in the period 1986–2014 (N – the number of fires, P – the annual burned area, P/N – the average annual burned area per fire)

	MOI-1 – monthly values											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg	Sep	Oct	Nov	Dec
N	0.317	0.393*	0.060	-0.446*	0.381*	0.423*	0.210	0.203	-	-	-	-
P	0.323	0.364	0.070	-0.459*	0.347	0.365	0.221	0.180	-	-	-	-
P/N	0.235	0.139	-0.286	0.020	0.337	0.375*	0.126	0.194	-	-	-	-
	MOI-1 – seasonal and annual values											
			Winter		Spring		Summer		Autumn		Annual	
N			0.417*		0.051		0.432*		-		0.376*	
P			0.406*		0.037		0.391*		-		0.361	
P/N			0.226		–0.073		0.364		-		0.333	
	MOI-1 – monthly values (phase shift – 1 year)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg	Sep	Oct	Nov	Dec
N	-0.061	0.108	-0.369*	0.238	0.080	0.254	-0.292	-0.025	-0.044	0.225	-0.123	0.185
P	-0.101	0.078	-0.347	0.320	0.139	0.241	-0.286	0.003	0.055	0.239	-0.168	0.182
P/N	0.239	0.131	-0.156	0.334	0.211	0.153	-0.035	0.364	0.079	0.068	-0.263	0.101
	MOI-1 – seasonal and annual values (phase shift – 1 year)											
			Winter		Spring		Summer		Autumn		Annual	
N			–0.029		–0.180		0.027		0.015		0.042	
P			–0.100		–0.095		0.035		0.033		0.051	
P/N			0.034		0.117		0.260		–0.134		0.249	

* signifficant p≤0.05; ** singifficant p≤0.01

Table 2 shows the results of the research of the correlation between MOI-2 and the forest fires in Romania (1986–2014).

Table 2: Pearson correlation coefficient (R): MOI-2 – forest fires in Romania in the period 1986–2014 (N – the number of fires, P – the annual burned area, P/N – the average annual burned area per fire)

	MOI-2 – monthly values											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg	Sep	Oct	Nov	Dec
N	0.239	0.475**	0.015	-0.234	0.364	0.556**	0.168	0.259	-	-	-	-
P	0.239	0.439*	0.025	-0.274	0.295	0.449*	0.169	0.238	-	-	-	-
P/N	0.159	0.143	-0.299	0.020	0.161	0.200	-0.013	0.121	-	-	-	-
	MOI-2 – seasonal and annual values											
			Winter		Spring		Summer		Autumn		Annual	
N			0.446*		0.077		0.507**		-		0.393*	
P			0.418*		0.044		0.439*		-		0.357	
P/N			0.162		–0.186		0.155		-		0.199	
	MOI-2 – monthly values (phase shift – 1 year)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg	Sep	Oct	Nov	Dec
N	-0.144	0.151	-0.415*	0.008	0.019	0.217	-0.306	-0.080	-0.033	0.098	-0.113	0.198
P	-0.165	0.146	-0.427*	0.026	0.060	0.173	-0.280	-0.066	0.052	0.085	-0.159	0.177
P/N	0.174	0.075	-0.306	0.048	0.146	0.031	-0.152	0.105	0.022	-0.111	-0.267	0.032
	MOI-2 – seasonal and annual values (phase shift – 1 year)											
			Winter		Spring		Summer		Autumn		Annual	
N			–0.098		–0.342		–0.074		–0.057		–0.059	
P			–0.153		–0.329		–0.078		–0.076		–0.080	
P/N			–0.074		–0.184		–0.008		–0.260		–0.043	

* signifficant p≤0.05; ** singifficant p≤0.01

In the calculation with the number of fires and MOI-2 the highest values of R (statistically significant at p≤0.01) at the monthly level were obtained for June (0.556) (Fig. 4) and February (0.475), and at seasonal level for summer (0.507). With the annual burned area and MOI-2 the highest values of R (statistically significant at p≤0.05) were obtained for June (0.449) (Fig. 5) and February (0.439), and for summer (0.439). In the calculation with the average annual burned area per fire there weren't any statistically significant values of R.

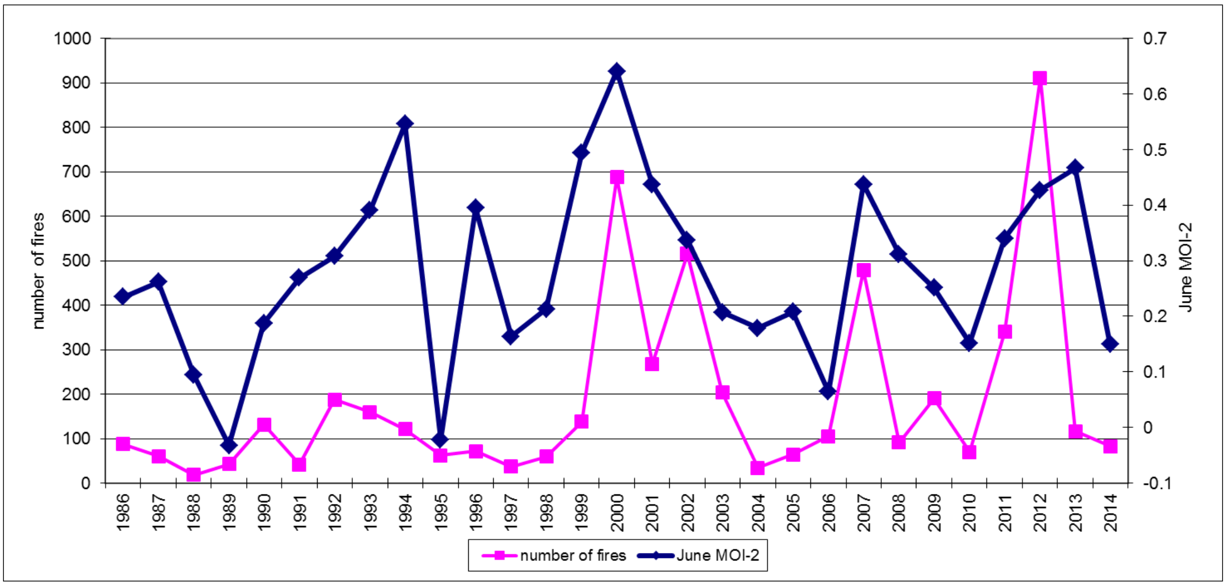

Fig. 4: The number of fires in Romania (1986–2014) and MOI-2 values for June: R=0.556 (significant p≤0.01)

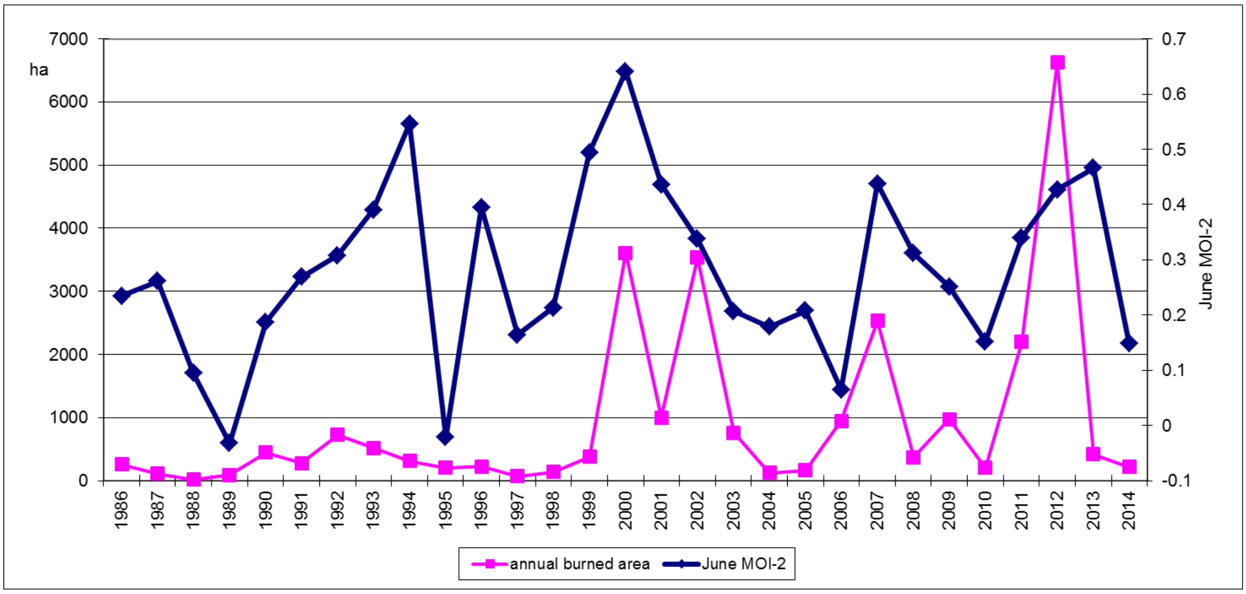

Fig. 5: The annual burned area in Romania (1986–2014) and MOI-2 values for June: R=0.449 (significant p≤0.05)

Therefore, the connection between MOI-2 and the forest fire data for Romania in the period 1986–2014 is stronger than the same connection for MOI-1. The results of the research could possibly be used as a basis for the long-term forest fire forecast. The short-term forecast should be based on the connection between the solar wind parameters and forest fires (Radovanović et al., 2013; Radovanović et al., 2015a; Radovanović et al., 2015b; Radovanović et al., 2015c). In the future more researches on different climate indices and solar wind parameters are necessary for the improvement of the forest fire forecast.

Important step in the future research should be the analysis of the connection between MOI and forest fires on the regional level. Forest fires are unevenly distributed in Romania. The greatest number of forest fires and the greatest burned area during the period 1968–2000 were recorded in the counties Caraş-Severin, Hunedoara, Gorj, Alba, Cluj and Maramureş. The months with the greatest fire activity by seasons were March-April, August and

November (Ene, Ciobanu & Borz, 2011). During the period 1990–2003, Caras-Severin, Gorj and Mehedinţi counties were the most severely affected by forest fires (Adam & Ureche, 2007). These three counties are located in the Southwestern part of Romania close to the border with Serbia. On the other side of the border, in Serbia, there is also a highly endangered area by fires – Deliblatska peščara (Milenković, Radovanović & Ducić, 2011).

The assessment of fire risk on the basis of the vegetation cover is very important for the efficient forest fire protection. In Romania many fires spread into the forest from the surrounding agricultural areas on which some cleaning actions with the help of fire are implemented (Adam, 2007).

Conclusion

In Romania, during the 1986–2014 period, increasing trends in the annual number of forest fires, total annual burned area and the average burned area per fire were recorded.

With MOI-1 and the number of fires the highest values of R (statistically significant at p≤0.05) were recorded for April (–0.446), June (0.423) and summer (0.432). In the calculation with MOI-1 and the annual burned area the highest values of R were obtained for April (–0.459) and winter (0.406), and with the average annual burned area per fire for June MOI-1 (0.375). With the 1 year phase shift recorded R values were lower.

With the number of fires and MOI-2 the highest values of R (statistically significant at the level of p≤0.01) were obtained for June (0.556), February (0.475) and summer (0.507). In the case of the annual burned area the highest values of R (statistically significant at p≤0.05) were recorded for June (0.449), February (0.439) and summer (0.439). At the average annual burned area per fire there weren't any statistically significant values of R.

The results of the research could be used in the long-term forest fire forecast.

Acknowledgements

The study is the result of project number 47007 III funded by Ministry of Education, Science and Technological Development of the Republic of Serbia.

The study used data from the European Commission Forest Fires in Europe, Middle East and North Africa 2014, Joint Report of JRC and Directorate-General Environment (2015).

References

Adam, I. (2007). Metodă de evaluare a riscului de incendiu în pădurile Românei. *Analele ICAS, 50*, pp. 261–271.

Adam, I., Ureche, M. (2007). Overview of the forest fires situation in Romania. http://www.fire.uni-freiburg.de/sevilla-2007/contributions/doc/SESIONES_TEMATICAS/ST3/Adam_Ureche_RUMANIA.pdf

Burić, D., Ducić, V., Mihajlović, J., Luković, J., Dragojlović, J. (2014). Relationship between the precipitation variability in Montenegro and the Mediterranean Oscillation. *Bulletin of the Serbian Geographical Society, XCIV, 4*, pp. 109–115.

Conte, M., Giuffrida, A., Tedesco, S. (1989). The Mediterranean Oscillation. Impact on precipitation and hydrology in Italy Climate Water. Publications of the Academy of Finland, Helsinki.

Ene, C., Ciobanu, V., Borz, S. A. (2011). Fire fuels models in Romania. MCBANTA'11 Proceedings of the 12th WSEAS international conference on Mathematics and computers in biology, business and acoustics, Romania — April 11–13, 2011, pp. 106–109. http://www.wseas.us/e-library/conferences/2011/Brasov2/MCBANTA/MCBANTA-17.pdf

Maheras, P., Kutiel, H. (1999). Spatial and temporal variations in the temperature regime in the Mediterranean and their relationship with circulation during the last century. *International Journal of Climatology, 19*, pp. 745–764.

Milenković, M., Ducić, V., Babić, V. (2016a). The Pacific Decadal Oscillation and forest fires in the USA in the period 1983–2015 (in Serbian, abstract and summary in English). *Šumarstvo (Forestry), 1–2*, pp. 91–100.

Milenković, M., Ducić, V., Burić, D., Lazić, B. (2016b). The Atlantic Multidecadal Oscillation (AMO) and the forest fires in France in the period 1980–2014. *Journal of the Geographical Institute "Jovan Cvijić" SASA, 66*(1), pp. 35–44.

Milenković, M., Radovanović, M., Ducić, V. (2011). The impact of solar activity on the greatest forest fires of Deliblatska peščara (Serbia). *Forum Geografic, 10*(1), 107–116.

Morgan, P., Heyerdahl, E.K., Gibson, C.E. (2008). Multi-season climate synchronized forest fires throughout the 20th century, northern Rockies, USA. *Ecology, 89*(3), pp. 717–728.

Norman, S. P., Taylor, A. H. (2003). Tropical and north Pacific teleconnections influence fire regimes in pine-dominated forests of north-eastern California, USA. *Journal of Biogeography, 30*(7), pp. 1081–1092.

Palutikof, J. P., Conte, M., Casimiro Mendes, J., Goodess, C. M., Espirito Santo, F. (1996). Climate and climate change. In: Brandt, C.J., Thornes, J.B., (eds) Mediterranean desertification and land use. London: John Wiley and Sons.

Palutikof, J. P. (2003). Analysis of Mediterranean climate data: measured and modelled. In: Bolle,

H. J. (ed): Mediterranean climate: Variability and trends. Berlin: Springer-Verlag.

Radovanović, M., Vyklyuk, Y., Jovanović, A., Vuković, D., Milenković, M., Stevančević, M., Matsiuk, N. (2013). Examination of the correlations between forest fires and solar activity using Hurst index. *Journal of the Geographical Institute »Jovan Cvijić« SASA, 63*(3), pp. 23–32.

Radovanović, M. M., Pavlović, T. M., Stanojević, G. B., Milanović, M. M., Pavlović, M. A., Radivojević, A. R. (2015a). The influence of solar activities on occurrence of the forest fires in South Europe. *Thermal Science, 19*(2), pp. 435–446.

Radovanović, M. M., Vyklyk, Y., Malinović-Milićević, B. S., Jakovljević, M. D., Pecelj, R. M. (2015b). Modelling of forest fires time evolution in the USA on the basis of long term variations and dynamics of the temperature of the solar wind protons. *Thermal Science,19*(Suppl. 2), pp. S437–S444.

Radovanović, M. M., Vyklyuk, Y., Milenković, M., Vuković, D. B., Matsiuk, N. (2015c). Application of adaptive neuro-fuzzy interference system models for prediction of forest fires in the USA on the basis of solar activity. *Thermal Science, 19*(5), pp. 1649–1661.

Schmuck, G., San-Miguel-Ayanz, J., Durrant, T., Boca, R., Libertà, G., Petroliagkis, T., Di Leo, M., Rodrigues, D., Boccacci, F., Schulte, E. (2015). Forest Fires in Europe, Middle East and North Africa 2014. European Commission, Joint Research Centre – Institute for Environment and Sustainability. Luxembourg: Publications Office of the European Union, 107 pp. (http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/)

Schoennagel, T., Veblen, T. T., Romme, W. H., Sibold, J. S., Cook, E. R. (2005). ENSO and PDO Variability Affect Drought-Induced Fire Occurence in Rocky Mountain Subalpine Forests. *Ecological Applications, 15*(6), pp. 2000–2014.

Schoennagel, T., Veblen, T. T., Kulakowski, D., Holz, A. (2007). Multidecadal climate variability and climate interactions affect subalpine fire occurrence, western Colorado (USA). *Ecology, 88*, pp. 2891–2902.

Sibold, J. S., Veblen, T. T. (2006). Relationships of subalpine forest fires in the Colorado Front Range with interannual and multidecadal-scale climatic variation. *Journal of Biogeography, 33*(5), pp. 833–842.

Supić, N., Grbec, B., Vilibić, I., Ivančić, I. (2004). Long-term changes in hydrographic conditions in northern Adriatic and its relationship to hydrological and atmospheric processes. *Annales Geophysicae, 22*(3), pp. 733–745.

https://crudata.uea.ac.uk/cru/data/moi/moi1.output.dat

https://crudata.uea.ac.uk/cru/data/moi/moi2.output.dat