O 28. DROUGHT ANALYSIS WITH STANDARDIZED SOIL MOISTURE INDEX USING HYDRO-METEOROLOGICAL DATA

Muhammet Cafer Ulker[1*], Cihangir Koycegiz[2], Meral Buyukyildiz[3]

[1]*Department of Civil Engineering, Konya Technical University, Turkey*
[2]*Department of Civil Engineering, Konya Technical University, Turkey*
[3]*Department of Civil Engineering, Konya Technical University, Turkey*

E-mail: ulker.mcafer@gmail.com, ckoycegiz@ktun.edu.tr, mbuyukyildiz@ktun.edu.tr

ABSTRACT: The drought, which directly affects the agriculture of a region and the living standards of the indigenous people, is an important climate event. In this study, it was aimed to interpret the drought periods in the headwater of the Çarşamba Subbasin of Konya Closed Basin by using the Hydrologiska Byråns Vattenbalansavdelning (HBV) model, which is a conceptual rainfall-runoff model. For this purpose, the standardized soil moisture index (SSI), which is a simple drought index, was used depending on daily soil moisture. Firstly, the HBV model to solve optimization problems was calibrated using the Generalized Reduced Gradient (GRG) code. The success of the HBV model for a region with data scarcity is sufficiently accurate with the percentage bias (P_{bias}) = 11.454% and the coefficient of determination (R^2) = 0.518. In this study, based on daily soil moisture data, years were divided into drought periods to better understand and interpret region drought. As a result, almost the same number of dry days was obtained in all years.

Keywords: Generalized Reduced Gradient, The HBV model, Hydrological modelling, Standardized Soil Moisture Index

1. INTRODUCTION

The hydrological cycle is one of the building blocks of the environmental process. Furthermore, it is indispensable for the life of all living things, including human beings. Therefore, it is extremely important to observe, understand and model this cycle. In this context, many hydrological models have been developed and some of them are used in order to simulate this process.

Drought, which is one of the most important climatic events, is very dangerous for environmental life. Being able to do drought analysis thanks to the hydrological models developed contributes to the formation of future strategies.

The Hydrologiska Byråns Vattenbalansavdelning (HBV), conceptual daily rainfall-runoff model, used in many different studies to estimate runoff. Van Loon et al. (2009), they investigated how successful the model would be to simulate propagation of drought in European catchment. They found that the model had some conceptual problems in simulating groundwater during dry periods. Liden and Harlin (2000), they examined the HBV model in different climate conditions. According to this study, the magnitude of the water balance components had a significant impact on the model performance. Xu et al. (2018), purpose of their research is to develop a soil moisture index which can give drought notice. Sridhar et al. (2008), they model soil moisture and examined the importance of soil moisture in quantifying drought through the development of a drought index. The results showed that the soil moisture influence was undoubtedly a quantitative indicator of drought.

To best of our knowledge, drought analysis has never been done using a conceptual model in the region. The aim of this study is to establish a conceptual model to the headwater of the Çarşamba Basin, located on Konya Closed Basin and to perform drought analysis using an easily interpretable index.

5. MATERIAL AND METHOD

5.1. Study Area

The model was established to determine the model-dependent drought level in the Çarşamba Basin, Turkey. The map of the region is exhibited in Figure 1. The headwater of the Çarşamba Basin, located on Konya Closed Basin, have 153.87 km^2 drainage areas. The elevation in the region is between 2400 m and 1100 m. The region is located between 37°14′ to 37°01′ north latitude and 31°58′ to 32°11′ east longitude (Koycegiz and Buyukyildiz, 2019).

In this study, potential evapotranspiration was predicted by using Penman-Monteith equation. Study basin is in a data-scarcity region hence we used the data of Seydisehir and Hadim meteorological stations nearby. The precipitation and potential evapotranspiration data, from 2006 to 2015, were transformed into meteorological data of the region using Thiessen method. It should be noted that snow routine was ignored.

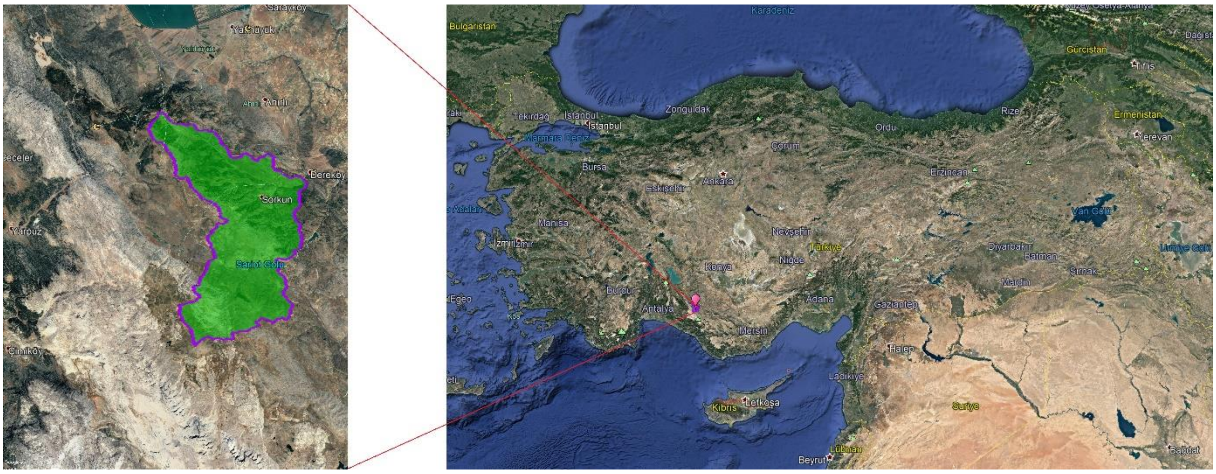

Figure 1. Study area map

5.2. Hydrological Model

The HBV, daily rainfall-runoff conceptual model, can produce the runoff when fed with daily precipitation, evapotranspiration and temperature data. In summary, the model tries to simulate the hydrological process in an area by using inputs and conceptual model parameters. The HBV model can also be used to analyse the drought level (Bergström, 1992).

5.3. Calibration and Performance Metrics

In this study, the HBV model to solve optimization problems was calibrated using the Generalized Reduced Gradient (GRG). GRG code.GRG algorithm tries to synchronize the simulated and observed flow values by changing the model parameters.

In this study, Nash-Sutcliffe Efficiency Coefficient (NSE), determination coefficient (R^2), percent bias (PBIAS) and Kling-Gupta efficiency (KGE) were used to gauge model performance (Nash and Sutcliffe, 1970), (Gupta et al., 1999), (Legates and McCabe, 1999), (Halefom et al., 2018).

5.4. Standardized Soil Moisture Index (SSI)

SSI is an agricultural drought index which dependent on daily soil moisture values of the model. This index is calculated by using 3 soil moisture values. These are daily soil moisture (SMi), annual mean soil moisture (mSM) and standard deviation of annual soil moisture (stdvSM). This index is as follows;

$$SSI=\frac{SMi-mSM}{stdvSM} \quad (1)$$

6. RESEARCH FINDINGS

In this study, GRG algorithm was used to calibrate the HBV model. Performance of the model was evaluated using performance metrics. The model performance values are given in Figure 2. The success of the HBV model for a region with data scarcity is sufficiently accurate. The results obtained for R^2 and NSE are satisfactory while PBIAS is good (Moriasi et al., 2007).

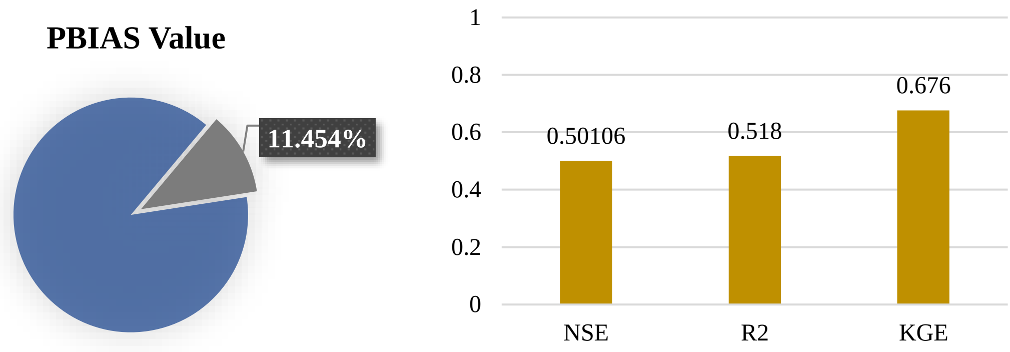

Figure 2. Results of the calibration

The model was more successful at the low flow values than peaks. Meteorological and climatic conditions of the region may mislead the model. Such that sudden melting snow create an unpredictable flow.

In this study, the SSI was calculated by the model-dependent soil moisture values annually. Drought analysis results are given in Figure3. According to Figure3, almost the same number of dry days was obtained in all years even if the most arid year is 2014. In addition, the model showed that on average, 55% of each year is arid. Bu it should be noted that this is an agricultural drought.

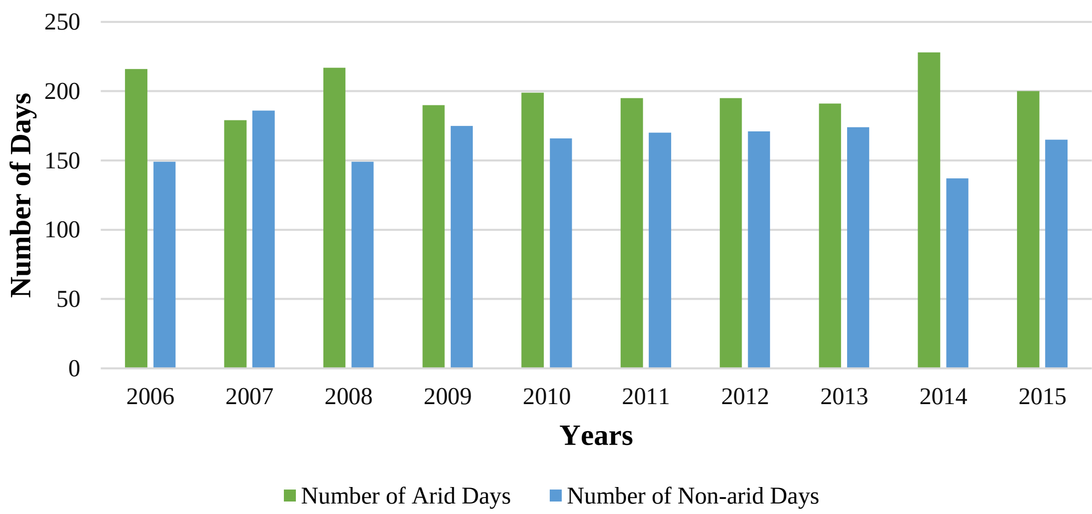

Figure 3. The drought analysis results

Figure 4 shows the change in mean amount of soil moisture by months. According to Figure 4, with the end of the spring months, rapid water loss occurs in soil. The dry season occurs in the second half of the year.

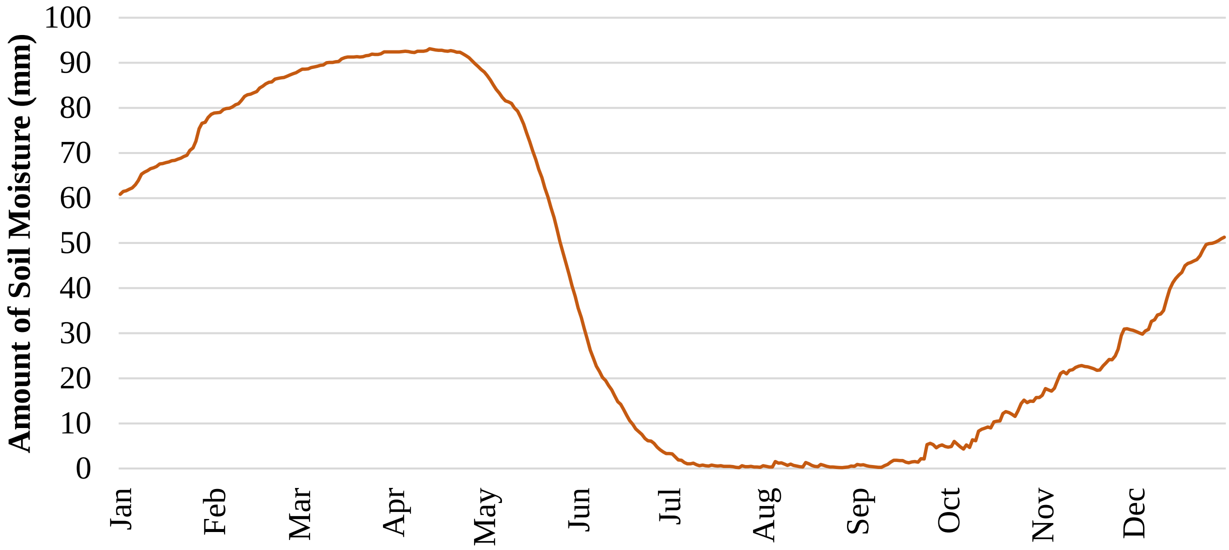

Figure 4. Mean amount of soil moisture by months

7. CONCLUSIONS AND DISCUSSION

In this study, the HBV, daily rainfall-runoff model, established to headwater of Çarşamba which is in a region data-scarcity. GRG algorithm was used to calibrate to model. Model performance is adequate. Standardized soil moisture index was calculated based on the daily soil moisture taken from the model. As a result, the model showed that about 55% of each year is arid. It should be noted that this is an agricultural drought.

To avoid drought, the region should be observed and measures such as afforestation. Afforestation is vital to avoid drought. About the importance of afforestation can be highlighted in 3 main headings. These are as follows;

- ❖ Trees reduce evaporation by protecting soil and water surfaces from sunlight. Decreasing evaporation will increase the soil moisture will occur.
- ❖ Convective precipitation increases since there will be more snow and rain held.
- ❖ Afforestation will create a rougher surface than the bare land. Therefore, the flow will be low. This means that the water will remain in the basin and soil moisture will increase.

On the other hand, we used an agricultural index based on soil moisture average and standard deviation. It means that in some short periods the soil moisture is well above average.

Plants that demand plenty of water for a period of the year and do not need it afterwards or easy-to-grow plants are recommended to individuals or organizations considering agricultural activities. If easy-to-grow plants are selected for harvest at the end of spring, dry plants may be preferred for the rest of the year.

In addition, long-term data connected to a meteorological station in the region will increase the success of the model and improve the results of drought analysis.

REFERENCES

Bergström, S., 1992, The HBV Model -its structure and applications, *SMHI Reports Hydrology*, No: 4.

Gupta, H.V., Sorooshian, S. and Yapo, P.O., 1999, Status of automatic calibration for hydrologic models: Comparison with multilevel expert calibration, *Journal of Hydrologic Engineering, 4, 135-143.*

Halefom, A., Sisay, E., Worku, T., Khare, D., Dananto, M. and Narayanan, K.,2018, Precipitation and Runoff Modelling in Megech Watershed,Tana Basin, Amhara Region of Ethiopia, *American Journal of Environmental Engineering,* 8(3), 45-53.

Koycegiz, C. and Buyukyildiz, M., 2019, Calibration of SWAT and Two Data-Driven Models for a Data-Scarce Mountainous Headwater in Semi-Arid Konya Closed Basin, *Water*, 11(1), 147.

Legates D.R., McCabe, G.J. 1999, Evaluating the use of "goodness-of-fit" measures in hydrologic and hydroclimatic model validation, *Water Resources Research*, 35 (1), 233-241.

Liden, R. and Harlin J., 2000, Analysis of conceptual rainfall-runoff modelling performance indifferent climates, *Journal of Hydrology*, 238, 231-247.

Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Bingner, R.L., Harmel, R.D. and Veith, T.L., 2007, Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations, *Transactions of American Society of Agricultural and Biological Engineers, 50(3), 885-900.*

Nash, J.E. and Sutcliffe, J.V., 1970, River Flow Forecasting through Conceptual Models, *Journal of Hydrology, 10, 282-290.*

Sridhar, V., Hubbard, K.G., You, J. and Hunt, E.D., 2008, Development of the Soil Moisture Index to Quantify Agricultural Drought and Its"User Friendliness" in Severity-Area-Duration Assessment, *Journal of Hydrometeorology*, 9, 660-676.

Van Loon, A.F., van Lanen, H.A.J, Seibert, J. and Torfs, P.J.J.F, 2009, Adaptation of the HBV model for the study of drought propagation in European catchments, *EGU General Assembly*, Vienna, Austria.

Xu, Y., Wang, L., Ross, K.W, Liu, C. and Berry, K et al., 2018, Standardized Soil Moisture Index for Drought Monitoring Based on Soil Moisture Active Passive Observations and 36 Years of North American Land Data Assimilation System Data: A Case Study in the Southeast United States, *Remote Sensing*, 10, 301.