PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 22 ISSUE 4 (2024), Page 212 – 226

METEOROLOGICAL DROUGHT RISK ASSESSMENT USING SPI NUMERICAL MODEL: A CASE STUDY OF HELMAND RIVER BASIN, AFGHANISTAN

Hayatullah Mushwani[1], Mohammad Haroon Hairan[2], Kawoon Sahak[3], Abidullah Arabzai[4], Lutfullah Safi[5], Mujib Rahman Ahmadzai[6], Hematullah Shirzai[7], Sayed Kazem Hashmi[8], and Sharifullah Peroz[9]

[1,4,7,9]*Department of Disaster Management, Faculty of Environment,*
[2,5,6]*Department of Natural Resource Management, Faculty of Environment,*
[3,8]*Department of Environmental Science, Faculty of Environment,*
KABUL UNIVERSITY (KU), AFGHANISTAN

Abstract

Meteorological droughts, which result from insufficient precipitation, can cause significant economic damage. While preventing meteorological droughts is impossible, their harmful effects can be reduced through close monitoring. This study aims to evaluate the meteorological drought in the Helmand River Basin using the Standardized Precipitation Index (SPI) model. The hydrometeorological data used for this analysis were collected from the Ministry of Energy and Water (MEW) in Afghanistan. The precipitation data collected from MEW covers a 40-year period from 1979 to 2021. The SPI analysis of precipitation shows that 1990, 1991, and 1992 were moderately wet, while 1982, 1983, 1995-1998, 2005, 2014, and 2015 were nearly normal. However, moderately dry conditions were observed in 2000, 2001, 2018, and 2021. Among the sampled stations, Waras and Gardez consistently had low drought levels, while Tarnak, Shila-i-charkha, and Khwabgah stations experienced moderate-level drought. Meanwhile, Lashkargah and Adraskan stations exhibited relatively high levels of drought. In conclusion, this research on the HRB, using the SPI method, has provided valuable knowledge for understanding drought dynamics in the region. The findings underscore the importance of conducting region-specific analyses, the necessity of implementing sustainable water management strategies, and the global significance of addressing drought as a pressing environmental challenge.

Keywords: Meteorological Drought, Standardized Precipitation Index, Risk Assessment, Precipitation, Helmand River Bain

---

[2] Assistant Professor at Faculty of Environment Kabul University.
Email: haroonhairan@gmail.com

INTRODUCTION

Drought, which is a consequence of climate change (Said et al., 2024), presents a significant threat. It leads to a long-lasting water deficit, loss of biodiversity, and disruptions to community livelihoods(Rahman & Lateh, 2016). It also increases the frequency of climatic hazards (Mishra & Singh, 2010). Global warming as an amplifier increases the global risk of drought (Tabari & Willems, 2023; Vicente-Serrano, Quiring, Peña-Gallardo, Yuan, & Domínguez-Castro, 2020), This disruption affects agricultural activities, water resources, and ecosystems (Cao et al., 2022; Geng et al., 2015; Lu et al., 2017; Potop & Türkott, 2010). Meteorological drought, a substantial outcome, arises from recurrent and transient natural adversities coupled with inadequate precipitation and possesses the potential to impose extensive economic ramifications. While the complete prevention of meteorological droughts remains unattainable, vigilant monitoring and the implementation of mitigative measures can improve their adverse impacts (Dash et al., 2012). Therefore, assessing drought is crucial for effectively managing water resources and for both short-term and long-term economic and social planning (Keskin et al., 2011). According to Hua et al. (2022), future projections for Central Asia suggest that there will be a rise in the frequency of droughts. This can be attributed to unsustainable land use practices and inadequate water management, which contribute to the risks associated with droughts (Abdullah & Rahman, 2015; Gleick, 2014; Lei et al., 2016; Wilhite, 2002).

Afghanistan faces the persistent threat of drought owing to its arid climate and minimal annual precipitation (Aliyar et al., 2022; Jiang & Gharabaghi, 2021; The World Bank, 2017). from 1980 to 2014, the country received a mere 217 mm of rainfall annually (Jiang & Gharabaghi, 2021). The primary contributors to the risk of drought include low average rainfall and poor water management practices (Christian et al., 2021; Mann & Gleick, 2015; Shahzaman et al., 2021). Additionally, insufficient progress in the energy industry has heightened the susceptibility to drought in the country (Shah et al., 2019). The severe impacts of drought in Afghanistan are reflected in the annual agricultural damage amounting to USD 280 million (The World Bank, 2017). with 80% of the population relying on the agriculture and livestock sectors for their daily needs (Jawid & Khadjavi, 2019; Rasooli et al., 2020; Samim et al., 2021). As of September 2018, over 50% Afghans faced severe water and food insecurity, with approximately 20 million people still grappling with these challenges. Moreover, 371,000 individuals have been internally displaced due to the drought-induced conditions in the country (*Lessons from drought response in Afghanistan*, 2022).

Afghanistan is highly susceptible to the impacts of climate change, including droughts, floods, intense heatwaves, and other weather-related disasters. According to projections from the Food and Agriculture Organization (FAO), it is estimated that around 90% of Afghanistan will experience drought conditions by 2050, with a water shortage anticipated as early as 2040 (Mayar, 2021). Climate change is contributing to the decline in vegetation cover in the country as well According to Nabizada et al. (2022), the droughts in 2001 and 2008 resulted in the lowest levels of vegetation coverage, reaching 6.2% and 5.5% respectively (Rousta et al., 2020). The Helmand River Basin (HRB), which is the largest among the five basins in Afghanistan (Goes et al., 2015; Nabizada et al., 2022), is located in the southern region of the country and has a semi-arid climate. It also extends into Iran and Pakistan (Goes et al., 2015). From 2007 to 2017, the Helmand River Basin experienced a temperature rise ranging from 0.9 ℃ to 2.5 ℃ in winter and 0.5 ℃ to 1.2 ℃ in summer (Nasimi et al., 2020). The mean annual precipitation varies from about 50 mm in the southwest to almost 300 mm in the northeast of the basin (Goes et al., 2016). Regarding precipitation in Afghanistan, the National Environmental Protection Agency (NEPA) anticipates a minor rise in the short term and a decline in the long term, with a projected decrease of 10–40 mm by 2090 (Goes et al., 2015). Over 50% of wheat, barley, and orchards in the HRB have been impacted by recent droughts (Qureshi & Akhtar, 2004).

Since the entire country is vulnerable to drought hazards , therefore, early warning systems can play a vital role in disaster risk reduction (Baudoin et al., 2016; Glade & Nadim, 2014; Hermans et al., 2022; Rogers & Tsirkunov, 2010). Drought risk assessment is required to assess drought hazards, risks, and impacts in specific regions (Belal et al., 2014; Nam et al., 2012; Vogt et al., 2018). The Standardized Precipitation Index (SPI) is an effective method widely used for drought assessment (Alahacoon & Edirisinghe, 2022; Karavitis et al., 2011; Liu et al., 2021). SPI analyzes rainfall trends, highlighting duration and severity over different periods (Augusto et al., 2021; Gadiwala, 2013; Khalili et al., 2011). It allows for calculations across various timescales, from one month to 72 months (Wu et al., 2005). The Standardized Precipitation Index (SPI), recognized by the World Meteorological Organization (WMO), serves as a suitable indicator for monitoring and assessing meteorological droughts. (Bera et al., 2021; Ekundayo et al., 2021). It has been widely utilized in studies conducted in Ethiopia (Wossenyeleh et al., 2022), the UK, (Rahmani & Fattahi, 2021), and Iran, (Fahimirad & Shahkarami, 2021).

A study conducted in the Punpun watershed, a tributary of the Ganga river basin, utilized the SPI method to assess meteorological drought hazards. The findings revealed drought periods from 2004 to 2006 and 2009 to 2010, with increasing intensity and duration after 2004 (Ojha et al., 2021). Another study conducted in West Bengal, India, also employed the SPI method and analyzed 117 years of rainfall data. The study identified frequent drought events with negative SPI values, indicating a rise in dry events and a decline in wet and normal events in the region (Bhunia et al., 2020). Similarly, a study conducted in the Yellow River Basin, Henan Province, China, using the SPI method, identified both meteorological and hydrological droughts occurring at a 2–4-year timescale (Wang et al., 2020). Conversely, a study conducted in the Bundelkhand region of Central India, utilizing the SPI method, identified seven major drought events from 1981 to 2016 (Pandey et al., 2022). Likewise, in Raya, Northern Ethiopia, meteorological drought results based on the SPI-3 evaluation showed mild-to-severe drought phenomena occurring once every 2-3 years (Gidey et al., 2018). In contrast, a meteorological drought assessment conducted in the Sakae Krang River basin of Thailand using the SPI method found moderate and mild drought events from 1970 to 2014 in different sub-basins (Wichitarapongsakun et al., 2016). The São Francisco River Basin in Brazil was evaluated for drought based on the SPI-12. The study identified a severe and prolonged drought episode between 2012 and 2020, with a duration of 103 months in the upper portion of the basin (Santos et al., 2017).

In this particular study, we have chosen the Standardized Precipitation Index (SPI) as one of the methods to evaluate drought hazards in the Helmand River Basin (HRB). This choice is based on the significance and widespread use of the SPI method in drought assessment. The main objective of our study is to assess meteorological drought in HRB, considering the region's vulnerability to drought hazards.

MATERIALS AND METHOD

STUDY AREA

Afghanistan, a landlocked country in South Asia, has an arid to semi-arid climate with cold winters and hot summers (Sabory et al., 2020). The country is divided into five major river basins: the Amu Darya River Basin, Northern River Basin, Harirud-Murghab River Basin, Kabul River Basin, and Helmand River Basin (Dost & Kasiviswanathan, 2023; Nagheeby & Warner, 2018). It can also be classified into five distinct climatic regions: the Hindukush Region, Northern Plains, Central Highlands, Eastern Slopes, and Southern Plateau (Jawid & Khadjavi, 2019). The Helmand River Basin (HRB), the largest among the five basins in Afghanistan, is located between latitudes 29° 18′ to 34° 48′ and longitudes 60° 18′ and 69° 36′ (Akbari & Torabi Haghighi, 2022; Sabory et al., 2020). It is a closed river basin situated in the semi-arid climate of southern Afghanistan, extending into Iran and Pakistan. The Helmand River, approximately 1300 Km in length, serves as a vital water resource shared by Iran and Afghanistan. The basin covers an area of about 400,000 km2, with 81.4% in Afghanistan, 15% in Iran, and 3.6% in Pakistan. Originating from the Hindu Kush mountains, the river flows through the Sistan plain and reaches Hamoun Helmand (Goes et al., 2016).

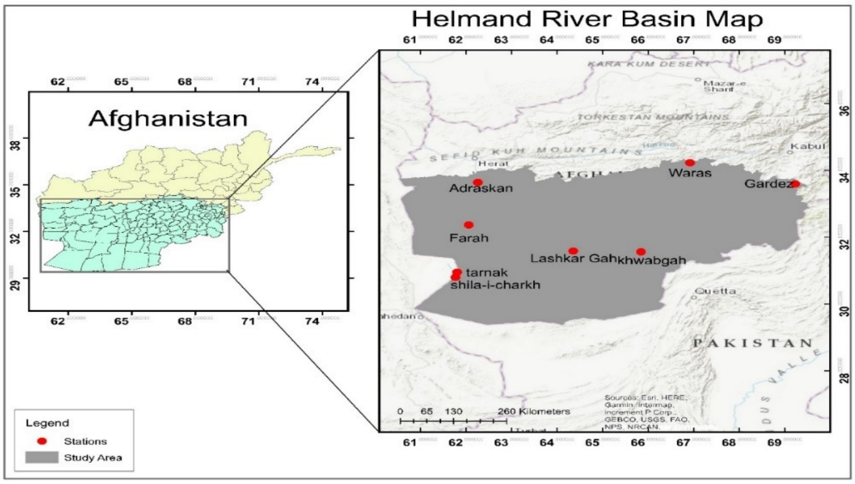

Figure 1: Study Area Map

DATA COLLECTION

The research used qualitative methods to evaluate drought risk in the Helmand River Basin (HRB) based on the Standardized Precipitation Index (SPI). Data on precipitation from the Ministry of Energy and Water, collected over a period of 40 years, were used. The Ministry provided data from seven stations: Farah, Khwabgah, Lashkargah, Shila-i-Charkh, Adraskan, Tranak, and Waras. The annual average rainfall was calculated from the monthly, quarterly, and half-year data. The study relied on SPI time scales of 1, 3, 6, 9, and 12, chosen based on relevant literature. After completing the SPI analysis, the severity of the drought was assessed and highlighted. Geostatistical analysis and interpolation techniques, implemented using ArcGIS, were used to map and evaluate drought hazards in the HRB. This approach allowed for a comprehensive understanding of the spatial distribution and intensity of drought conditions in the study area.

RESULTS AND DISCUSSION

PRECIPITATION

Table 1 presents data on annual rainfall in the Helamd River Basin from various stations including Farah, Khwabgah, Lashkargah, Shila-i-Charkh, Adraskan, Tarnak, and Waras. Among these stations, Khwabgah received the least amount of rainfall, with an average of 72.4 mm, a minimum of 4.32 mm, and a maximum of 196.7 mm. Lashkargah and Shila-i-Charkh experienced moderate levels of rainfall, averaging 96.4 mm (with a range of 27.0 mm to 204 mm) and 61.47 mm (with a range of 5.17 mm to 141 mm), respectively. In contrast, Adraskan had the highest average rainfall at 210 mm, with a minimum of 36 mm and a maximum of 367 mm. For a more detailed overview of the rainfall characteristics at each location, please refer to Table 1.

Table 1: Annual Rainfall Characteristics of HRB

Station	Mean (mm)	Minimum (mm)	Maximum (mm)
Adraskan	210	36	367
Farah	117	17.8	293
Gardiz	207	49	432
Khwabgah	72.4	4.32	196.7
Lashkargah	96.4	27.0	204
Shila-i-Charkh	61.47	5.17	141
Tarnak	173	46	412
Waras	211	69	389

Table (2) presents the categorization of Standardized Precipitation Index (SPI) values, which are utilized for assessing wetness or dryness. The SPI is a well-established tool for monitoring drought conditions. The categorization classifies SPI values into seven distinct categories, ranging from extremely wet (SPI > 2.0) to extremely dry (SPI < -2.0). SPI values between -1.0 and 1.0 indicate near-normal conditions. These criteria are helpful in determining the severity of drought and can offer valuable insights for decision-making processes related to water resource management, agriculture, and disaster response planning.

Table 2: Categorization of SPI values

State	Criteria
Extremely wet	SPI > 2.0
Very wet	1.5 < SPI < 2.0
Moderately wet	1.0 < SPI < 1.5
Near Normal	-1.0 < SPI < 1.0
Moderately dry	-1.5 < SPI < -1.0
Severely dry	<2.0 < SPI < -1.5
Extremely dry	SPI < -2.0

METEOROLOGICAL DROUGHT ANALYSIS

The research findings on the Helmand River Basin (HRB) using the SPI indicate varying levels of wetness and dryness for specific years. The SPI classification system, widely used in meteorology, categorizes drought conditions into different categories, including Extremely Wet, Very Wet, Moderately Wet, Near Normal, Moderately Dry, Severely Dry, and Extremely Dry. Based on the SPI calculations, several years in the HRB were identified as near-normal conditions (SPI < 1.0). For example, the years 1984, 1986, 2009, 2013, and 2018 were classified as near-normal based on SPI-1, and the years 1981, 1982, 1997, 2005, and 2014 were categorized as near-normal based on SPI-12. Comparatively, based on the SPI different indices, seven major drought events were identified in the Bundelkhand region of Central India between 1981 and 2016 (Pandey et al., 2022). Additionally, SPI-12 identified 1990, 1991, 2014, 2019, and 2020 as moderately wet years (1.0 < SPI < 1.5), and SPI-9 identified 1991, 1992, and 1993 as moderately wet years.

Conversely, the analysis revealed some years characterized as moderately dry (SPI values between -1.5 and -1.0) and severely dry (SPI values below -1.5). Specifically, SPI-12 identified 2000, 2001, 2018, and 2021 as moderately dry years, and SPI-9 classified 2017, 2018, and 2021 as severely dry years (See Figure 2). The analysis of multiple SPI indices (SPI-1, SPI-3, SPI-6, SPI-9, and SPI-12) provided insights into the wetness and dryness patterns in the HRB (see Figure 2). Several years exhibited normal wet conditions across different SPI indices, such as 1982, 1983, 1996, 1997, 1998, and 2015. Additionally, the years 1991, 1992, 2005, and 2019 were consistently categorized as moderately wet based on SPI-12.

The study conducted in Southeast Australia utilized SPI methods and found severe drought from 2013 to 2019 (Yildirim and Rahman et al., 2022). This finding is similar to the HRB, which identified severe drought periods from 2018 to 2021. In contrast, the study done in the Sakae Krang River basin of Thailand found moderate and mild drought levels in different sub-basins (Wichitarapongsakun et al., 2016). This differs from the HRB research, which did not specifically mention the presence of moderate or mild drought levels.

Furthermore, based on the São Francisco River Basin study, findings showed severe and prolonged drought between 2012 and 2020 (Freitas et al., 2022). This finding aligns with the HRB research, which found severe drought in 2018.

Overall, the comparison of the HRB research findings with studies conducted in other regions reveals both similarities and differences in terms of identified drought occurrences, severity, and duration. These comparisons emphasize the need for region-specific analysis and highlight the importance of understanding local climate and hydrological conditions when assessing drought hazards and implementing effective water management strategies.

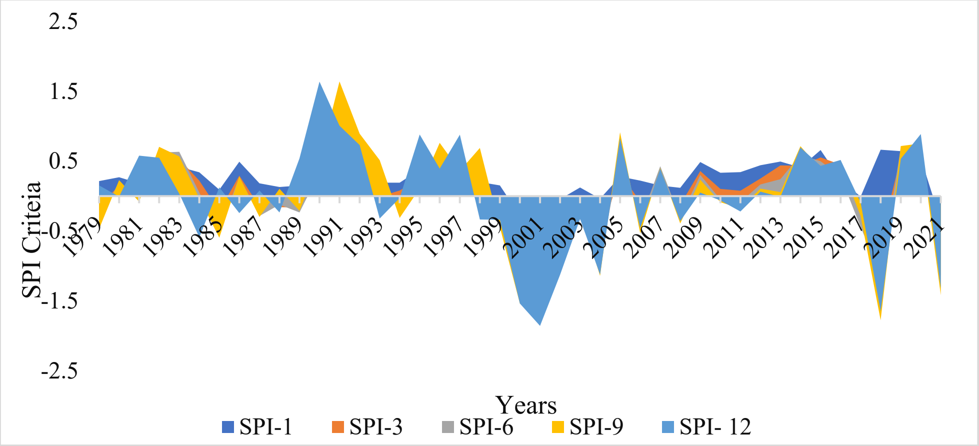

Figure 2: Various SPI indices of HRB between 1979 and 2021

According to SPI values of 1, 3, 6, 9, and 12, the years 1990, 1991, and 1992 were moderately wet. Additionally, the years 1982, 1983, 1995, 1996, 1997, 1998, 2005, 2014, and 2015 experienced drought conditions that were close to normal, with SPI values between -1.0 and 1.0. On the other hand, the years 2000, 2001, 2018, and 2021 were moderately dry, with SPI values between -1.5 and -1.0 (Figure 3).

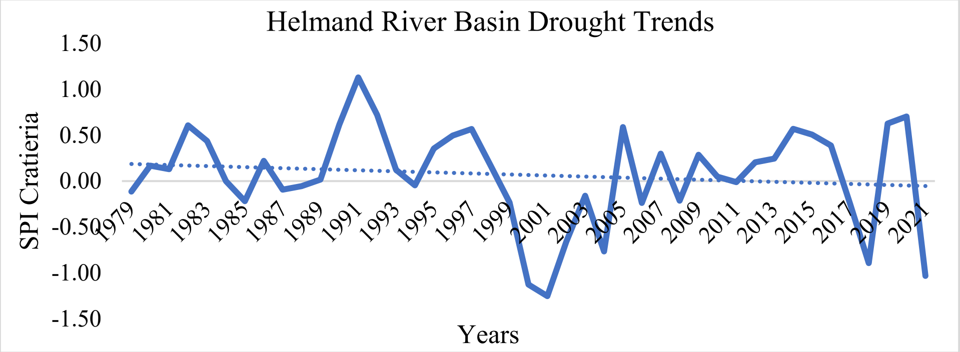

Figure 3: Drought Trends in HRB between 1979 and 2021

Using ArcGIS, we analyzed SPI data from 1979 to 2021. SPI measures precipitation deviation from the long-term averageand helps assess drought severity. We examined SPI values at different time scales (SPI-1, SPI-3, SPI-6, SPI-9, and SPI-12) using ArcGIS for analysis and visualization. As we interpreted the SPI values on the map, we found that the Waras and Gardez stations in the Helmand River Basin consistently experienced low levels of drought throughout the analyzed period. On the other hand, the Tarank, Shila-i-charkh, and Khwabgah stations showed a moderate level of drought, indicating relatively better precipitation conditions compared to Waras and Gardez. Lashkargah and Adraskan stations had a relatively high level of drought, suggesting relatively favorable precipitation conditions in those areas (Figure 4).

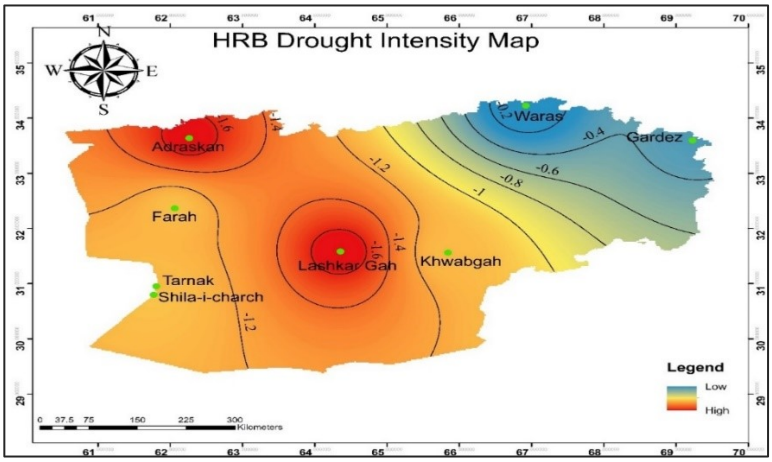

Figure 4: Drought Intensity in Helmand River Basin

CONCLUSION

The research conducted in the Helmand River basin (HRB) using SPI has provided valuable insights into the patterns of wetness and dryness in the region. The SPI has enabled the identification of specific years characterized by varying levels of wetness or dryness by classifying drought conditions into different categories. The analysis revealed near-normal conditions, moderately wet years, and severely dry years in the Helmand River Basin. These findings highlight the dynamic nature of climate patterns in the region and their significant impact on water availability and agricultural productivity. Interestingly, when comparing the results from the HRB with studies conducted in other regions, both similarities and differences emerged. Some regions experienced severe and prolonged drought periods, while others witnessed moderate or mild drought levels. These variations underscore the importance of understanding local climate and hydrological conditions when assessing drought hazards and implementing water management strategies.

The comparison also emphasizes the need for region-specific analysis. While there are similarities in terms of drought occurrences, severity, and duration, each region has unique characteristics that influence its vulnerability to drought. Therefore, it is crucial to consider these local variations in order to develop effective strategies for mitigating the impacts of drought and ensuring sustainable water management. Moreover, the findings from the HRB research align with studies conducted in different parts of the world, demonstrating the global nature of the drought challenge. Similar patterns of drought occurrences and their impacts on local communities and ecosystems were observed from Southeast Australia to Raya in Northern Ethiopia, the Punpun watershed in India to the São Francisco River Basin in Brazil. These similarities highlight the interconnectedness of our planet's climate systems and the urgent need for coordinated efforts to address the increasing frequency and severity of drought events worldwide.

In conclusion, the research on the HRB using the SPI method has contributed valuable knowledge to our understanding of drought dynamics in the region. The findings emphasize the importance of region-specific analysis, the need for sustainable water management strategies, and the global significance of addressing drought as a pressing environmental challenge. As the physical and psychological comfort of humans is based on the availability of water (Ying et al., 2023), integrating scientific research, local knowledge, and international cooperation can help us work towards building resilience, adapting to changing climate patterns, and securing a sustainable future for all.

CONFLICTS OF INTEREST

The authors state that they do not have any known financial interests or personal relationships that could have potentially influenced the work presented in this paper.

REFERENCES

Abdullah, H. M., & Rahman, M. M. (2015). Initiating rain water harvest technology for climate change induced drought resilient agriculture : scopes and challenges in Bangladesh. *Journal of Agriculture and Environment for International Development*, *109*(2), 189–208. https://doi.org/10.12895/jaeid.20152.334

Akbari, M., & Torabi Haghighi, A. (2022). Satellite-based agricultural water consumption assessment in the ungauged and transboundary Helmand Basin between Iran and Afghanistan. *Remote Sensing Letters*, *13*(12), 1236–1248. https://doi.org/10.1080/2150704X.2022.2142074

Alahacoon, N., & Edirisinghe, M. (2022). Novel Index for Hydrological Drought Monitoring Using Remote Sensing Approach: Standardized Water Surface Index (SWSI). *Remote Sensing*, *10*(14). https://doi.org/https://doi.org/10.3390/rs14215324

Aliyar, Q., Zulfiqar, F., Datta, A., & Kuwornu, J. K. M. (2022). International Journal of Disaster Risk Reduction Drought perception and field-level adaptation strategies of farming households in drought-prone areas of Afghanistan. *International Journal of Disaster Risk Reduction*, *72*(February), 102862.

https://doi.org/10.1016/j.ijdrr.2022.102862

Lessons from drought response in Afghanistan, 69 Forced Migration Review 4 (2022). https://www.fmreview.org/sites/fmr/files/FMRdownloads/en/climate-crisis/amoli-jones.pdf

Augusto, C., Santos, G., Moura, R., Neto, B., Victor, T., Marques, R., Mishra, M., & Gomes, T. (2021). Science of the Total Environment Geospatial drought severity analysis based on PERSIANN-CDR-estimated rainfall data for Odisha state in India (1983 – 2018). *Science of the Total Environment*, *750*, 141258. https://doi.org/10.1016/j.scitotenv.2020.141258

Baudoin, M., Fernando, S. H. N., Sitati, A., & Zommers, Z. (2016). From Top-Down to "" Community-Centric "" Approaches to Early Warning Systems : Exploring Pathways to Improve Disaster Risk Reduction Through Community Participation. *International Journal of Disaster Risk Science*, *7*(2), 163–174. https://doi.org/10.1007/s13753-016-0085-6

Belal, A. A., El-Ramady, H. R., Mohamed, E. S., & Saleh, A. M. (2014). Drought risk assessment using remote sensing and GIS techniques. *Arabian Journal of Geosciences*, *7*(1), 35–53. https://doi.org/10.1007/s12517-012-0707-2

Bera, B., Shit, P. K., Sengupta, N., Saha, S., & Bhattacharjee, S. (2021). Trends and variability of drought in the extended part of Chhota Nagpur plateau (Singbhum Protocontinent), India applying SPI and SPEI indices. *Environmental Challenges*, *5*(June), 100310. https://doi.org/10.1016/j.envc.2021.100310

Bhunia, P., Das, P., & Maiti, R. (2020). Meteorological Drought Study Through SPI in Three Drought Prone Districts of West Bengal, India. *Earth Systems and Environment*, *4*(1), 43–55. https://doi.org/10.1007/s41748-019-00137-6

Cao, S., Zhang, L., He, Y., Zhang, Y., Chen, Y., Yao, S., Yang, W., & Sun, Q. (2022). *Science of the Total Environment Effects and contributions of meteorological drought on agricultural drought under different climatic zones and vegetation types in Northwest China*. *821*. https://doi.org/10.1016/j.scitotenv.2022.153270

Christian, J. I., Basara, J. B., Hunt, E. D., Otkin, J. A., Mishra, V., Xiao, X., Randall, R. M., & Furtado, J. C. (2021). Global distribution, trends, and drivers of flash drought occurrence. *Nature Communications*, *12*(6330), 1–11. https://doi.org/10.1038/s41467-021-26692-z

Dash, B. K., Rafiuddin, M., Khanam, F., & Islam, M. N. (2012). Characteristics of meteorological drought in Bangladesh. *Natural Hazards*, *64*(2), 1461–1474. https://doi.org/10.1007/s11069-012-0307-1

Dost, R., & Kasiviswanathan, K. S. (2023). Quantification of Water Resource Sustainability in Response to Drought Risk Assessment for Afghanistan River Basins. *Natural Resources Research*, *32*(1), 235–256. https://doi.org/10.1007/s11053-022-10129-5

Ekundayo, O. Y., Okogbue, E. C., Akinluyi, F. O., Kalumba, A. M., & Orimoloye, I. R. (2021). Spatiotemporal drought assessment using vegetation health index and standardized precipitation index over Sudano-Sahelian region of Nigeria. *African Geographical Review*, *40*(4), 412–424. https://doi.org/10.1080/19376812.2020.1841658

Fahimirad, Z., & Shahkarami, N. (2021). The Impact of Climate Change on Hydro-

Meteorological Droughts Using Copula Functions. *Water Resources Management*, *35*(12), 3969–3993. https://doi.org/10.1007/s11269-021-02918-z

Gadiwala, M. S. (2013). *A Study of Drought over Sindh (Pakistan) Using Standardized Precipitation Index (SPI) 1951 to 2010*. *9*(18), 15–22.

Geng, S. M., Yan, D. H., Zhang, T. X., Weng, B. S., Zhang, Z. B., & Qin, T. L. (2015). Effects of drought stress on agriculture soil. *Natural Hazards*, *75*(2), 1997–2011. https://doi.org/10.1007/s11069-014-1409-8

Gidey, E., Dikinya, O., Sebego, R., Segosebe, E., & Zenebe, A. (2018). Modeling the Spatio-Temporal Meteorological Drought Characteristics Using the Standardized Precipitation Index (SPI) in Raya and Its Environs, Northern Ethiopia. *Earth Systems and Environment*, *2*(2), 281–292. https://doi.org/10.1007/s41748-018-0057-7

Glade, T., & Nadim, F. (2014). Early warning systems for natural hazards and risks. *Natural Hazards*, *12*(70), 1669–1671. https://doi.org/10.1007/s11069-013-1000-8

Gleick, P. H. (2014). Water, Drought, Climate Change, and Conflict in Syria. *American Meteorological Society*, *7*, 331–340. https://doi.org/0.1175/WCAS-D-13-00059.1

Goes, B. J. M., Howarth, S. E., Wardlaw, R. B., Hancock, I. R., & Parajuli, U. N. (2015). Integrated water resources management in an insecure river basin: a case study of Helmand River Basin, Afghanistan. *International Journal of Water Resources Development*, *32*(1), 3–25. https://doi.org/10.1080/07900627.2015.1012661

Goes, B. J. M., Howarth, S. E., Wardlaw, R. B., Hancock, I. R., & Parajuli, U. N. (2016). Integrated water resources management in an insecure river basin: a case study of Helmand River Basin, Afghanistan. *International Journal of Water Resources Development*, *32*(1), 3–25. https://doi.org/10.1080/07900627.2015.1012661

Hermans, T. D. G., Šakić, R., & Marc, T. (2022). Exploring the integration of local and scientific knowledge in early warning systems for disaster risk reduction : a review. *Natural Hazards*, *114*(2), 1125–1152. https://doi.org/10.1007/s11069-022-05468-8

Hua, L., Zhao, T., & Zhong, L. (2022). Journal of Hydrology : Regional Studies Future changes in drought over Central Asia under CMIP6 forcing scenarios. *Journal of Hydrology: Regional Studies*, *43*(February), 101191. https://doi.org/10.1016/j.ejrh.2022.101191

Jawid, A., & Khadjavi, M. (2019). Adaptation to climate change in Afghanistan: Evidence on the impact of external interventions. *Economic Analysis and Policy*, *64*, 64–82. https://doi.org/10.1016/j.eap.2019.07.010

Jiang, A., & Gharabaghi, B. (2021). *The Role of Large Dams in a Transboundary Drought Management Co-Operation Framework — Case Study of the Kabul River Basin*.

Karavitis, C. A., Alexandris, S., Tsesmelis, D. E., & Athanasopoulos, G. (2011). Application of the Standardized Precipitation Index (SPI) in Greece. *Water (Switzerland)*, *3*(3), 787–805. https://doi.org/https://doi.org/10.3390/w3030787

Keskin, M. E., Terzi, Ö., Taylan, E. D., & Küçükyaman, D. (2011). Meteorological drought analysis using artificial neural networks. *Scientific Research and Essays*, *6*(21), 4469–4477. https://doi.org/10.5897/sre10.1022

Khalili, D., Farnoud, T., Jamshidi, H., Kamgar-Haghighi, A. A., & Zand-Parsa, S. (2011). Comparability Analyses of the SPI and RDI Meteorological Drought Indices in

Different Climatic Zones. *Water Resources Management*, *25*(6), 1737–1757. https://doi.org/10.1007/s11269-010-9772-z

Lei, Y., Zhang, H., Chen, F., & Zhang, L. (2016). Science of the Total Environment How rural land use management facilitates drought risk adaptation in a changing climate — A case study in arid northern China. *Science of the Total Environment, The*, *550*, 192–199. https://doi.org/10.1016/j.scitotenv.2016.01.098

Liu, C., Yang, C., Yang, Q., & Wang, J. (2021). Spatiotemporal drought analysis by the standardized precipitation index (SPI) and standardized precipitation evapotranspiration index (SPEI) in Sichuan Province ,. *Scientific Reports*, 1–14. https://doi.org/10.1038/s41598-020-80527-3

Lu, H., Wu, Y., Li, Y., & Liu, Y. (2017). Effects of meteorological droughts on agricultural water resources in southern China. *Journal of Hydrology*, *548*, 419–435. https://doi.org/10.1016/j.jhydrol.2017.03.021

Mann, M. E., & Gleick, P. H. (2015). Climate change and California drought in the 21st century. *Commentary*, *112*(13), 3858–3859. https://doi.org/10.1073/pnas.1503667112

Mayar, M. A. (2021). *Droughts on the Horizon: Can Afghanistan manage this risk?* Afghanistan Analysts Network. https://www.afghanistan-analysts.org/en/reports/economy-development-environment/droughts-on-the-horizon-can-afghanistan-manage-this-risk/

Mishra, A. K., & Singh, V. P. (2010). A review of drought concepts. *Journal of Hydrology*, *391*(1–2), 202–216. https://doi.org/10.1016/j.jhydrol.2010.07.012

Nabizada, A. F., Rousta, I., Dalvi, M., Olafsson, H., Siedliska, A., Baranowski, P., & Krzyszczak, J. (2022). Spatial and Temporal Assessment of Remotely Sensed Land Surface Temperature Variability in Afghanistan during 2000–2021. *Climate*, *10*(7). https://doi.org/10.3390/cli10070111

Nagheeby, M., & Warner, J. (2018). The geopolitical overlay of the hydropolitics of the Harirud River Basin. *International Environmental Agreements: Politics, Law and Economics*, *18*(6), 839–860. https://doi.org/10.1007/s10784-018-9418-9

Nam, W.-H., Choi, J.-Y., Yoo, S.-H., & Jang, M.-W. (2012). A decision support system for agricultural drought management using risk assessment. *Paddy and Water Environment*, *10*(3), 197–207. https://doi.org/10.1007/s10333-012-0329-z

Nasimi, M. N., Sagin, J., & Wijesekera, N. T. S. (2020). Climate and Water Resources Variation in Afghanistan and the Need for Urgent Adaptation Measures. *International Journal of Food Science and Agriculture*, *4*(1), 49–64. https://doi.org/10.26855/er.2020.02.009

Ojha, S. S., Singh, V., & Roshni, T. (2021). Comparison of meteorological drought using spi and spei. *Civil Engineering Journal (Iran)*, *7*(12), 2130–2149. https://doi.org/10.28991/cej-2021-03091783

Pandey, V., Srivastava, P. K., Mall, R. K., Munoz-Arriola, F., & Han, D. (2022). Multi-satellite precipitation products for meteorological drought assessment and forecasting in Central India. *Geocarto International*, *37*(7), 1899–1918. https://doi.org/10.1080/10106049.2020.1801862

Potop, V., & Türkott, L. (2010). *Drought episodes in the Czech Republic and their potential effects in agriculture*. 373–388. https://doi.org/10.1007/s00704-009-

0148-3

Qureshi, A. S., & Akhtar, M. (2004). A survey of drought impacts and coping measures in Helmand and Kandahar provinces of Afghanistan. In *International Water Management Institute* (Issue February). https://www.preventionweb.net/publication/survey-drought-impacts-and-coping-measures-helmand-and-kandahar-provinces-afghanistan

Rahman, M. R., & Lateh, H. (2016). Meteorological drought in Bangladesh: assessing, analysing and hazard mapping using SPI, GIS and monthly rainfall data. *Environmental Earth Sciences*, *75*(12). https://doi.org/10.1007/s12665-016-5829-5

Rahmani, F., & Fattahi, M. H. (2021). A multifractal cross-correlation investigation into sensitivity and dependence of meteorological and hydrological droughts on precipitation and temperature. *Natural Hazards*, *109*(3), 2197–2219. https://doi.org/10.1007/s11069-021-04916-1

Rasooli, M. W., Bhushan, B., & Kumar, N. (2020). Applicability Of Wireless Sensor Networks & Iot In Saffron & Wheat Crops : A Smart Agriculture Perspective. *International Journal of Technology Research*, *9*(February), 2456–2461.

Rogers, D., & Tsirkunov, V. (2010). *Costs and Benefit of Early Warning Systems* (Issue 1). https://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Rogers_&_Tsirkunov_2011.pdf

Rousta, I., Olafsson, H., Moniruzzaman, M., Zhang, H., Liou, Y. A., Mushore, T. D., & Gupta, A. (2020). Impacts of drought on vegetation assessed by vegetation indices and meteorological factors in Afghanistan. *Remote Sensing*, *12*(15). https://doi.org/10.3390/RS12152433

Sabory, N. R., Danish, M. S. S., & Senjyu, T. (2020). Afghanistan's Energy and Environmental Scenario. In Muhammad Asif (Ed.), *Energy and Environmental Outlook for South Asia* (1st ed., Issue December, p. 22). CRC. https://doi.org/https://doi.org/10.1201/9781003131878

Said, M. Z., Gapor, S. A., & Hamat, Z. (2024). Flood Vulnerability and Adaptation Assessment in Padang Terap District, Kedah, Malaysia. *Planning Malaysia*, *22*(2), 1–16. https://doi.org/10.21837/pm.v22i31.1450

Samim, S. A., Hu, Z., Stepien, S., Amini, S. Y., Rayee, R., Niu, K., & Mgendi, G. (2021). Food Insecurity and Related Factors among Farming Families in Takhar Region , Afghanistan. *Sustainability (Switzerland)*, *13*(18), 1–17. https://doi.org/https://doi.org/10.3390/su131810211

Santos, C. A. G., Brasil Neto, R. M., Passos, J. S. de A., & da Silva, R. M. (2017). Drought assessment using a TRMM-derived standardized precipitation index for the upper São Francisco River basin, Brazil. *Environmental Monitoring and Assessment*, *189*(6), 250. https://doi.org/10.1007/s10661-017-5948-9

Shah, S. A. A., Zhou, P., Walasai, G. D., & Mohsin, M. (2019). Energy security and environmental sustainability index of South Asian countries : A composite index approach. *Ecological Indicators*, *106*(66), 105507. https://doi.org/10.1016/j.ecolind.2019.105507

Shahzaman, M., Zhu, W., Ullah, I., Mustafa, F., Bilal, M., Ishfaq, S., Nisar, S., Arshad, M., Iqbal, R., & Aslam, R. W. (2021). Comparison of Multi-Year Reanalysis , Models , and Satellite Remote Sensing Products for Agricultural Drought Monitoring over South Asian Countries. *Remote Sensing*, *13*(3294). https://doi.org/https://doi.org/10.3390/rs13163294

Tabari, H., & Willems, P. (2023). Global risk assessment of compound hot-dry events in the context of future climate change and socioeconomic factors. *Climate and Atmospheric Science*, *6*(74), 1061. https://doi.org/10.1038/s41612-023-00401-7

The World Bank. (2017). *Afghanistan Disaster Risk Profile*. GTDRR.

Vicente-serrano, S. M., Quiring, S. M., Peña-gallardo, M., Yuan, S., & Domínguez-castro, F. (2020). Earth-Science Reviews A review of environmental droughts : Increased risk under global warming ? *Earth-Science Reviews*, *201*(November 2018), 102953. https://doi.org/10.1016/j.earscirev.2019.102953

Vogt, J. V, Naumann, G., Masante, D., Spinoni, J., Cammalleri, C., Erian, W., Pischke, F., Pulwarty, R., & Barbosa, P. (2018). *Drought Risk Assessment and Management - A Conceptual Framework* - (Vol. 2018, Issue August). https://doi.org/10.2760/057223

Wang, F., Wang, Z., Yang, H., Di, D., Zhao, Y., Liang, Q., & Hussain, Z. (2020). Comprehensive evaluation of hydrological drought and its relationships with meteorological drought in the Yellow River basin, China. *Journal of Hydrology*, *584*(January), 124751. https://doi.org/10.1016/j.jhydrol.2020.124751

Wichitarapongsakun, P., Sarin, C., Klomjek, P., & Chuenchooklin, S. (2016). Rainfall prediction and meteorological drought analysis in the Sakae Krang River basin of Thailand. *Agriculture and Natural Resources*, *50*(6), 490–498. https://doi.org/10.1016/j.anres.2016.05.003

Wilhite, D. A. (2002). Combating drought through preparedness. *Natural Resources Forum*, *26*(4), 275–285.

Wossenyeleh, B. K., Kasa, A. S., Verbeiren, B., & Huysmans, M. (2022). Drought propagation in the hydrological cycle in a semiarid region: a case study in the Bilate catchment, Ethiopia. *Hydrogeology Journal*, *30*(3), 751–766. https://doi.org/10.1007/s10040-022-02459-8

Wu, H., Hayes, M. J., Wilhite, D. A., & Svoboda, M. D. (2005). The effect of the length of record on the standaraized precipitation index calulation. *International Journal of Climatology*, *520*(14624), 505–520. https://doi.org/10.1002/joc.1142

Ying, L. J., Hassan, L. S., Abidin, N. Z., Lim, N. H. H., & Hasnan, L. (2023). Assessing the Social Values of Historical Waterfront: a Case Study of Sungai Petani, Kedah, Malaysia. *Planning Malaysia*, *21*(6), 130–143. https://doi.org/10.21837/PM.V21I30.1391

Received: 5th Jan 2024. Accepted: 23rd May 2024