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# Water yield assessment for major river basins of Afghanistan using GR4J and GR4JSG models

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**Abstract:** Sustainable water management is a global issue driven by increasing water demand for domestic water consumption and irrigation to feed a growing world population. While every country in Central Asia is experiencing water scarcity to some extent, the problems of scarcity are especially acute in Afghanistan where majority of the population experiences water stress, and about half of the population suffers from water shortages. With the growing population, water demand in Afghanistan likely to increase significantly in the future. Managing the growing water demand under changing supply is a huge challenge that will require strategies and policies informed by science. This study is an attempt to assess the water sources in Afghanistan and quantify the annual average water yield across the country.

Afghanistan is a mostly semi-arid country and depends on water from snow and glacier melt in the northeastern part of the country and neighbouring Tajikistan and Pakistan, to produce food for its population. To assess water yield across the country, we reconfigured and calibrated regional hydrological models for five major river basins of Afghanistan (Helmand, Harirod-Murghab, Kabul, Northern and Panj Amu). These models were initially developed by the eWater Ltd for training the Afghan government staff and were handed over to National Water Affairs Regulation Authority (NWARA) of Afghanistan in 2019. We have used a combination of GR4J and GR4JSG hydrological models to simulate runoff from these basins. The area of the river basins varies from 71,995 $km^2$ (Northern Basin) to 327,660 $km^2$ (Helmand Basin). For hydrological modelling, each river basin was divided into multiple sub-catchments totalling 207. Each sub-catchment was divided into multiple functional units (FUs). Since precipitation generally occurs as snowfall over the higher elevations and melting snow and glaciers are significant contributors to streamflow, FUs were derived using elevation bands at 500 m intervals to facilitate snowmelt modelling. The current model setup uses input data from 122 streamflow gauging stations, 19 weather stations and 28 snow sampling stations. Daily time series of observed flow and precipitation data for the period of 2008 to 2020 were obtained from NWARA. Precipitation data were gap-filled and interpolated to sub-catchments using the inverse distance weighted technique. Model parameters were calibrated using the daily Nash Sutcliffe Efficiency (NSE) and bias penalty as the objective function and shuffled complex evolution as the optimisation function. For each river basin, model parameters were calibrated for two to three headwater catchments by comparing observed and simulated flow hydrographs. Calibrated parameters from the best performing sub-catchment were transferred to other sub-catchments in that river basin.

Results show that the mountainous areas in the north-east (e.g. parts of Panj-Amu and Kabul basins) are the main source of water, particularly from the Hindu Kush mountains. Across the country, modelled water yield in the 207 subcatchments varies from 0.3 mm in a subcatchment in Helmand Basin to 248 mm in the Panj-Amu Basin, with an average of 72.1 mm for the entire country. Area averaged water yields in the five river basins are 36, 83, 97, 69 and 174 mm in the Helmand, Harirod-Murghab, Kabul, Northern and Panj-Amu basins respectively. For the same period, mean annual precipitation for the entire country is 234.0 mm, indicating a water yield of 30.8%. The nation-wide average water yield of 72.1 mm is equivalent to 46.3 billion cubic meters (BCM) of surface water for the country. In addition, about 28.9 BCM generates annually in the subcatchments of neighbouring Tajikistan and Pakistan from melting snow and glaciers of the Hindu Kush mountains. Proportion of this water flows to Afghanistan through Panj and Konar rivers. Water yield in Afghanistan varies spatially and temporally. In general, yields are higher in the Kabul and Panj-Amu basins compared to other basins primarily due to higher precipitation and partly due to low evapotranspiration. While water yield in some years is more than other years, there is no consistent increasing or decreasing trend. Compared to the inter-annual flow, water yield between months varies significantly with about 60 to 70% occurring between March and June. Limited data, the unreliability of observed data sets and the recent collapse of the institutional set up make it difficult to estimate the true picture of current water availability. It is important to note that we worked with Government of Afghanistan up until 2021.

***Keywords:*** *Water balance, eWater Source model, Afghanistan, model calibration, functional unit*