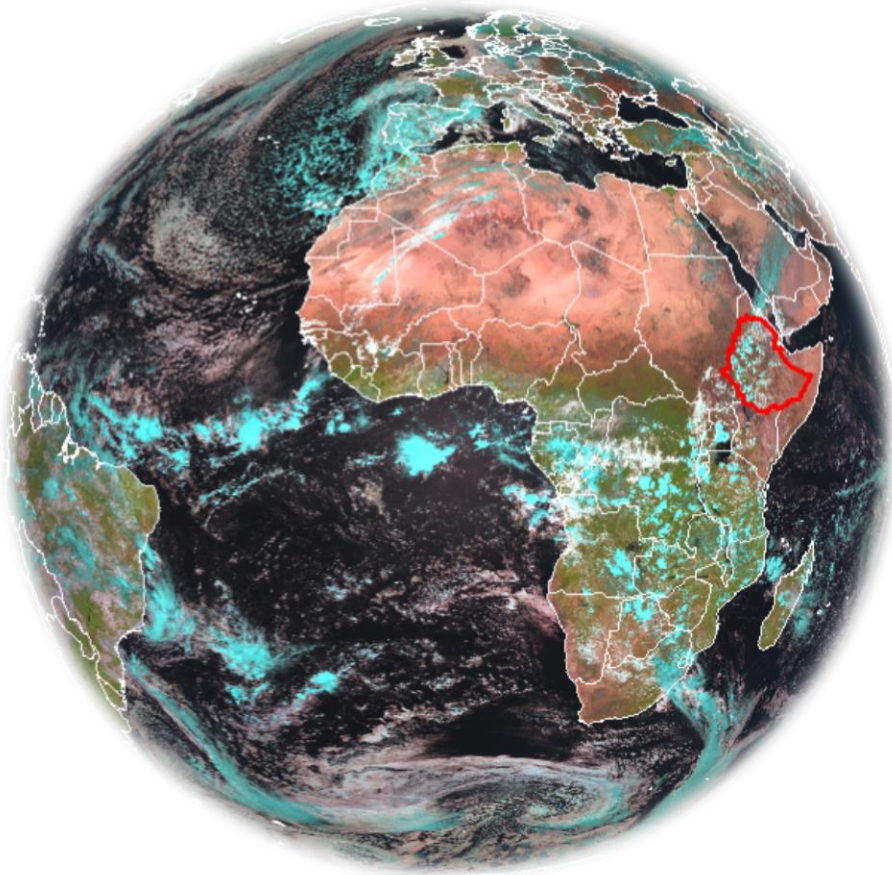# Effects of Physical Catchment Characteristics on River Flow

A Tale of Two Tributaries
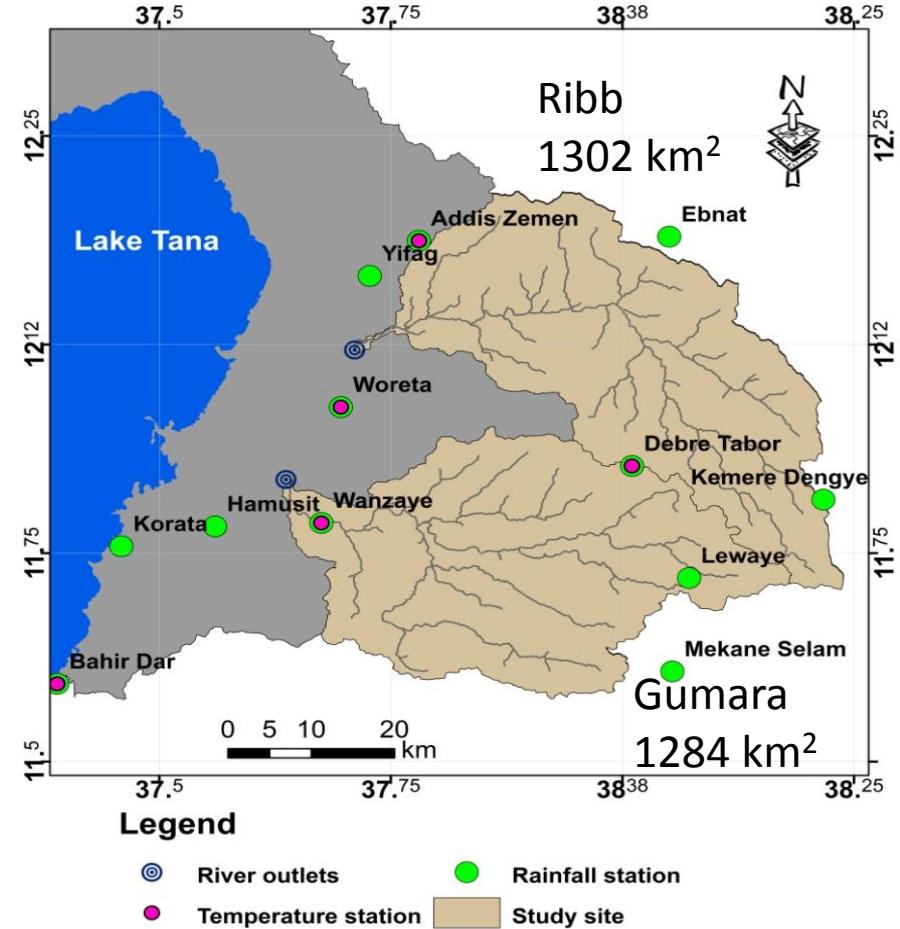
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SWAT 2015, Sardinia, 25 June 2015

Lake Tana & Two Tributaries (Ribb & Gumara Rivers)

MSG satellite image from BDU Satellite image reception station (12:00, March 12 2011)

Spatial distribution of meteorological stations and river network in the Ribb and Gumara watersheds.
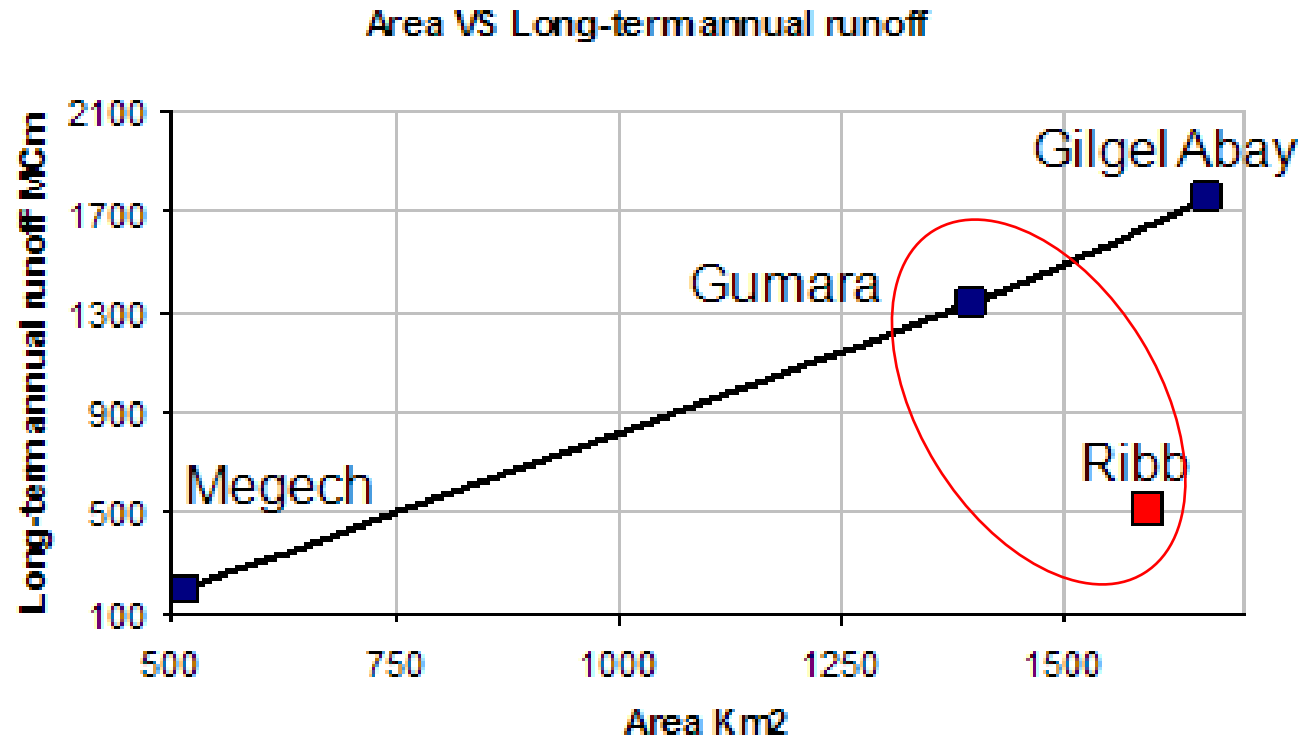
The Problem

- Why do observations of two similar adjacent watersheds in the Lake Tana sub-basin of the upper Blue Nile exhibit extreme variation in their long-term annual yield?

Long-term mean annual yield (1994 – 2008):

Gumara = 9580 m^3/ha/year

Ribb = 3920 m^3/ha/year

Relationship between catchment area and long-term annual runoff of Lake Tana major tributaries

Objective

❑ To examine the effects of physical catchment characteristics on stream flow in both catchments:
- ➢ climate
- ➢ geography
- ➢ physiography
- ➢ geology
- ➢ soil
- ➢ land-use
- ➢ land cover

Methods

❑ Extract physical catchment characteristics (PCCs) from observed metrological data, land-use, soil and a topographic data for Ribb and Gumara watersheds and compare each other to identify the differences contributing to Ribb River's low flow.

❑ Simulate the two rivers to capture observed flow through model calibration.

❑ Compare calibrated and validated model parameters of Ribb and Gumara to see whether the parameters have captured the PCCs difference.

❑ Then simulate Ribb using Gumara model parameters to see if the Ribb behaves like Gumara watershed.

2 Tributaries, 7 Scenarios

- ***Scenario one****: rerun Ribb model with *Gumara areal average evaporation & runoff parameters*.
- ***Scenario two****: rerun Ribb model with *Gumara areal average slope parameters*.
- ***Scenario three****: rerun Ribb model with *Gumara areal average soil parameters*.
- ***Scenario four:*** rerun Ribb model with *Gumara areal groundwater parameters*.
- ***Scenario five****: rerun Ribb watershed with *Gumara areal channel parameters*.
- ***Scenario six****: simulating Ribb with all *Gumara parameters*.
- ***Scenario seven****: rerun Ribb with *Gumara areal rainfall*.

Watershed Characteristics

Geography and physiography	Ribb	Gumara
Catchment area (km²)	1302	1284
Longest flow path length (km)	84.00	99.60
Average slope (degree)	21.55	17.88

Climate characteristics	Ribb	Gumara
Areal rainfall (mm/year)	1265	1435
Areal Evaporation (mm/year)	1225	1234
Climate index (Rainfall/Evap)	1.09	1.2

Longest flow path length

Minor slope distribution
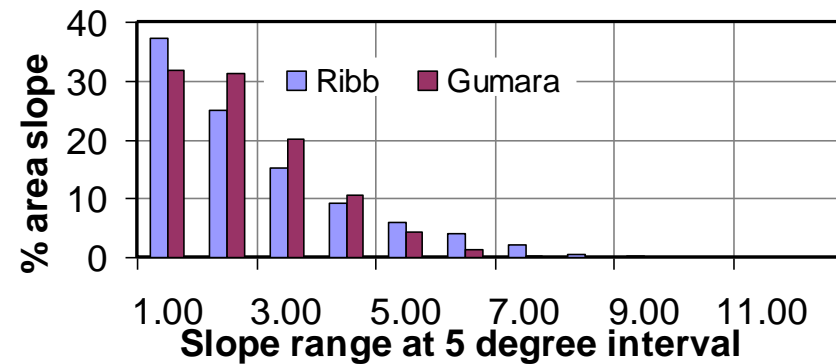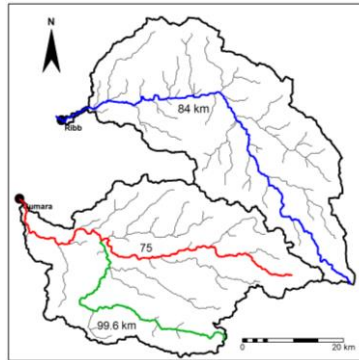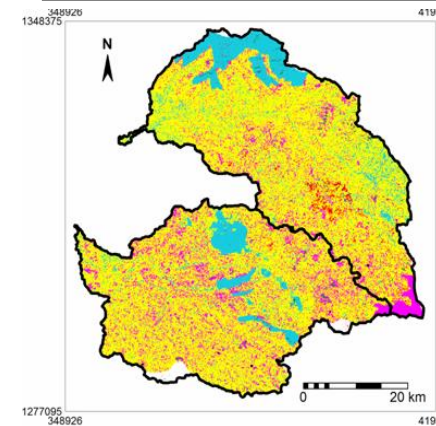
Land-use/land cover

Geology and Soil:
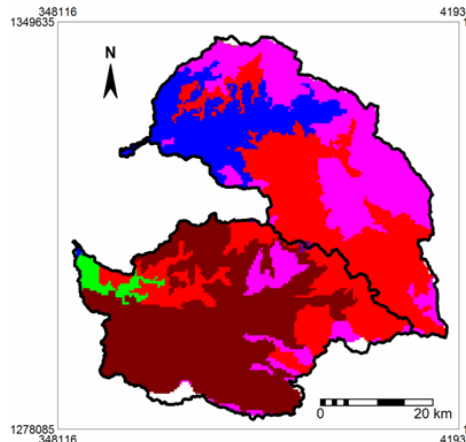
Percentage of soil	Gumara	Ribb
Chromic Luvisols	24.4	39.7
Eutric Fluvisols	0.5	23.9
Eutric Leptosols	8.2	36.2
Eutric Vertisols	3.5	0.0
Haplic Luvisols	63.4	0.0
Haplic Nitisols	0.0	0.2

% of Land use/cover	Gumara	Ribb
BL: Bare Land	0.53	1.79
CL: Crop Land	71.12	70.48
F: Forest	0.81	1.06
GL: Grass Land	10.17	15.28
UB: Urban and Built-Up	0.07	0.07
WS: Woody Savanna	17.29	11.31

7

Watershed Characteristics

Major PCC's group	PCC's	Ribb	Gumara	Difference	Percent difference
Climate	Areal rainfall	1265	1435	Moderate	6.30
	Areal Evaporation	1225	1234	Low	0.37
	Climate index	1.09	1.2	Low	4.80
Physiographic	Catchment area	1302	1284	Moderate	0.70
	Longest flow path length (km)	84.00	99.60	Low	8.50
	Circularity ratio	0.26	0.35	Low	14.75
	Average slope (D)	21.55	17.88	Moderate	9.31
Geology and Soil	Drainage density	301	284	Moderate	2.91
	% of Chromic Luvisols	39.70	24.40	Moderate	23.87
	% of Eutric Fluvisols	23.90	0.50	High	95.90
	% of Eutric Leptosols	36.20	8.20	High	63.06
	% of Haplic Luvisols	0.00	63.40	High	100.00
Land-use	% of Crop Land	70.48	71.12	Low	0.45
	% of Forest	1.06	0.81	Low	13.37
Base flow	Base flow index (BFI)	0.45	0.51	Moderate	6.25

Simulated and Observed River Flow
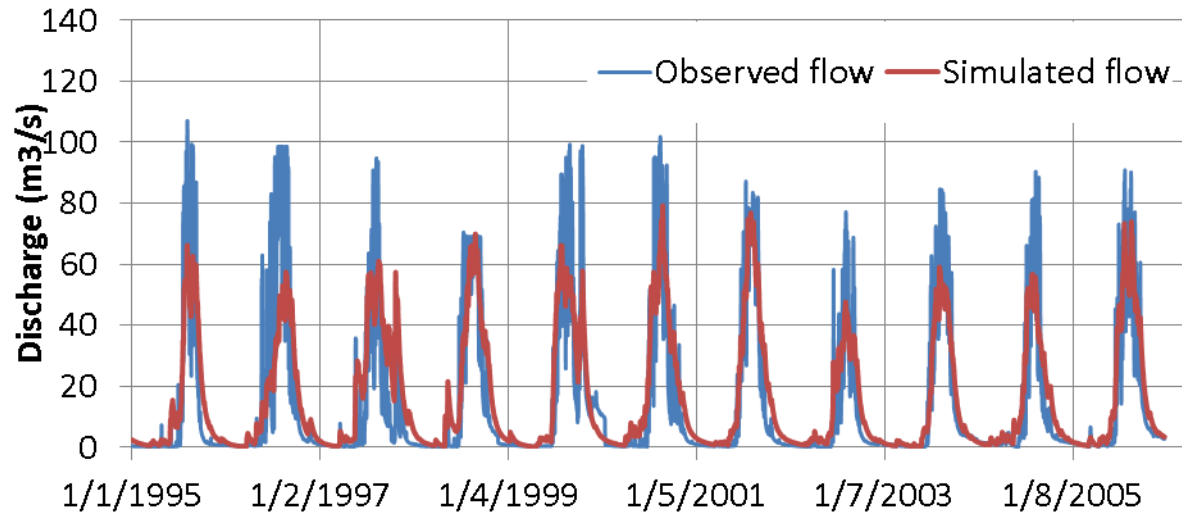
Daily simulated and observed flow of Ribb

Model performance

		Gum	Ribb
Calibration (1995-2004)	NSE	0.70	0.68
	R-squared	0.74	0.68
	RVE (%)	4.0	7.0
Validation (2005-2008)	NSE	0.77	0.72
	R-squared	0.71	0.70
	RVE (%)	9.0	8.0
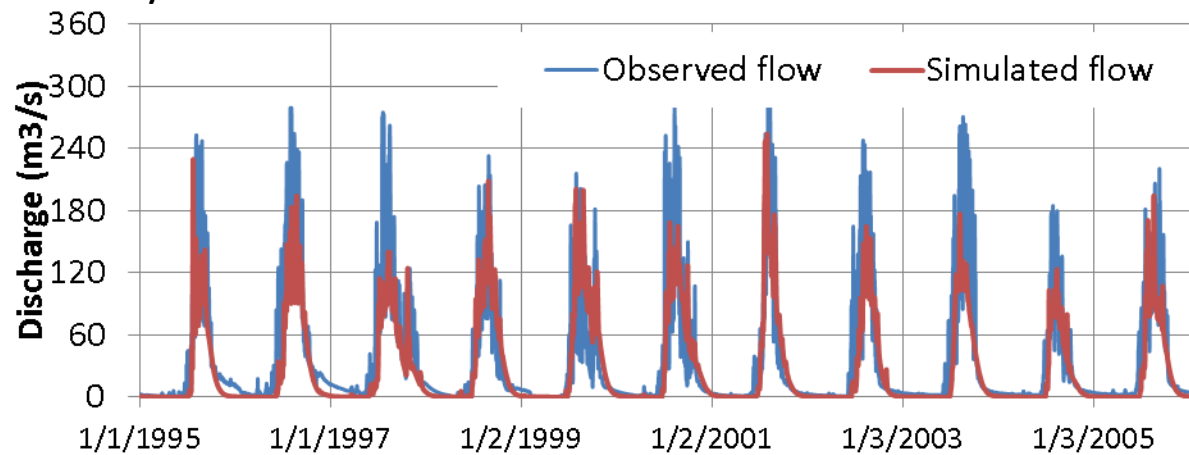
Daily simulated and observed flow of Gumara
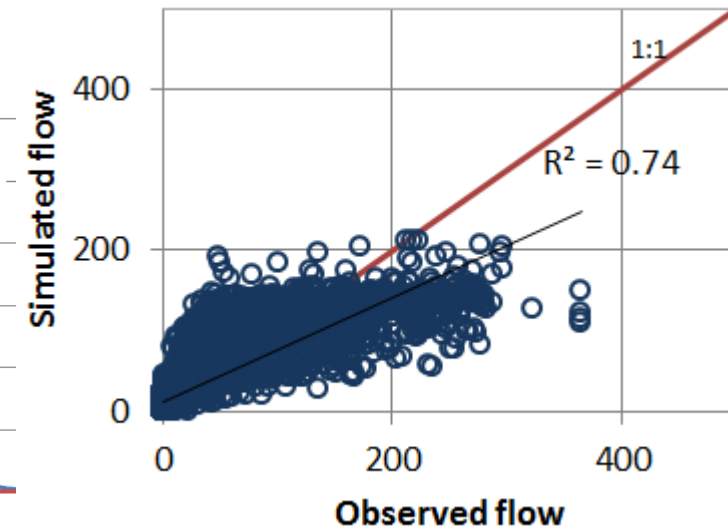
Gumara Sim vs Obs

Running Ribb Model with Gumara Parameters

Ribb Model was simulated with Gumara areal average model parameters sets and areal rainfall of Gumara watershed. Ribb rerun with Gumara parameter increased river flow from 3920 m³/ha/year to 8299.5 m3/ha/year which compares well will Gumara at 9580 m3/ha/year.
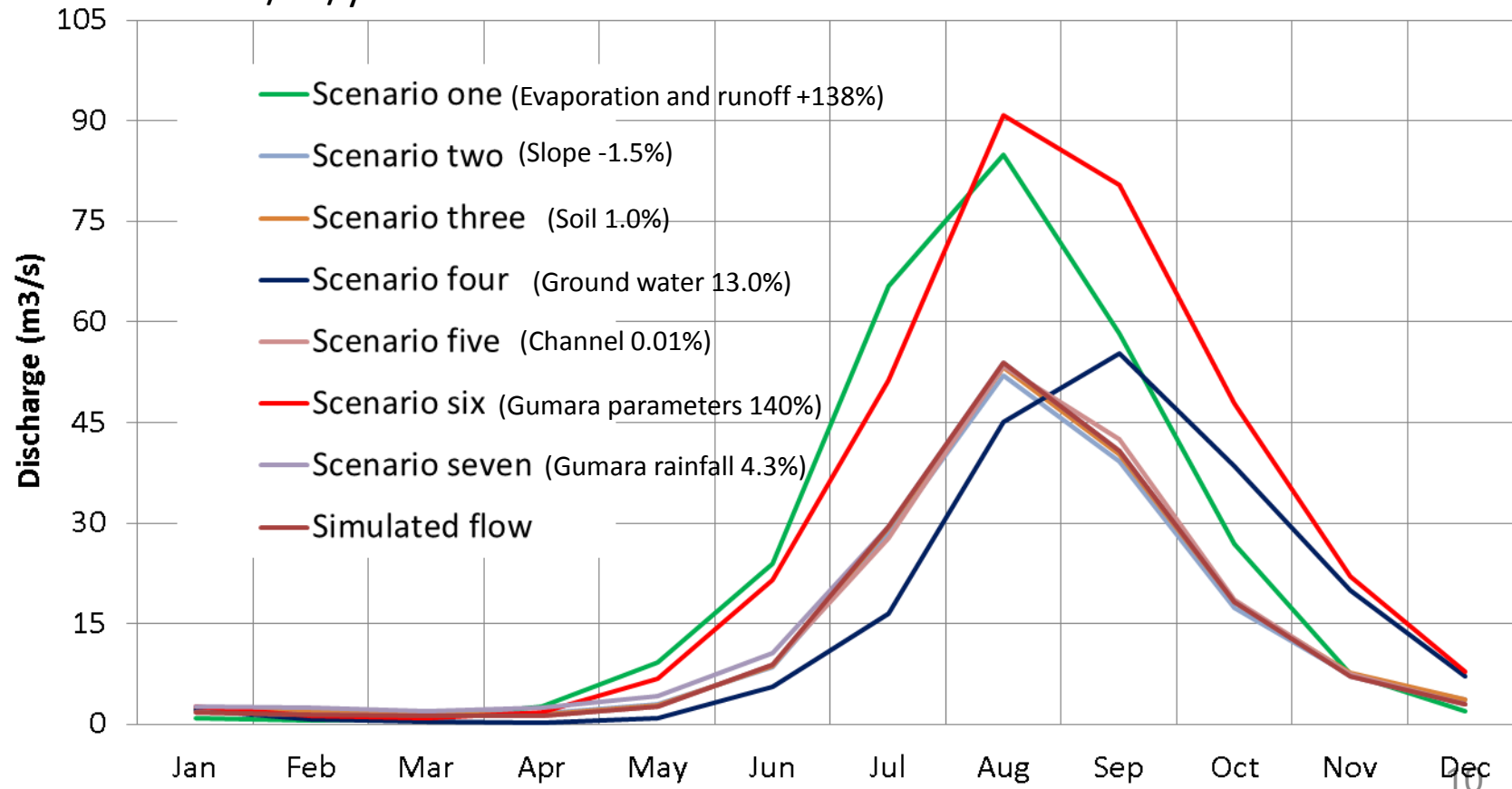
Summary and Conclusion

- The PCCs result indicated a minor difference in climate, physiographic and land use/cover conditions between Ribb and Gumara watersheds.
- A major difference is observed in soil characteristics with:
  - Gumara is dominated by Haplic Luvisols and Chromic Luvisols (87%) characterized by higher clay content (60%).
  - Ribb is dominated by significant proportion of Eutric Leptosols (36%) characterized by shallow and extremely gravelly soils.
  - The models captured the observed flow through calibration with a NSE of 0.71 and 0.68 for Gumara and Ribb, respectively from 1995 to 2004.
  - Model parameters indicate significant differences in groundwater, channel and evaporation controlling parameters between Ribb and Gumara.
  - Ribb rerun with Gumara parameters suggest slope, soil and channel parameters have insignificant effect on the flow.
  - Runoff and evaporation parameters of Gumara increased Ribb flow by 138% probably due to increased evaporation from lower layers when is it not met by the upper layer.