Presenting a Model for Predicting Meteorological and Hydrological Drought Risk by Statistical Methods under the Influence of Climate Change (Case study: Afin Catchment Area)

Ghazale Kavakebi a, Mohammad Mousavi Baygi b*, Amin Aizadeh b, Abolfazl Mosaedi b, Mehdi Jabbari Noghabi c

a PhD of Agricultural Meteorology, Department of Water Science and Engineering, Ferdowsi University of Mashhad.
b Professor, Department of Water Science and Engineering, Ferdowsi University of Mashhad
b Professor, Department of Water Science and Engineering, Ferdowsi University of Mashhad
b Professor, Department of Water Science and Engineering, Ferdowsi University of Mashhad
c Assistant Professor, Department of Mathematical Sciences, Ferdowsi University of Mashhad

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1. Introduction

Drought is a common, natural climate phenomenon on the earth with various effects on the economic, social, and environmental aspects of life. The impact of drought on agriculture, water access, and socioeconomic activities of the region depends on various physiological, environmental, and social factors. Due to declined rainfall in specific and efficient periods, drought could lead to water scarcity. Hydrological drought is defined as the reduction of available water in all its forms (Ma, Ren, Singh, Yuan, Chen, Yang, & Liu, 2016). Climate change could influence the frequency and severity of droughts. Therefore, drought vulnerability depends on several factors, such as topographic features, development of soil, land, and water resources, groundwater utilization, and the regional water demand for domestic, industrial, and agricultural activities. Since these impacts may be local or regional, it is difficult to evaluate the effects of drought on various sectors. Risk is often recognized as the combined probability of a specific event (e.g., drought) and its negative consequences. Risk is defined as the endangerment of a system, which could often be the environment, where drought is interpreted as an environmental risk. The response of the environment to a hazard depends on the severity of the hazard and environmental properties, which could be classified into four categories of economic, social, physical, and environmental factors. The previous studies in this regard have mainly introduced economic and social factors as the risk factors for the occurrence of droughts. In the aforementioned studies, field questionnaires have not been used to assess drought vulnerability, while in the present study, the main research instrument was a questionnaire to estimate drought vulnerability. The present study aimed to assess the risk status of drought in a region in Iran based on observational data and the climatic downscaled data obtained from the
coordinated regional climate downscaling experiment (CORDEX) project in order to predict the risk of drought.

2. Study Area

Afin sub-basin covers an area of 655 square kilometers. The Afrin basin is between 33 degrees and 42 minutes north to 33 degrees and 58 minutes north and 52 degrees 35 minutes east to 53 degrees and 31 minutes north. Khoshbakht river is the permanent river of this basin and part of a larger sub-basin known as Esfedan, which is connected to Zuzan (northeast) and Khat salt pan. It is also connected to Qaen (northwest), Sharokht (southeast), and Saddeh and Birjand (southwest). The average precipitation in Afin sub-basin is approximately 156.4 millimeters, and the average temperature in the region is 14.7°C (Figure 1).

Based on the climate classification methods proposed by Amberje, the climate of Afin sub-basin is arid-cold. The arid-cold climate of the area is suitable for the growth of barberries. The economy of the village in the vicinity of Afin sub-basin has historically relied on agriculture, especially the cultivation of barberries. In fact, most of Iran's barberry is produced in this region.

3. Materials and Methods

At the first stage, the standardized precipitation evapotranspiration index (SPEI), effective reconnaissance drought index (eRDI), and standardized runoff index (SRI) were applied as the hydrological indices in this regard. The base period was the year 1983, and the utilized data included the monthly data on the average maximum temperature, average minimum temperature, mean surface air temperature, precipitation, and river flow data of Khoshbakht River in Afin sub-basin. Drought Hazard is defined as the probability of drought occurring at various levels of severity. In the current research, the probability of drought occurrence, and the probability of drought occurrence in each drought class was calculated using the normal z-score table. Vulnerability is a set of economic, social, and environmental conditions, which determine the sensitivity of an environment to risk. In the present study, a questionnaire consisting of 35 items was prepared in order to identify the extent of the impact of each vulnerability factor, and exploratory factor analysis and confirmatory factor analysis were applied to determine the vulnerability level of the selected area. Risk is defined as the result of the interactions between a system (environment), natural hazards, and socioeconomic vulnerability relative to the risk. The level of drought risk could be estimated after calculating the drought hazard and its vulnerability based on the definition of risk. In order to access the required meteorological data in the future (as mentioned in the Methodology section) and due to the level of access to the CORDEX project data, only three models of GFDL-ESM2M, CNRM-CERFAC, and ICHEC-EC-EARTH were selected in the current research since all the required meteorological parameters must have historical data, RCP4.5, and RCP8.5. In the present study, the IHACRES model was utilized to obtain the future runoff data. Since the vulnerability level obtained by the questionnaire was considered constant over time in the modeling of drought risk, hazard modeling was carried out. After the prediction of the hazard,
future drought risk was estimated by multiplying the vulnerability value as described in the previous section. Two methods were exploited for the modeling of the drought risk, including the bootstrapped quantile regression (500 repetitions) and loess nonparametric regression.

4. Results and Discussion

Correlation-coefficient (R), explanation coefficient (R²), and Nash-Sutcliffe coefficient (NS) were used to assess the predictive ability of the climate models. After correction, the combined model for the precipitation and temperature parameters was determined using the weighted average method and Bayesian approach. According to the obtained results, the ICHEC-EARTH model had the highest coefficient as an integrated model based on the RCP4.5 scenario. Based on the two scenarios, the amount of runoff will have no significant changes in the upcoming years. Increased temperature and the subsequent probability of excessive rainfall in the studied area may be the reason for the lack of runoff in the upcoming years. Based on the completed questionnaires, the vulnerability score was 0.53 for Afin sub-basin, which indicated that about half of the sub-basin vulnerability was due to the economic, social, and environmental factors of the sub-basin. Furthermore, the vulnerability value was considered to be a mediator of the sensitivity of the mentioned factors. According to the results based on the mentioned meteorological drought indices, most variations in the drought risk were observed in winter. The results of drought risk assessment indicated that most variations in the frequency of droughts occurred in winter compared to the base season. On the other hand, the SRI findings showed no significant risk of severe droughts in any of the time scales within the next three periods based on the RCP4.5 and RCP8.5 scenarios.

5. Conclusion

The present study aimed to provide a model to predict the drought risk status in the future in the form of a case study of Afin sub-basin in Iran based on the meteorological drought indices of SPEI and eRDI and hydrological drought index of SRI. In general, the obtained results could be summarized as follows:

- SPEI and eRDI had the same performance in estimating the frequency of drought events, while eRDI showed higher drought intensity compared to SPEI, which could be due to the use of effective precipitation as an input in this index. In addition, SPI and eRDI indicated approximately equal drought severity.
- A slight increase was observed in the runoff of the future years based on the RCP8.5 scenario.
- Based on the meteorological drought indices, the possibility of highly severe droughts within the next 27 years is lower compared to the mid and far future periods.
- The meteorological drought indices showed that most drought changes in the investigated time scales occur in winter.

**Keywords:** Drought Hazard, Drought Vulnerability, Drought Risk, Climate Change
References (In Persian)

References (In English)


