ABSTRACT

Drought is a natural disaster and can virtually occur in any climatic zones. About 94% of natural disasters occur due to four major causes: earthquakes, tropical cyclones, floods and droughts. With an increase in the frequency and severity of droughts in different parts of world, there is a serious concern about this hydro-meteorological disaster. This study was conceived with an overall goal of drought assessment and management for mitigating drought impacts in Sina River basin of Maharashtra. It is located in the semi-arid region of Western India, which has a frequency of severe drought in 8 to 9 years. Water scarcity is a common problem in the study area, especially during dry periods. To accomplish the goal of this study, four specific objectives were formulated: (i) assessment of the performance of salient drought indices for characterizing droughts in the study area, (ii) evaluation of softcomputing techniques for forecasting droughts, (iii) investigation of the risk of hydro-climatic variability on groundwater using multivariate copula technique, and (iv) development of management strategies to mitigate drought impacts in the study area. The hydro-climatic data of nine rainfall stations, four climate stations and ENSO Index data along with the seasonal groundwater-level data of 135 sites for the 1985-2009 period were used in this study. In addition, thematic layers such as land use/cover, soil, drainage density, runoff coefficient, and slope were also used.

To fulfill the first objective, based on the data availability, five meteorological drought indices were considered for comparative evaluation namely, Percent Departure from Normal (PDN), Effective Drought Index (EDI), Standardized Precipitation Index (SPI), Reconnaissance Drought Index (RDI), and Standardized Precipitation Evapotranspiration Index (SPEI). The performance of drought indices was evaluated using five decision criteria, viz., robustness, tractability, sophistication, transparency, and extendibility. For the second objective, four types of ANN models were developed for drought forecasting: simple ANN model and three hybrid ANN models, (a) wavelet-based ANN (WANN), (b) bootstrap-based ANN (BANN), and (c) wavelet-bootstrap-based ANN (WBANN). The performance of these models were evaluated using suitable statistical and graphical indicators. For the efficient management of droughts in the study area, in the third objective, the response of post-monsoon groundwater levels in the unconfined aquifer of the basin to the monsoon (June to October) rainfall and the ENSO Index was investigated using copula modeling. Finally, for the fourth objective, to mitigate the impacts of drought, rainwater harvesting (RWH) potential in the study area was evaluated and suitable sites/zones were identified for RWH structures

using geospatial techniques, Multicriteria Decision Analysis (MCDA) and Boolean Logic.

The performance of drought indices indicated that SPEI at 9-month scale is the most suitable drought index for characterizing the droughts in the study area. For drought forecasting, SPEI-12 at lead times of 1 to 6 months was found to be the best as compared to SPEI-3 and SPEI-6. Further, among the ANN models developed in this study, the performance of the WANN and WBANN models is superior to the simple ANN and BANN models. Hence, WANN and WBANN models are recommended for effective drought forecasting in the study area. The results of copula modeling indicated that the post-monsoon groundwater level (PMGL) and rainfall pair is best modelled by the Clayton copula, and the PMGL-ENSO Index pair is best modelled by the Frank copula. The Clayton copula-based conditional probability of PMGL being less than or equal to its average value at a given mean rainfall was above 70% for 33% of the study area. In contrast, the spatial variation of the Frank copula-based probability of PMGL being less than or equal to its average value was 35-40% in 23% of the study area during El Niño phase, while it was below 15% in 35% of the area during La Niña phase. Moreover, the GIS-based MCDA techniques revealed that in 'normal' years, the zone having 'moderate' rainwater harvesting potential zone is dominant in 80% of the study area (9802 km^2) followed by 'good' rainwater harvesting potential in 16% of the study area (1930 km^2). For the cost-effective implementation of proposed RWH structures, 11% of the agricultural area was prioritized for the construction of farm ponds and 284 sites were prioritized for check dams. The findings of this study are useful for improved understanding of drought characteristics and for formulating efficient management strategies, which in turn can ensure effective mitigation of drought impacts in the study area.

Keywords: *Drought Indices, Drought forecasting, Softcomputing technique, Copula modeling, Rainwater harvesting, Geospatial techniques, Semi-arid region.*