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Joint meteorological and hydrological drought model: a management tool for proactive water resources planning of semi-arid regions

Arash Modaresi Rad (1), Samira Ahmadi Ardakani (2), Zahra Ghahremani (3), Bijan Ghahreman (4), and Davar Khalili (5)

(1) Ferdowsi University of Mashhad, water engineering, Shiraz, Iran, Islamic Republic Of (arashmod@yahoo.com), (2) Ferdowsi University of Mashhad, water engineering, Mashhad, Iran, Islamic Republic Of (S.ahmadi9010@yahoo.com), (3) Ferdowsi University of Mashhad, water engineering, Mashhad, Iran, Islamic Republic Of (zahraghahremani71@yahoo), (4) Ferdowsi University of Mashhad, water engineering, Mashhad, Iran, Islamic Republic Of (bijangh@um.ac.ir), (5) Shiraz University, water engineering, Shiraz, Iran, Islamic Republic Of (dkhalili@shirazu.ac.ir)

Conventionally drought analysis has been limited to single drought category. Utilization of models incorporating multiple drought categories, can relax this limitation. A copula-based model is proposed, which uses meteorological and hydrological drought indices to assess drought events for ultimate management of water resources, at small scales, i.e. sub-watersheds. The study area is a sub basin located at Karkheh watershed (western Iran), utilizing 41-year data of 4 raingauge stations and one hydrometric station located upstream and at the outlet respectively. Prior to drought analysis, time series of precipitation and streamflow records are investigated for possible dependency/significant trend. Considering the semi-arid nature of the study area, boxplots are utilized to graphically capture the rainy months, which used to evaluate the degree of correlation between streamflow and precipitation records via nonparametric correlations and bivariate tail dependence. Time scales of 3- and 12-month are considered, which are used to study vulnerability of early vegetation establishment and long-term ecosystem resilience, respectively. Among four common goodness of fit tests, the Cramér-von-Mises is found preferable for defining copula distribution functions through Akaike & Bayesian information criteria and coefficient of determination. Furthermore the uncertainty associated with different copula models is measured using the concept of entropy. A new bivariate drought modeling approach is proposed through copulas. The proposed index, named standardized precipitation-streamflow index (SPSI) is compared with two separate indices of streamflow drought index (SDI) and standardized precipitation index (SPI). According to results, the SPSI could detect onset of droughts dominated by precipitation as is similarly indicated by SPI index. It also captures discordant case of normal period precipitation with dry period streamflow and vice versa. Finally, combination of severity-duration-frequency (SDF) of drought events through copulas resulted in SDF curves that can assess drought related ecosystem failure.