Effect of antecedent rainfall on daily flow forecasting using a soil moisture accounting algorithm

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1. Introduction

Understanding the soil water is important for managing our water resources especially for cases such as landslides, floods, and sediment/flow estimation using hydrological models (Oliveira et al.,2017). In natural ecosystems soil moisture links hydrological processes such as rainfall, surface water, groundwater, and plant water (Ma et al.,2022). Generally, a term called hydrological losses is used in those models which is simply the difference between precipitation and runoff. Rainfall, soil moisture content, and catchment characteristics are among the main controlling factors on hydrological loss (Hill and Mein, 1996). Both rainfall and soil moisture have a noticeable impact on the daily runoff generation. Since in many cases, measured soil moisture data are unavailable, the anticipated soil moisture is considered through a proxy called the sum of precipitation over a certain duration. Numerous studies have found that precipitation is the most important factor determining soil moisture and have calculated the initial soil moisture based on the antecedent precipitation (Philip,1991; Chen et al.,2022; Ma et al.,2022).

This means that the daily soil moisture is a direct function of the total rainfall of the previous days. Such studies (Philip,1991; Chen et al.,2022; Ma et al.,2022) have shown there exists a relationship between previous rainfall and runoff production. Some other works like NRCS have found the summation of rainfall over five days ago is an important factor in this regard. Here we had a look at the effect of duration from the first day until a few days before on the direct runoff by fitting nonlinear curves, and analysis of their correlation factors as a descriptor for rainfall loss.

2. Study area

The Kuhesookhteh Watershed is part of the larger Behesht abad catchment, geographically located in the Chaharmahal-va-Bakhtiariprovince in western Iran, and lying mostly in the Zagros Mountains (Fig. 1).The watershedstretches between 45° 49′ - 53° 48′ E longitude and 35° 5′ -36° 32' N latitude, with a total area of 2915.48 km2. Elevations range from 1972 to 3413m, with an average slope of about 19%. The study area receives an average annual rainfall of 320 mm. Daily precipitation and discharge data for the study area were collected for a period of 20 years from 2000 to 2020 by the Meteorological Organization and Regional Water Organization of Chaharmahal-va-Bakhtiari Province.

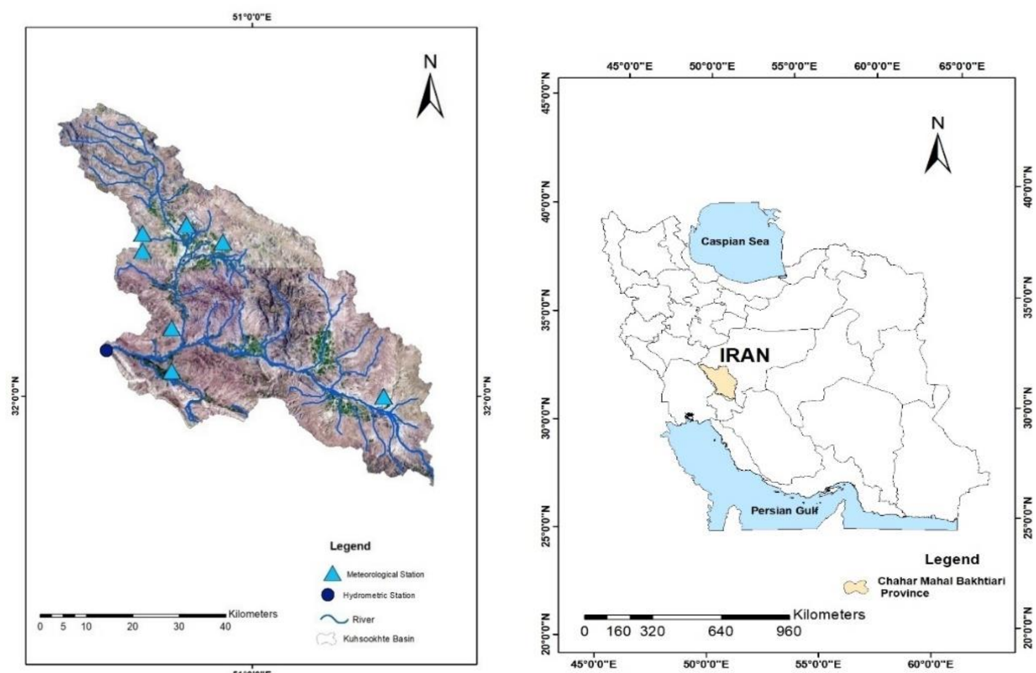

Fig.1 The location of study area and its meteorological and hydrometric stations

3. Methodology

A time series with 21 years of daily rainfall–runoff was simulated by Soil Moisture Accounting Algorithm and the results of the continuous simulation were compared with the corresponding observations for the period of 2000-2021. Results showed a well-model efficiency with a Nash=0.67 after calibration. Precipitation losses were calculated through the difference of total precipitation with effective precipitation and the residual values were calculated through the difference between observed flow and modeled values.

The soil moisture accounting is five layers as a representation of interception, surface depression, soil storage, and upper and lower groundwater components. These layers are used to model the dynamics of surface and sub-surface water. Surface runoff occurs when the rainfall exceeds hydrological loss. A maximum infiltration rate has been assumed as the maximum amount of water that can enter from surface storage into the soil profile. Tension storage is another component in the upper layer of soil that works against infiltration (Singh and Jain, 2015).

4. Results

Fig 2 and Fig 3 show daily simulating discharge values using a soil moisture accounting algorithm for both calibration and validation stages. Fig 4 explores the effect of antecedent rainfall on the simulated flows. The results of constructing a non-linear curve out of mathematical functions show that to some extent there is a correlation between simulated residuals and daily antecedent rainfall (Fig 5). The correlation between losses and daily antecedent rainfall is given in Fig

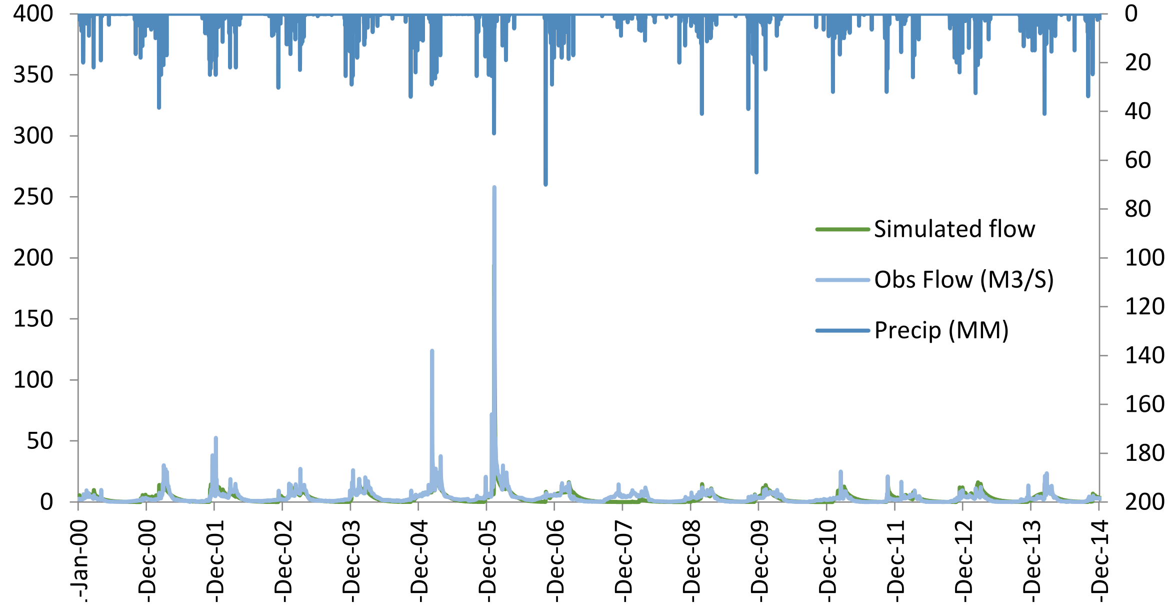

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Fig 2. daily simulated flows flow using a soil moisture accounting algorithm for the calibration period

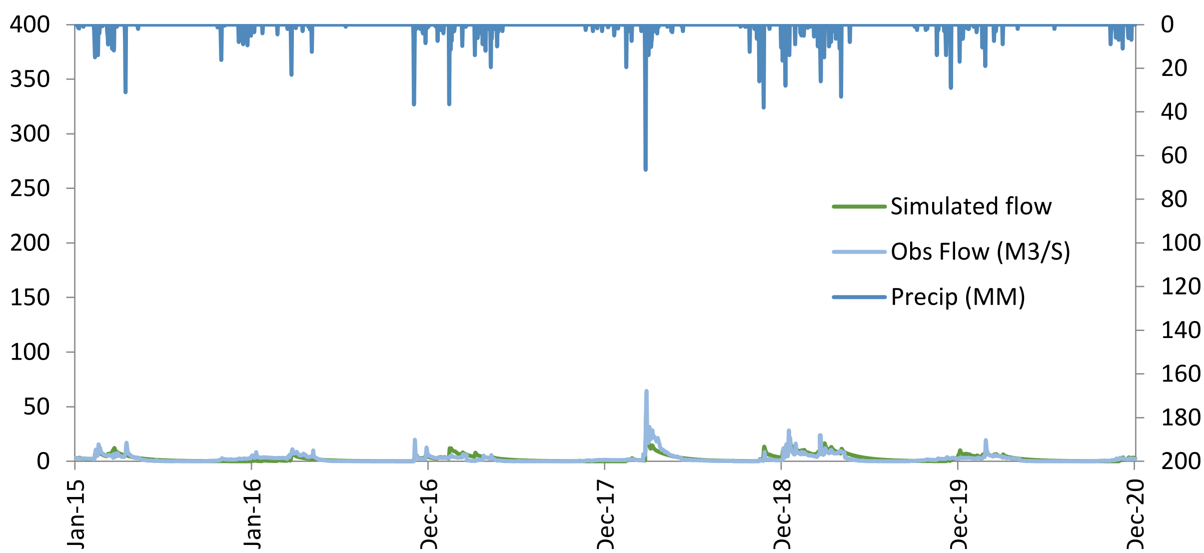

Fig 3. daily simulated flows flow using a soil moisture accounting algorithm for the validation period

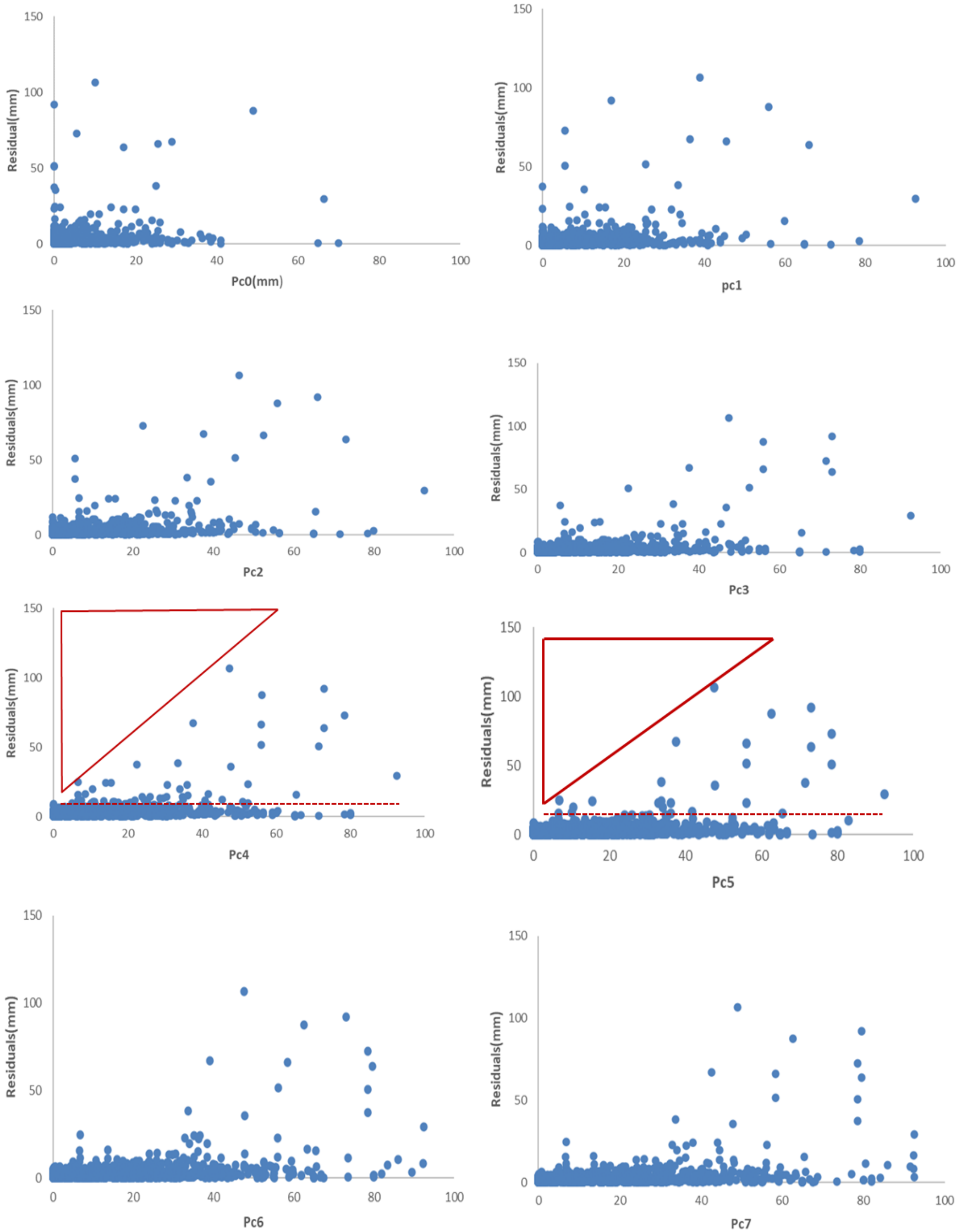

Fig 4. The scatter plot of the simulated flow residuals against the cumulative precipitation over 0-7 days ago

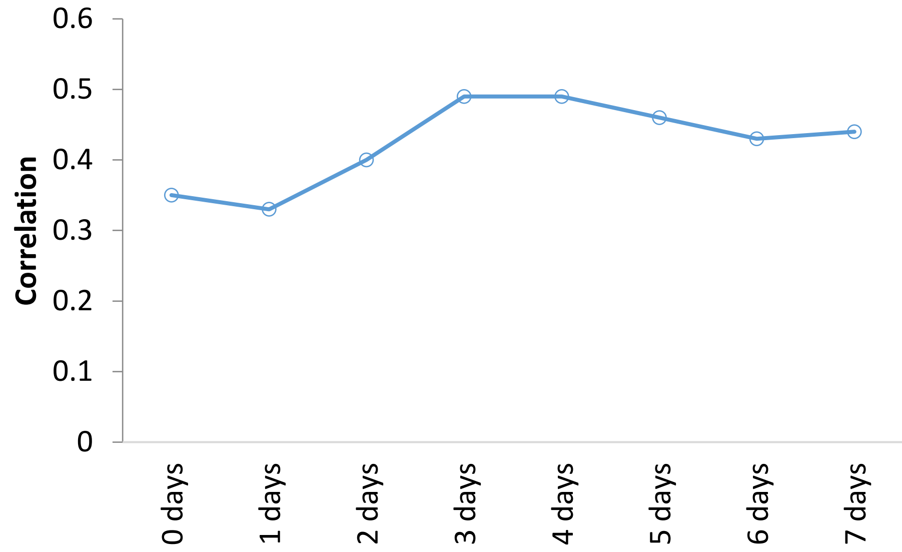

Fig 5. Correlation between simulated residuals and forecasted flow using a soil moisture accounting algorithm

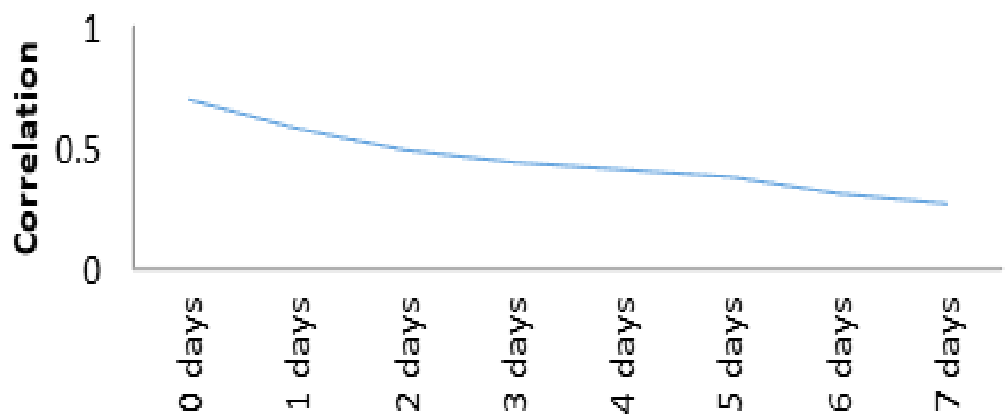

Fig 6. Correlation between losses and daily antecedent rainfall

5. Discussion and Conclusions

The comparison of daily simulated and observed flows shows the soil moisture accounting algorithm did not forecast the high values of streamflow well. Fig 4 shows there is a relationship between the previous precipitation and the residuals of the flow simulation. Visual interpretations of this figure show that an empty triangle cloud is forming for the case of sum of the four days ago rainfall. The correlation has an increasing trend but it almost reaches to steady state after considering the effect of cumulative rainfall of the previous four days. Since antecedent rainfall can be considered as a proxy for the wetness condition of the soil, we can conclude that this process acts like a system memory with the ability to retain information for four days.

6. Selected References

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