Flow Characterization of the River Ajay Using GIS-Based Hydrological Modelling

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Abstract

The river Ajay is one of the major easterly flowing tributaries of the river Bhagirathi-Hugli in West Bengal. It brings a lot of sediments from the Chotonagpur plateau region during monsoon months and empties it into the river Bhagirathi. The river Ajay originates from a small hill at Munger in Bihar. The river flows through Jharkhand and enters West Bengal at Simjuri, near Chittaranjan. The total length of the river is 288 km. The length of the river from Simjuri to Katwa (23°39'23.40"N & 88° 7'55.71"E), where the river joins with the river Bhagirathi (Fig. 1), is 152 km. The rivers Dhadhwa, Pathro, Jamti, Hinglow, Tumoni, Kanur, and Gangatikuri are the major tributaries of the river Ajay (Fig. 1). Freshwater flow from the river Ajay helps to increase the capacity of the river Bhagirathi. The lower Ajay River basin is especially vulnerable to devastating floods. The flow information of the river Ajay is not available in the public domain as it is a part of the lower Ganges basin and the flow data of the rivers in the Ganges basin are classified. Unavailability of the long-term hydrological data restricts water resource management within the river basin. There is hardly any literature focusing on flow availability in the river Ajay. In these circumstances, the present study is an attempt to assess the long-term flow information of the river using a GIS-based hydrological model.

Numerous hydrological models have been developed to assess the basin scale water availability, in which the GIS-based hydrological model, SWAT (Soil and Water Assessment Tool) was extensively used by researchers all over the world. A wide range of SWAT applications in Indian river basins proves that the model is efficient enough to assess the water availability in a river basin and may be used to assess the flow information of the river Ajay and its tributaries. To generate flow data of a river basin, the SWAT model requires the digital elevation model (DEM), land use land cover (LULC) information, soil information and weather data. The SWAT model utilized the SRTM DEM to prepare the flow direction and the flow accumulation map of a region. The river network, river basin, and sub-basins of the Ajay were generated from these maps using the SWAT model. Land use/ land cover is one of the major controlling factors of run-off yield. Landsat 5 TM images were downloaded from the USGS website to generate the LULC map of the Ajay River basin. The atmospheric correction was carried out using the ATCORE 14 tool in ERDAS Imagine software. A supervised classification was done using the maximum likelihood method to prepare the LULC map of the Ajay river basin. The map was classified into six broad land use classes (i.e. Water, Forest, Barren Land, Crop Land, Fallow Land, and Settlement) as per the SWAT model guideline. An accuracy assessment was carried out to assess the precision of the classification. Overall accuracy (81%) and the kappa (0.80) were estimated and were found to be satisfactory. The soil type of a river basin has a major effect on the surface runoff as it controls the rate of infiltration. The FAO-soil map was used to prepare the soil map of the Ajay River basin. Different climatic parameters (precipitation, temperature, relative humidity, wind speed, and solar radiation) of the IMD weather stations within the study area were analyzed statistically for the last fifty years to prepare the weather generator data for the SWAT model. The daily precipitation and temperature data during the study period were generated from APHRODITE and IMD gridded rainfall (0.25° X 0.25°) and temperature (1° X 1°) data. The model was run successfully in an ARC-GIS platform to assess the flow data of the river Ajay and its tributaries under the study. The SUFI-2 algorithm of the SWAT-CUP model was used for model calibration, validation, uncertainty analysis, and accuracy assessment. The model performance was evaluated using six statistical parameters (i.e. P-factor, R-factor, Nash-Sutcliff efficiency, Percentage Bias, RMSE observations Standard Deviation ratio, and Coefficient of Determination) and found to be satisfactory.

The SWAT model was successfully calibrated and validated in the Ajay River basin in the present study. The study indicates that the model uncertainty is within permissible limits. From the performance rating criteria, the SWAT performance is found to be “Very good” during the calibration period and “Good” during the validation period. High values of Coefficient of Determination and Nash-Sutcliff efficiency and low values of Percentage Bias and RMSE observations Standard Deviation ratio indicate a high correlation between the observed and simulated flow. The observed and simulated mean monthly flow of the river Ajay at Amuliaghat (Validation point) were 87 cumec and 93 cumec respectively, which indicates an overestimation of the simulated streamflow by 7%. The average flow of the river Ajay at Katwa has been observed to range between 7 to 535 cumec (Fig. 2). In a flood year, the peak flow of the river may increase up to 1200 cumec, whereas in a drought year, the peak flow of the river may diminish below 250 cumec (Fig. 2). The hydrographs (Fig. 3) of the major tributaries (Dhadhwa at Bishunpur, Pathro at Barmariya, Jamti at Gaura, Hinglow at Palashdanga, Tumoni at Deul Park, Kanur at Natunhat and Gangatikuri at Enayetpur) of the river Ajay demonstrate that, the river Pathro is a major contributor to the flow of the river Ajay. The flow in the river Pathro at Barmariya (Fig. 3) ranges between 1 to 86 cumec in dry period to monsoon months. The rivers, Hinglow, Kanur and Jamti have almost similar contribution. Flow in these rivers ranges from < 1 cumec (Dry season) to 75 cumec (Monsoon months). The contribution of the river Gangatikuri is comparatively small (41 cumec in monsoon months), whereas the contribution of the rivers Dhadhwa (23 cumec in monsoon months) and Tumoni (only 13 cumec in monsoon months) are minimal (Fig. 3).

The study ascertains that the GIS-based hydrological model SWAT is efficient enough to estimate the flow data in an un-gauged river basin. The model can easily be utilized for water resource management, as well as in drought and flood mitigation in the Ajay river basin.

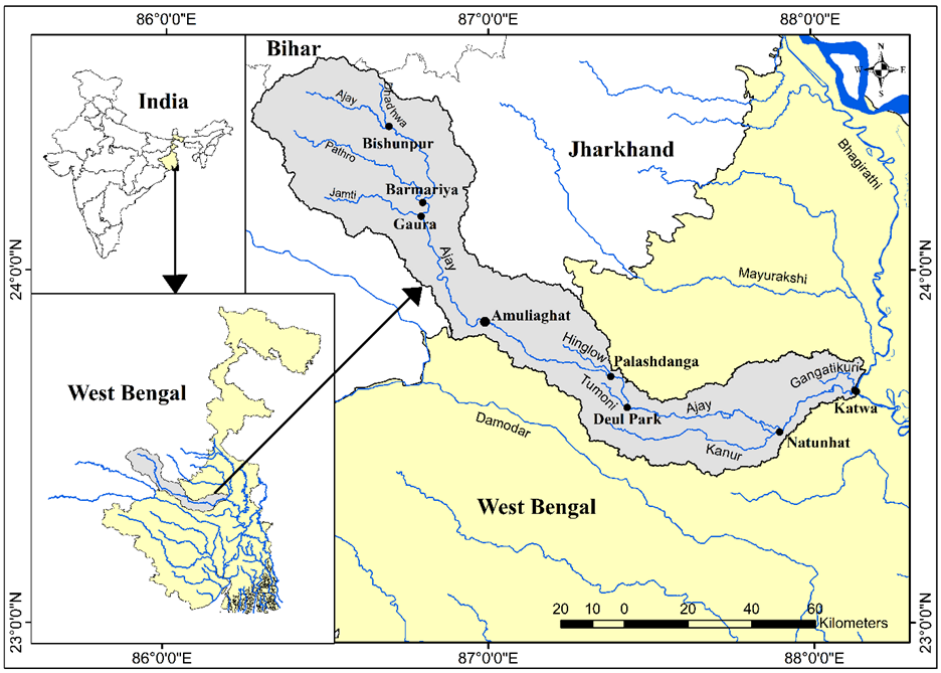

Figure 1: Location of the Ajay River Basin

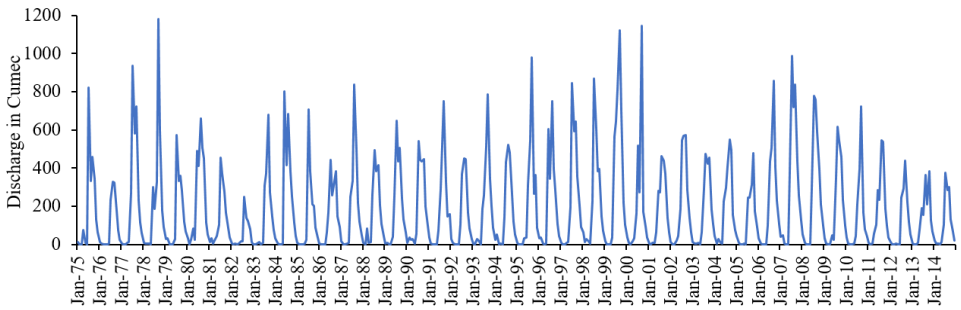

Figure 2: Hydrograph of the Ajay River at Katwa (from Jan. 1975 to Dec. 2014)

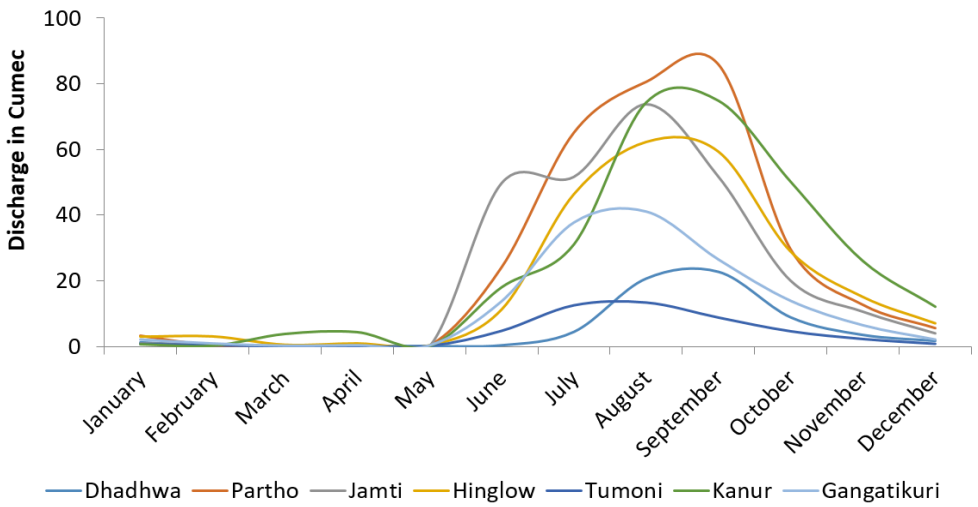

Figure 3: Hydrographs of the major tributaries of the river Ajay