Testing the Feasibility of GR4J Rainfall Runoff Model in Bagmati Basin

Anita Khadka[1], Laxmi P. Devkota[2]

[1,2] Nepal Development Research Institute, Pulchowk, Lalitpur, Kathmandu, Nepal

1 Introduction

- A model is a simple representation of a reality. Models are classified into different categories whose output is driven by input data, model structure and model parameters. All these models share a common problem of parameter identification or accuracy and model equifinality.
- Physically based models are data intensive, and time consuming that require measurements from the field. Too many parameters or over parameterization increase the model complexity and does not necessarily provide the true representation of the system.
- Conceptual models on the other hand, are simple in structure and are less data driven that can fairly represent the catchment characteristics.
- Against this backdrop, this research aims to test the capability of the conceptual hydrological model to simulate high and low flows using multiple objective functions.

2 Materials and Methods

2.1 Study area

- Bagmati basin
- Area = 2827 Km^2
- Elevation Range = 121 – 2913 m
- 73% of basin lies < 500 m – 1500 m
- 27% of basin lies > 1500 m
- Channel length = 134 km
- Landcover: Forest = 66.2%, Agriculture = 26.56%, Builtup area = 2.67%, Bare area = 4.57%
- Hydropower: Pharping = 500 KWh and Sundarijal = 640 KW
- Shivapuri National Park = 159 Km^2

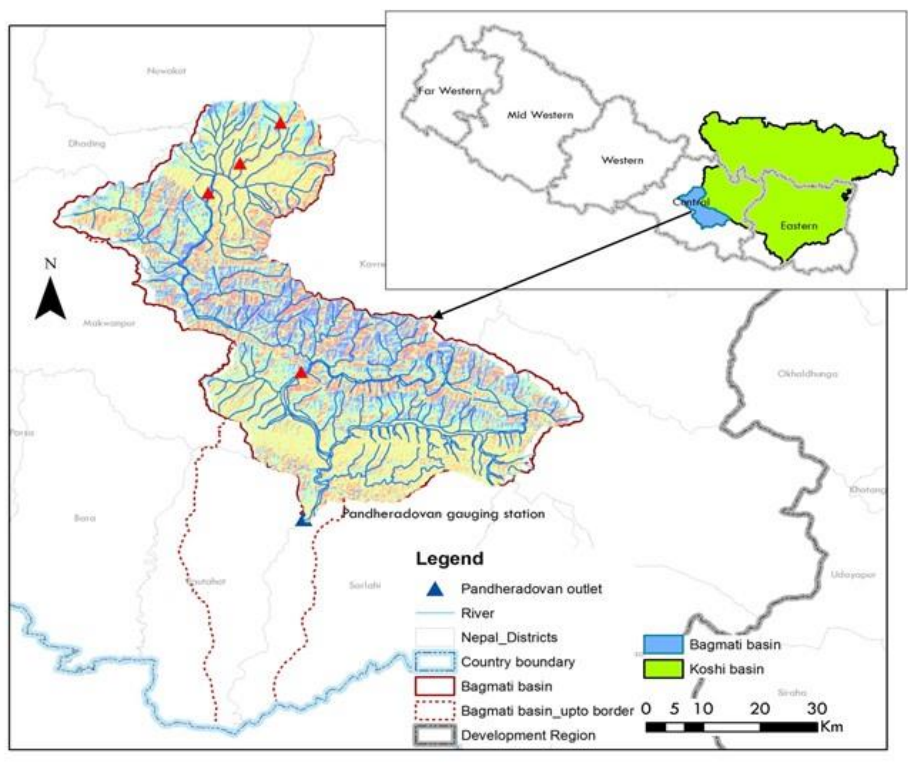


Figure 2.1: Bagmati river basin

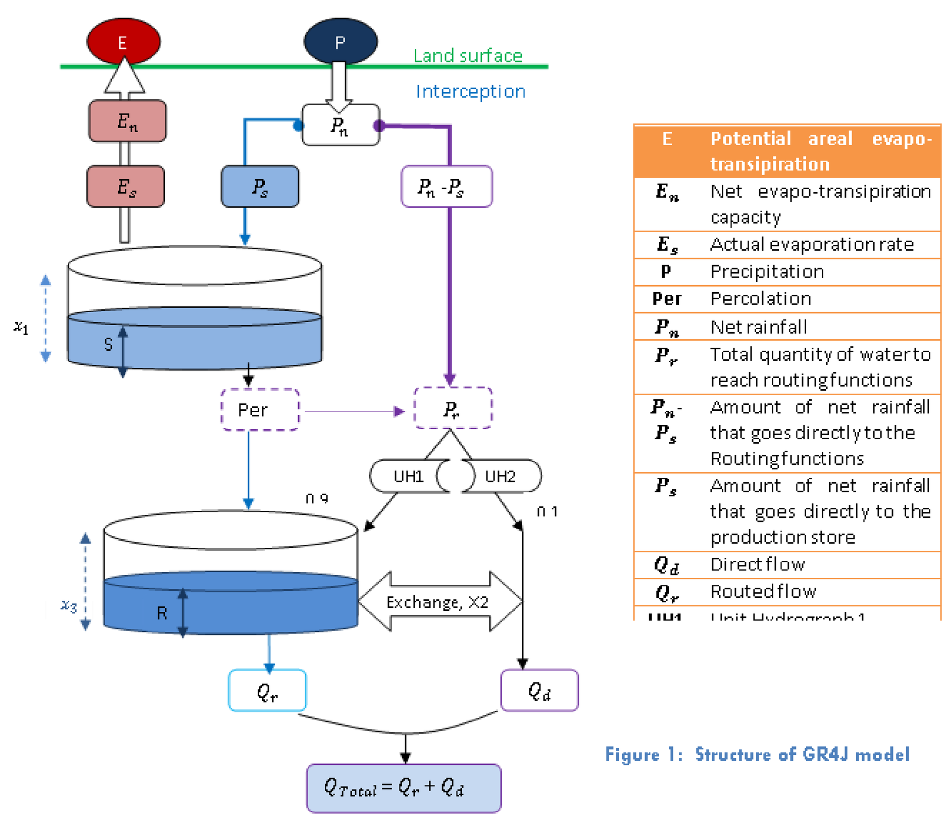


Figure 2.2: Structure of the model

2.2 Input data

- Digital Elevation model (DEM): SRTM 30m
- Land cover: MODIS
- Daily precipitation data: 23
- Daily discharge data: 5 gaging station - Sundarijal, Gaurighat, Khokana, Bhorleni and Pandheradovan
- Long term average class-A PAN PET data from Khumaltar station

2.3 GR4J model

- Simple parsimonious conceptual, lumped, water balance model based on node-link network
- Four parameter model

x_1 = production store [mm]
x_2 = Water exchange coefficient
x_3 = Routing store [mm]
x_4 = Unit hydrograph time base/time lag

- Proven to perform better than Tank model, IHACRES, HBV, SMAR, TOPMODEL etc.
- Optimization function also in auto-calibration mode: Shuffle Complex Evolution (SCE), Uniform Random Sampling, Rosenbrock, SCE then Rosenbrock
- Independent calibration at each nodes or joint calibration can be performed

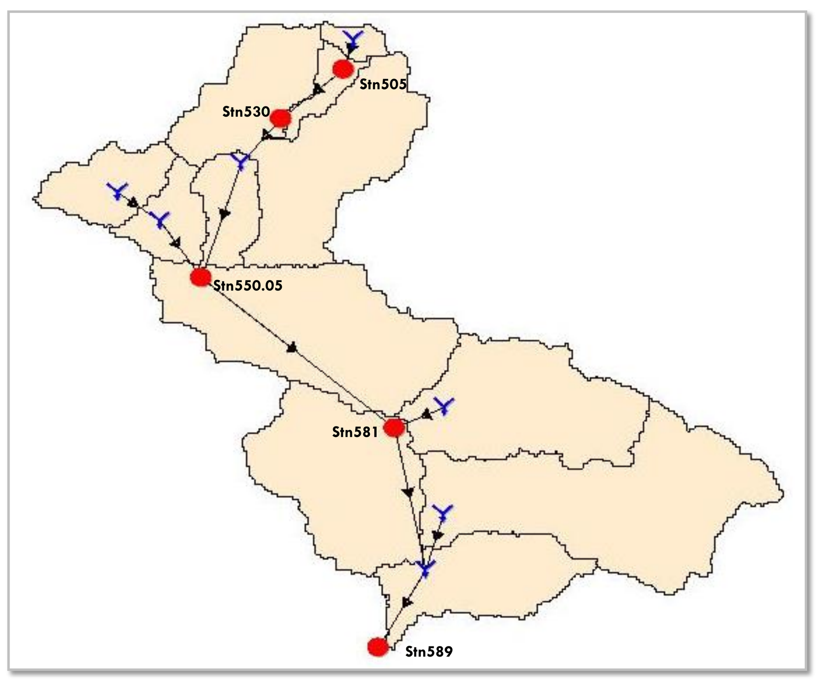


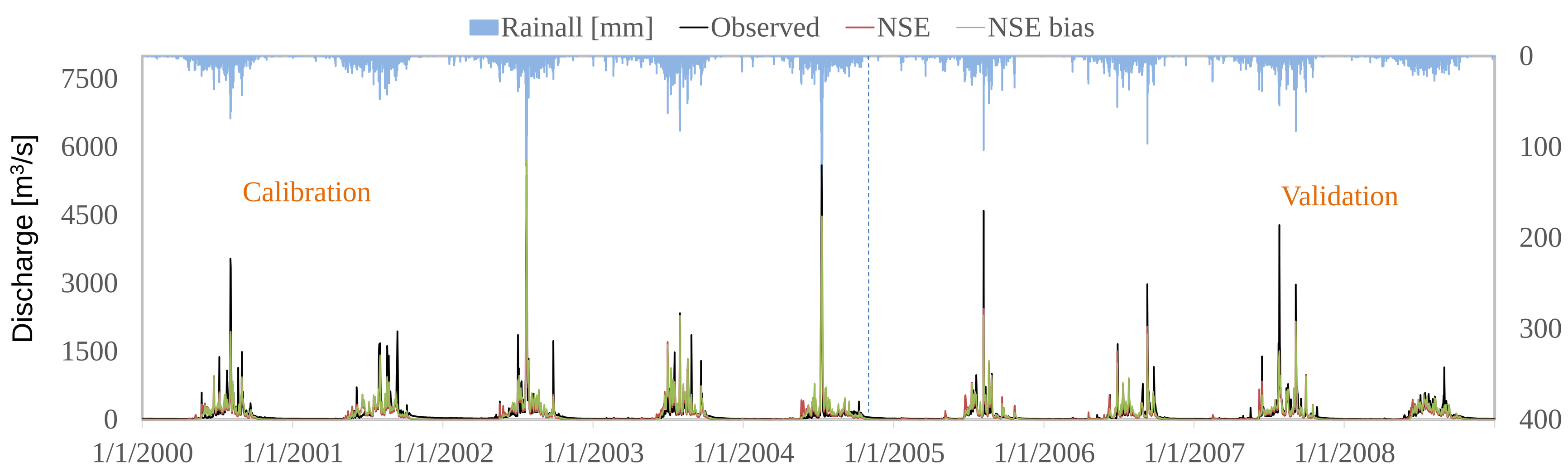
Figure 2.3: Node link structure of GR4J model

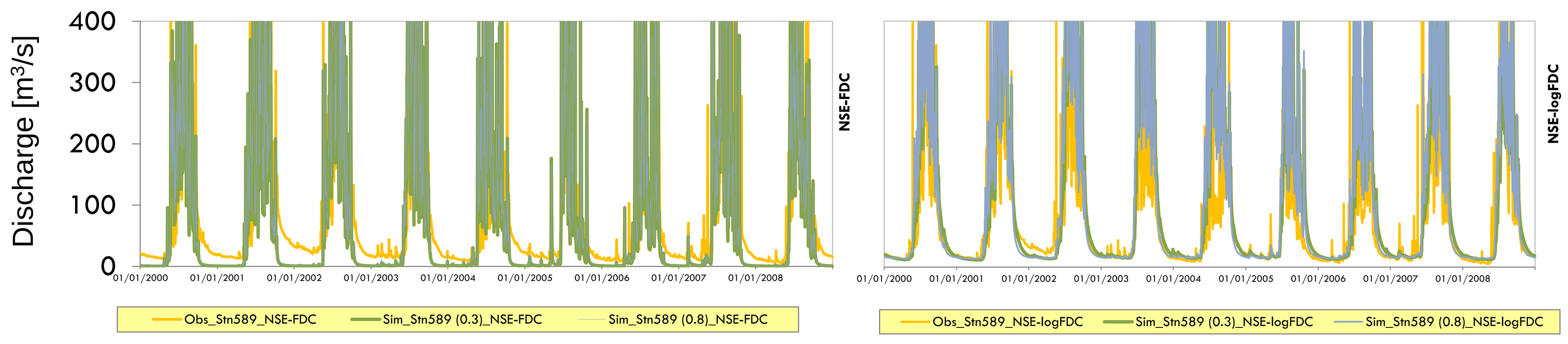
2.4 Model calibration and validation

- Warm up: 1998 to 1999
- Calibration: 2000 to 2004 - Pandheradovan gauging station
- Validation: 2005 to 2008
- Automatic calibration: Shuffle Complex Evolution and Rosenbrock process
- Individual calibration and joint calibration performed using 4 different objective function: NSE, NSEbias, NSE-FDC, NSE-logFDC

3 Results and Discussion

3.1 Calibration and validation with different objective function





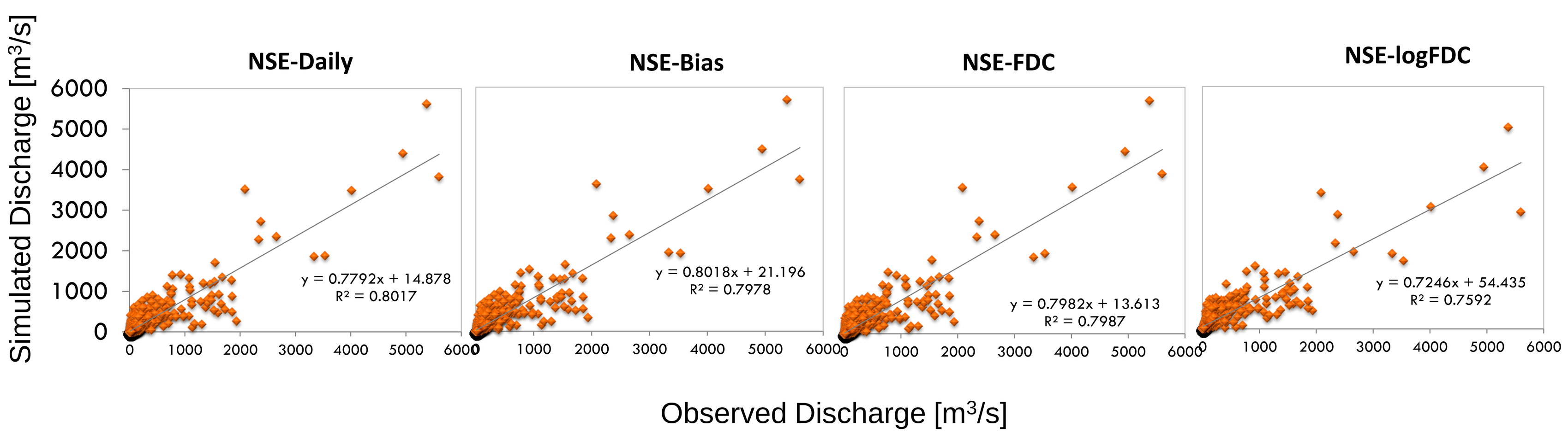


Table 3.1: Statistical performance of the model

Objective function	Calibration		Validation	
	Volume	Efficiency	Volume	Efficiency
NSE daily	-9.89	0.80	-13.42	0.66
NSE-Bias	-2.44	0.798	-8.42	0.67
NSE-FDC	-9.018	0.798	-14.468	0.658
NSE-logFDC	17.114	0.754	14.334	0.604

4 Summary of Findings

- Decrease in model efficiency in validation periods – with more deviation in flow volumes.
- Underestimation of high flows (Calibration period: Q_{max} = 5600 m^3/s, Q_{max} simulated = 5620 m^3/s, Validation period: Q_{max} = 4600 m3/s, Q_{max} simulated = 2294 m^3/s)
- Flows above 2500 m^3/s well captured in calibration period but not in validation period.
- Difference in overall flows in calibration period (wetter, Rainfall = 1962 mm; Q_{av} = 302.67 m^3/s) than validation period (slightly drier, Rainfall = 1641 mm, Q_{av} = 241.41 m^3/s); Also decrease in precipitation & discharge especially in monsoon and pre-monsoon period in validation period.
- Parameters calibrated with different period might not have been able to reproduce flows in validation period.
- NSE and NSE-Bias objective function more efficient in simulating daily flows in overall, timing and volume ratios; NSE-log FDC objective function better for simulating base flows.
- NSE-bias is calibrated by optimizing NSE. It improves low flow performance and is strongly influenced by moderate and high flows.
- NSE-FDC & NSE-logFDC performs under a weighted combination of different calculations of NSE. The first calculation is based on the daily data of observed and predicted flows. The second calculation is the NSE on the points in the flow duration curves of both the observed and predicted flows.
- Parameters production store (x_1) and ground water exchange coefficient (x_2) sensitive in terms of balancing base flows.
- Peak flow event of 5380 m^3/s during 1 July to 7 Aug of 2002 is well captured by GR4J model (NSE 0.92) along with its rising and recession limb compared to GeoSFM model output (NSE 0.91) of the same event.

Acknowledgement:

This project was made possible with funding from Common Wealth Scientific and Research Organization (CSIRO). The author acknowledges Luis Neumann and Dave Penton for their feedback during the project.

The author also acknowledges Department of Hydrology and Meteorology (DHM) for providing hydro-meteorological data of the study basin.