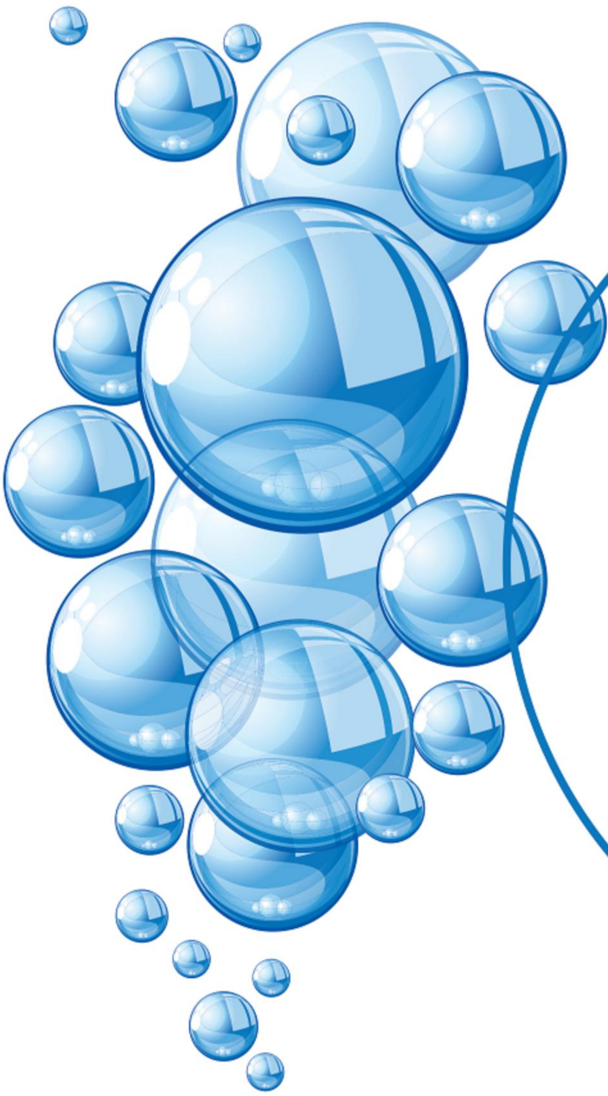
International Symposium



Water Resources Management: New Perspectives and Innovative Practices

PROCEEDINGS BOOK

http://www.swarm.ni.ac.rs/symposium

September 23rd – 24th, 2021
Novi Sad, Serbia

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International Symposium

Water Resources Management:
New Perspectives and Innovative Practices

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PREFACE

The University of Novi Sad, Faculty of Technical Sciences hosted the **International Symposium "Water Resources Management: New Perspectives and Innovative Practices"** from 23rd-24th September 2021. The Symposium was a part of the activities realized under the CBHE KA2 project SWARM "Strengthening of master curricula in water resources management for the Western Balkans higher education institutions (HEIs) and stakeholders" co-funded by the Erasmus+ Programme of the European Union. SWARM project is implemented by a consortium made up of seven HEIs from the Western Balkan Region and six HEIs from Program Countries: University of Niš, University of Novi Sad, University of Priština in Kosovska Mitrovica, University of Montenegro, University of Sarajevo, Džemal Bijedić University of Mostar, Academy of Applied Sciences of Kosovo and Metohija, University of Natural Resources and Life Sciences from Vienna, Norwegian University of Life Sciences, Aristotle University of Thessaloniki, University of Architecture, Civil Engineering and Geodesy from Sofia, University of Rijeka, Faculty of Civil Engineering, Universidade de Lisboa, and Public Water Management Company "Vode Vojvodine".

The main objective of the SWARM project is the education of water management experts in the Western Balkan Region in accordance with the national and European Union policies. This objective is further broken down into the following specific objectives:

- To improve the level of competencies and skills in higher education institutions by developing new and innovative master programmes in the field of water resources management in line with the Bologna requirements and national accreditation standards.
- To design and implement new laboratories in Western Balkan HEIs, in cooperation with project partners from Program Countries.
- to develop and implement LLL courses for professionals in water sector in line with EU Water Framework Directive.

The International Symposium was an interdisciplinary forum where the research results and best practices in the field of Water Resources Management were shared with all SWARM fellows and stakeholders from the entire world. At the same time, the event was the place for the promotion of the SWARM results to a wider audience.

We would like to express our sincere thanks to all session chairs, keynote speakers, presenters, Organizing and Scientific committees, as well as to many others who contributed to the success of this Symposium.

We are confident that the solid foundation created by the SWARM project will continue to build up and strengthen our unique international network.

In Novi Sad, September 2021

Symposium Chairs

Maja Petrović

Milan Gocić

CONTENTS

VISUALIZATION OF AVERAGE ANNUAL PRECIPITATION IN SERBIA FOR THE PERIOD FROM 1946 TO 2019

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Abstract: Precipitation is one of the key players in analysing of natural hazards such as droughts and floods. Thanks to a reliable source of precipitation data on precipitation in the territory of Serbia, a good analysis of data and its visual presentation can be performed. Based on the data collected from meteorological stations, it is necessary to process and visualize them and do an assessment and possibly a warning. This paper presents the application of GIS (geographic information system) which enables visualization of average precipitation annual data in Serbia for the period 1946-2019.

Keywords: *GIS application, precipitation, Serbia*

INTRODUCTION

Climate changes which have been studied and analysed in plenty of publications have a great impact on the environment (Ekström et al., 2005; Kjellström, 2004; Philandras et al., 2011). The main goal is to provide information that should help in the further process of planning, decision-making as well as reducing the harmful impact on the environment. This monitoring of climate change impacts requires an interdisciplinary approach, where IT experts still need to be involved to create web applications and systems that should provide data collection, storage, management and analysis for climate change research.

Climate change is a long-term process, the analysis requires the processing of a large amount of data (big data) collected over a long period of time-related to a specific area of the world. The amount of collected data is quite large due to the measurement of various meteorological parameters. Data sources can usually be collected from manual or automatic meteorological stations, satellite observations, radar data, and smart mobile devices.

Processing a large amount of data is a very demanding process which, due to the longer period of time and the observation in which the data are collected, it is necessary to devise appropriate methods for their processing. Therefore, the Geographic Information System (GIS) can be used as a part of climate data processing (Gad and Tsanis, 2003). One of the approaches to data analysis is a spatio-temporal analysis for example precipitation data (Martins et al., 2012; Ruiz Sinoga et al., 2011; Tosic, 2004).

Nowadays, there are a large number of quality tools in the field of GIS systems (ArcGIS, QGIS (Quantum GIS) and SAGA GIS) that have been developed to provide support in the analysis of collected data. Such tools provide opportunities for general statistical analysis such as mathematical or scientific. These tools have support for various types of analysis of vector and raster spatial data.

Data from different sources are often linked in order to obtain more accurate results in climate change analysis. The most common sources of precipitation data are meteorological radars, satellite observations, and sometimes rain gauges.

The research, design and practical implementation presented in this paper was the development of a specialized GIS application using some of the statistical software such as R to present average annual precipitation data in Serbia.

MATERIALS AND METHODS

Study area

Serbia is selected as a case study and monthly precipitation time series from 28 meteorological stations from the period 1946-2019 were analysed. The data have been collected from annual publications of the Republic Hydrometeorological Service of Serbia. A map of Serbia with designated measuring stations in Serbia through a GIS application using the R language and its packages is presented in Figure 1.

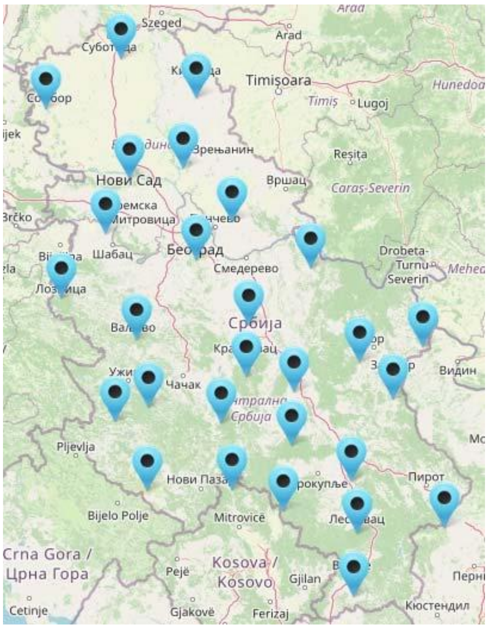


Figure 1. GIS application in the programming language R for displaying data from meteorological stations in Serbia

The geographical description and statistical parameters (mean, standard deviation and coefficient of variation (CV)) for the annual precipitation data of the selected meteorological stations are given in Table 1. The coefficient of variation is ranged from 17.3% (Zlatibor and Loznica) to 32.2% (Kopaonik). The majority of Serbia has a coefficient of variation less than 20%.

Table 1. Geographical descriptions and statistical parameters of the meteorological stations used in the study for the period 1946-2019

Station name	Longitude (E)	Latitude (N)	Elevation (m a.s.l.)	Mean (mm)	Standard deviation (mm)	CV (%)
1. Banatski Karlovac	20°48'	45°03'	89	629.5	141.6	22.5
2. Belgrade	20°28'	44°48'	132	693.8	137.2	19.8
3. Crni Vrh	21°58'	44°08'	1027	792.4	155.5	19.6
4. Cuprija	21°22'	43°56'	123	660.1	125.6	19.0
5. Dimitrovgrad	22°45'	43°01'	450	641.0	123.6	19.3
6. Kikinda	20°28'	45°51'	81	553.0	123.7	22.4
7. Kopaonik	20°48'	43°17'	1711	767.7	247.2	32.2
8. Kragujevac	20°56'	44°02'	185	638.2	117.0	18.3
9. Kraljevo	20°42'	43°43'	215	755.6	137.5	18.2
10. Krusevac	21°21'	43°34'	166	652.0	139.7	21.4
11. Kursumlija	21°16'	43°08'	383	646.3	135.1	20.9
12. Leskovac	21°57'	42°59'	230	625.0	114.0	18.2

13. Loznica	19°14'	44°33'	121	829.2	143.8	17.3
14. Negotin	22°33'	44°14'	42	648.7	146.1	22.5
15. Nis	21°54'	43°20'	204	587.0	116.2	19.8
16. Novi Sad	19°51'	45°20'	86	621.7	151.0	24.3
17. Palic	19°46'	46°06'	102	556.4	118.0	21.2
18. Pozega	20°02'	43°50'	310	753.8	141.6	18.8
19. Sjenica	20°01'	43°16'	1038	731.8	138.8	19.0
20. Smederevska Palanka	20°57'	44°22'	121	646.1	124.4	19.2
21. Sombor	19°05'	45°47'	87	597.2	128.1	21.4
22. Sremska Mitrovica	19°38'	44°58'	82	619.8	119.3	19.3
23. Valjevo	19°55'	44°17'	176	783.9	145.6	18.6
24. Veliko Gradiste	21°31'	44°45'	80	670.2	142.5	21.3
25. Vranje	21°55'	42°33'	432	608.9	117.7	19.3
26. Zajecar	22°17'	43°53'	144	610.3	125.1	20.5
27. Zlatibor	19°43'	43°44'	1028	965.6	167.4	17.3
28. Zrenjanin	20°21'	45°24'	80	579.2	122.6	21.2

Precipitation data in Serbia

Annual precipitation amounts increase on average with altitude. In the lower regions of Serbia, the annual precipitation ranges from 540 to 820 mm. In areas with an altitude of over 1000 m, the stations have an average of 700 to 1000 mm of precipitation, and in some mountain peaks in the southwestern parts of Serbia, precipitation goes up to 1200 mm (Figure 2). In most parts of Serbia, the continental precipitation regime prevails, with a larger amount in the warmer part of the year, and in the southwestern parts, most precipitation is measured in autumn (Gocic and Trajkovic, 2013, 2014). The rainiest month is June, with an average of 12 to 13% of the total annual precipitation.

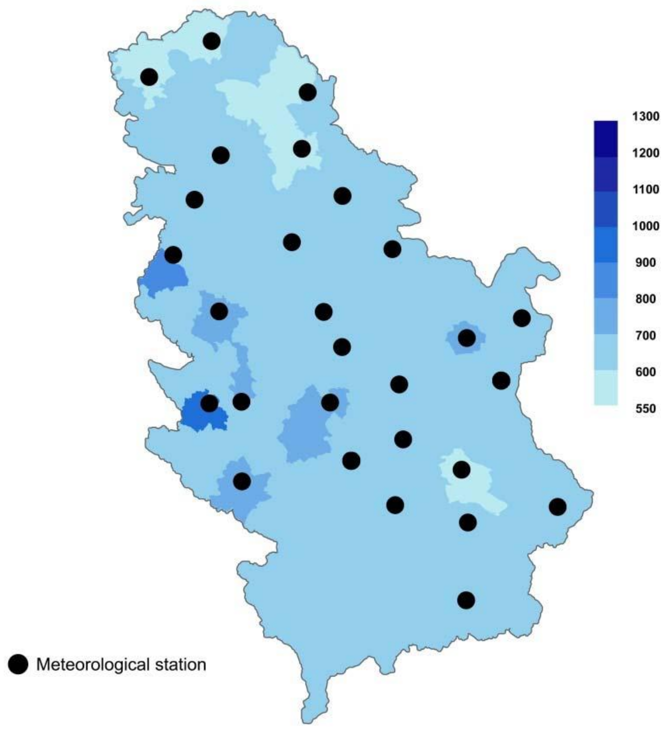


Figure 2. Spatial distribution of mean annual precipitation in Serbia for the period 1946-2019

R programming language and used packages

R programming language as an open-source programming language and software environment is used for statistical computing and creating graphics. Input data for the calculation of annual precipitation, standard deviation and other statistical indicators are given from more Excel documents to R programming language. In order for the data to be used for further analysis, it was necessary to transfer them from Excel to a file that uses the programming language R.

Using R language packages such as shiny, RSQLite, and sqldf data can be loaded and visualize (Figure 3). Information related to a specific location such as average annual precipitation can be read for the selected station.

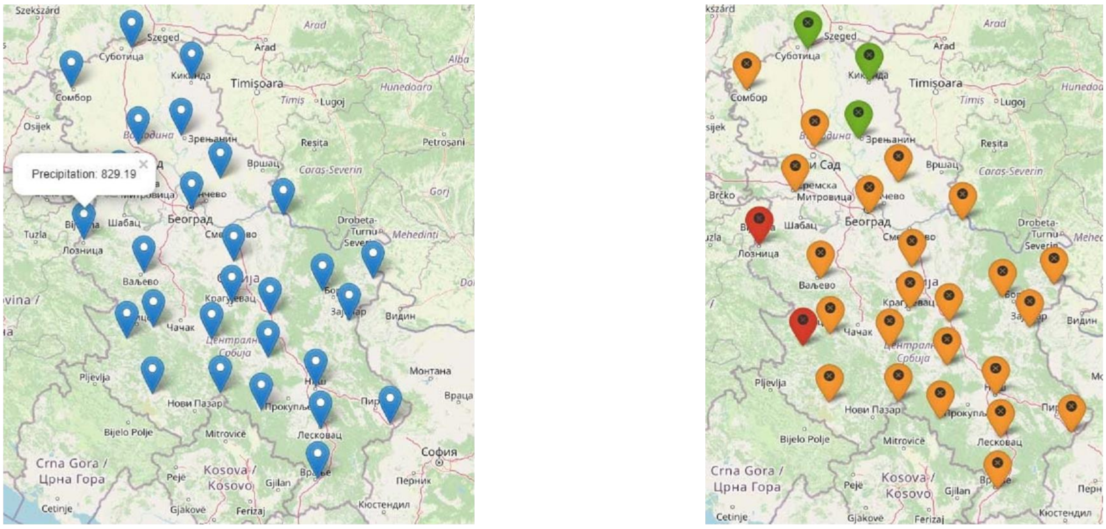
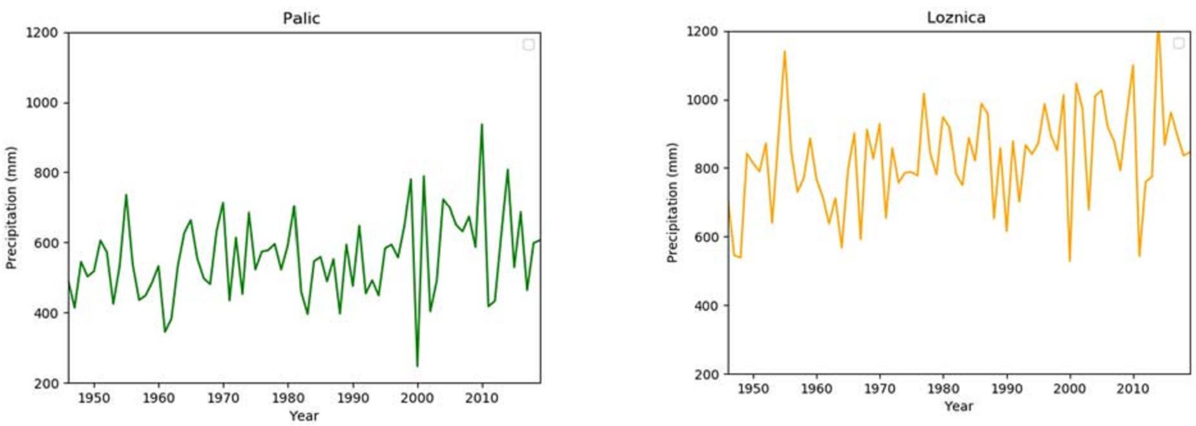


Figure 3. GIS application in the programming language R for displaying the average amount of annual precipitation from meteorological stations in Serbia

VISUALIZATION OF AVERAGE ANNUAL PRECIPITATION

The time series of annual precipitation of the selected five meteorological stations in Serbia (Palic, Loznica, Cuprija, Nis, Vranje) are presented in Figure 4. In order to analyse the collected data, the last graph contains the data from all five stations. The average annual precipitation of selected stations varied between 553 mm (Kikinda) to 965.6 mm (Zlatibor) for the period 1946-2019.



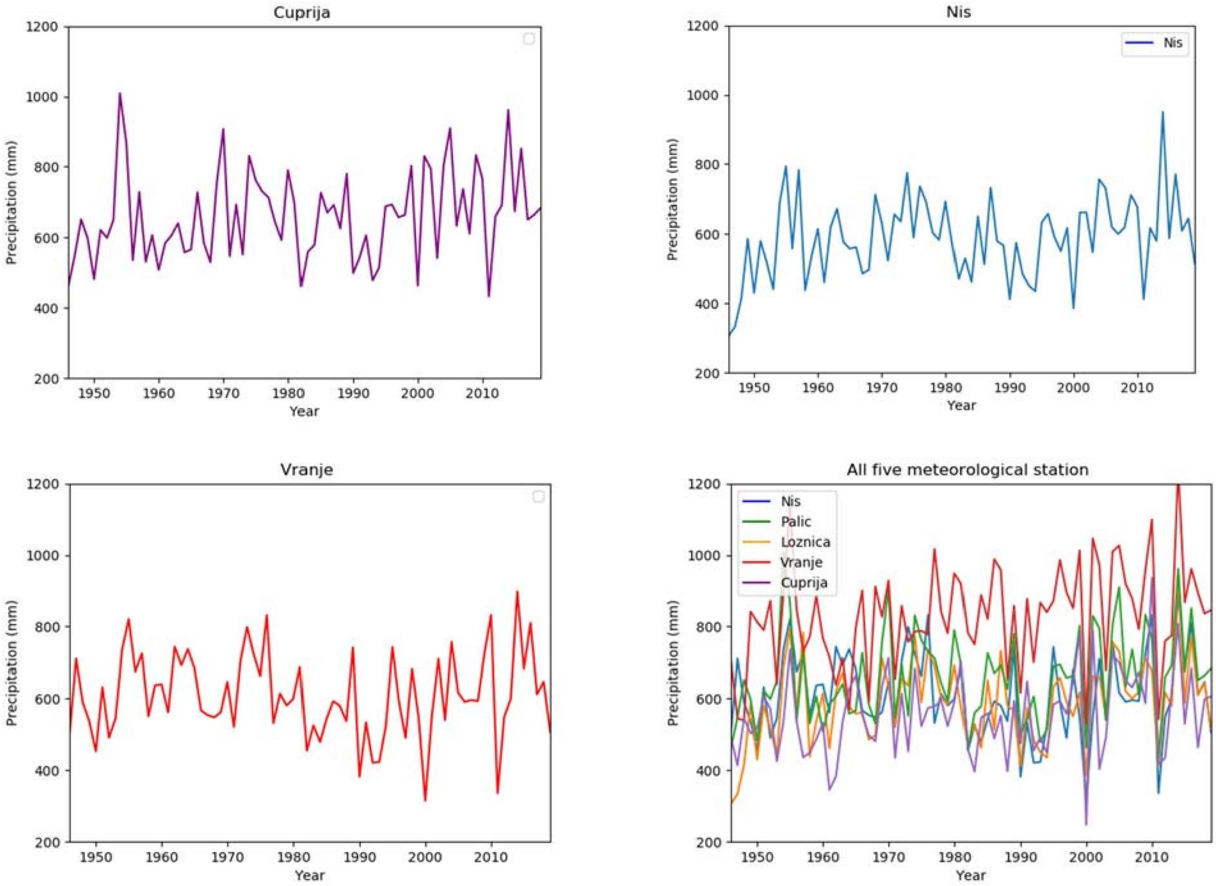


Figure 4. Annual precipitation time series at five selected meteorological stations

The annual amount of precipitation is shown on the map of Serbia in different colors i.e. for precipitation below 580 mm the representation of the meteorological station is green, for precipitation between 580 and 800 mm the meteorological stations are presented in orange, and for precipitation over 800 mm the stations are presented in red.

Figure 5 shows the average annual precipitation for the following stations: a) Nis presented in orange, b) Loznica presented in red and c) Palic presented in green measuring station of the city of Cuprija represented in orange.

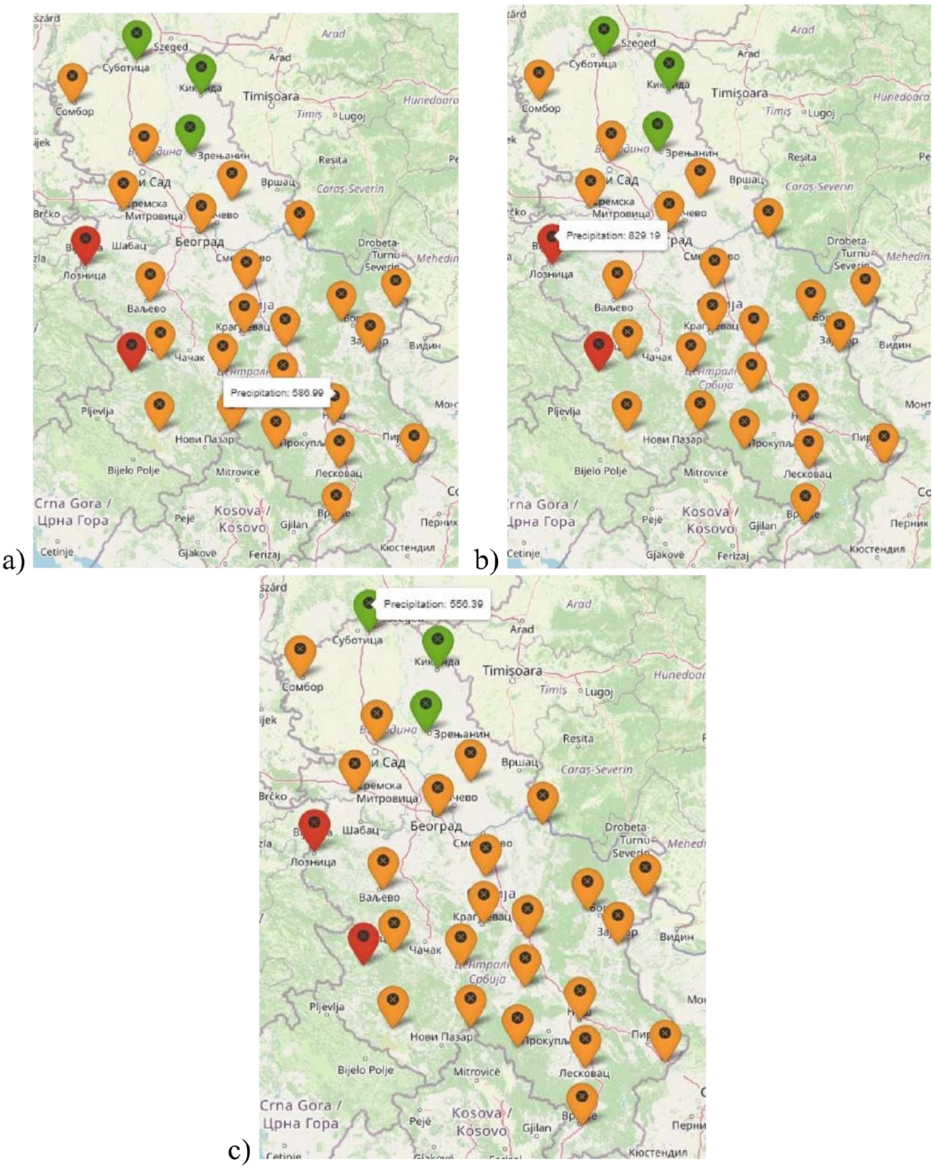


Figure 5. Average annual precipitation for the following stations: a) Nis presented in orange, b) Loznica presented in red and c) Palic presented in green

CONCLUSIONS

In this study, the approach for visualizing average annual precipitation data for 28 meteorological stations in Serbia for the period 1946-2019 is presented. The spatial distribution of precipitation data can help us to better plan water resources. The obtained results can be useful for the planning and management of water resources and agricultural production. The presented application can be a part of the hydro-information system for drought analysing.

Further research should be oriented towards monitoring natural hazards depending on precipitation data such as drought and flood and how to find mathematical and soft-computing methodologies to predict them.

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