EGU21-16318, updated on 24 Sep 2021
https://doi.org/10.5194/egusphere-egu21-16318
EGU General Assembly 2021

Short-term hydrological drought forecasting in the Paute river basin, Ecuadorian Andes

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Hydrological droughts can trigger socioeconomic disruptions which can cause large impacts on societies. Therefore, their forecast is extremely important for early warning and disaster mitigation. Several modelling approaches have been developed for this purpose, and models based on machine learning have become popular during the last decades. In this study, we evaluated the performance of five commonly used models in drought forecasting: Autoregressive Integrated Moving Average (ARIMA), multiple linear (MLM), Random Forest (RF), K-nearest Neighbours (KN) and Artificial Networks (ANN) models.
The study site was the Paute River basin (4816.56 km2) located in the mid-high and eastern part of the Ecuadorian Andes. The "Daniel Palacios" dam, the oldest of 4 strategic dams and which alone generates 35% of Ecuador's national energy demand, was considered the lowest point in the basin. The basin is susceptible to hydrological droughts, which have led to power shortages in the past (e.g., in 1995, 1999 and 2009).
As hydrological drought predictand we used the monthly Standardized Streamflow Index (SSI) accumulated at 1-, 3-, 6- and 12-months, while the predictor variables were precipitation, temperature, river flow and the climatic indices associated with the El Niño-Southern Oscillation, ENSO (El Niño 1+2, El Niño 3, El Niño 4, and El Niño 3.4, which are strongly related to droughts in Ecuador). Data were obtained from the National Institute of Meteorology and Hydrology (INAMHI) and the Climate Prediction Centre of NOAA.
The models were evaluated for lead times of 1, 3, 6 and 12 months through the determination coefficient (R2), the Nash-Sutcliff efficiency (NSE) and the Root Mean Square Error (RMSE). The models' capability to distinguish between occurrence and non-occurrence of droughts (here defined as SSI≤-1) was assessed with a receiver operating characteristic (ROC) diagram. Models were validated using the expanding window (walk forward approach) as a back testing strategy starting as calibration and validation periods Aug/1984-Dec/2010 and Jan/2011-Dec/2019 (75 and 25% of the data, respectively).
As expected, SSI at longer aggregations can be predicted more accurately than at shorter ones with all models. This fact is explained because the former ones more effectively reduce the noise than the latter due to the increase in filter length. The greater the lead time, the less reliable the prediction. Considering a lead time of 1 month, the best model was the ANN for SSI-1 and SSI-3

(R^2=0.64, ROC=0.67; and R^2=0.78, ROC=1.00 respectively), and the MLM model for SSI-6 and SSI-12 (R^2=0.86, ROC=0.66, and R^2=0.96, ROC=0.99 respectively). However, very similar performances were obtained in the latter cases by the ANN model (R^2=0.86, ROC=0.66 R^2=0.91 and ROC=0.75 respectively) and the ARIMA model (R^2=0.83, ROC=0.98 R^2=0.93 and ROC=0.99 respectively). ARIMA models showed large errors for lead times longer than 1 month, so an ANN model is recommended. However, to maximize their potential, further research could explore modifications of the ANN architecture or the input data. Results indicate that these models can be used to forecast hydrological droughts in the Paute river basin and can be used to support reservoir operation decisions.