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Analysis of meteorological drought in northwest Iran using the Joint Deficit Index

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SUMMARY

Probabilistic assessment and prediction of drought provides valuable information for water resources planners and policy makers for developing drought mitigation strategies. In this study an evaluation of drought conditions in northwest of Iran was performed by means of the Joint Deficit Index (JDI). Monthly precipitation data from 1970 to 2007 based on 50 gauge stations uniformly distributed across the area were used for calculating the JDI. Results show that the JDI provides a comprehensive assessment of droughts and that it is capable of reflecting both emerging and prolonged droughts reported in the data. Furthermore, the method provides a basis for determining the amount of precipitation required to reach normal conditions in future months (1–3 months examined in this study), and the exceedance probability of this precipitation amount. Performance evaluation based on 6 years of independent precipitation data from the region showed Critical Success Index of 0.61 (0.64) for the 1-month (3-month) ahead prediction of the drought conditions. The analysis in this study indicated a good skill in predicting the evolution of drought conditions for the region based on JDI evaluated from monthly precipitation data.

1. Introduction

Drought is a climatic extreme affecting more people than any other form of natural disaster (e.g. Wilhite, 2000). Of all natural disasters, droughts are globally occurring most frequently, have longer durations, impact larger areas and the most vulnerable populations on earth affecting food security through significant losses in agricultural production (e.g. WMO, 1997). Drought may occur in any part of the world, but duration and intensity of droughts vary greatly across different climatic zones (e.g. Wilhite, 1993). Drought causes serious agricultural, environmental and socioeconomic damages. For example, the average annual cost in agriculture losses due to droughts in the United States is estimated between $6 and $8 billion. Another example is the 2001 drought in Iran caused by precipitation shortfalls in the winter–spring seasons that constitutes one of the worst and most prolonged droughts of the country's history. This drought affected about 37 million people (half of the country's population) and caused damages to agriculture and livestock estimated to about $2.5 billion (Agrawala et al., 2001).

When a drought event occurs, moisture deficits are observed in many hydrologic variables, such as precipitation, streamflow, soil moisture, snow pack, groundwater levels and reservoir storage. Droughts are categorized according to various types of deficits. For example, meteorological droughts are based on deficits in precipitation, agricultural droughts on deficits in soil moisture, and hydrologic droughts on streamflow deficits (Dracup et al., 1980). Assessment and prediction of drought provides valuable information for water resources planners and policy makers to cope with drought consequences. Because of the complex relationship among the different physical factors affecting the initiation and persistence of a drought, it is difficult to provide a precise definition of drought that would work in all circumstances. This is a main reason as to why policy makers and water resource planners have difficulty recognizing and planning for a drought. Therefore, drought management relies on statistical indices to decide when to start implementing water conservation or mitigation measures (Khadr et al., 2009).

Drought indices summarize different data on rainfall, snowpack, streamflow, and other water supply indicators into a comprehensive picture of drought occurrence (Heim, 2002). Several indices have been proposed by researchers for quantifying drought severity that are derived from hydro-meteorological variables. Some of the popular drought indices include: the Palmer Drought

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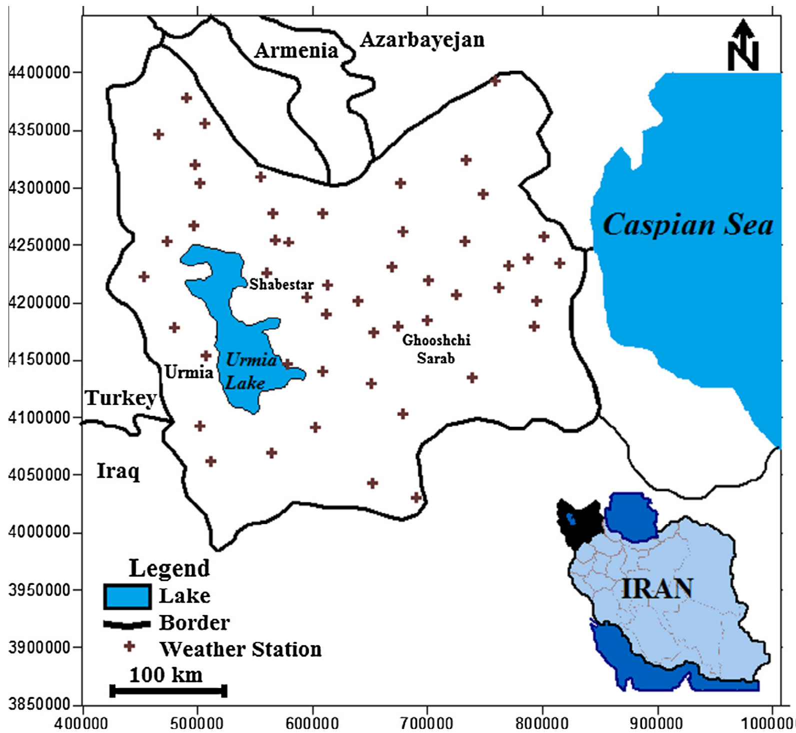

Fig. 1. Study area map and location of meteorological stations over northwest of Iran.

Severity Index (PDSI; Palmer, 1965), Crop Moisture Index (CMI; Palmer, 1968), Surface Water Supply Index (SWSI; Shafer and Dezman, 1982), Standardized Precipitation Index (SPI; McKee et al., 1993), the Reclamation Drought Index (RDI; Weghorst, 1996), Effective Drought Index (EDI; Byun and Wilhite, 1999), Streamflow Drought Index (SDI; Nalbantis and Tsakiris, 2009), Standardized Hydrological Index (SHI; Sharma and Panu, 2010), Standardized Precipitation Evapotranspiration Index (SPEI; Vicente-Serrano et al., 2010) Evaporative Drought Index (EDI; Yao et al., 2010), Regional Drought Area Index (RDAI; Fleig et al., 2011) and Agricultural Reference Index for Drought (ARID; Woli et al., 2012). Every index has its own strengths and weaknesses. Mishra and Singh (2010) have given a comprehensive review of the different drought indices summarizing their usefulness and limitations. Besides, a

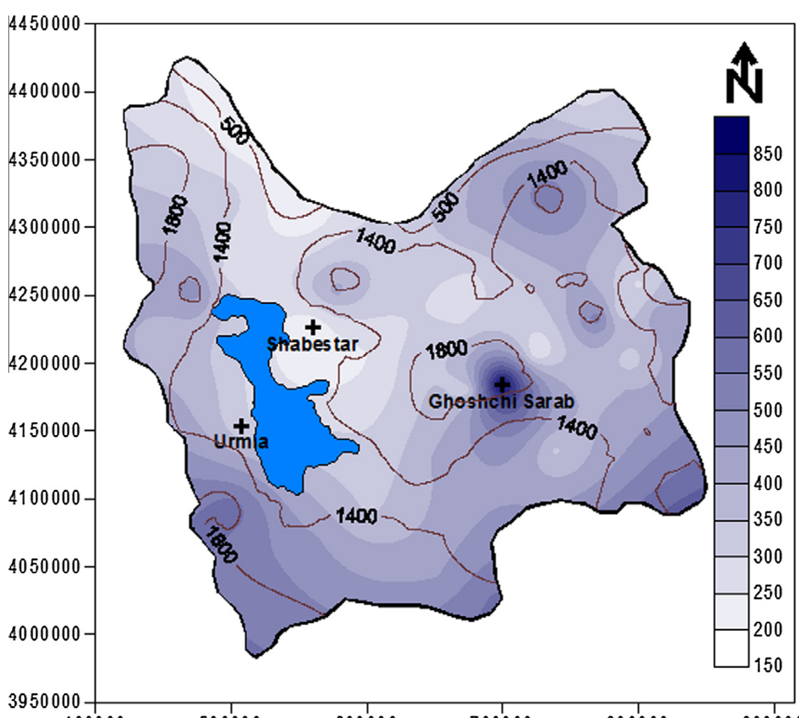

Fig. 2. Mean annual precipitation (mm) over northwest of Iran (1970–2007). The solid lines represent topographic contours.