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ARIDITY IN KOSOVO AND METOHIJA, SERBIA

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Abstract: We are investigating aridity in Kosovo and Metohija (KaM), Serbia and calculated two parameters: De Martonne aridity index and the Pinna combinative index. These indices were chosen as the most adequate for the analysis of climate of KaM. Calculation was based on data obtained from 10 meteorological stations for the period 1965–1999. The spatial distribution of the annual and seasonal De Martonne and Pinna combinative indices, as well as the mean monthly values of the De Martonne index and aridity trends of these indices, are presented. There were two, four, and six types of climate on an annual, seasonal, and monthly basis in KaM, respectively, according to the De Martonne climate classification consisting of a total seven types. In addition, semi-humid and humid climate types where present in the region, were included in the study on an annual basis. The winter season was dominated by wetter types of climate, while the spring season was characterized as semi-dry and dry. Three climate types, which can be indentified using the Pinna combinative index, where registered in the KaM region. The most dominant climate type was the semi-dry climate, with some Mediterranean vegetation in the south-west part of KaM. A small part of territory identified as semi-arid type is also in the central part of KaM. Therefore, it can be considered that there were no recent aridity changes during the observed period of 35 years.

Keywords: Kosovo and Metohija, aridity, De Martonne, Pinna, climate, trends

1. INTRODUCTION

In this century, issues of climate variability and climate change have been the target of many scientific studies. Global climate variability and change, caused by natural processes as well as anthropogenic factors, are major and important environmental issues that may cause changes of the world climate during the twenty-first century (Hulme et al., 1999; Kenny et al., 2001; Baltas & Mimikou, 2005; IPCC, 2007). Recent global climate change has now the main role (Croitoru et al., 2013), as well as temperature changes and the possible effect of climate change (Jones et al., 1999). These include many new effects not previously so widespread on Earth, as rising sea levels, floods, and droughts. Aridity plays a significant role in understanding climate conditions and natural processes. Frequently observed aridity is not only important as an indicator of the growth and development of plants but also as a factor for explaining characteristics of the landscape. The aridity index is widely used for the climate-based land classification from the standpoint of dryness (Arora, 2002). Numerous climate indices, used as diagnostic tools to define the state of a climate system and the understanding of the various climate mechanisms have been improved by using several climate variables (Deniz et al., 2011). Aridity was defined by various indicators of which some include both temperature and precipitation, such as De Martonne aridity index (1925) and Pinna combinative index (Baltas, 2007). However, most scientists identify aridity conditions by employing indices originating from climatic elements. All of these indices are based on the potential or reference evapotranspiration, calculated using different formulas (Palmer, 1965;

Cook et al., 2004; Wu et al., 2006; Zhao et al., 2007; Croitoru et al., 2013). They are based on the Thornthwaite (1948) proposed aridity index as the ratio between the mean annual precipitation and the mean annual potential evapotransporation. The Johansson continentality index and the Kerner oceanity index (Baltas, 2007; Deniz et al., 2011) are used for the global climate classifications of continental and oceanic climates. We decided to use the De Martonne aridity index and the Pinna combinative index, since these indices are the most adequate for analysis of climate properties in Serbia, as it was shown by Hrnjak et al., (2014). Therefore, we assume that these two indices can give a good result for Kosovo and Metohija (KaM) region in the Southern Province of Serbia, Serbia.

2. TERRITORY AND DATA

KaM is located on the north-western part of the Balkan Peninsula (Fig. 1). The physical and geographical location consists of two main areas; Kosovo and Metohija. Kosovo is a plateau of a consistent relative height and Metohija is a hilly area bordered by high mountains in the south (Durmitor, Šar Mountain, Paštrik, Koritnik). These areas are connected by a common drainage point (Drmanska head on Mount Crnovljeva 926 m, the Hydrographic node of Serbia), Urošević (1965). The territory of KaM covers an area of 10887 km². It is elongated in the direction to the northeast. Near the town of Uroševac, Kosovo valley is wide open towards Gornjemoravska valley, and is exposed to the influence of different air masses during the year. While the hilly area of Metohija is affected by the factors of geographical location and proximity to the Adriatic Sea (Ducić & Radovanović, 2005). Mediterranean influence is stronger in the south than in the north. This is why the air masses in the summer bring precipitation. The climate of KaM is moderate continental with cold winters, and warm, and humid summers, with huge range of extreme temperatures (Gavrilov at al., 2017) and varying distribution of precipitation over months. The mean annual air temperature is 10.3 °C and the annual amount of precipitation is 686.84 mm.

Select indices are calculated using surface air temperatures and precipitation data which were extracted from the climatic database of the Hydrometeorological Service of Serbia (HMSS, 2014) for 10 meteorological stations on KaM (Fig. 1 and Table 1), for the period 1965–1999. These stations were operated by the HMSS until the NATO bombing of Federal Republic of Yugoslavia in 1999. After the Military Technical Agreement from Kumanovo in June 1999 (Stevanović, 2015) and the issuing of UN Security Council Resolution 1244 on 10 June 1999, most of the meteorological stations were handed over to the new local authorities on KaM. Some stations, such as Kosovska Mitrovica, were closed, while the station Dragaš continued to work, however outside the HMSS. The fate of the other stations is unclear. Despite the operation of some stations after 1999, their meteorological data were not available for this study. The same applies to new stations established after 1999.

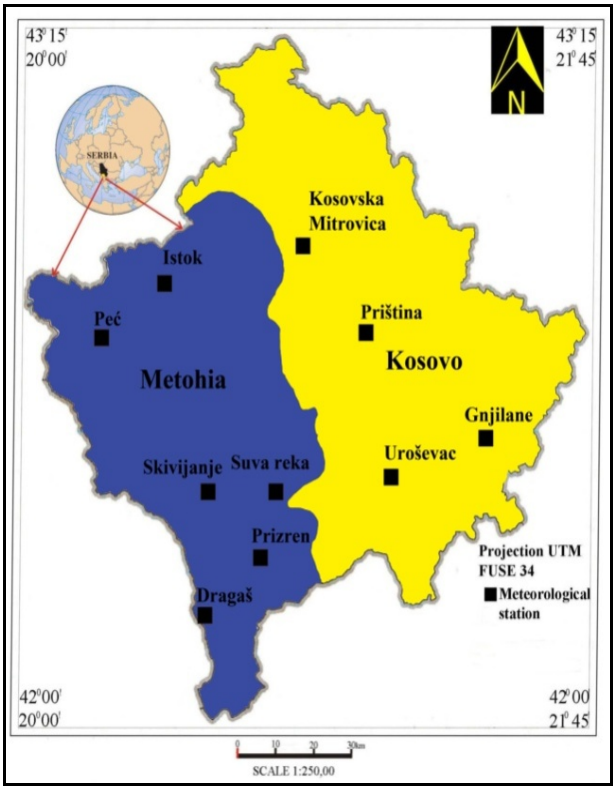

Figure 1. KaM and distribution of meteorological stations

Table 1. The aridity indices were calculated from 1965 to 1999 for 10 meteorological stations on KaM

No.	Met. Station	Lat. (^{0})	Long. (^{0})	Alt.(m)
1	Priština	42.39	21.09	537
2	Peć	42.40	20.18	498
3	Prizren	42.13	20.44	402
4	Kosovska Mitrovica	42.53	20.52	510
5	Istok	42.47	20.30	465
6	Skivijane	42.28	20.21	415
7	Suva Reka	42.21	20.49	420
8	Gnjilane	42.28	20.29	520
9	Uroševac	42.23	20.10	580
10	Dragaš	42.04	20.30	1060

Data sets for each of the stations were analyzed and processed for calculation of monthly, seasonal, and annual values of the mean surface temperature and the amount of precipitation. Before the previous calculation, the homogeneity of the temperature data was examined according to the Alexandersson (1986) test. The test showed that the time series are not inhomogeneous for a significance level of 5 %. The same results were obtained in Gavrilov et al., (2017), where air temperatures trends on KaM are analyzed using the same set of data.

3. METHODS

3.1. The De Martonne aridity index

The De Martonne aridity index is one of the best known and most widely used aridity/humidity indices in applied climatology (De Martonne, 1925; Croitoru et al., 2013). This index is very important in the arid/humid classification. Nevertheless, the fact that it is one of the oldest indices, it is still used with good results worldwide in order to identify dry/humid conditions of different locations (Coscarelli et al., 2004; Baltas, 2007; Shahid, 2008; Zarghami et al., 2011; Haider & Adnan, 2014). This annual index is given by equation:

$$I_{DM} = \frac{P}{T+10}, \quad (1)$$

where P and T are the annual precipitation in mm and the mean annual surface-air temperature in ^{o}C, respectively. The index may be calculated also on the shorter time scale. The monthly value of the De Martonne aridity index is calculated by the following equation:

$$Im_{DM} = \frac{12P_M}{Tm+10}, \quad (2)$$

where Pm and Tm are the monthly precipitation and the mean monthly surface temperature, respectively. For seasonal aridity, the index is expressed in the following form:

$$Is_{DM} = \frac{4Ps}{Ts+10}, \quad (3)$$

where Ps and Ts are the seasonal precipitation and the mean seasonal surface temperature, respectively.

Table 2. De Martonne index climatic classification

Types of climate	Values of I_{DM}
Arid	I_{DM}<10
Semi-arid	10≤I_{DM}<20
Mediterranean	20≤I_{DM}<24
Semi-humid	24≤I_{DM}<28
Humid	28≤I_{DM}<35
Very-humid	35≤I_{DM}≤55
Extremely humid	I_{DM}>55

De Martonne created a classification of climates based on the values of I_{DM} and it is shown in table 2. It can be seen that an increase in the value of I_{DM}, at constant temperature implies an increase of precipitation and vice versa.

3.2. The Pinna combinative index

The Pinna combinative index (Baltas, 2007; Croitoru et al., 2013) is defined as:

$$I_p = \frac{1}{2}\left(\frac{Pma}{Tma+10} + \frac{12P'd}{T'd+10}\right), \quad (4)$$

where Pma, Tma, $P'd$, and $T'd$ are the annual precipitation, mean annual surface temperature, as well as the precipitation, and the mean surface temperature of the driest month. When the value of I_P is less than 10, the climate is characterized as dry, and when the value of I_P varies between 10 and 20, the climate is considered semi-dry Mediterranean with formal Mediterranean vegetation (Baltas, 2010). The climate is identified as humid if the value of I_P is greater than 20. Contrary to the De Martonne aridity index, the Pinna combinative index cannot be calculated for shorter time periods than year. Thus, it can be a very good tool for presenting climate conditions in the driest period of a year, which is very important for agriculture and irrigation activities on the KaM territory.

3.3. Aridity trend

Two statistical approaches are used to investigate the aridity trend (Hrnjak et al., 2014). The first approach was to calculate the tendency (trend) equation using linear interpolation (e.g. Gavrilov et al., 2015; 2016) of the mean annual values of both aridity indices for whole KaM. This method was used to determine the direction of the aridity trends. In the second statistical approach, the Mann-Kendall (MK) test was used (Kendall, 1938; Mann, 1945; Gilbert, 1987) to indicate statistically significant trends.

In using the MK test to define statistically significant trends, two hypotheses were tested: the null hypothesis, H0, that *there is no trend* in the time series; and the alternative hypothesis, Ha, that *there is a significant trend* in the time series for a given significance level. Probability p in percent (e.g. Karmeshu, 2012; Gavrilov et al., 2015) was calculated to determine the level of confidence in the hypothesis. If the computed value p is lower than the chosen significance level α (e.g. α=5 %), the H0 (*there is no trend*) should be rejected, and the Ha (*there is a significant trend*) should be accepted; and if p is greater than the significance level α than the H0 is accepted (or cannot be rejected). MK tests are widely used in environmental sciences around the world, for example: temperature, precipitation, sunshine hours, cloud cover, relative humidity and wind speed (e.g. Marin et al., 2014); temperature and precipitation (e.g. Karmeshu, 2012); precipitation (e.g. Çiçek & Duman, 2015); extreme temperatures (e.g. Serra et al., 2001; Gavrilov at al., 2017); hail (e.g. Gavrilov et al., 2010, 2011, 2013); aridity (e.g. Hrnjak et al., 2014); evapotranspiration (e.g. Tabari et al., 2011); and atmospheric deposition (e.g. Drapela & Drapelova, 2011); because it is simple, robust, and it can cope with missing values.

3.4. Software

In order to calculated the De Martonne aridity index, I_{DM}, and the Pinna combinative index, I_P, we using the program MICROSOFT EXCEL and special software for aridity indices calculation (Hrnjak et al., 2013). For calculating the probability, p, and hypothesis testing, XLSTAT's statistical analysis software was used. For spatial interpolation and graphical map visualization for both indices Geographical information system (GIS) was used as a powerful tool for numerical modeling and displaying of many geophysical data, including climatological data (e.g. Franke, 1982; Collins & Bolstad, 1996).

4. RESULTS AND DISCUSSION

4.1.The De Martonne aridity index

The spatial distribution of the De Martonne aridity index, I_{DM}, is shown in figure 2. The low indices are recorded in the central and north parts of KaM, and lowest values of 30.0 are around Priština and Istok. Values of the index increases to the southern quadrant. The highest values 37.5, 40.0 to 45.0 are recorded in three areas around Dragaš, Gnjilane and Skivijane, respectively. This can be correlated with higher annual precipitation caused by orographic influence of the Paštrik, Koritnik and Prokletije Mountains to the south. According to the previous concept, we can point out that the northern part of the KaM region has a humid climate, while its southern parts have rather a very-humid climate influence. Generally, about 83 % of the territory of KaM is characterized by humid climate and the rest of the territory is characterized by the semi-humid climate which is specific for the central part of the region and very-humid in the southwestern part of region.

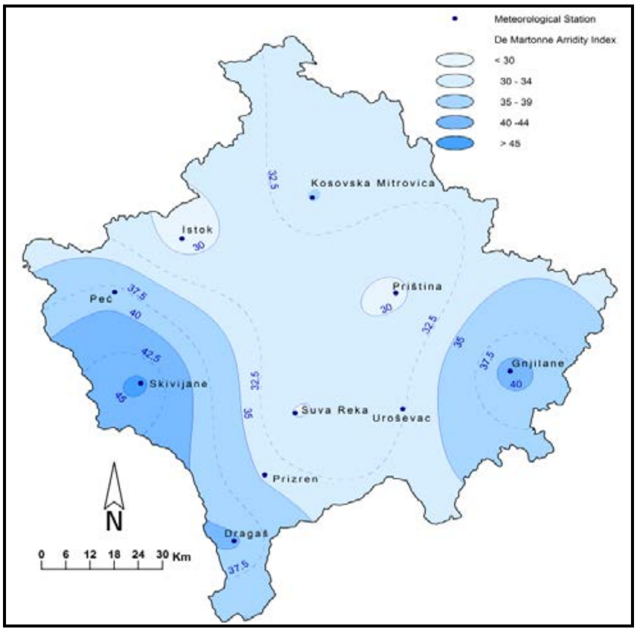

Figure 2. Spatial distribution I_{DM} , from 1965 to 1999

The spatial distribution of the seasonal De Martonne aridity index, Is_{DM}, is shown for calendar seasons: winter, spring, summer, and autumn in Fig. 3a–d, respectively. The spring is dominated by semi-humid climate 23.0. During the winter, values of indexes vary from 11.0 to a maximum of 28.0. As can be seen, most of KaM has humid conditions, except for a small isolated area in the central part of KaM where is climate semi-humid. The summer season is mostly dominated by semi-arid climate conditions with values ranging from 10.0 to 20.0. Only parts of the south-western area are extremely humid. This season is the driest, based on average values of the indices, compared to the winter, spring and autumn values. Finally, the autumn is characterized by the humid but not very humid conditions >30.0.

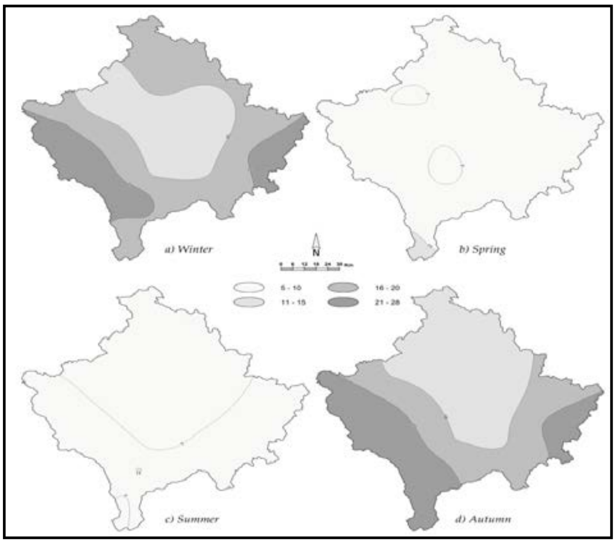

Figure 3. Spatial distribution Is_{DM}, per season

The mean distribution of the monthly De Martonne aridity index, Im_{DM}, is shown in figure 4. As can be seen, six of seven climate types of the De Martonne classification have been identified in KaM. Four months: November, December, January and February, are characterized by extremely humid index values, March, April and October are characterized by a very-humid climate. May is characterized by a semi-humid climate. In September climate index is humid. The greatest diversity of climate types is during June and August because each month is characterized as having the Mediterranean climate index. A more detailed analysis of the seasonal and monthly aridity indices shows great variability of their values. The minimum value of the monthly index is recorded in November 1973 as 0.01, corresponding to arid conditions, while a value of 816.6 mm in January 1967 indicates extremely humid conditions. The minimal seasonal value of 4.8 recorded in the summer of 1971 indicates arid conditions, while maximal value of 90.1 in the winter of 1973 indicates extremely humid conditions in KaM. These details, as well as all of the above-mentioned suggests that KaM region is characterized by a great climate diversity.

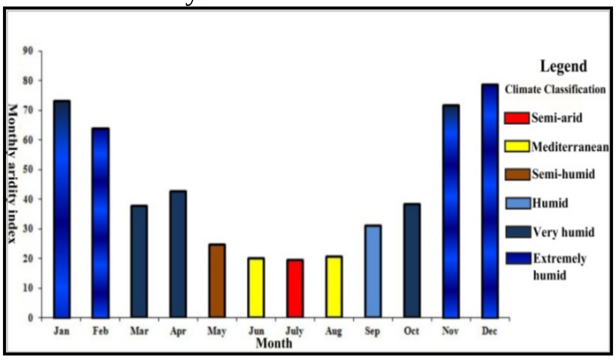

Figure 4. The monthly distribution, Im_{MD}

4.2. The Pinna combinative index

The Pinna combinative aridity index, Ip, ranged from 17.0 to 24.0 based on measurements from 10 stations. But for a more subtle analysis of this index, spatial distribution shown in Fig. 5 will be used. As can be seen, there are two areas of low and three areas of high values of the presented index. First area of low values is located in the central part of KaM with its center in the Priština station, where the value is 17.0, while the second one is located in the south-east directions with the center in, where index value is 18.6. Three centers which are characterized by high values of I_P are located in three directions. The first one is Dragaš with a value of 24.0, and the second one is Peć with value of 23.9, and finally Gnjilane with value of 23.8. Taking into account the above mentioned facts, the following conclusions can be drawn. Most of the area at 10 stations in KaM, is presented by humid climate with mixed forest and shrubs vegetations. In the rest of the territory in the vicinity of station other values with values of 21.0.

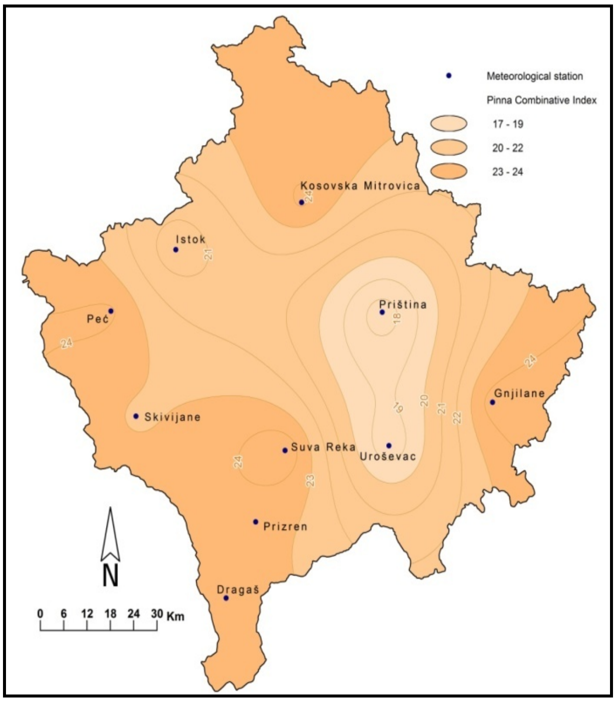

Figure 5. The spatial distribution, I_P, from 1965 to 1999

4.3. Trends

By calculating trends from the mean annual values of I_{DM} and I_P, the following two tendency equations (linear trend) are obtained:

$$y = -0.129x + 37.94, \quad \tau = 0.07, \quad p = 55.4, \quad (5)$$

$$y = 0.065x + 20.66, \quad \tau = -0.15, \quad p = 21.3, \quad (6)$$

where y represents the mean annual values of the aridity indices, x is the time in years, τ is the Kendall's tau (takes values between −1 and +1), p is the probability in percent; the significance level α=5 % is the same in both cases.

Figure 6 and Eq. (5) show that for I_{DM} the trend is negative. MK testing will prove whether this statement is true. As the probability p in Eq. (5) is greater than the significance level, α=5 %, the H0 cannot be rejected. Risk to reject the H0 while it is true is 55.4 %.

Figure 7 and Eq. (6) show that the I_P trend is positive. MK testing will prove whether this statement is true. As the probability p in Eq. (6) is greater than the significance level, α=5 %, the H0 cannot be rejected. Risk to reject the H0 while it is true is 21.3 %.

Looking in this way and concerning De

Martonne aridity index and Pinna combinative index, it seems that there is no aridity change in KaM in the recent period from 1965 to 1999.

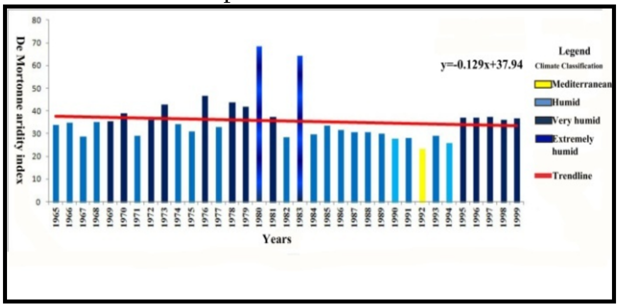

Figure 6. I_{DM} linear trend from 1965 to 1999

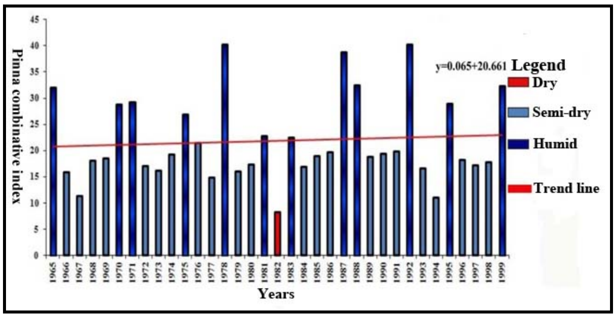

Figure 7. I_P linear trend from 1965 to 1999

5. CONCLUSIONS

For the territory of KaM, which is situated in the north-western part of the Balkan Peninsula, aridity was investigated in a recent period from 1965 to 1999. For this purpose, all operational data of surface-air temperatures and precipitation from 10 meteorological stations relatively evenly distributed over KaM, were used. Meteorological data sets were used to calculate the three types of De Martonne aridity indices: annual I_{DM}, monthly Im_{DM}, and seasonal Is_{DM}; and the Pinna combinative index I_p; as the most suitable parameters for the description of aridity and climate on KaM. A more diversified distribution of climate types in KaM is obtained using the De Martonne aridity index, than using the Pinna combinative index. Such a conclusion is given since it is known that the De Martonne aridity index is more suitable for the analysis of aridity in moderate continental climate such as the KaM region.

From seven types of climate according to the De Martonne climate classification, the annual aridity index gave three values for the semi-humid, humid and extremely type, whereby, the index value increased from north to south. In the case of the Is_{DM}, six out of seven climate types were represented here. The spatial distribution of Is_{DM} showed that during the winter and summer the humid and semi-arid types of climate dominated, respectively. In the spring, situation was different. The central region of KaM had the semi-humid type of climate, while the rest of the area had humid climate conditions. In autumn, there were also three types of climate, humid in the central region, very humid in the southwest, and extremely humid on the southern border with Albania. From the standpoint of the climate type diversity, the case of the Im_{DM} is very interesting. Six types of climate appeared during the year: semi-arid (July), Mediterranean (June, August), semi-humid (May), humid (September), very-humid (March, April, October), and extremely-humid (January, February, November, December). Late autumn and winter months were the wettest, while the spring and early summer months were more humid than the late summer and early autumn months. Using the Ip, three types of climate have been identified. The semi-dry type was dominant, the humid type was present is some parts of the south-west region of KaM and the dry type was present in some parts of the northwest. Indices are used for aridity assessment in very different climatic conditions.

In contrast to the relatively high diversity of climate types per both aridity indices, annual trends of both aridity indices showed no statistically significant changes during the 35 years covered by this research. A similar result, with no significant changes in annual aridity in the region of Vojvodina (Northern Serbia), was obtained in Hrnjak et al., (2014).

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REFERENCES

Alexandersson, H., 1986. *A homogeneity test applied to precipitation data*. Journal of Climatology, 6, 661-675.

Arora, V. K., 2002. *The use of the aridity index to assess climate change on annual runoff*. Journal of Hydrology, 265, 164-177.

Baltas, E., 2007. *Spatial distribution of climatic indices in northern Greece*. Meteorological Applications, 14, 69–78. doi:10.1002/met.7

Baltas, E., 2010. *Surface representation of climatic variables and indices in Greece using GIS methods*. International Journal of Meteorology, 35, 123–136.

Baltas, E. & Mimikou, M., 2005. *Climate change impacts on the water supply of Thessaloniki*.

International Journal of Water Resources Development, 21, 341–353. doi:10.1080/07900620 500036505

Çiçek, İ. & Duman, N., 2015. *Seasonal and annual precipitation trends in Turkey*. Carpathian Journal of Earth and Environmental Sciences, 10, 2, 77-84.

Collins, F. C. & Bolstad, P. V, 1996. *A comparison of spatial interpolation techniques in temperature estimation*. In Proceedings of the Third International Conference/Workshop on Integrating GIS and Environmental Modeling. National Center for Geographic Information Analysis (NCGIA). Santa Fe, NM, Santa Barbara, CA, January 21–25.

Cook, E. R, Woodhouse, C. A, Mark, E. C., Meko, D. M. & Stahle, D. W., 2004. *Long-term aridity changes in the western United States*. Science, 306, 1015-1018.

Coscarelli, R., Gaudio, R. & Caloiero, T., 2004. *Climatic trends: an investigation for a Calabrian basin (southern Italy).* Proceedings of the UNESCO/IAHS/1WHA Symposium held in Rome, December 2003, IAHS Publ., 286, 255-266.

Croitoru, A. E., Piticar, A., Imbroane, A. M. & Burada, D. C., 2013. *Spatiotemporal distribution of aridity indices based on temperature and precipitation in the extra-Carpathian regions of Romania*. Theoretical and Applied Climatology, 112, 597-607. doi:10.1007/s00704-012-0755-2

Jones, P. D., New, M., Parker, D. E., Martin, S. & Rigor, G., 1999. *Surface air temperature and its variations over the last 150 years*. Reviews of Geophysics, 37, 173-199. doi:10.1029/1999 RG900002

De Martonne, E., 1925. *Traité de géographie physique, Vol. I: Notions generales, climat, hydrographie*. Geographical Review, 15, 336–337.

Deniz, A., Toros, H. & Incecik, S., 2011. *Spatial variations of climate indices in Turkey*. International Journal of Climatology, 3, 394–403. doi:10.1002/joc.2081

Drapela, K. & Drapelova, I., 2011. *Application of Mann-Kendall test and the Sen's slope estimates for trend detection in deposition data from Bílý Kříž (Beskydy Mts., the Czech Republic) 1997–2010*. Beskydy, *4*, 133-146.

Ducić, V. & Radovanović, M., 2005. *Climate of Serbia*. Institute for Textbooks and Teaching Aids, Belgrade, (in Serbian). p. 191.

Franke, R., 1982. *Scattered Data Interpolation: Tests of Some Methods*. Mathematics of Computation, 38, 181–200. doi:10.2307/2007474

Gavrilov, M. B., Lazić, L., Pešić, A., Milutinović, M., Marković, D., Stanković, A. & Gavrilov, M. B., 2010. *Influence of hail suppressionon the hail trend in Serbia*. Physical Geography, 31, 441–454. doi:10.2747/0272-3646.31.5.441

Gavrilov, M. B., Lazić, L., Milutinović, M. & Gavrilov, M. M., 2011. *Influence of hail suppression on the hail trend in Vojvodina, Serbia*. Geographica Pannonica, 15, 36–41.

Gavrilov, M. B., Marković, S. B., Zorn, M., Komac, B., Lukić, T., Milošević, M. & Janićević, S., 2013. *Is hail suppression useful in Serbia? – General review and new results*. Acta Geographica Slovenica, 53, 165–179. doi: 10.3986/AGS53302

Gavrilov, M. B., Marković, S. B., Korać, V. & Jarad, A., 2015. *The analysis of temperature trends in Vojvodina (Serbia) from 1949 to 2006*. Thermal Science, 19, 339-350. doi: 10.2298/tSCI 150207062G

Gavrilov, M. B., Tošić, I., Marković, S. B., Unkašević, M. & Petrović, P., 2016. *Analysis of annual and seasonal temperature trends using the Mann-Kendall test in Vojvodina, Serbia*. IDŐJÁRÁS, 120, 183-198.

Gavrilov, M. B., Marković, S. B., Janc, N., Nikolić, M., Valjarević, A., Komac, B., Zorn, M., Punišić, M. & Bačević, N., 2017. *Assessing average annual air temperature trends using the Mann-Kendall test in Kosovo*. Acta Geographica Slovenica (in press). doi: 10.3986/AGS.1309

Gilbert, R. O., 1987. *Statistical Methods for environmental Pollution Monitoring*. Van Nostrand Reinhold Company Inc, New York, p. 336.

Haider, S. & Adnan, S., 2014. *Classification and Assessment of Aridity Over Pakistan Provinces (1960-2009)*. International Journal of Environmental, 3, 24-35. doi:10.3126/ije.v3i4. 11728

Hrnjak, I., Gavrilov, M. B., Marković, S. B., Lukić, T., Tošić, I. A. & Unkašević, M., 2013. *Special software for aridity indices calculation (AICS); Vojvodina, Serbia case study*. Journal of the Geographical Institute Jovan Cvijic, 63, 83-94. doi: 10.2298/IJGI1303083H

Hrnjak, I., Lukić, T., Gavrilov, M. B., Marković, S. B., Unkašević, M. & Tošić, I. A., 2014. *Aridity in Vojvodina, Serbia*. Theoretical and Applied Climatology, 115, 323-332. doi:10.1007/s00704-013-0893-1

Hulme, M., Barrow, E. M., Arnell, N. W., Harrisson, P. A., Johns, T. C. & Downing, T. E., 1999. *Relative impacts of human-induced climate changeand natural climate variability*. Nature, 397, 688–691.

IPCC (**Intergovernmental Panel on Climate Change**), 2007. *Climate Change*. The physical science basis. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds.), Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York. p. 851.

Karmeshu, N., 2012. *Trend detection in annual temperature & precipitation using the Mann Kendall test – a case study to assess climate change on select states in the northeastern United*

States. Master's thesis, University of Pennsylvania, Philadelphia, p. 27.

Kendall, M., 1938. A new measure of rank correlation. Biometrika, 30, 81–89.

Kenny, G. J., Ye, W., Flux, T. & Warrick, R. A., 2001. *Climate variations and New Zealand agriculture: the CLIMPACTS system and issues of spatial and temporal scale*. Environment International, 27, 189-194.

Marin, L., Birsan, M. V., Bojariu, R., Dumitrescu, A., Micu., D. M. & Manea, A., 2014. *An Overview of annual climatic changes in Romania: trends in air temperature, precipitation, sunshine hours, cloud cover, relative humidity and wind speed duration the 1961–2013 period*. Carpathian Journal of Earth and Environmental Sciences, 9, 4, 253-258.

Mann, H. B., 1945. *Non-parametric Tests Against Trend*. Econometrica, 13, 245–259.

Palmer, W. C., 1965. *Meteorological drought*. RESEARCH PAPER NO. 45, Office of Climatology, U. S. Department of Commerce, Weather Bureau, Washington D.C., p. 65.

Serra, C., Burgueño, A. & Lana, X., 2001. *Analysis of maximum and minimum daily temperatures recorded at Fabra Observatory (Barcelona, NE Spain) in the period 1917-1998*. International Journal of Climatology, 21, 617-636. doi: 10.1002/joc.633

Shahid, S., 2008. *Spatial and temporal characteristics of droughts in the western part of Bangladesh*. Hydrological Processes, 22, 2235–2247. doi:10.1002/hyp.6820

Stevanović, O., 2015. *Kumanovski sporazum (Agreement Kumanovo)*. Academy of Criminalistic and Police Studies, Belgrade, p. 345, (in Serbian).

Tabari, H., Marofi, S., Aeini, A., Talaee, P. H. & Mohammadi, K., 2011. *Trend analysis of reference evapotranspirationin the western half of Iran*. Agricultural and Forest Meteorology, 151, 128–136. doi: 10.1016/j.agrformet.2010.09.009

Thornthwaite, C. W., 1948. *An approach toward a rational classification of climate*. Geographical Review, 38, 55-94.

Urošević, A., 1965. *Kosovo*. Serbian Academy of Sciences and Arts, Belgrade, (in Serbian) p.387.

Wu, S., Yin, Y., Zheng, D. & Yang, Q., 2006. *Moisture conditions and climate trends in China during the period 1971–2000*. International Journal of Climatology, 26, 193–206. doi:10.1002/joc.1245

Zarghami, M., Abdi, A., Babaeian, I., Hassanzadeh, Y., Kanani, R., 2011. *Impacts of climate change on runoffs in East Azerbaijan, Iran*. Global Planet Change, 78, 137–146. doi:10.1016/j.gloplacha. 2011.06.003

Zhao, D., Zheng, D., Wu, S., Wu, Z., 2007. *Climate changes in northeastern China during last four decades*. Chinese Geographical Science, 17, 317–324. doi:10.1007/s11769-007-0317-1.

*****HMSS,** 2014. Hydrometeorological Service of Serbia, http://www.hidmet.gov.rs.

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