How to cite: Abd-Elhamid, H F., Zeleňáková, M., Soľáková T., Ovciarka M. (2025) Assessment of Meteorological Drought Risks in Eastern Slovakia in Response to Climate Change Utilizing Reconnaissance Drought Index. *"Air and Water – Components of the Environment" Conference Proceedings*, Cluj-Napoca, Romania, p. 131-144, https://doi.org/10.24193/AWC2025_13 .

ASSESSMENT OF METEOROLOGICAL DROUGHT RISKS IN EASTERN SLOVAKIA IN RESPONSE TO CLIMATE CHANGE UTILIZING RECONNAISSANCE DROUGHT INDEX

ABD-ELHAMID, Hany F.[1,2], ZELEŇÁKOVÁ, Martina[1], SOĽÁKOVÁ Tatiana[1], OVCIARKA Matej[1]

ABSTRACT. Assessment of Meteorological Drought Risks in Eastern Slovakia in Response to Climate Change Utilizing Reconnaissance Drought Index. Meteorological drought is a natural phenomenon that is increasing in frequency because of climate change, which leads to modifications in the temperature and precipitation patterns over time. Drought monitoring has become a worldwide key issue because of increasing global warming and climate change. A variety of drought indices can be employed to assess and forecast the onset of various droughts. While there are various drought indices to monitor extreme drought conditions, this study uses the Reconnaissance Drought Index (RDI) because of its precision and its dependence on both rainfall and temperature. This research examines the temporal and spatial changes of meteorological droughts in Eastern Slovakia utilizing the RDI calculated based on 12 months' timescale. Analysis of drought is carried out for data from seven meteorological stations over a period of 50 years from 1972 to 2022. The classification of historic droughts has been categorized into moderate, severe, and extreme using RDI-12. The findings indicate that the average inter arrival time of various drought categories in Eastern Slovakia for the studied period from 1972 to 2022 ranged from 65 to 144 months for moderate drought, from 35 to 58 months for severe drought and from 21 to 34 months for extreme drought. However, the total number of months for different drought categories ranges from 54 to 74 months for moderate drought, from 23 to 29 months for severe drought and from 3 to 6 months for extreme drought. The results showed that the driest years where extreme drought occurred were: 1986, 2006, 2012, 2014, 2016 and 2022. This comprehensive regional assessment of drought risk using RDI index provides valuable insights for efficient drought management in Eastern Slovakia. The execution of strategies aimed at reducing the adverse effects of droughts resulted from climate change on surface water and groundwater levels, is crucial for the regions of Eastern Slovakia.

Keywords: Meteorological drought risks assessment, climate change, meteorological data, RDI, Eastern Slovakia.

1. INTRODUCTION

Drought is a natural phenomenon primarily caused by variations in average precipitation over a specific timeframe in a given area. This can result in various

[1] Department of Environmental Engineering, Faculty of Civil Engineering, Technical University of Kosice, 04001 Košice, Slovakia, hany.abdelhamid@tuke.sk, martina.zelenakova@tuke.sk, tatiana.solakova@tuke.sk, matej.ovciarka@student.tuke.sk
[2] Department of Water and Water Structures Engineering, Faculty of Engineering, Zagazig University, Zagazig, 44519, Egypt, hany_farhat2003@yahoo.com

forms of drought, such as meteorological, agricultural and hydrological, depending on the time scale being examined. Drought is regarded as an expensive natural disaster across all climatic regions, having extensive impacts that influence various economic sectors and hinder the degradation of environmental components. Numerous studies indicated that with the ongoing progression of global warming, droughts are increasingly regarded as a significant future risk to humanity on a global scale. Consequently, it is essential to determine suitable drought indices to accurately evaluate drought occurrences and track their intensity. These drought indices serve as the primary tools for observing variations in drought conditions by utilizing agricultural, climatic, and water-related data.

Drought indices can be applied locally, regionally or globally to assess the drought risks and define their type based on the time scale of occurrence and the impacts. Knowing how drought spreads is of key importance to regions, as it helps to manage water efficiently and prepare appropriate water management plans. A key factor in any drought is inadequate rainfall, in terms of timing, speed and intensity, while the severity of a drought may be exacerbated by the impact of low water availability, high demand and use in certain regions (Mishra and Singh, 2010). The Reconnaissance Drought Index RDI (Tsakiris et al., 2006) is used worldwide for meteorological drought detection and forecasting using different climate variables. Indices like RDI measure the intensity of drought occurrences, indicating that lower index values correspond to an increased vulnerability to drought. The RDI can be computed for various timescales of 1, 3, 6, 9, 12, and 24 months. RDI is based on precise net precipitation and actual evapotranspiration data. These data reflect actual losses of soil and vegetation and are a true representation of the water availability of the region (Afzal and Ragab, 2020; Marini et al., 2019). This data can additionally mitigate financial losses by facilitating a greater range of options in at-risk areas. Previous studies have shown that drought is occurring frequently because of climate change. For a region such as Slovakia, knowledge of the historical effects and their temporal distribution in natural elements is essential to mitigate droughts impacts.

RDI is applied in a number of studies for assessing current and future drought scenario, as potential evapotranspiration is a key element in the water cycle, particularly in the event of global warming, and cannot be ignored in the forecasting of future droughts (Khan et al., 2017, Yang, 2018, Afzal and Ragab, 2020; Pathak and Dodamani 2020). The use of RDI Index and the testing of trends by Mann-Kendall have been reported in studies such as Zarch et al. (2015), Merabti et al. (2017), Khanmohammadi et al., (2018), Marini et al. (2019), Pathak and Dodamani (2020), Dehghani et al. (2022), Bouregaa (2023). The Mann-Kendall test on the SPI and RDI time series across 5 drought regions from 1960 to 2009 was used by Zarch and Co. (2015), illustrating the spatial distribution of drought trends (decreasing, increasing, and negligible) in different regions. Merabti et al. (2017), used SPI and the RDI for the analysis of drought trends in north-eastern Algeria based on monthly precipitation data from 123 weather stations collected between 1979 and 2013. They discovered that there were no notable patterns in the frequency and intensity of droughts across all time scales. Also, Khan Mohammadi et al. (2018) used SPI and RDI indices to examine the dry and wet trends for 30 stations in Iran over the period from 1960 to 2014. It was observed that across all examined stations, the behavior of both indices was almost identical, and the difference between them was not statistically significant.

Over the years different drought indexes have been applied to evaluate drought risks in different regions. Pathak and Dodamani (2020) compared various weather-related drought indices (SPI, RDI and SPEI) for the Ghataprabha river basin in India, including 25 stations, over the period 1970 to 2013 in 3, 6 and 12 months. A trend analysis shows that precipitation is falling, and temperatures are rising significantly at all stations in the basin. This means that the region may be faced with serious droughts. They confirmed that RDI and SPI show alike results for all considered stations. Abbas et al. (2021) used RDI and SRI to examine meteorological and hydrological drought from 1984 to 2015 in the Soana river basin in Pakistan and found that drought has increased in recent years. Recently, Vergoni et al. (2021) applied well known standardized indices: SPI, SPEI, RDI and SDDI for the assessment of sunflower yields in central Italy from 1980 to 2019. Mohamed et al. (2023) used SPS and the RDI to study drought and precipitation in Tunisia from 1958 to 2020 and found that SPI exhibited an upward trend, whereas the RDI trend in Northern Tunisia was on the decline.

SPI-3, RDI-3 and SPEI-3 indices were used for detecting droughts over mainland China (1961-2012) by Xu et al. (2015). All the indices exhibited non-significant trends as per the Mann-Kendall test and are not suitable for demonstrating the variation in water scarcity throughout China. Del Toro-Guerrero and Kretzschmar (2020) conducted analysis for hydro-climatic and temperature trends, as well as extreme events and drought occurrences in California's Guadalupe Valley from 1979 to 2016. Their findings indicate that annual and seasonal precipitation has diminished by 110-172 mm, while average annual and seasonal temperatures have risen by 0.76-1.82°C, particularly during the wet winter months. Bazrafshan et al. (2019) used SPI, RDI and SPEI in several time scales to analyses drought risks in Iran for the period 1996-2016. The results showed that the trend towards more frequent droughts is increasing in dry climates and decreasing in cold climates. Nagy and Zeleňáková (2020) used RDI and SDI indices at 13 locations to analyze drought occurrences between 1960 and 2015 in Slovakia. The Mann-Kendall test was employed to identify drought trends in indices and revealed significant trends at only 5 stations from the 13 studied locations.

This study aims to evaluate meteorological drought risks in Eastern Slovakia by utilizing the drought index (RDI-12), which is derived from meteorological data collected from seven stations distributed uniformly on the studied region. The RDI is capable of detecting moderate, severe, and extreme drought conditions across various time scales. By considering the different time scales, it aids in the preparation for potential future droughts in diverse sectors such as agriculture and water resource management.

2. MATERIALS AND METHODS

The rising water demand is influenced by both population growth and climate change which exacerbated the aggravating effects of frequent droughts in recent years at different regions. For example, regions with higher temperatures are experiencing a surge in evaporation, which will further increase pressure on water supplies (Zarch et al., 2015). Consequently, comprehending the historical occurrences of droughts in the Eastern Slovakia and their adverse effects is crucial for water resources management in that area. The RDI drought index is employed to analyze drought conditions based on meteorological data from 7 stations over a span of 50 years, from 1972 to 2022.

2.1. Description of the study area and data collection

The boundaries of eastern Slovakia are Poland to the north, Ukraine to the east, and Hungary to the south. According to the research, there are seven meteorological stations situated in the East Slovak region. Table 1 presents the coordinates and elevations of these meteorological stations in eastern Slovakia, while Figure 1 depicts their geographical distribution.

Table 1. Elevation and coordinates of the 7 stations in Eastern Slovakia

Precipitation station	Elevation	Longitude	Latitude
Bardejov	312	49°17'56"N	21°16'45"E
Červený Kláštor	469	49°24'00"N	20°25'01"E
Kamenica and Cirochou	176	48°55'00"N	22°59'00"E
Košice	208	48°43'16"N	21°15'29"E
Spišské Vlachy	389	48°56'59"N	20°47'50"E
Štós	516	48°42'40"N	20°47'10"E
Skalnaté Pleso	1778	49°11'22"N	20°14'01"E

Skalnaty Pleso records the highest average precipitation at 113.4 mm, whereas Košice and Spišskou Vlach have the lowest average precipitation at 51.98 mm. The most important agricultural region in the country is the area in the south-east, also known as the Eastern Lowlands.

Meteorological data over a period of 50 years (1972 to 2022) have been collected by the Institute of Hydrometeorology in Košice. The 7 stations are geographically spread over the Research Area as shown in Figure 1. The meteorological data collected have been analyzed. The minimum and maximum temperature were 38.1^{o} C in the east and -35.6^{o} C in the north. The recorded minimum and maximum precipitation levels show that the highest precipitation reached 490.2 mm, while the lowest was 0.5 mm. Furthermore, the maximum evapotranspiration measured 262.8 mm, with the minimum being roughly 0.5 mm.

2.2. Methodology

For the analysis of drought risks, the Slovak Hydrometeorological Institute in Košice provided monthly precipitation and temperature data over a period of 50 years from 1972 to 2022 for 7 meteorological stations.

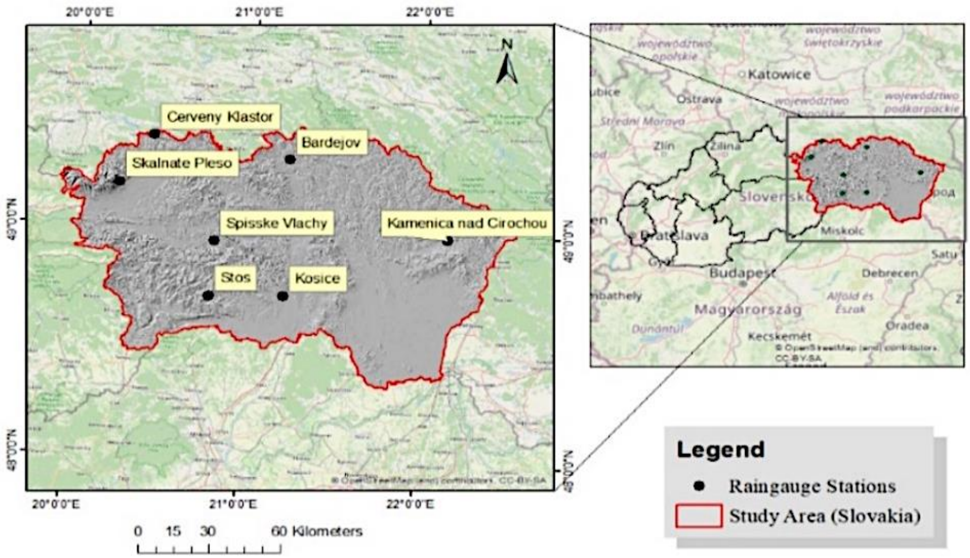

Figure 1. The location of meteorological stations in Eastern Slovakia

The Reconnaissance Drought Index (RDI) for 12 months' time scale is calculated for the period from 1972 to 2022. The division of drought hazards is very useful for drought detection and water resources management. The risk of drought could be divided into different categories. Table 2 shows the classification of droughts according to the RDI (Sienz et al., 2012; Blain et al., 2012). The study emphases three drought events: moderate, severe and extreme drought.

Table 2. Drought classification (Sienz et al., 2012; Blain et al., 2012).

Drought index intervals	Drought index RDI classes
≥ 2.0	Extreme humidity
1.5 to 1.99	High humidity
1.0 to 1.49	Mild humidity
0.99 to -0.99	Almost normal humidity
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	severe drought
≤ -2.0	Extreme drought

3. RESULTS AND DISCUSSION

Drought indices are practical tools for tracking and predicting drought conditions. The drought risks in Eastern Slovakia are evaluated using RDI that rely on meteorological data from 7 stations over the past 50 years, from 1972 to 2022. The Drought Indices Calculator (DrinC) is used to calculate the RDI on a monthly basis.

The RDI used climate data; precipitation, temperature and potential evapotranspiration to evaluate drought risk. DrinC is simple and user-friendly tool with full graphical user interface (GUI) (Tigkas et al. 2015). The time scale usedd in this study is 12 months to analyze the long-term droughts risks. The total number of months for the moderate, severe, and extreme drought categories, as determined by RDI, is shown in Table 3.

Table 3. The total number of months for different droughts categories

Station	Moderate drought	Severe drought	Extreme drought
Bardejov	74	23	3
Červený Kláštor	61	24	16
Kamenica and Cirochou	74	23	3
Košice	74	25	4
Spišské Vlachy	55	29	10
Štós	54	26	12
Skalnaté Pleso	74	23	3

Table 3 shows that at nearly all the stations, the total number of months decreases as the drought category increases and moderate drought providing the highest number of months. Table 4 displays 12-month time scale, the inter-arrival times of drought categories by RDI. According to RDI-12, the interval arrival times and return periods for various drought categories. The results show that the return period ranges from 1.8 to 2.8 years for moderate drought, 3 to 4.8 years for severe drought and 6.6 to 12.1 years for extreme drought.

The spatial repartition of total number of months for different droughts categories is presented in Figure 2.

Table 4. The average inter arrival time (month) and average return period (year) of different drought categories

Station	Moderate drought		Severe drought		Extreme drought	
	Average Inter arrival time	Average Return period	Average Inter arrival time	Average Return period	Average Inter arrival time	Average Return period
Bardejov	79.0	6.6	44.5	3.7	21.5	1.8
Červený Kláštor	107.3	8.9	58.0	4.8	30.5	2.5
Kamenica and Cirochou	79.0	6.6	44.5	3.7	21.5	1.8
Košice	65.0	5.4	35.9	3.0	21.6	1.8
Spišské Vlachy	144.8	12.1	55.0	4.6	32.4	2.7
Štós	142.0	11.8	44.5	3.7	34.1	2.8
Skalnaté Pleso	79.0	6.6	44.5	3.7	21.5	1.8

The temporal analysis of drought in Eastern Slovakia over the period (1972 to 2022) is presented in Figures 3 to 9 for the 7 stations. The figures show RDI-12 at the 7 meteorological stations considered in this study. Assessment of drought hazards at all stations is explained in the following sections.

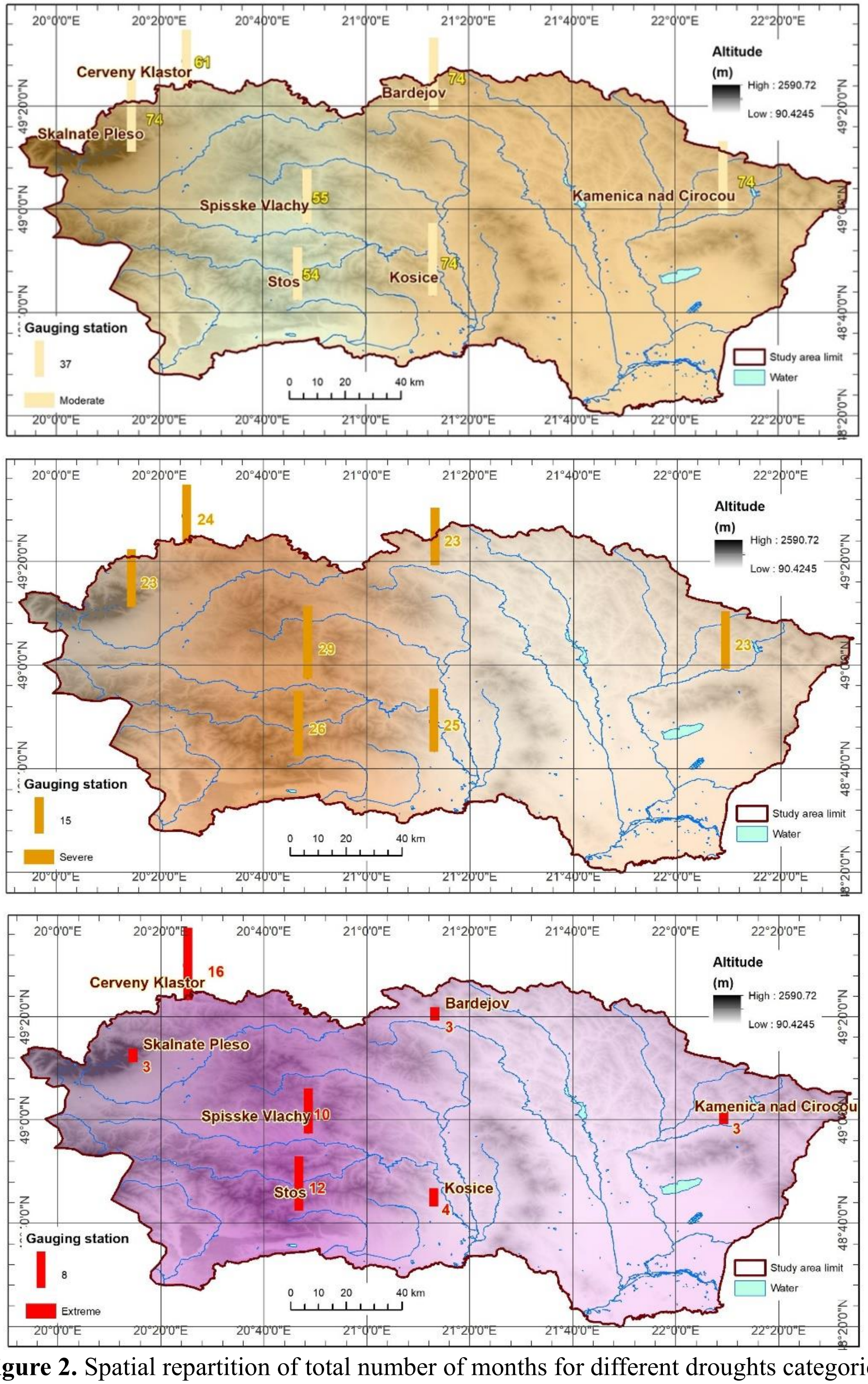

Figure 2. Spatial repartition of total number of months for different droughts categories (WGS84 cartographic projection)

3.1 Bardejov station

The results of RDI-12 at the Bardejov station are shown in Figure 3. The results show that the total duration for different droughts (moderate, severe and extreme) is 74, 23 and 3, respectively. The average inter arrival time of different droughts (moderate, severe and extreme) are 79.0, 44.5 and 21.5 months, respectively. The extreme drought was detected in the years 2003, 2011, 2016 and 2022. Bardejov station recorded the longest duration of moderate drought (74 months) and the shortest inter arrival time for extreme drought (21.48 months). The average return period for moderate, severe and extreme droughts is 6.6, 3.7 and 1.8 years, respectively.

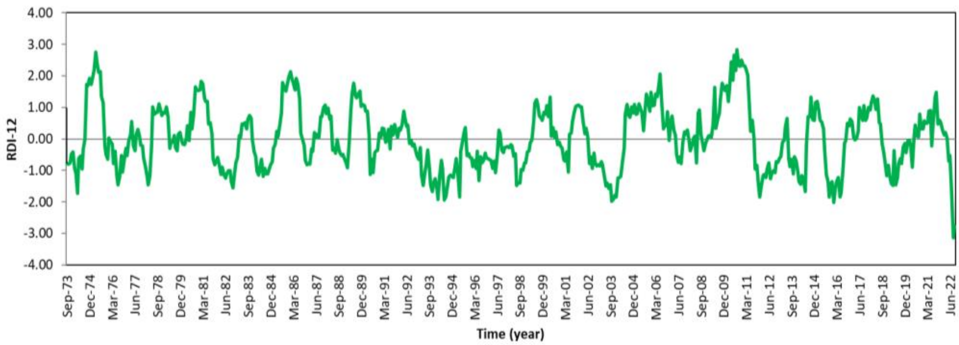

Figure 3. RDI-12 at Bardejov station for the period (1972-2022)

3.2 Červený Kláštor station

At Červený Kláštor station the results of RDI-12 (see Figure 4) show that in the years 1986, 1994, 2012 and 2022 extreme drought was recorded. The average inter arrival time of moderate, severe and extreme droughts are 107.3, 58.0 and 30.5 months, respectively. However, the average return period is 8.9, 4.8 and 2.5 for moderate, severe and extreme droughts, respectively. Moreover, the duration for moderate, severe and extreme droughts are 61, 24 and 16 months respectively. Červený Kláštor station recorded the longest duration for extreme drought (16 months).

3.3 Kamenica and Cirochou station

In Kamenica and Cirochou stations, the extreme drought was recorded in the years 2003, 2007, 2015, 2016 and 2019 as shown in Figure 5. The total number of months 74, 23 and 3 for moderate, severe and extreme droughts, and the average inter arrival time of 79.0, 44.5 and 21.5 were recorded at the Kamenica and Cirochou station for the studied period from 1973 to 2022. Moreover, the average return periods for the three categories were 6.6, 3.7, and 1.8 months. This station also gave a short inter arrival time for extreme drought (21.48 months) like Bardejov station.

3.4 Košice station

Figure 6 shows the results of RDI-12 at Košice station. The extreme drought detected by RDI index is at the years 1977, 1986 and 1992. The average inter arrival time of moderate, severe and extreme droughts are 65.0, 35.9 and 21.6 months, and the average return period is 5.4, 3.0 and 1.8 years. Moreover, the duration of the three droughts categories 74, 25 and 4 months respectively. Kosice station gives the shortest duration of moderate drought (65 months) compared to other stations.

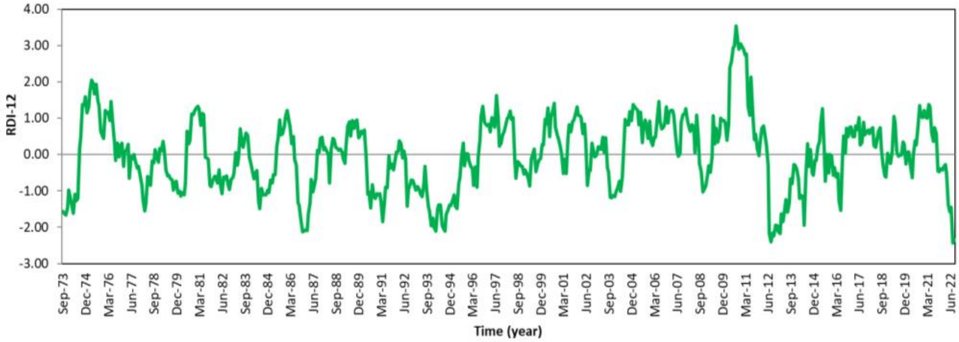

Figure 4. RDI-12 at Červený Kláštor station for the period (1972-2022)

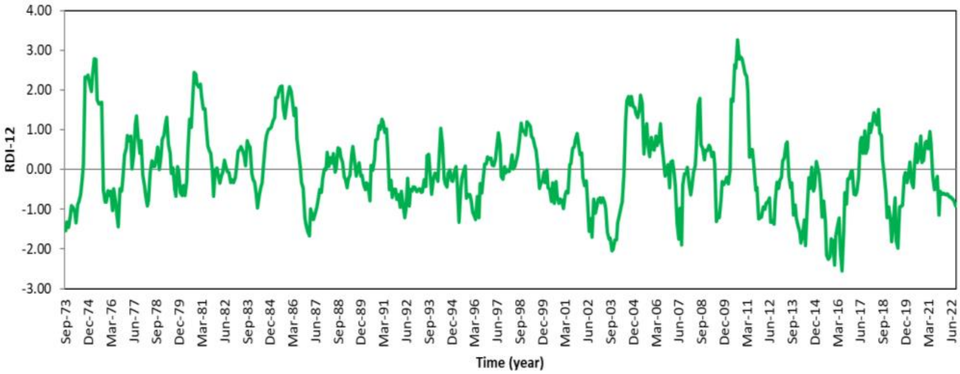

Figure 5. RDI-12 at Kamenica and Cirochou station for the period (1972-2022)

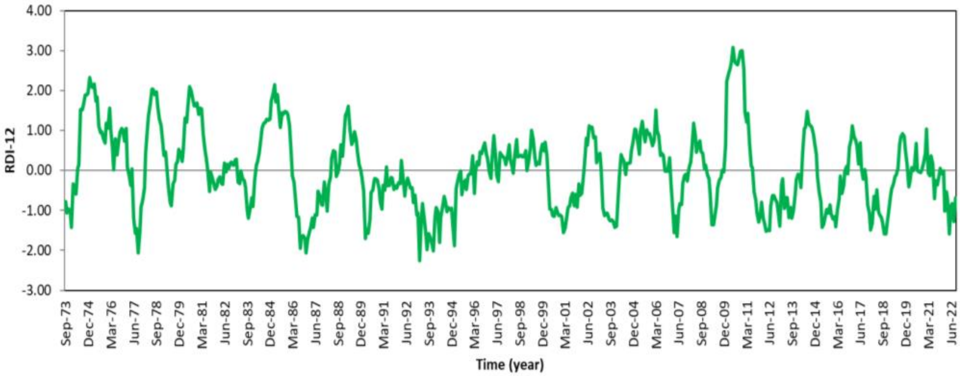

Figure 6. RDI-12 at Košice station for the period (1972-2022)

3.5 Spišské Vlachy station

At Spišské Vlachy station the extreme droughts detected by the index in the years 1982, 2014 and 2022 (see Figure 7). However, for the studied period from 1973 to

2022, the total number of months was 55, 29 and 10 for moderate, sand extreme droughts and the average inter arrival time was 144.75, 55.0 and 32.39 months for the three droughts categories. Moreover, the average return period was 12.1, 4.6 and 2.7 for the three droughts categories. The Spišské Vlachy station gives the longest inter arrival time of moderate drought (144.75 months) compared to other stations.

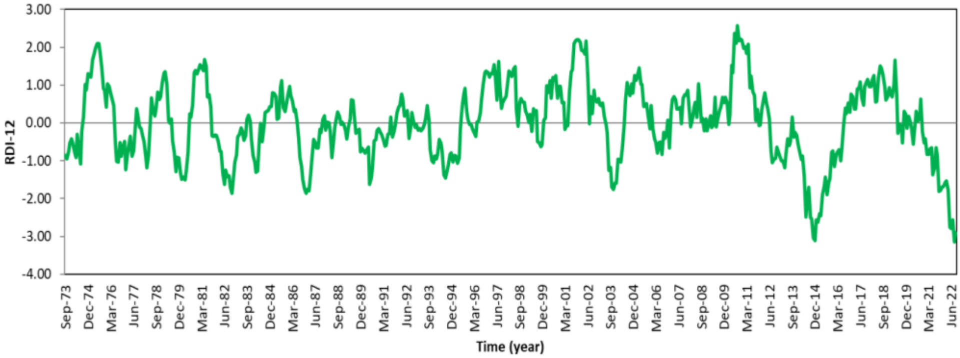

Figure 7. RDI-12 at Spišské Vlachy station for the period (1972-2022)

3.6 Štós station

Figure 8 shows the results of RDI-132 index at Štós station. The extreme drought detected by the index was in the years 1986, 1992 and 2022. The total number of months 54, 26 and 12 for moderate, severe and extreme droughts, and average inter arrival time of 142.0, 44.5 and 34.1 for the three droughts categories were recorded at the Kamenica and Cirochou station for the studied period from 1973 to 2022. The average return period for the three categories of droughts are 11.8, 3.7 and 2.8 years. However, the analysis reveals that Štós station gave the longest inter arrival time of extreme drought (34.1 months) compared to other stations.

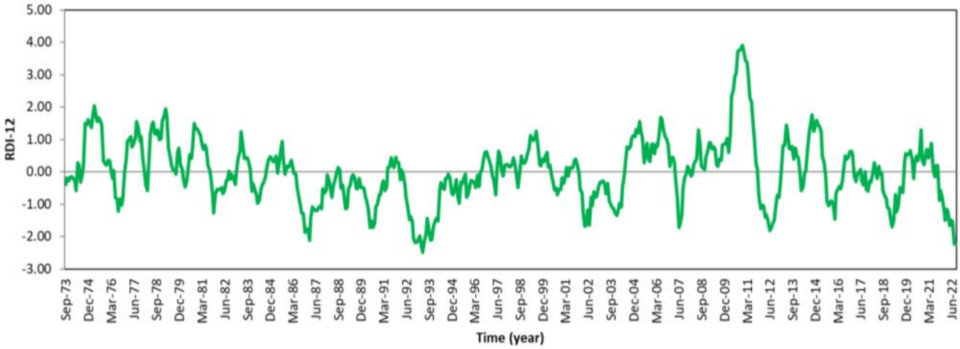

Figure 8. RDI-12 at Štós station for the period (1972-2022)

3.7 Skalnaté Pleco station

The extreme drought detected by the indices at Skalnaté Pleso station was in the years 1973, 1986, 1993, 2012, 2016 and 2022 (see Figure 9). The average inter arrival time of moderate, severe and extreme droughts are 79.0, 44.5 and 21.5 months, with average return periods of 6.6, 3.7 and 1.8 years. Moreover, the duration for the three droughts categories is 74, 23 and 3 respectively. Like Bardejov station, the Skalnaté Pleco station recorded the longest number of months for moderate drought (74 months) and the shortest inter arrival time for extreme drought (21.5 months) compared to the other stations.

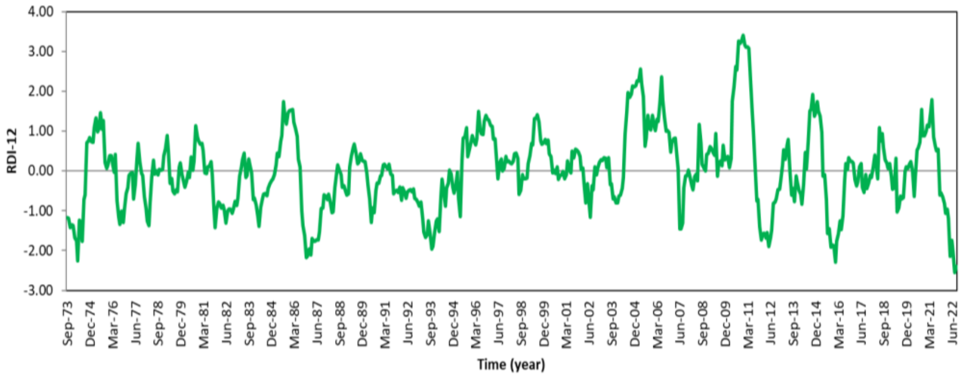

Figure 9. RDI-12 at Skalnaté Pleso station for the period (1972-2022)

4. DISCUSSION

The analysis of droughts is essential to analyze past records and provide information to decision makers on what may happen in the future. Also, estimating the main parameters for drought; severity, intensity, duration and inter arrival time are essential for the drought risk assessment. The monthly meteorological data of 7 stations in Eastern Slovakia for 50 years over the period (1973-2022) were used for drought analysis and detections of drought risks and presented in Figures 2 to 8. The figures show that extreme droughts have occurred frequently over the period (1973-2022).

The distribution of the total number of months for moderate, sever and extreme drought is presented in Figures 10. The figure shows high variation in the total duration between the three categories of droughts where moderate drought gave higher values compared to Sever and Extreme droughts. The distribution of the average inter-arrival time for moderate, sever and extreme drought is presented in Figures 11. The results reveal that the interarrival time for severe and extreme droughts is very close, but they are much less than the moderate drought. Figure 12 shows the distribution of the average return period for the different categories of drought. The return period ranged from 1.8 years for extreme drought to 12.1 years for moderate drought.

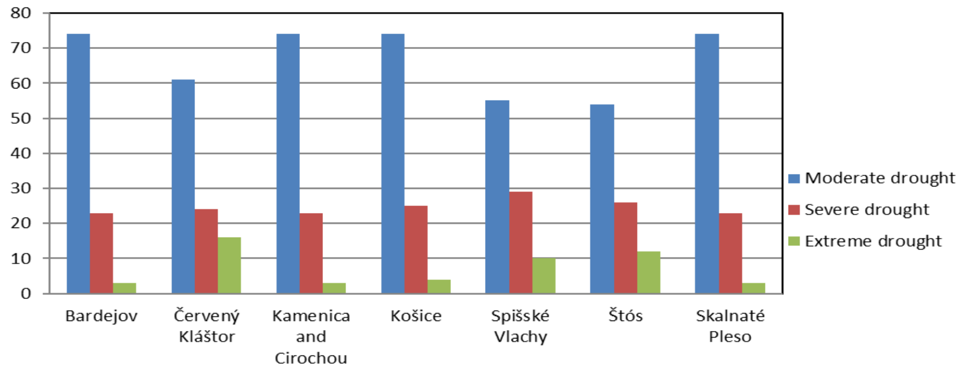

Figure 10. Comparison between the total number of months for different drought categories in Eastern Slovakia

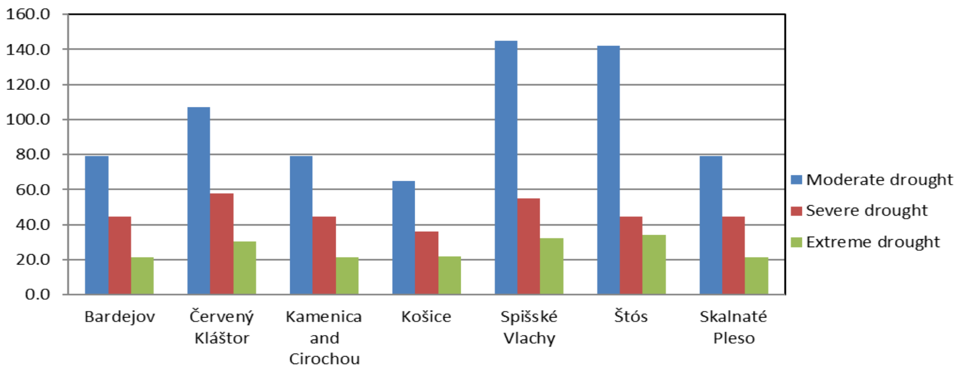

Figure 11. Comparison between the average inter arrival time for different drought categories in Eastern Slovakia

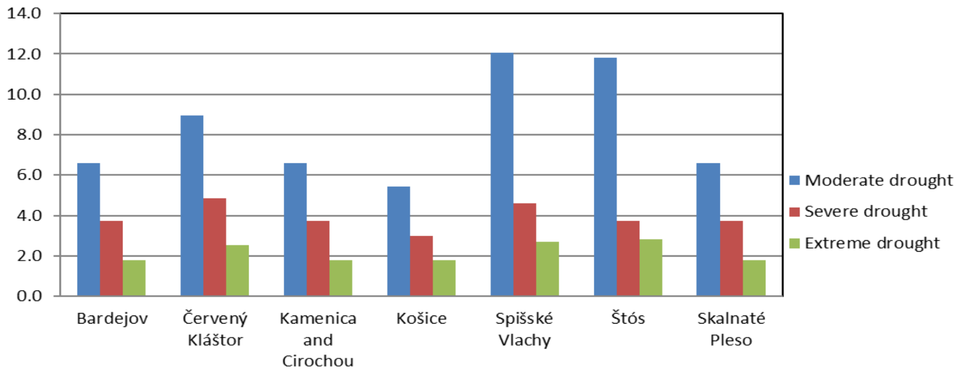

Figure 12. Comparison between the average return periods of different drought categories in Eastern Slovakia

5. CONCLUSION

Monitoring droughts is an important challenge arising from the global climate change. Drought indices are the most widely used methods for monitoring drought. Such indices are based on precipitation distribution and evapotranspiration. These indices are important for the analysis and forecasting of spatial and temporal drought. The results of the drought analysis provide an opportunity to put in place the necessary measures to reduce the likely droughts. In addition, they help to understand the impact of climate change on weather patterns. In the last 138 years, the mean air temperature in Slovakia has risen by 1.7 to 1.8° C. Therefore, it is very important in the future study to examine various indices to predict future drought events. In this study, the RDI is used for analyzing 12-month droughts and trends in Eastern Slovakia using climatic data for the period (1972 to 2022). RDI is used to detect drought in the long term and in hydrological terms. The main parameters for drought; severity, intensity, duration and inter arrival time to have also been estimated for different drought categories (moderate, severe and extreme).

The results show that the average time of arrival of the different drought categories in eastern Slovakia over the period (1972-2022) ranged from 21 to 144 months and the average return period ranged from 1.8 to 12.1 years. Moreover, the total number of months varied between 3 and 74 for the different drought categories. The highest severity of drought was recorded in the years 2006, 2012, 2014, 2016 and 2022. Utilizing RDI for drought risk assessment provides valuable insights for effective drought management in Eastern Slovakia. This methodology can be used for analysis and for estimating the severity, intensity, duration and average recovery times of floods and droughts in other parts of the world. The results confirmed that the RDI is a useful tool for predicting the timing of drought that could help decision makers to develop effective drought risk management plans to mitigate the impact of these disasters.

ACKNOWLEDGMENTS

This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-20-0281.

REFERENCES

1. Abbas A., Waseem M., Ullah W., Zhao Ch. and Zhu J. (2021) Spatiotemporal Analysis of Meteorological and Hydrological drought and Their Propagations. Water 2021, 13:2237
2. Afzal M. & Ragab R. (2020) Assessment of the potential impact of climate change on the hydrology at catchment scale: modeling approach including prediction of future drought events using drought indices. Applied Water Science 10:215
3. Bazrafshan O., Mahmoudzadeh F., Asgarinezhad A. and Bazrafshan J. (2019) Adaptive Evaluation of SPI, RDI, and SPEI indices in Analyzing the Trend of Intensity, Duration, and Frequency of Drought in Arid and Semi-Arid Regions of Iran. Irrigation Sciences and Engineering 42(3):117-131

4. Blain G.C. (2012) Revisting the probabilistic definition of drought strengths, limitations and an agrometeorological adaptation. Bragantia 71(1), 132-141.
5. Bouregaa T. (2023) Change point detection and trend analysis of drought over Algeria from 1901 to 2018. Arabian Journal of Geosciences 16:168
6. Dehghani F., Khalili D., Zand-Parsa S. & Kamgar-Haghighi A. A. (2022) Influence of Climatic Variability on Detected Drought Spatio/Temporal Variability and Characteristics by SPI and RDI. Iranian Jurnal of Science and Technolog, Transactions of Civil Engineering 46:3369-3385
7. Del-Toro-Guerrero F. J. and Kretzschmar T. (2020) Precipitation-temperature variability and drought episodes in northwest Baja California, México. Journal of Hydrology: Regional Studies 27, 100653 p. J
8. Khan M. I., Liu D., Fu Q., Saddique Q., Faiz M. A., Li T., Qamar M. U., Cui S. & Cheng Ch. (2017) Projected Changes of Future Extreme Drought Events under Numerous Drought Indices in the Heilongjiang Province of China. Water Resources Manage 31: 3921-3937
9. Khanmohammadi N., Rezaie H. & Behmanesh J. (2018) The spatial-temporal variation of dry and wet periods in Iran based on comparing SPI and RDI indices. Stochastic Environmental Research and Risk Assessment 32:2771-2785
10. Marini G., Fontana N. & Mishra A. K. (2019) Investigating drought in Apulia region, Italy using SPI and RDI. Teoretical and Applied Climatology 137: 383-397
11. Merabti A., Martins D. S., Meddi M. & Pereira L. S. (2017) Spatial and Time Variability of Drought Based on SPI and RDI with Various Time Scales. Water Resources Management 32:1087-1100
12. Mishra K, Singh P (2010) A review of drought concepts. In: Journal of Hydrology. 391(1-2):202-216
13. Mohamed M. A. E, Moursy F. I., Darrag M. H., El- Mahdy M. E. (2023) Assessment of long term trends and mapping of drought events in Tunisia. Sientific African. 21, e01766 p.
14. Nagy P., Zeleňáková M. (2020) Drought indices and trend analysis. Journal of civil engineering 15:39-45
15. Pathak A. A. & Dodamani B. M. (2020) Comparison of Meteorological Drought Indices for Different Climatic Regions of an Indian River Basin. Asia-Pacific Journal of Atmospheric Sciences 56:563-576
16. Sienz, F., Bothe, O. and Fraedrich, K. (2012) Monitoring and quandifing future climate projections of dryness and wetness extremes: SPI bias. Hydrology and Earth Systém Sciences 16(7), 2143-2157.
17. Tigkas D, Vangelis H, Tsakiris G (2015) DrinC: a software for drought analysis based on drought indices. Earth Science Informatics 8(3), 697-709.
18. Tsakiris G., Pangalou D., and Vangelis H. (2006) Regional drought Assessment Based on the Reconnaissance Drought Index (RDI), Water Resources Management 21: 821-833
19. Vergoni L., Vinci A., Todisco F. (2021) Effectiveness of the new standardized deficit distance index and other meteorological indices in the assessment of agricultural drought impacts in central Italy. Journal of Hydrology 603, 8, 126986 p.
20. Xu K., Yang D., Yang H., Li Z., Qin Y., Shen Y. (2015) Spatio-temporal variation of drought in China during 1961-2012: A climatic prespective. Journal of hydrology 526:253-264
21. Zarch M. A. A. (2022) Past and Future Global Drought Assessment. Water Resources Management 36:5259-5276
22. Zarch M. A. A., Sivakumar B., Sharma A. (2015) Drought in a warming climate: A global assessment of Standardized precipitation index SPI and Reconnaissance drought index RDI. Journal of Hydrology 526: 183-195