Flood forecasting in Ruvubu River Basin using TRMM data

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Abstract

The scientific challenges of hydrological modelling of data-scarce catchment with particular reference to the Ruvubu River Basin in Burundi. Is presented Due to limited availability of relevant data most of the information was gathered from the public domains. A digital elevation model was created and the catchment was delineated using ASTER data. A lumped rainfall-runoff (RR) model was built using the public-domain tool HEC-HMS, which made use of the freely available information about land-use and soil. Time series record of daily precipitation at a number of catchment locations was available and was used to build the rainfall-runoff model. The RR model is the first of its kind for the basin and provides a basis for catchment-scale hydrological studies, which was used to generate daily runoff data to be used in flood-frequency curves. A flood forecasting model is also built. The daily rainfall data was disintegrated using the 3-hourly rainfall data from Tropical Rainfall Measurement Mission (TRMM) by adopting an adjustment procedure.

Case study: Ruvubu catchment

Fig.1 The study area.

The study area is Ruvubu River Basin in Burundi in central Africa (Fig. 1); it is located in the mouth of Kagera River Basin. The area experiences four seasons of the Inter-Tropical Convergence Zone (ITCZ). There are two rainy seasons and two dry seasons, namely, heavy and long rains (March to May), and short rains (October to December) associated with ITCZ.

Catchment modelling

A catchment model using HEC-HMS at a daily simulation time step was built using a soil moisture accounting model. The model was calibrated using 3-months' hourly discharge data at three locations: Ruvyironza-Kibaya, Ruvubu-Gitega and Muyinga-Bac. The calibration results showed that the model could reproduce the general trend of the discharge with the Nash-Sutcliffe Coefficient (NSC) 0.7 and 0.3 (two locations). In general, the model underestimates the peak, the maximum error being within 10%.

Due to the limited availability of discharge data the monthly peak and average discharge data (measured) available at Ruvyironza-Kibaya, Ruvubu-Gitega and Muyinga-Bac gauging stations for the period 1980 to 1989 were used for validation.

At the Ruvyironza-Kibaya gauging station the NSC was 0.86 and R^2 was 0.89. Some of the peak average values were under-estimated, such as of April 1982 and April 1985. The general pattern was reproduced well; peaks were underestimated.

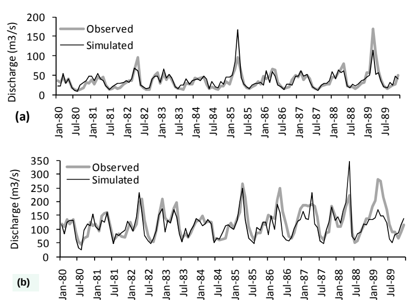

Fig. 3: Monthly max discharges at a) Ruvyironza-Kibaya and b) Muyinga-Bac gauging stations..

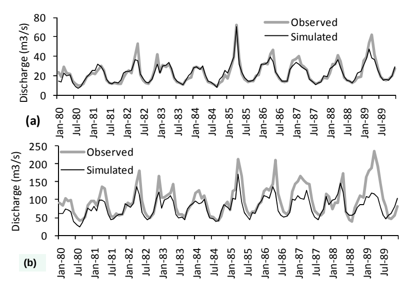

Fig. 2 Monthly average flows at a) Ruvyironza-Kibaya and b) Muyinga-Bac gauging stations.

The monthly peak discharge trend was reproduced well with some underestimation of peaks (e.g. April 1988 at Muyinga-Bac). The model's predictions during the non-flood seasons were more reliable. The model performance was higher for smaller sized sub-basins.

A Log Pearson type III distribution was fitted for the annual peak discharge dataset to generate flood inundation maps corresponding to some preset frequencies, which can be used in developing flood risk maps.

Using TRMM data in flood forecasting

The 3-hourly TRMM rainfall estimates for the period 1998 to 2006 was used to disintegrate daily rain gauge data.

$$\sum_{s=(i-1)k+1}^{ik} X_s = Z_i$$

where k is the number of sub-periods within each period; Z_i represents the time series at higher-level time period and X_s represents the time series at lower-level time period

The disintegrated rainfall time series is computed as (Xs = initially estimated time series at lower level)

$$X_s = \tilde{X}_s \left(Z / \sum_{j=1}^{k} \tilde{X}_j \right)$$

The R^2 for Ruvyironza sub-basin during the period 1999 to 2005 was 0.3. After adopting the adjustment procedure the R^2 was 0.9 (Fig 4)

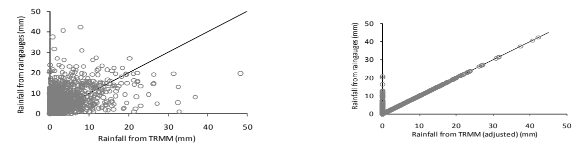

Fig. 4. Comparison of rainfall estimates from TRMM with in-situ measurements before and after adopting the adjustment procedure

The generated 3-hourly rainfall data was used in 3-hourly forecast. The monthly peak flow in Dec '99 was 42.5 m³/s while in May '03 it was 48 m³/s (Fig 5). The peak simulated flood was 44.2 and 45.6 m³/s respectively. The time of occurrences was not known. The hydrograph of monthly peak simulated and observed flow at Ruvyironza Kibaya gauging station shows some over-estimated (Fig 6).

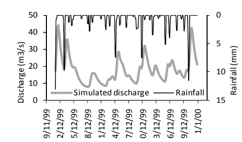

Fig. 5 Forecasted flood for the Ruvyironza-Kibaya basin.

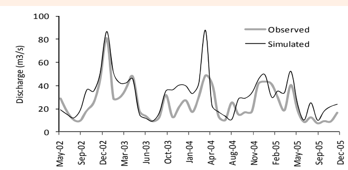

Fig. 6 Comparison of monthly peak floods at the Ruvyironza-Kibaya basin.

Conclusions

- The methodology presents new opportunities of building hydrological models in data-scarce catchments.
- The predicted monthly peak and average discharge were close to the observed ones; no information about time of occurrence of the peak discharge was known.

Reference: Pontien, N. and Bhattacharya, B. (2011). Hydrological modelling in data-scarce catchments - the example of Ruvubu River Basin in Burundi, Proc. Of IAHR Congress 2011.

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