Modelling streamflows for estimating hydrological PLF of a small hydropower scheme in an ungauged mountainous watershed in Western Ghats in India using SWAT

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Kapil K. Narula, A. K. Gosain, Shilpa Nischal

Context

- India has huge hydropower potential that remains to be harnessed
- Deregulation of energy markets and attractive economic incentives have resulted in growing private investments
  - an increase in hydrologic, energy and feasibility studies for potential run-of-river SHPs
- Such assessments aim to provide reliable estimation of flows
  - in case of ungauged sites (mostly the case)
    - Catchment area proportionate method or limited data unable to capture hydrological uncertainty that underlies variability of flow
  - lack of proper parameterization leads to
    - erroneous results
    - non-operational plants
    - loss of capital
    - environmental degradation in the ecologically sensitive areas

Physically based approaches help spatially-explicit parameterization based watershed modelling

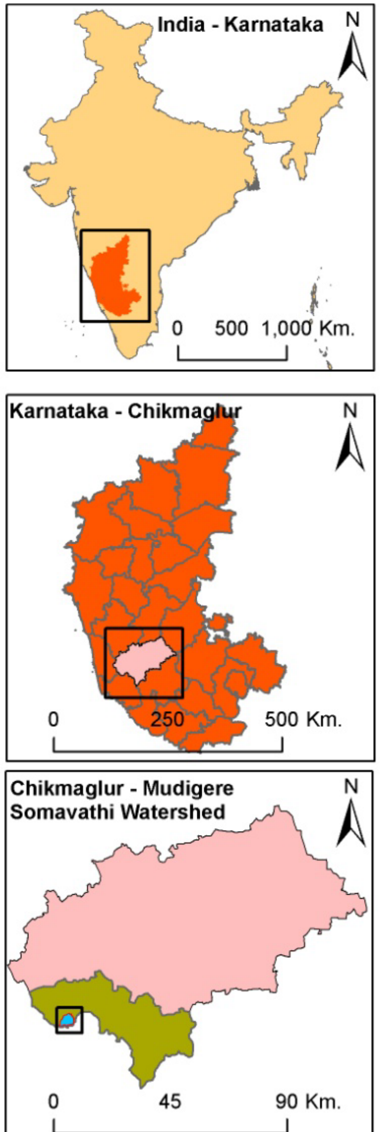
Application of SWAT to an ungauged mountainous watershed for modeling streamflows

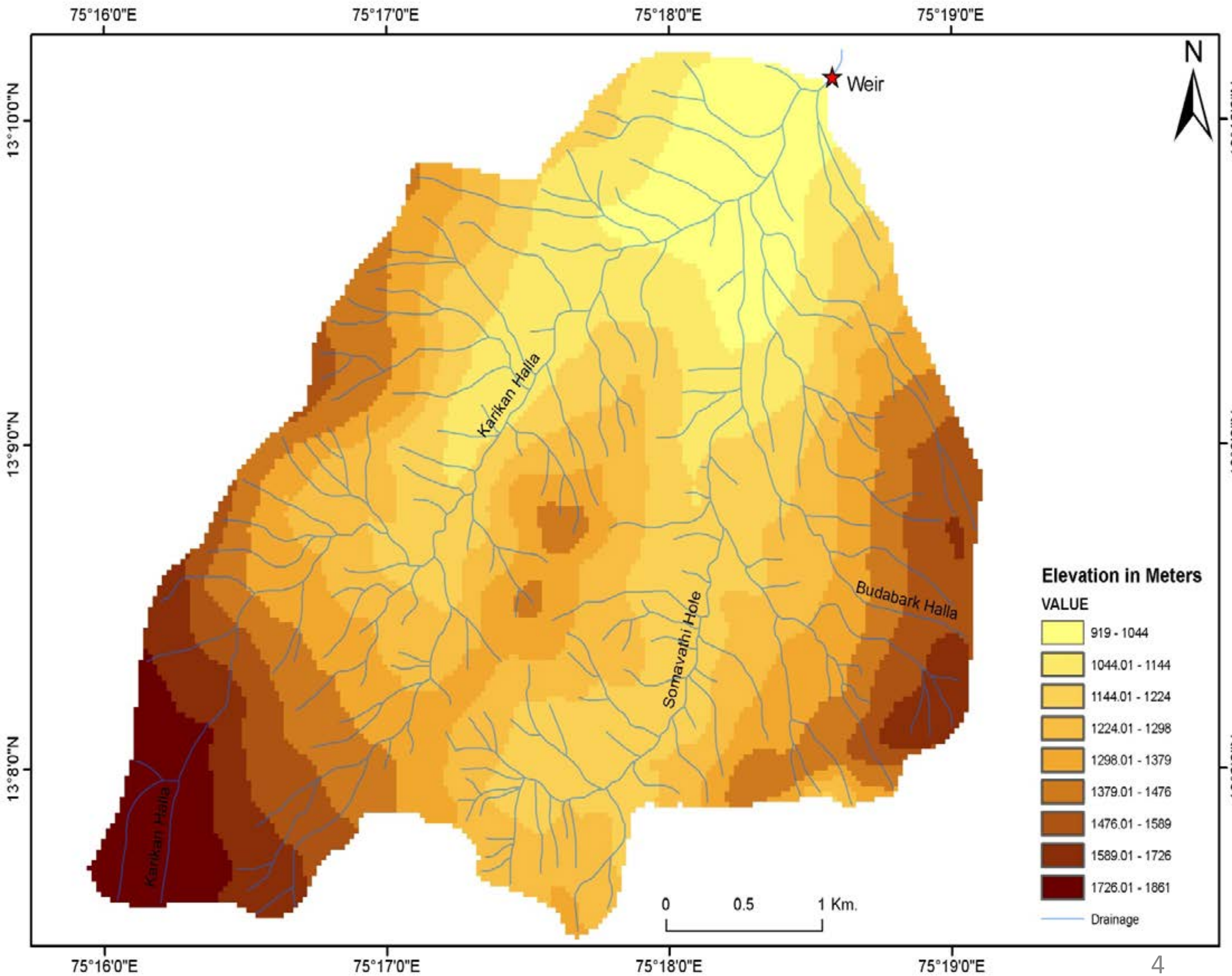
- Watershed Parameterization (spatial distribution of parameters)
- Site visit and literature review
- Rainfall distribution

Study area: Somavathi watershed

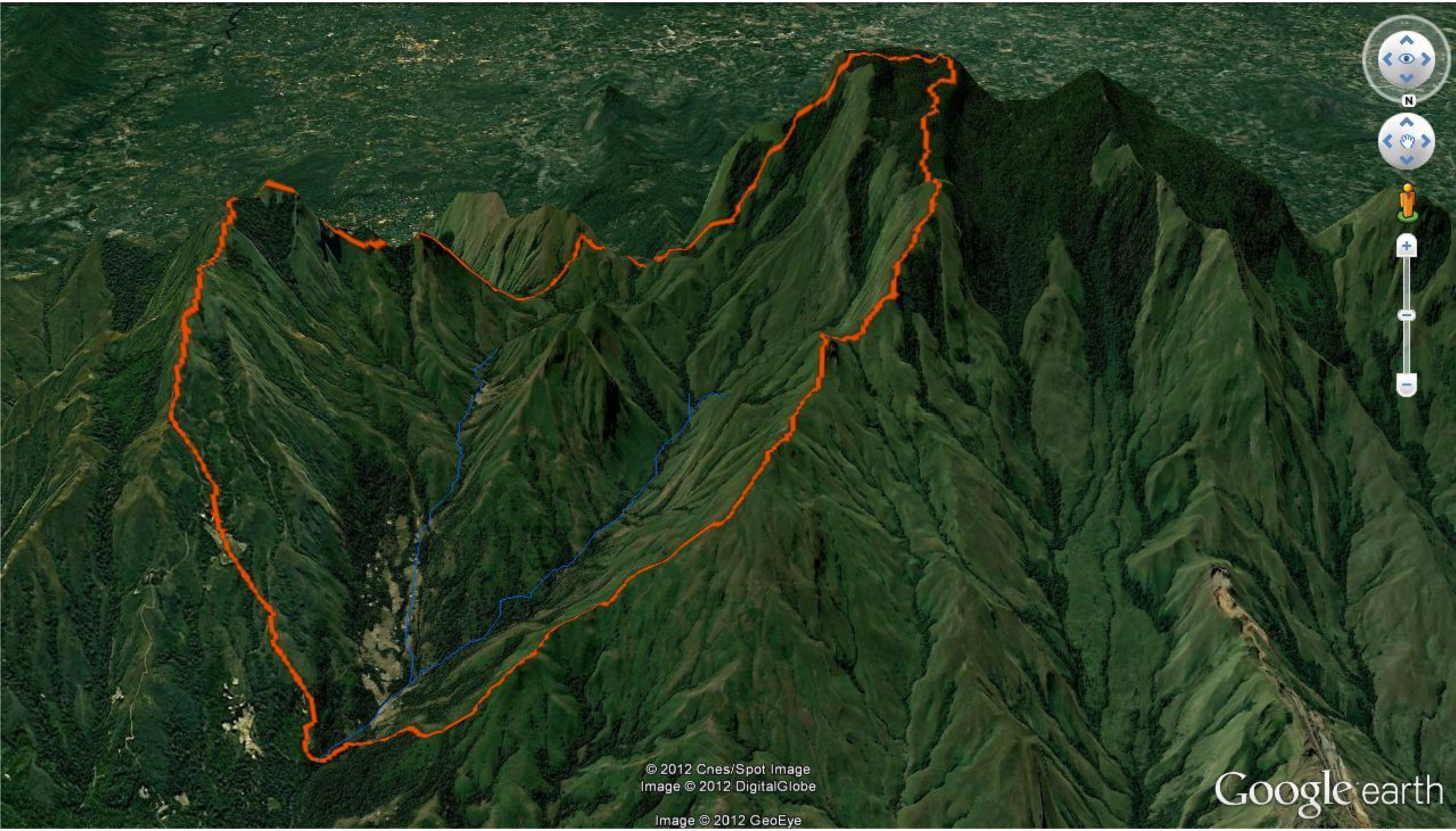
Location: Chikmaglur district, Karnataka, India; ***Watershed area:*** 18.6 km^2

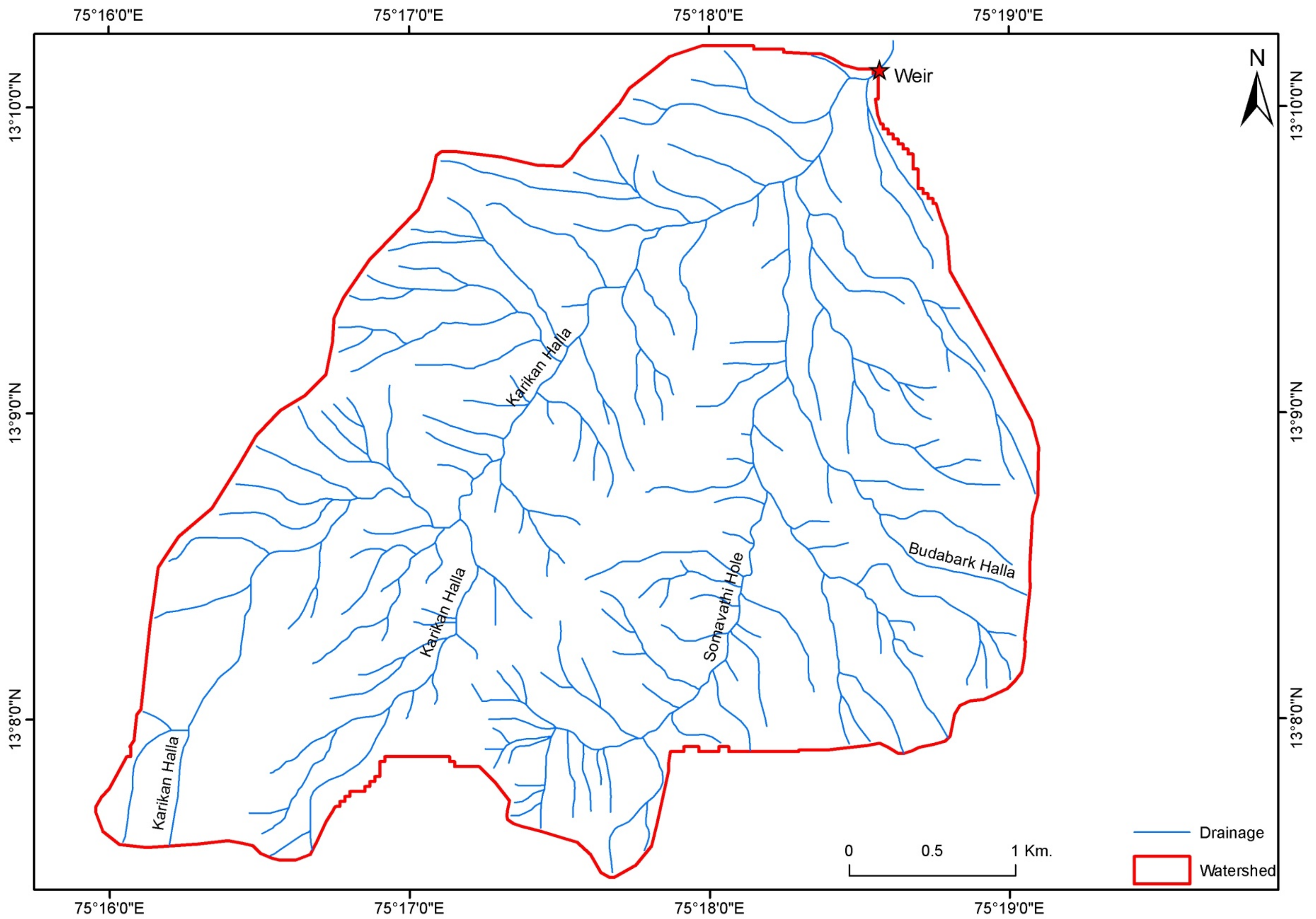
Topography: Elevation from 919m amsl to 1872m amsl; high elevation towards south-west





Somavathi watershed: 3-D view from Google Earth





Drainage: Drained by streams originating in mountains, which flow in the north and north east direction and join to form Somavathi stream.

Description of the study area

– *Landuse:* Grasses and pastures (63%); mixed forests (31.4%); exposed barren land (4%).

– *Soils*: Red soils predominant with saturated hydraulic conductivity estimated in the range of 10-180 mm/hour.

- *Hydrometeorology*
  - Average annual rainfall is about 6440mm, 85% occurs during monsoon
  - months (June to August); CoV is 18.5%.
  - Probability of wet day following wet day > 0.9 (monsoon months).
  - Minimum and maximum temperature : 21.8^{0}C (Jan) to 32.7^{0}C (March).

Input data: Spatial and Non-spatial

(1) Digital Elevation Model (DEM) with spatial resolution of 30 m (ASTER)

(2) Landuse map from Landsat image; updated from Quick Bird (0.6m resolution)

(3) Soil map at scale of 1:100 000 in which physical soil layer properties (texture, bulk density, available water capacity, saturated conductivity, soil albedo and organic carbon) collected from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) Handbook and field data

(4) Climate data from IMD Climatological tables (1951-1980) (mean monthly rainfall, maximum and minimum mean monthly air temperature, mean monthly wind speed, solar radiation, and relative humidity); and daily rainfall from four raingauges in and around watershed (Water Resources Development Organisation, Government of Karnataka)

Results and inferences

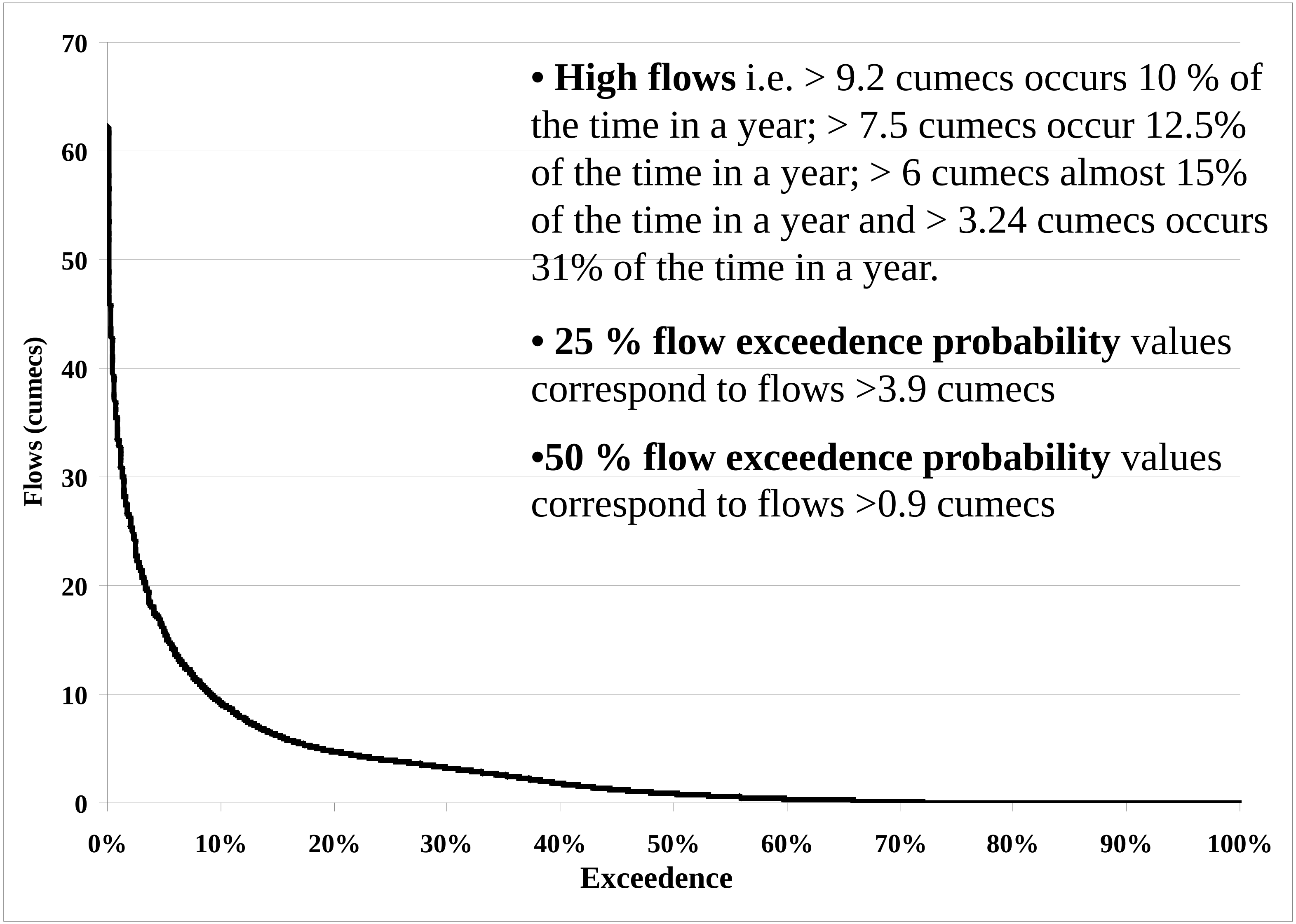
a) Flow Duration Curve (FDC), hydrological PLF and comparison of PLF with nearby geomorphologically similar sites

b) Baseflow filter technique

c) Comparison of instantaneous values with percentile bands

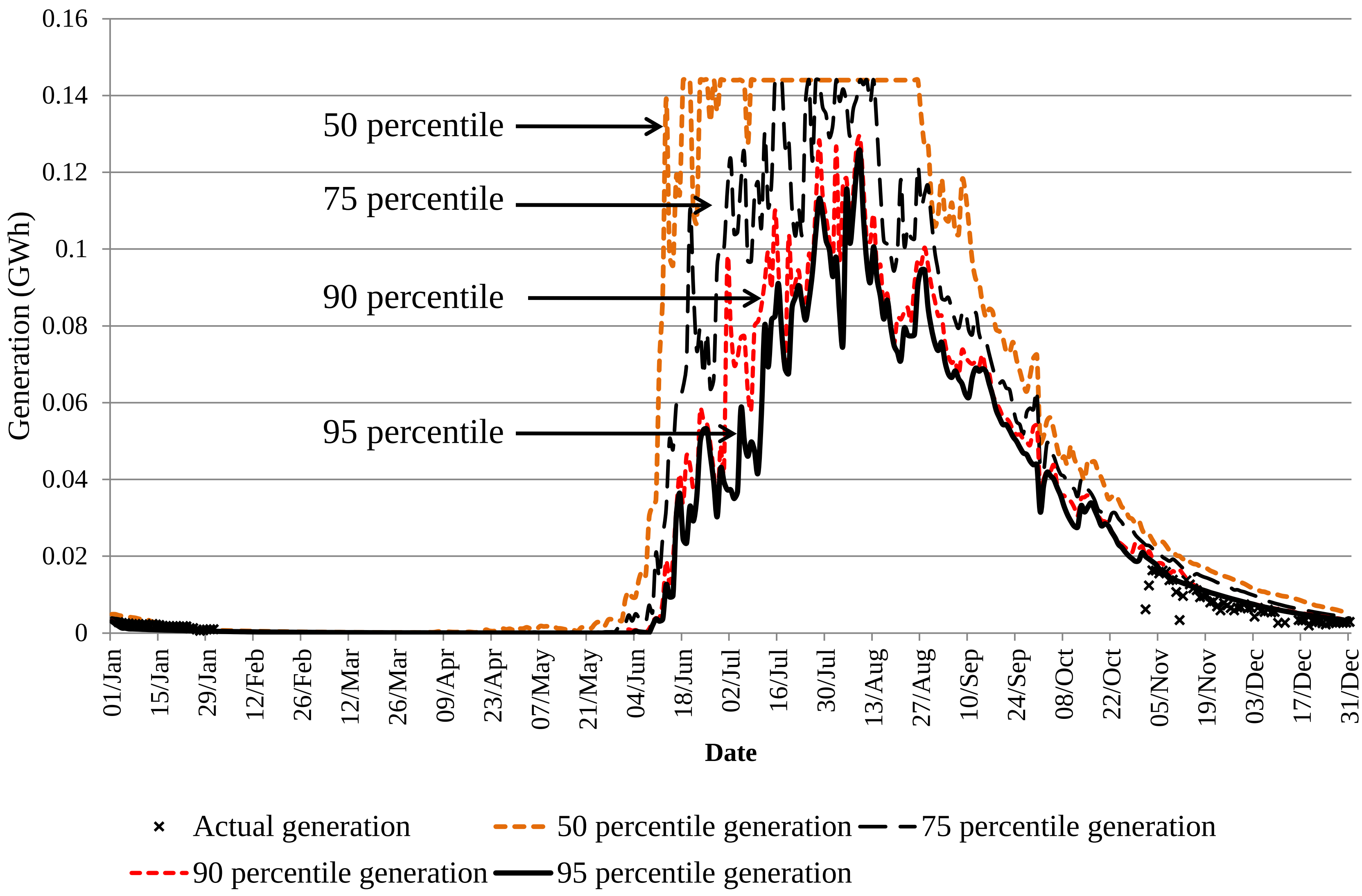
Flow Duration Curve

The simulated flow series used to determine the simulated flow duration curve



- **High flows** i.e. > 9.2 cumecs occurs 10 % of the time in a year; > 7.5 cumecs occur 12.5% of the time in a year; > 6 cumecs almost 15% of the time in a year and > 3.24 cumecs occurs 31% of the time in a year.
- **25 % flow exceedence probability** values correspond to flows >3.9 cumecs
- **50 % flow exceedence probability** values correspond to flows >0.9 cumecs

Comparison of instantaneous values with different percentile bands



Parameter sensitivity analysis

- Sensitivity analysis undertaken to identify sensitive surface runoff and lateral flow related parameters

- Combination of manual and automated methods

- *Latin Hypercube One-factor-At-a-Time (LH-OAT)* method used for undertaking sensitivity analysis in SWAT
  - Selected parameters adjusted over a range of values through stepwise process that utilized both automated methods (van Griensven and Bauwens, 2003), and manual refinement.

  - Sensitivity analysis resulted in a list of parameters from most to least sensitive.

Sensitivity analysis for the mountainous watershed of Western Ghats

Parameter	Description	Range used Min	Range used Max	Sensitivity	Rank LH-OAT
Curve Number (CN2)	Curve number for moisture condition II	25	52.65	High	5
ESCO	Soil Evaporation Compensation Factor	0.74	0.95	High	2
AWC (mm mm^{-1}) varying with depth	Soil Available Water Content	0.07	0.165	High	1
SOL_K (mm h^{-1}) varying with depth	Soil Hydraulic Conductivity	10	300	Moderate/ Low	6
SOL_Z (mm)	Soil depth and number of layers (SOL_LY)	2100* (2)	4500 (6)	High	3
ALPHA_BF	Baseflow Alpha factor	0.039	0.048	High	4
CH_K2 (mm h^{-1})	Channel Conductivity	0	75	Low	
GW_DELAY (days)	Groundwater delay time	1	50	Low	7
SURLAG	Surface lag coefficient	1	4	Low	8

* figures in brackets refer to number of soil layers

Sensitivity analysis: key results

Soil-landuse related parameters found to be sensitive for the watershed. These included:

- Soil Evaporation Compensation Factor (ESCO)
- Soil Available Water Content (SOL_AWC)
- Soil depth (SOL_Z) and soil layers
- Groundwater baseflow (ALPHA_BF)
- Curve number (CN2)

These portray a unique characteristic in case of Western Ghats

Conclusions

- SWAT successfully simulated various components of the land phase of the hydrological cycle in an ungauged watershed
- Unique findings for watersheds in Western Ghats:
  - Contributions from dynamic subsurface flow that appear as consistent release of water and responsible for considerable quantities of available water throughout the year (concept of **pipeflow** and nature of **pipenets)**
  - Such subsurface flows contribute to the hydrological PLF of a small hydropower generation scheme
  - Baseflow ratio estimated to be 0.55
- It is concluded that for wet forested mountainous areas like the Western Ghats, the catchment response is shaped by the sub-surface flow pattern, in addition to surface flow
- Watershed parameterization is essential
- Uncertainty analysis will further help refining the methodology – future work

Thank you

kapilkumar.narula@gmail.com