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SPECIAL SOFTWARE FOR ARIDITY INDICES CALCULATION (AICS); VOJVODINA, SERBIA CASE STUDY

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Abstract: Knowledge of aridity is necessary to explain the characteristics of the geographical landscape. Increasing aridity due to global warming can be a real hazard, with the threat of desertification. The main aim of this paper is to introduce special software for aridity indices calculation (AICS), and on the basis of those data to peruse aridity as a natural hazard. These indices were calculated from data obtained from 10 meteorological stations in the Vojvodina region for the period from 1949 to 2006. In order to calculate the De Martonne aridity index, IDM, and the Pinna combinative index, IP, software was created using C# programming language. Not only that this software shows the values of indices, but also it shows to which class it belongs according to the De Martonne climate classification. Graphical presentation of both calculated indices is also enabled. Further development of AICS is planned. As additional software package here was used ArcMap 10.1 for the spatial representation and visualization of the aridity indices.

Key words: aridity, hazard, Serbia, software, Vojvodina region

Introduction

The last few decades represent a period of time when occurrence of extreme weather and climate events was frequent. Global climate variability and change, caused by natural processes as well as anthropogenic factors, are major and important environmental issues that may affect the world during the twenty-first century (Baltas & Mimikou, 2005; Hrnjak et al., 2013; Hulme et al., 1999; IPCC, 2007; Kenny, Ye, Flux & Warrick, 2001). According to the IPCC Fourth Assessment Report, annual precipitation is very likely to decrease in the most area of the southern Europe including our country. Furthermore the global mean surface temperature is rising. Europe's average temperature has risen even faster than the global mean- about 1°C. The southern part of the Europe has dried by as

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much as 20% in the last century. Climate and land use change influence the characteristics of water balance (IPCC, 2007).

Droughts have become a recurrent phenomenon in many regions of the world, especially in the subtropics and mid-latitudes, affecting more and more ecosystems and society. Even though, aridity and drought are not synonymous, increasing aridity is a real hazard, with the threat of desertification. Aridity is a measure of long-term average climatic conditions. Both humid and arid regions experience droughts. A fundamental distinction exists between aridity, which is a long-term climatic phenomenon and droughts which can alternatively be broadly defined as a temporary, recurring reduction in the precipitation in an area. But, aridity as well as drought can be good indicator for climate change analyzing (Maliva & Missimer, 2012).

Definition and characterization of aridity and its intensity were done by several methods and indicators. Aridity is a term that most people conceptually understand, and it evokes images of dry, desert lands with sparse natural surface-water bodies and rainfall, and commonly only scant vegetation, which is adapted to a paucity of water. Aridity, and associated water scarcity, is a long-term, hydrologic and climatic condition with which local populations must adapt irrespective of its cause. However, the cause of aridity is significant within the context of global climate change, which may impact global atmospheric circulation patterns (Maliva & Missimer, 2012).

Fields like agriculture and water supply seem to can have the most severe damage because of increasing aridity. Such condition can be a limiting factor affecting plant growth and distribution when associated with a certain temperature. This is the main reason why researchers have become increasingly concerned about the frequent occurrence of this phenomenon (Croitiru, Piticar, Imbroane & Burada, 2012).

An areal study of aridity needs index. Aridity index is a result of the interactions of several parameters providing a simple way to describe the ratio of precipitation to temperature and it is useful for assessing areas sensitive to desertification processes (Deniz, Toros & Incecik, 2011). Numerous numerical indices have been proposed to quantify the degree of dryness of a climate at a given location, and thus define climatic zones. Two commonly used aridity indices were discussed herein to illustrate basic concepts. Those were De Martonne aridity index (IDM) and Pinna combinative index (IP).

To facilitate the calculation of aridity indices, we decided to create software, actually WPF application by way of using C# programming language. It enables calculating values of the De Martonne aridity index as well as the Pinna combinative index for 10 meteorological stations for each year, for the period from 1949 to 2006 in the Vojvodina region. Not only that this software shows the values of indices, but also it shows to which class it belongs according to the De Martonne climate classification. This application can be a very good tool for presenting climate conditions in the region, in this case, in Vojvodina, Serbia. This application was implemented as MS Windows Application. It may be used in climatology and related fields because aridity plays a significant role for understanding climate.

Study area

Area of Vojvodina is situated in the southeastern part of Pannonian Basin. In the most part it is represented as a flat terrain with the exception of two low mountains, Fruška Gora and Vršac Mountains (Vasiljević et al., 2011). It is characterized by the presence of quaternary sediments in the geological structure of the lowland part, from which more than 60 % of this lowland area is covered by loess and loess-like sediments (Marković, Oches, Sümegi, Jovanović & Gaudenyi, 2006; Marković et al., 2008). Numerous rivers flow through Vojvodina among them the largest in the Pannonian basin are Danube, Tisa, Sava, Tamiš, Begej. The climate of Vojvodina is moderate continental, with cold winters and hot and humid summers with huge range of extreme temperatures and non-equal distribution of rainfall (Tošić et al., 2013). Taking into consideration that this is a typical agricultural area, the drastic varying of amount of precipitation in the vegetation period can be a big problem. High water deficit during the vegetation season is increased by the coinciding higher temperatures, evaporation and evapotranspiration.

The De Martonne Aridity Index

A measure of aridity of a region, proposed by De Martonne (1925), is given by the following relationship:

$$I_{DM} = \frac{P}{T+10} \tag{1}$$

where P is the annual amount of precipitation (mm) and T (°C) is the mean annual air temperature. The equation is appropriate for temperatures greater than –9.9 °C (Maliva & Missimer, 2012). The De Martonne aridity (IDM) index decreases (approaches zero) with increasing aridity. To identify the arid/humid characteristic of a specific month/season, monthly and seasonal values can be determined, also (Hrnjak et al., 2013).

Pinna Combinative index

Another index used to determine aridity conditions based on temperature and precipitation data is the Pinna combinative index (IP). This index describes in a better way the regions and seasons, where irrigation is necessary as it takes into account the precipitation and air temperature of the driest month. This index takes into account the mean annual temperature and mean annual account of precipitation as well as the precipitation and air temperature of the driest month. This index can be calculated by the following formula:

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

where Pma, Tma, P'd and T'd are the annual amount of precipitation (mm), mean annual surface temperature (°C), the amount of precipitation (mm) and mean surface temperature of the driest month (°C), respectively (Deniz et al., 2011; Hrnjak et al., 2013; Zambakas, 1992).

Database

For the purpose of accurate and detailed analysis of aridity in Vojvodina, it was necessary to create database which consisted of temperature and precipitation parameters. The data were obtained by the Republic Hydrometeorological Service of Serbia for the period from 1949 to 2006. The climatological analysis used values from ten meteorological stations, which are located in the territory of Vojvodina (Figure 1). Data sets for each of the stations were analyzed and processed for the calculation of the mean monthly, seasonal, and annual values of precipitation and surface temperature. After that, the unique database was formed for the purpose of aridity indices calculation.

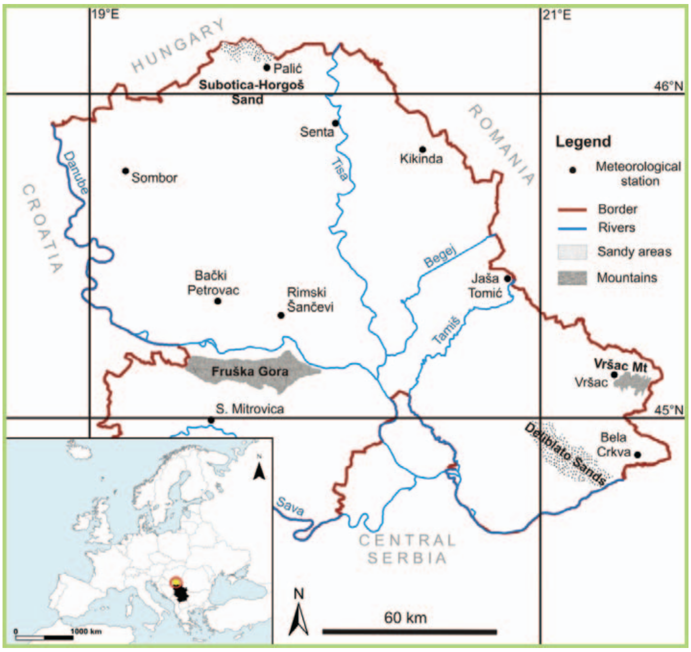

Figure 1. Geographical distribution of meteorological stations in the Vojvodina region (Hrnjak et al., 2013)

Special software for aridity indices calculation (AICS)

Special software for aridity indices calculation (AICS) was created using C# programming language which represents a modern object-oriented programming language that works in accordance with Visual Studio 2010. Visual Studio supports Visual C# with a full-featured code editor, compiler, project templates, designers, code wizards, a powerful and easy-to-use debugger, and other tools. C# is a programming language that is designed for building a variety of applications (Sharp, 2010).

AICS was realized through Windows Presentation Foundation (WPF) application where the editable source code was maintained in a separate file from the code which was generated by Visual Studio. Actually, XAML (Extensible Application Markup Language) is an XML-like language used by WPF applications to define the layout of a form and its contents.

On the beginning, basic form was created using distinctive tools from standard toolbox, but also from DXperience which represents all-inclusive development toolset designed to create applications for Windows.

Software solution was made using 3 models. Precipitation Model (PM), Temperature Model (TM) and Result Model (RM). Each model represents class which consists of properties. Property is one or two code blocks, representing a get-accessor and a set-accessor. The code block for the get accessor is executed when the property is read; the code block for the set accessor is executed when the property is assigned a new value. Both PM and TM consist of four properties. PM consists of: Station, year, annual precipitation and precipitation of driest month. Temperature model (TM) is created from 4 properties: Station, year, annual temperature, and temperature of the driest month. All this data were imported using Spire.xls component which enables importing data from xls files.

Finally, third model- RM contains: Station, year, IDM , IP, and classification. This class actually represents result of the De Martonne aridity index and Pinna combinative index calculation using equations (1) and (2), after which result list could be formed with all mentioned objects. Graphical presentation of indices for each meteorological station in the form of rectangular bars with lengths proportional to the values that they represent is enabled when the values were calculated.

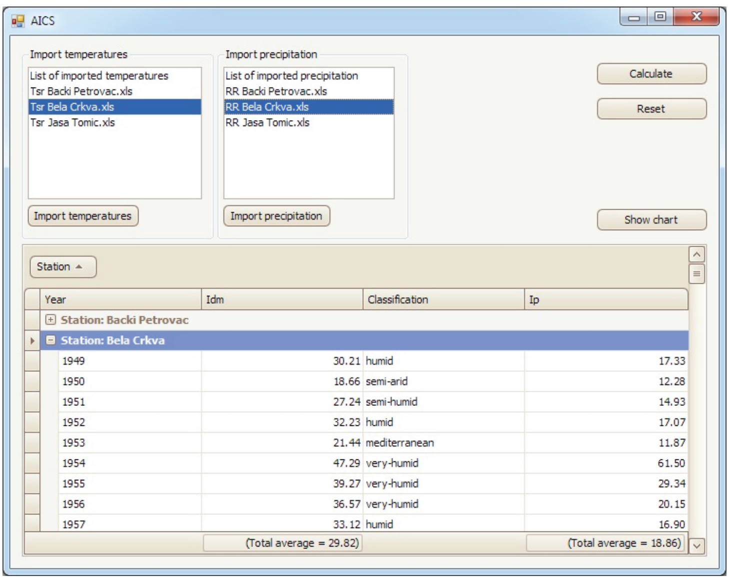

Figure 2. Main window of AICS

As can be seen from Figure 2, application is consisted of main window which includes two list boxes, where strictly defined xls files with all necessary data have to be imported. The first list box is situated in the upper left corner. Files which are consisted of temperature data are stored in this list box, while xls files with precipitation data are stored in the second one which is located right next to the first.

In the list boxes can be loaded data from only one, few or all meteorological stations in the Vojvodina region. Also, the protection of application was made. E.g. If name of the meteorological station from the temperature list box does not correspond to the name of the station in precipitation list box, message box will appear with appropriate error message.

When data are imported, this WPF application enables calculating values of the De Martonne aridity index as well as the Pinna combinative index, using equations (1) and (2) for all 10 stations for each year, for the observed period in the Vojvodina region. Results are shown in table. Not only that this software shows the values of indices, but also it shows to which class it belongs according to the De Martonne climate classification.

AICS software application also provides graphic visualization of the calculated indices for a selected meteorological station (Figure 3). Average values of these indices can be presented in the footer of the application.

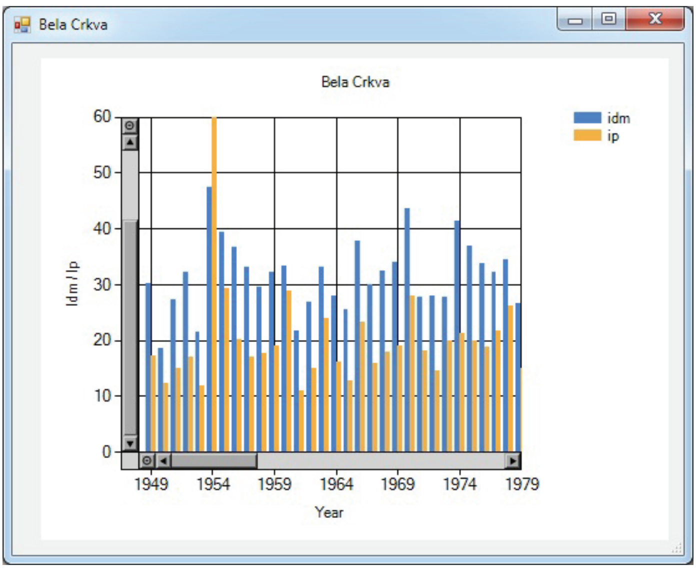

Figure 3. Graphical presentation of both calculated indices IDM (blue) and IP (yellow) for selected meteorological station in the main window (e.g Bela Crkva)

Discussion and results

After indices calculation with AICS, this data are interoperable with other software. ArcMap 10 was used as additional software for the spatial modeling of aridity at various timescales. Ordinary kriging method was used because of isotropy of our data. This method was employed in this paper through extension of Spatial Analyst. It includes autocorrelation or the statistical relationship among the measured points. It takes into account the distance and the degree of variation between known data points (Johnston, VerHoef, Krivoruchko & Lucas, 2001; Nalder & Wein, 1998;).

As Hrnjak et al. (2013) demonstrated, the annual aridity index gave only the values for the semi-humid and humid type, whereby, the index value increased from north to south from seven types of climate according to the De Martonne climate classification (Figure 4).

Using the Pinna combinative index, two types of climate from a total of three types have been identified. The semi-dry Mediterranean type was dominant, while in one small area in the southwest of Vojvodina, humid type was presented. Sremska Mitrovica has more humid influence because of higher annual precipitation caused by orographic influence of the Fruška Gora Mountain. Furthermore, the spatial distribution of the Pinna index is quite similar to that of De Martonne index. It can be concluded that the climate gets drier from the south to the north.

Evaluating the results of the two indices, we consider that it is better to use De Martonne aridity index because of its higher number of classes, than the IP for the area under study. The impossibility of calculating the IP for a shorter periods makes it a very improper to use. Also, there can be found cases where amplitude of this index is very high between two neighboring years. E.g. Value of Pinna combinative index for meteorological station of Sremska Mitrovica in 1953 was 15.9, and next year its value increased to 109. It is because it takes into consideration temperature of driest month, and this can be temperature of distinctive months of a year like in this case.

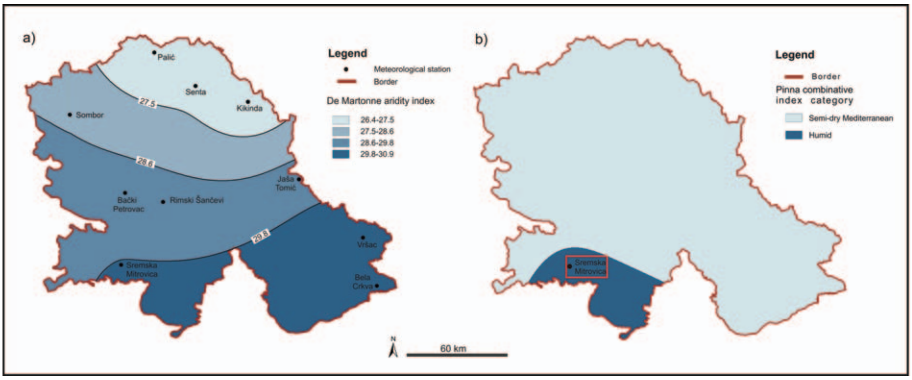

Figure 4. a) Spatial distribution of IDM in Vojvodina region for the period from 1949 to 2006. b) Spatial distribution of IP in Vojvodina region for the period from 1949 to 2006.

In most parts of Vojvodina, present precipitation per summer season is hardly adequate for good crop yields, and further decrease in precipitation may seriously damage agriculture and ecosystems. Although, Hrnjak et al. (2013) demonstrated that there is no aridity change in Vojvodina for observed period, because trends of both analyzed aridity indices were negligibly small, it has to be said that it is according annual values. Seasonal values, especially for summer shows lower level of IDM which means increased aridity.

Taking into consideration Fourth Assessment Report by IPCC, the decrease in precipitation and the largest increase in temperature can change values of indices. In other words, it can resultate with increasing aridity not only in Vojvodina but also in whole southeastern region. As a result of future climatic change, it may have serious consequences for the economy of the country.

Future development of AICS

It is evident that there are many advantages for the use of the AICS application. Speed, accuracy and ease of calculation of indices actually show some of them. AICS is interoperable application that allows exporting data to other software. For now, this application serves only as an extra software in analyzing the aridity of the area of Vojvodina, but its future development is planned.

The future of applications like this one is perfect construction, so AICS will be able to include multiple operations. It is planned that AICS will be developed in at least two directions. The first one is a generalization of the software to be used in other regions around the world. This expansion involves the database in strictly formatted files. The periods for indices calculation could be much longer if all necessary data are included in the files.

Another direction of development could be related to the involvement of other aridity indices, especially those which are based on (potential or reference) evapotranspiration because most of the scientists prefer to identify aridity conditions employing indices developed based on more climatic elements (Onder D., Aydin, Berberoglu, Onder S. & Yano, 2009; Tabari, Aeini, Hosseinzadeh Talaee & Shifteh Some’e, 2011; Zhao, Zheng, Wu S. & Wu Z., 2007).

Also, it is important to maintain and develop interoperability with other software packages (e.g. ArcMap, XLSTAT, etc.) because effective and efficient exchange between programs has increasing trend.

Conclusion

In the last years it became more and more evident that in all countries in the Balkan subregion and in the surrounding countries aridity has had a major impact on many forms and areas of life and the economy, on the whole society and on the environment. The knowledge of aridity is needed to explain landscape characteristics, the rational utilization of water resources but also to determine what influence it has on a global climate and socio-economic hardship that a society could face.

To facilitate understanding of aridity, Aridity indices calculation software was presented here. Software formulation model called AICS was implemented in MS Windows environment using C# programming language. At the same time, the application allows the calculation of the De Martonne aridity index as well as Pinna combinative index of some meteorological stations only if necessary data are strictly formulated in xls files. Here is presented case study of Vojvodina region for the period of 58 years. Also, graphical visualization is enabled for selected meteorological station.

For more detailed aridity analysis this software should be further developed. It is planned that AICS will be developed in at least two directions. The first one is a generalization of the application and the second one is application expansion for calculating other indices which may be of importance not only for agricultural management, but also for better understanding climate conditions of study area.

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