DISTRIBUTED MODELLING SIMPLIFIED

HYDROLOGICAL PROCESS MODELS for HUMID AREAS

Nile BDC Symposium on Modeling in the Blue Nile Basin
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DISTRIBUTED HYDROLOGICAL MODELS: AN OVERVIEW

- Usually require hundreds of distributed parameters that a…

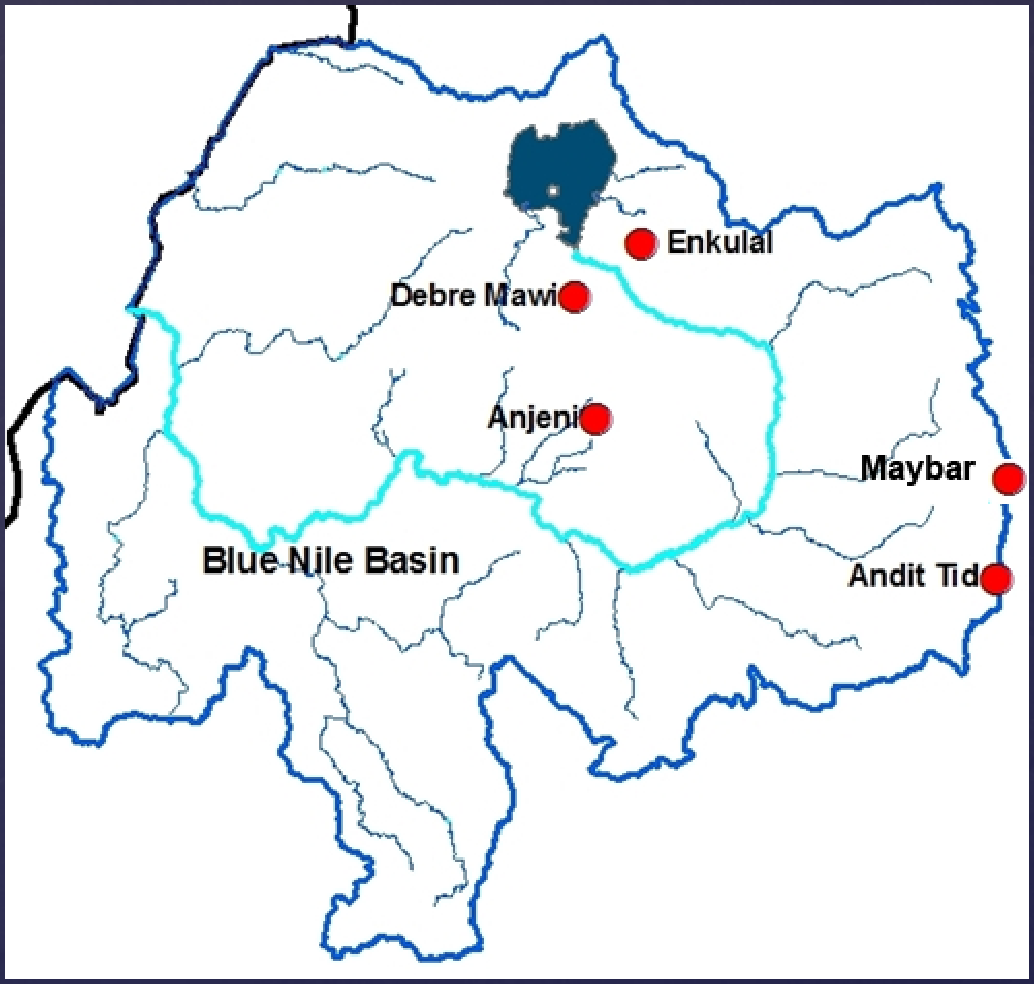
More input parameters not necessarily give better results

but give more flexibility in applications

OVERVIEW OF PRESENTATION

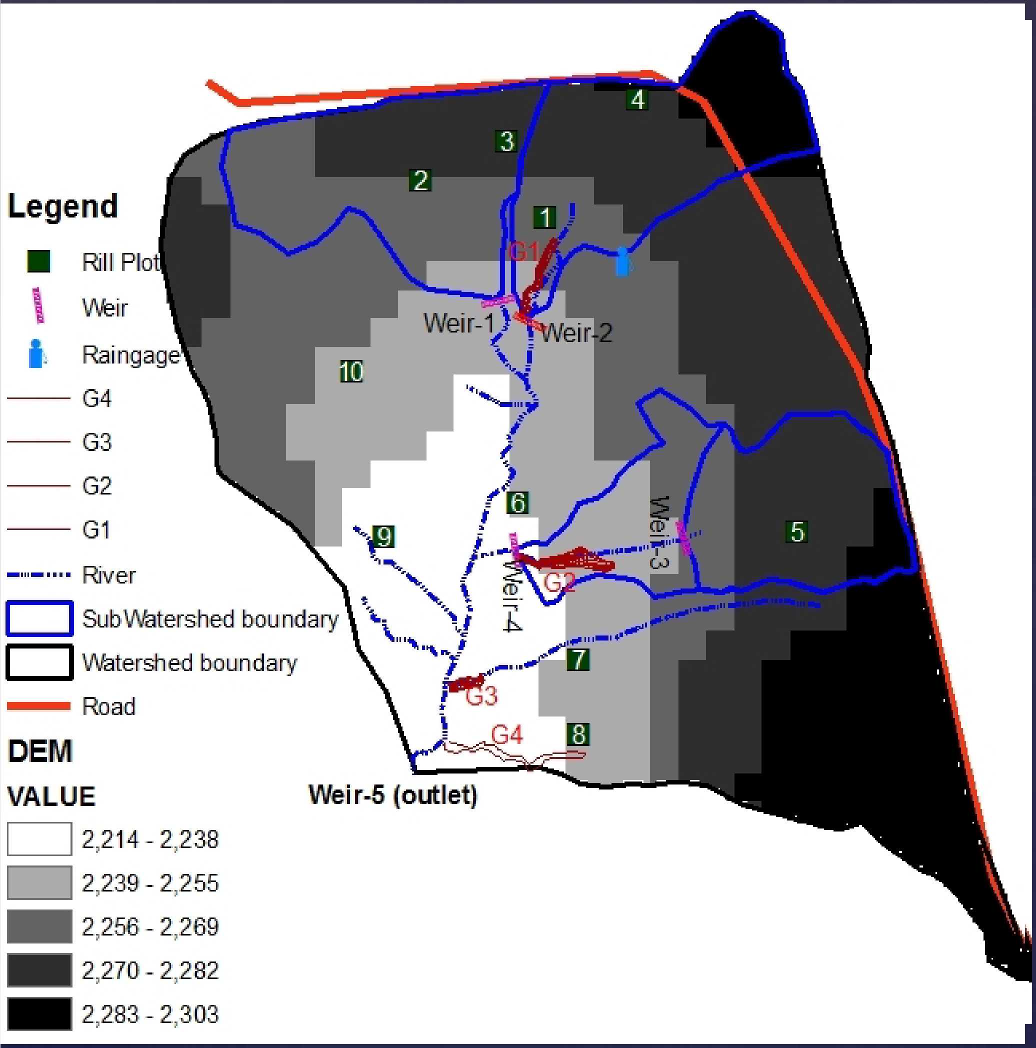
1. Experimental
   a) Data shows that infiltration is greater than rainfall intensity for well vegetated watersheds
   b) Soils need to wet up before runoff occcurs
   c) Runoff and erosion occurs from saturated bottom lands and degraded hillsides with shallow soils
2. Modeling
   a) Show simulations for runoff and erosion with saturated contributing areas
3. Applications

Experimental Watersheds



- Cornell, BDU and IWMI started research in 2008 employing many students. ARARI cooperation since 2002

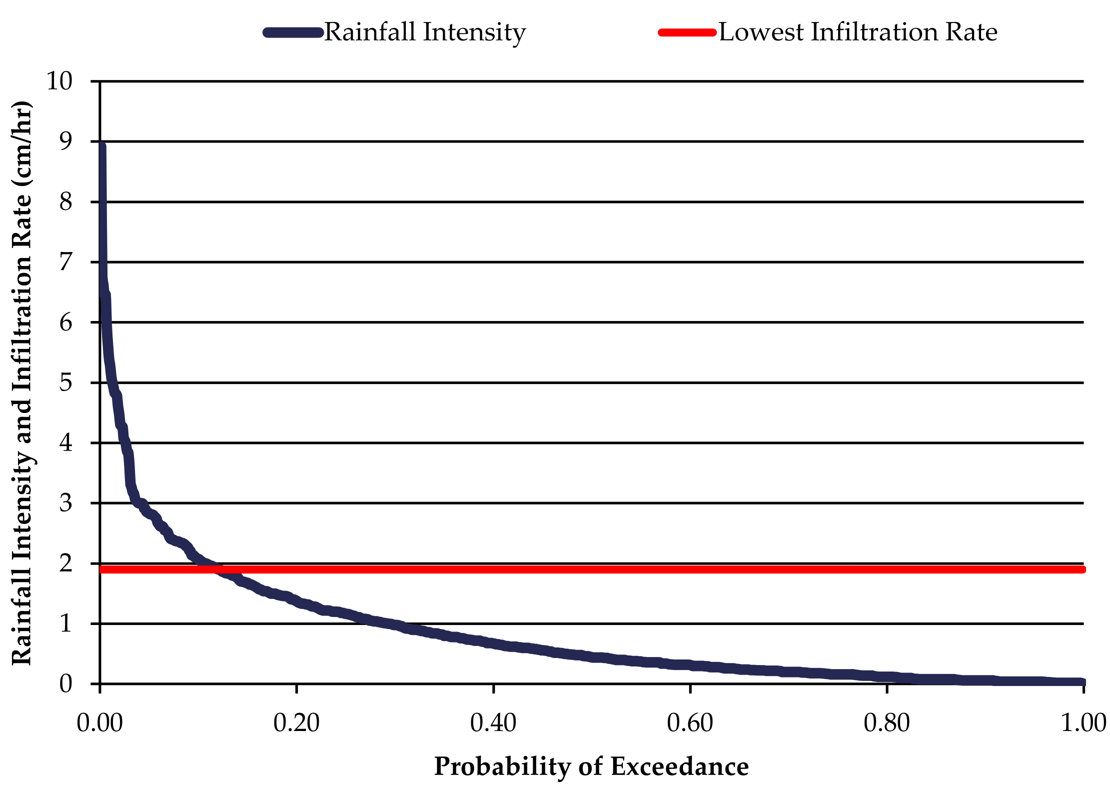
Debra Mawi



- 1 Automatic Rain Gauge
- 4 weirs installed & measured storm runoff (40 -50 events)
- 1 weir at the outlet (Adet Research Center)
- 19 piezometers to measure ground Water level
- 14 infiltration test
- Sediment concentration from 5 weirs (40 -50 events)
- Rill measurement from 10 agricultural fields
- 4 Gully profile measurement

Infiltration Rate vs. Rainfall Intensity

Maybar



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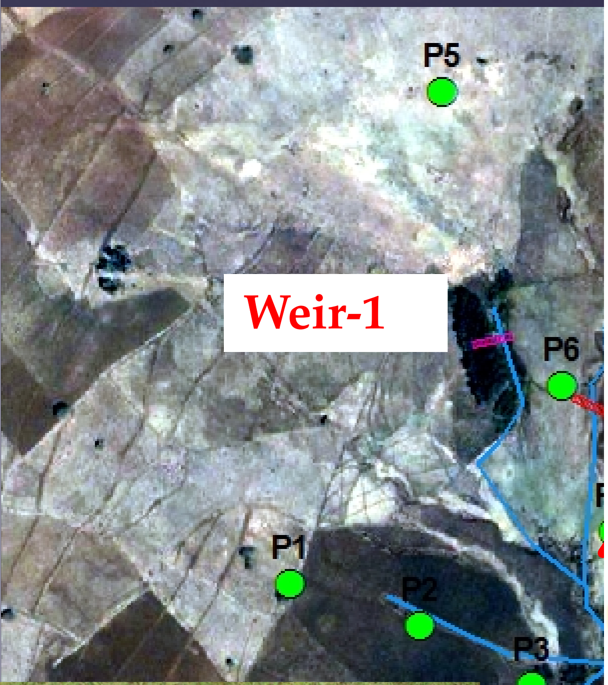
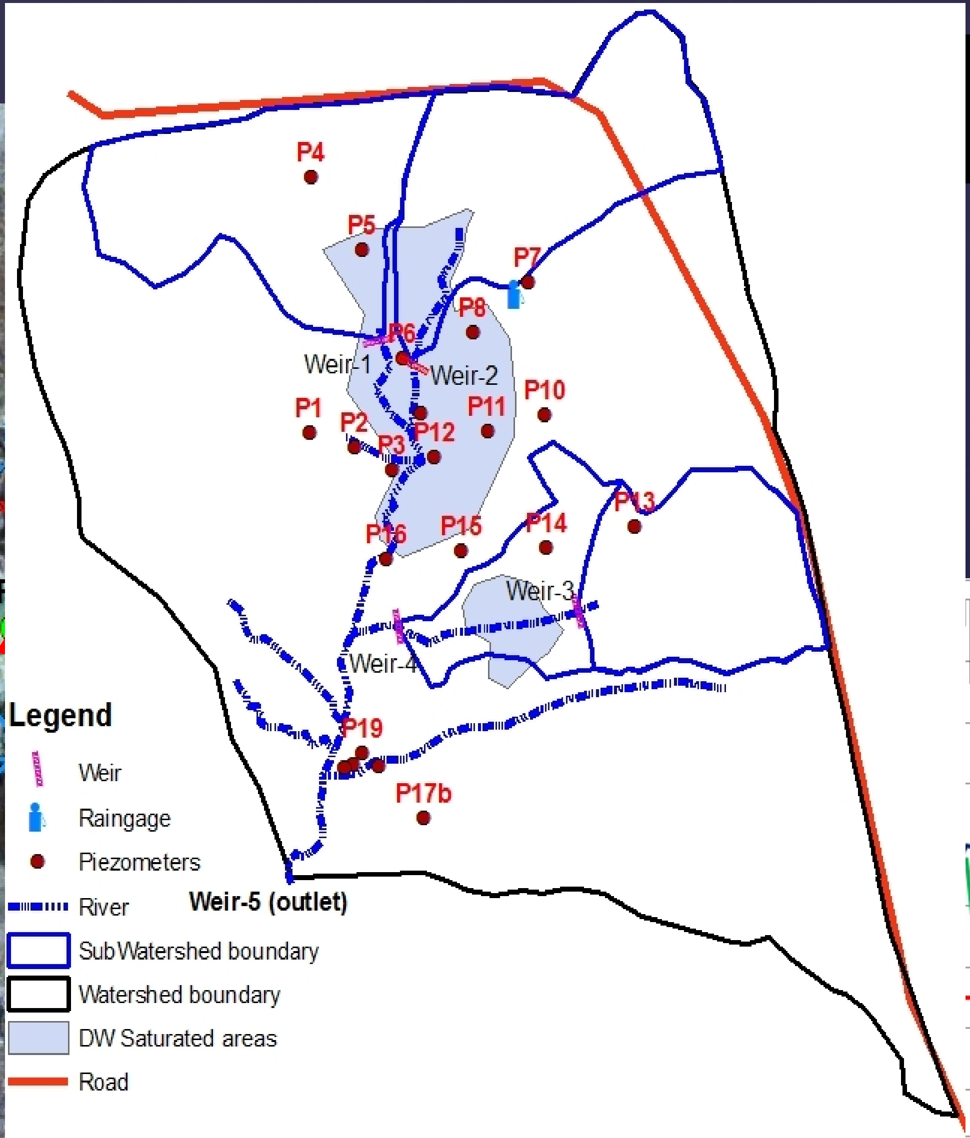
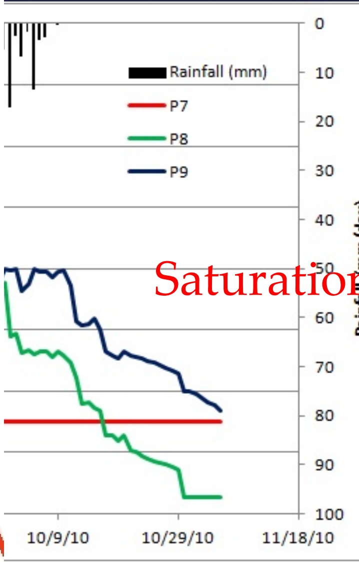
Ecohydrology

Saturated Areas

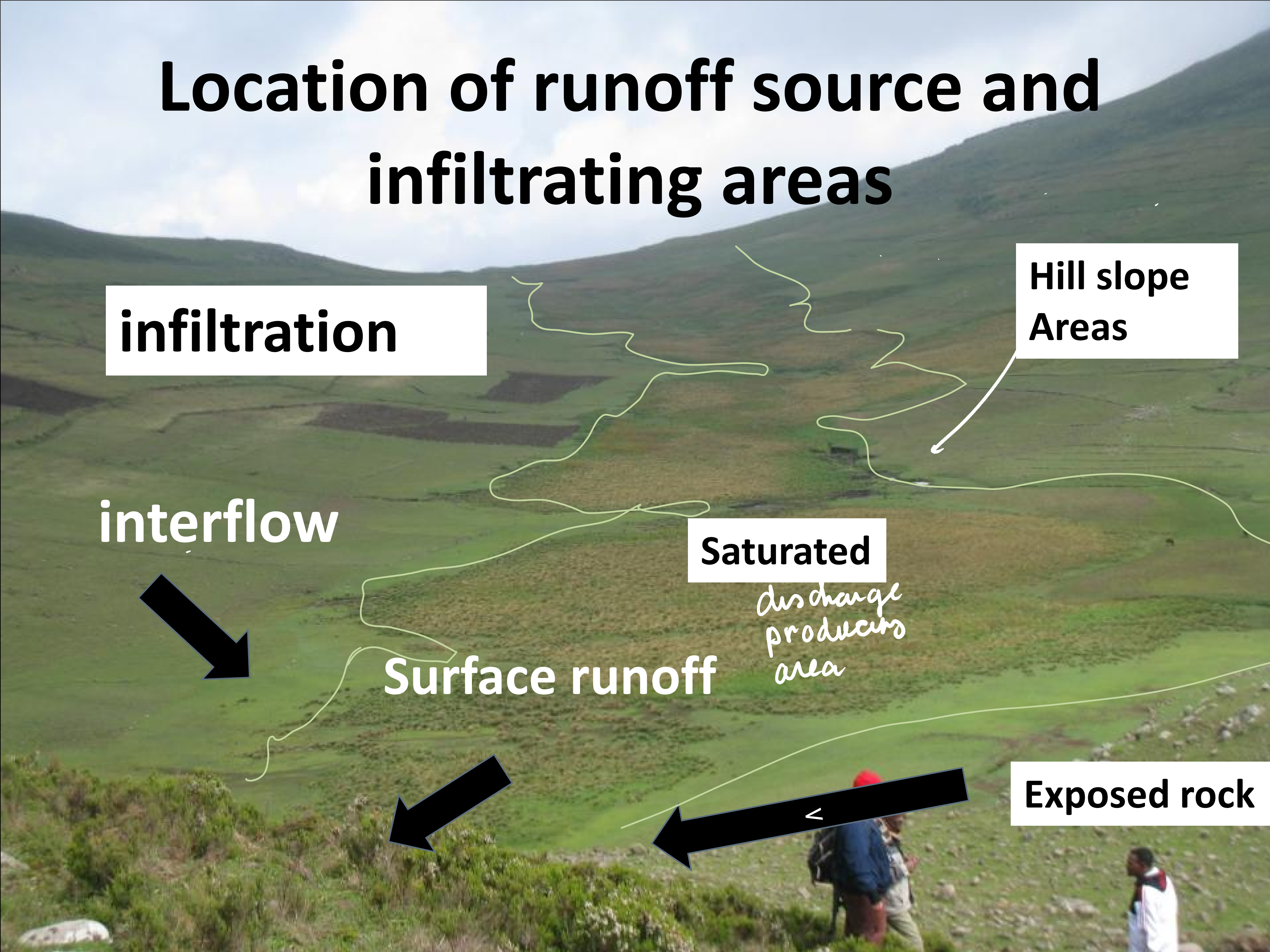
= 10%







Location of runoff source and infiltrating areas



RUNOFF PLOTS (MAYBAR)
SURFACE RUNOFF DECREASES WITH STEEPNESS

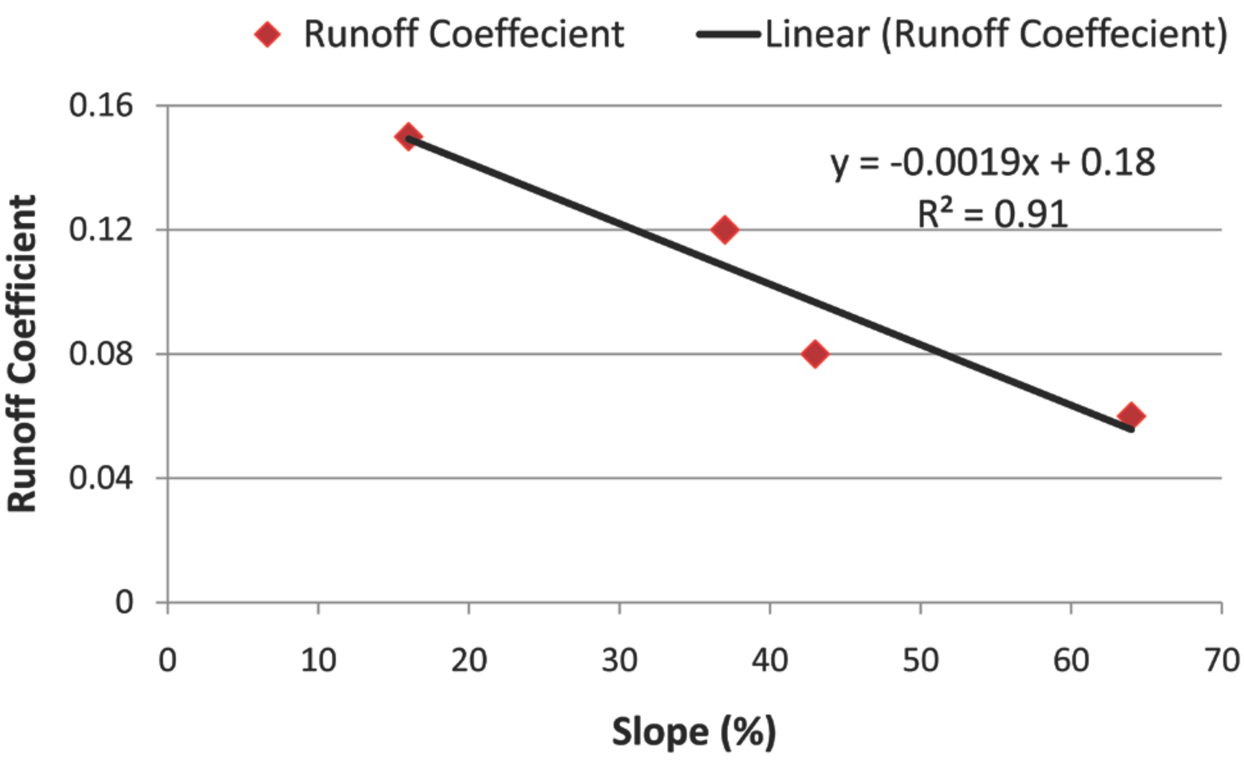
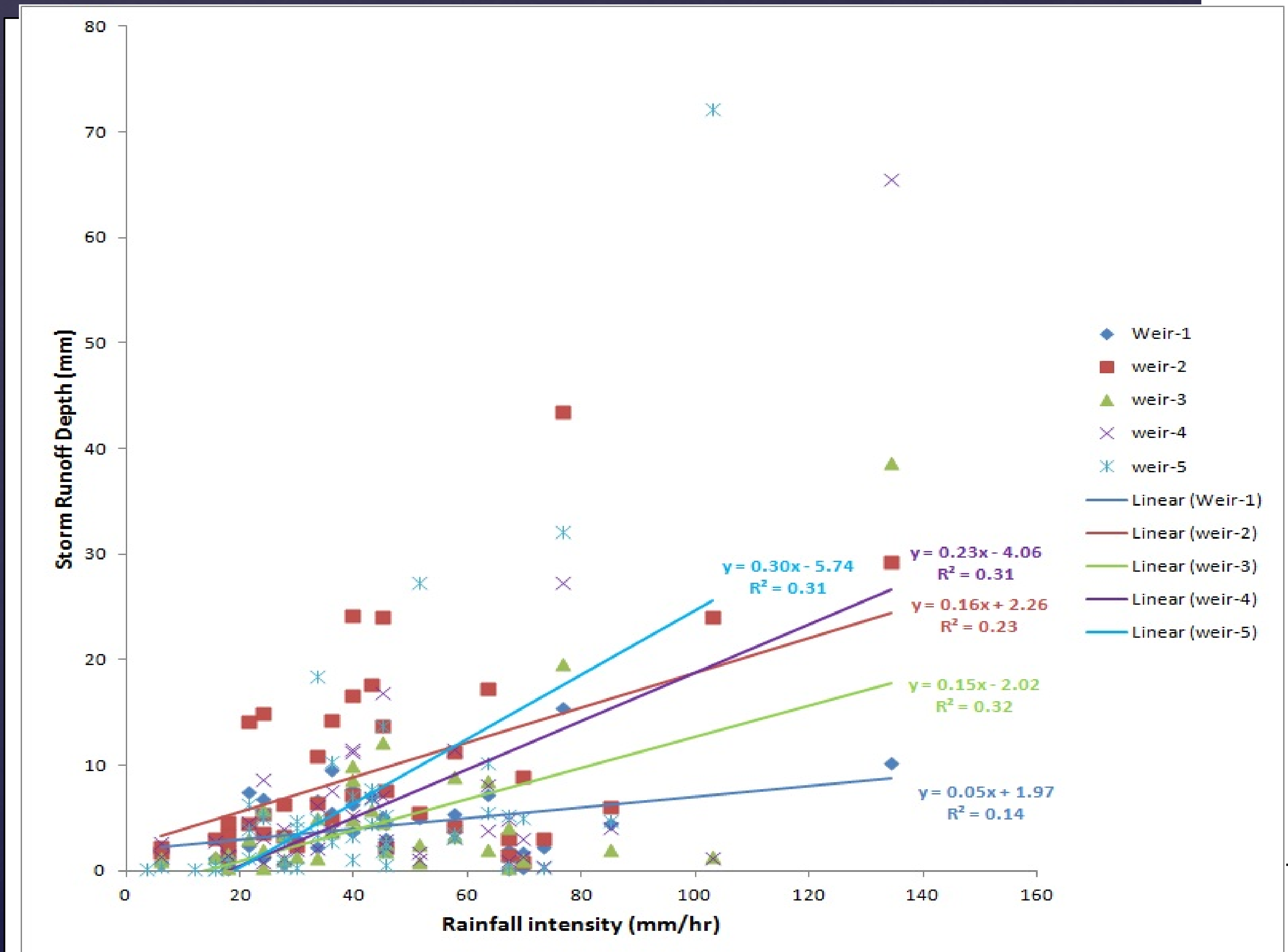


Figure 6

Runoff



= 0.82

= 0.58

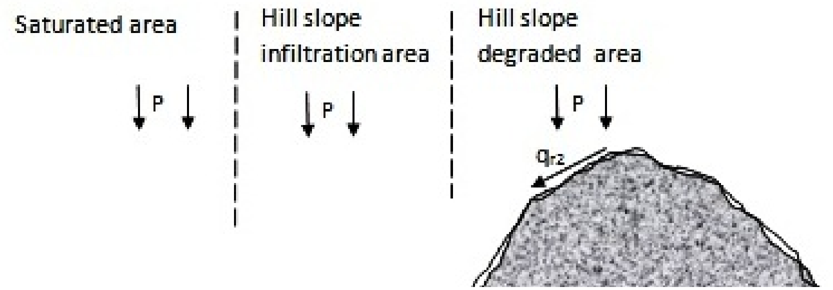
= 0.75

= 0.66

= 0.59

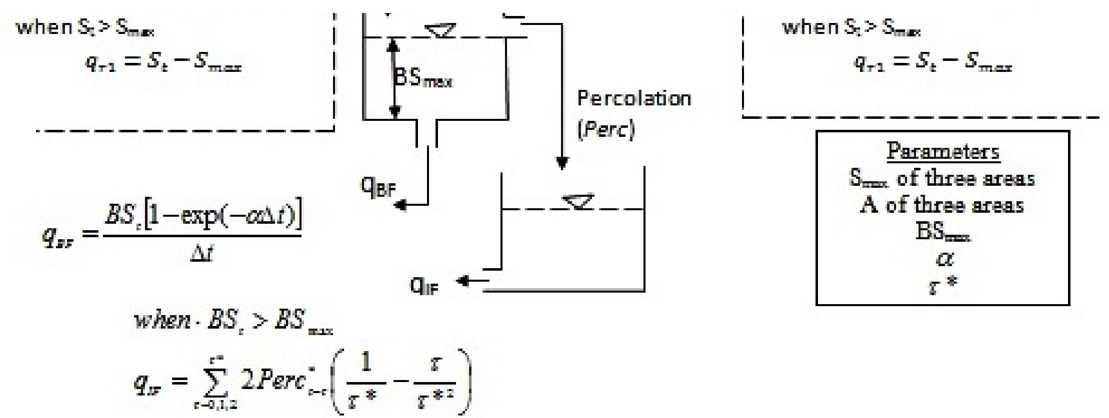
120

Modeling

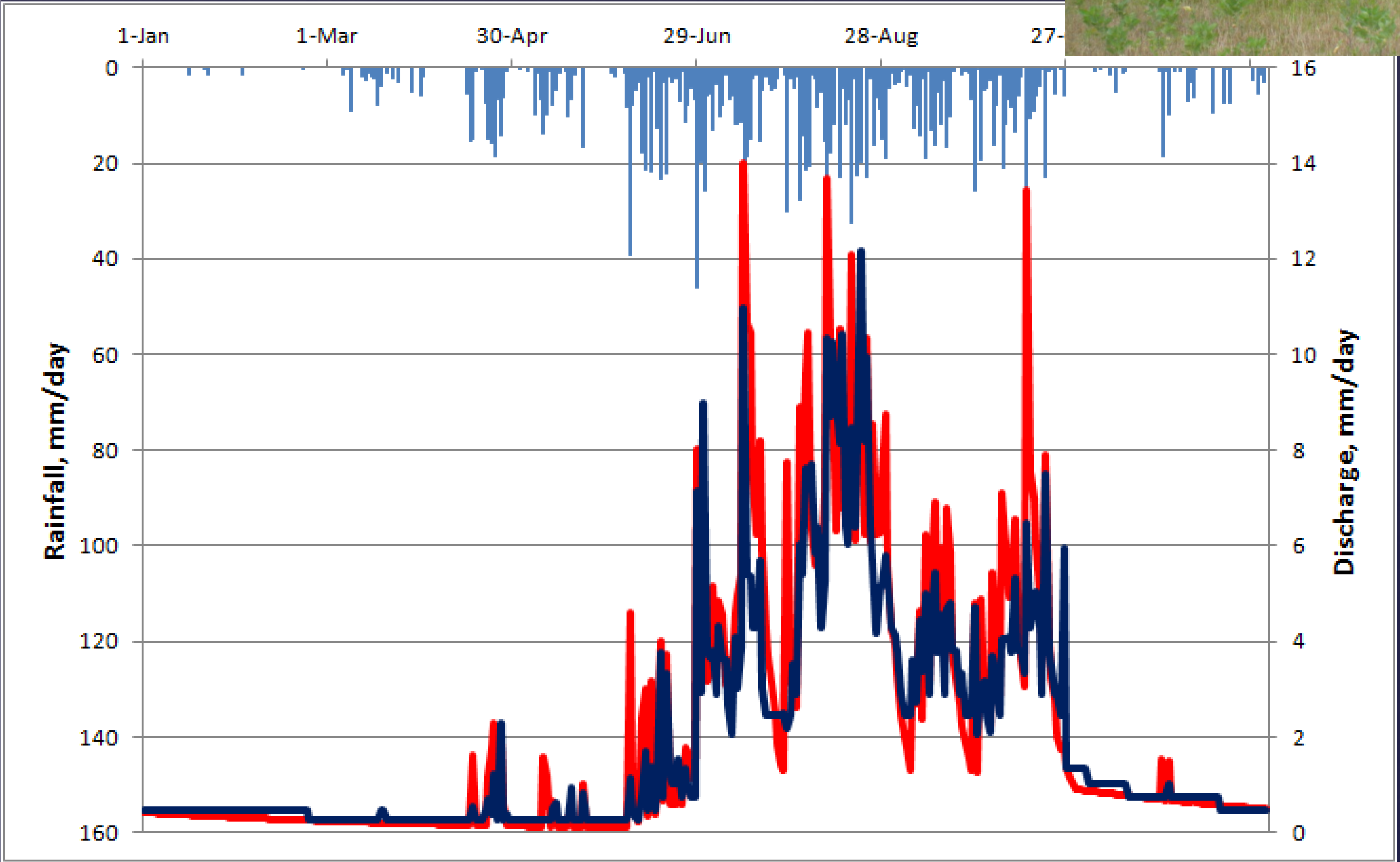


- Constant area for
  outflow from two
  after the threshol
  exceeded
- Rain infiltrates in
  remaining area ar
  becomes subsurfa
- Amount of runoff
  recharge can be simulated
  by a water balance

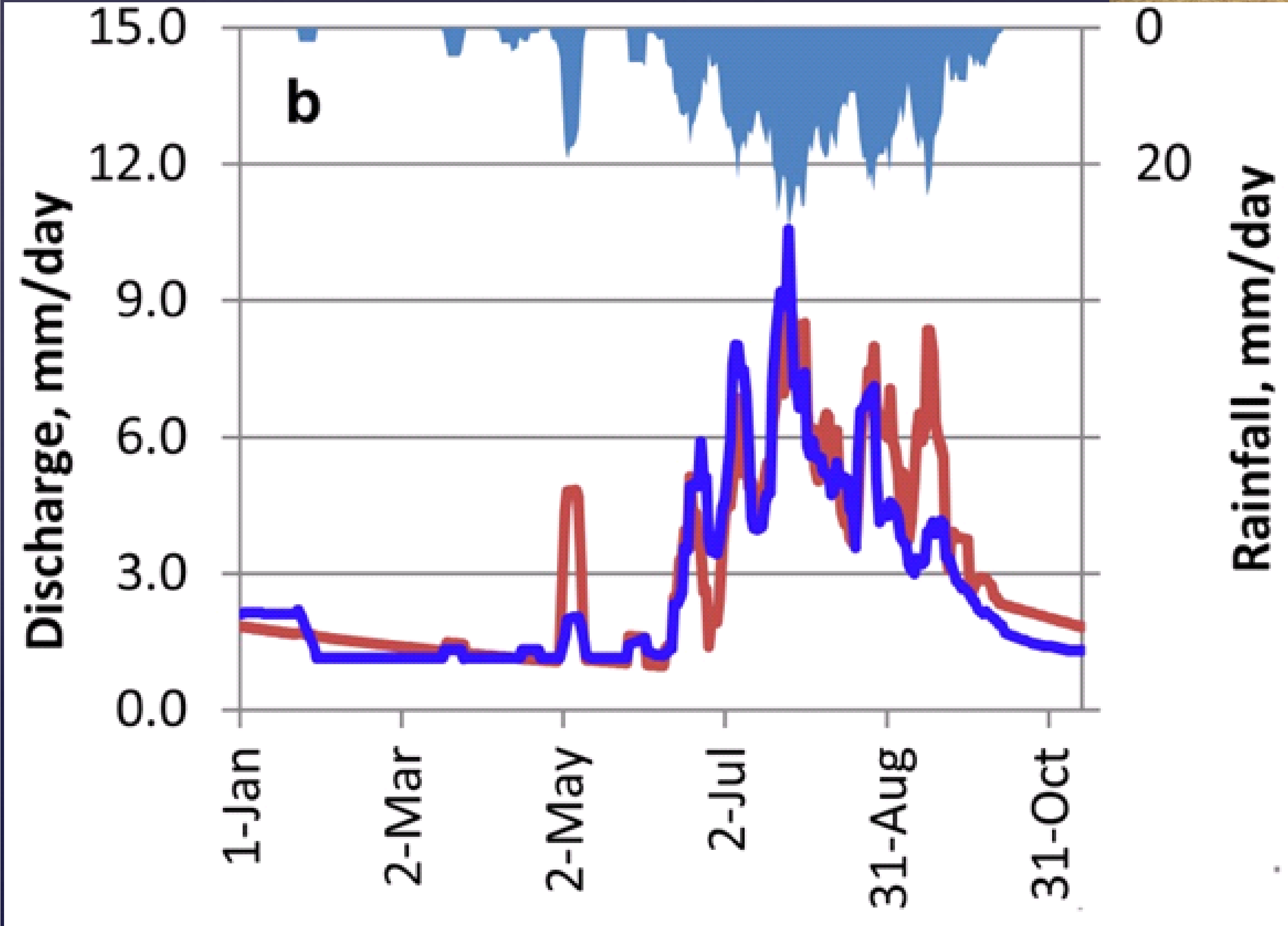
LOOKS COMPLICATED BUT MODEL HAS ONLY NINE INPUT PARAMETERS AND CAN BE RUN IN A SPREADSHEET



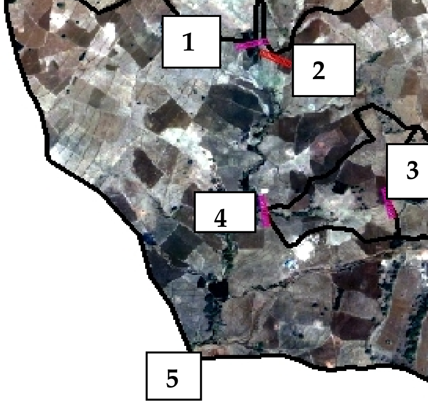
Discharge Anjeni 113 ha

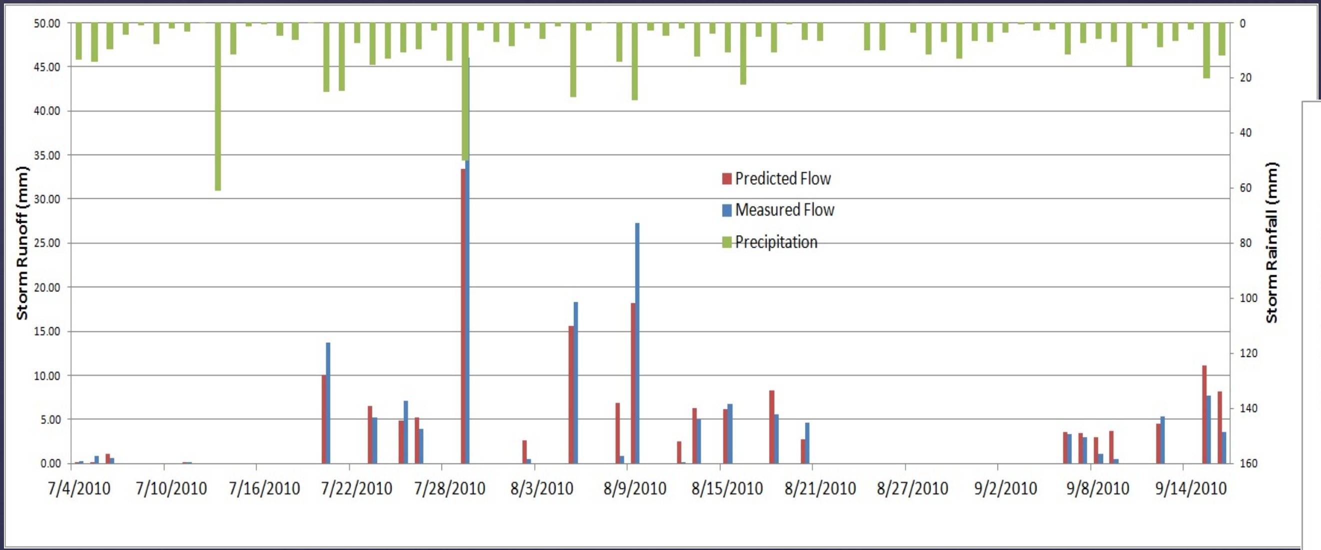


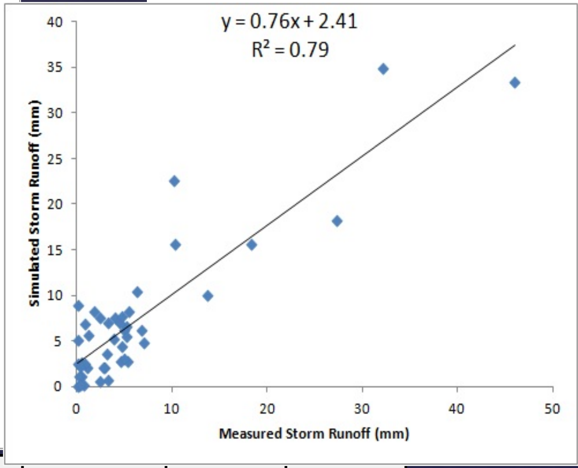
Discharge Enkulal watershed, 400 ha



Debra Mawi



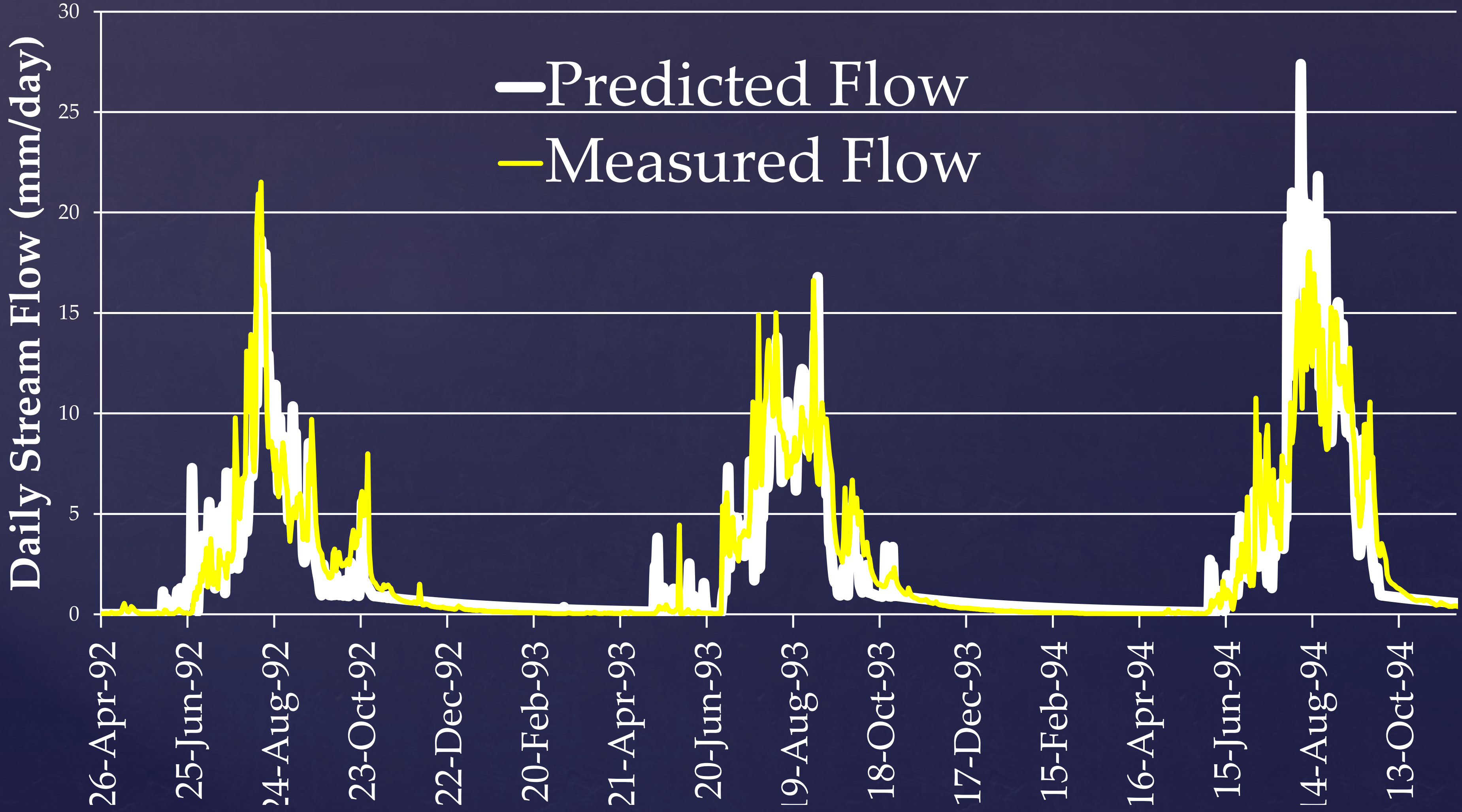




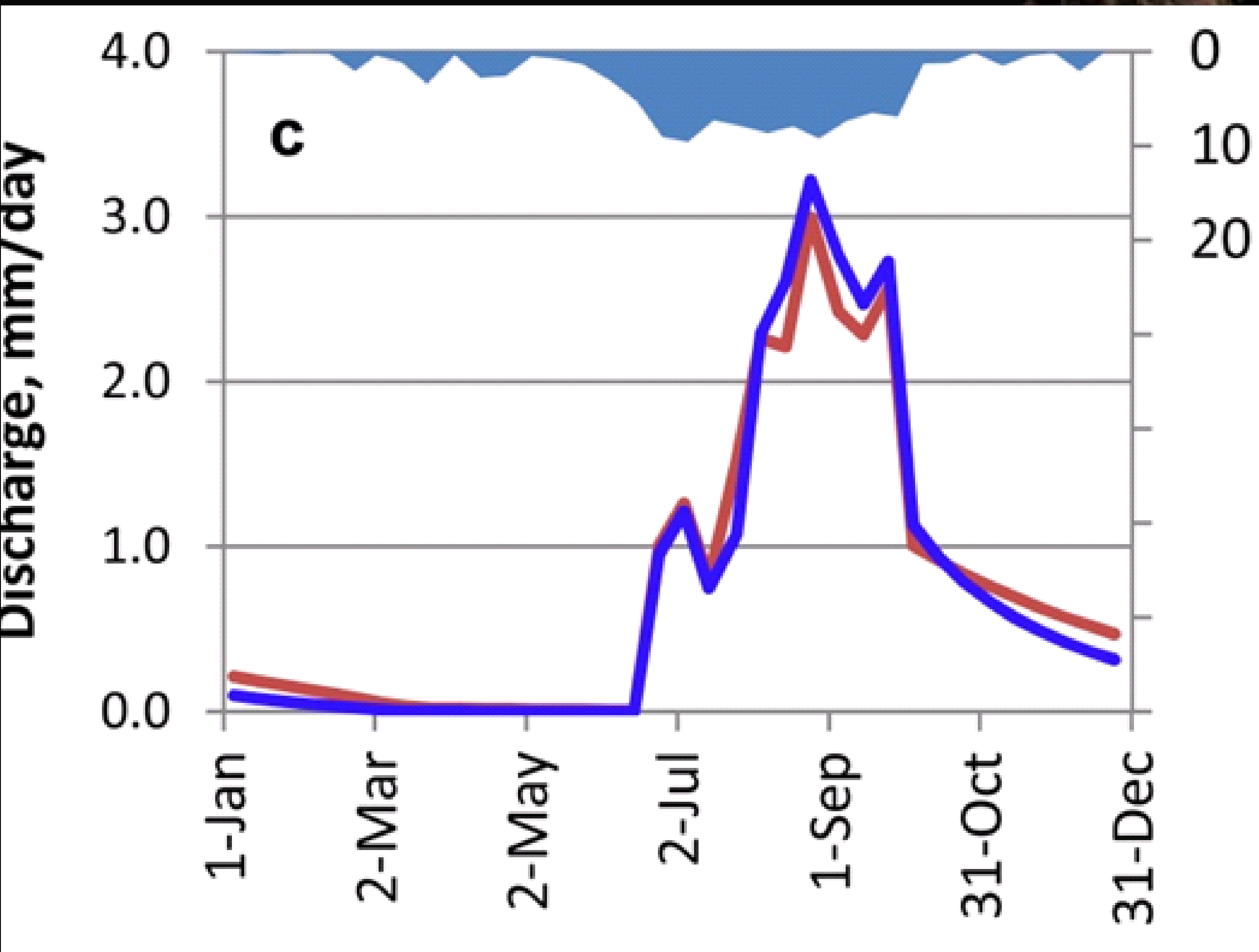
Locations	Parameters	Area A_1	S_{max} in A_1	Area A_2	S_{max} in A_2	Area A_3	S_{max} in A_3	BS_{max}	$t_{½}$	τ*
Weir	Unit	%	mm	%	mm	%	mm	mm	days	days
5	Magnitude	**15**	80	**30**	30	**55**	60	80	70	5
4		**20**	80	**30**	30	**25**	60	80	70	5
3		**5**	80	**30**	30	**15**	60	80	70	5
1		**10**	80	**20**	30	**40**	60	80	70	5

Gumura
1200 km^2

Nash Sutcliff = 0.74 on daily values
Time of calibration:
Bahir Dar to Addis Ababa by plane



Discharge
Blue Nile watershed, 180,000 km^2



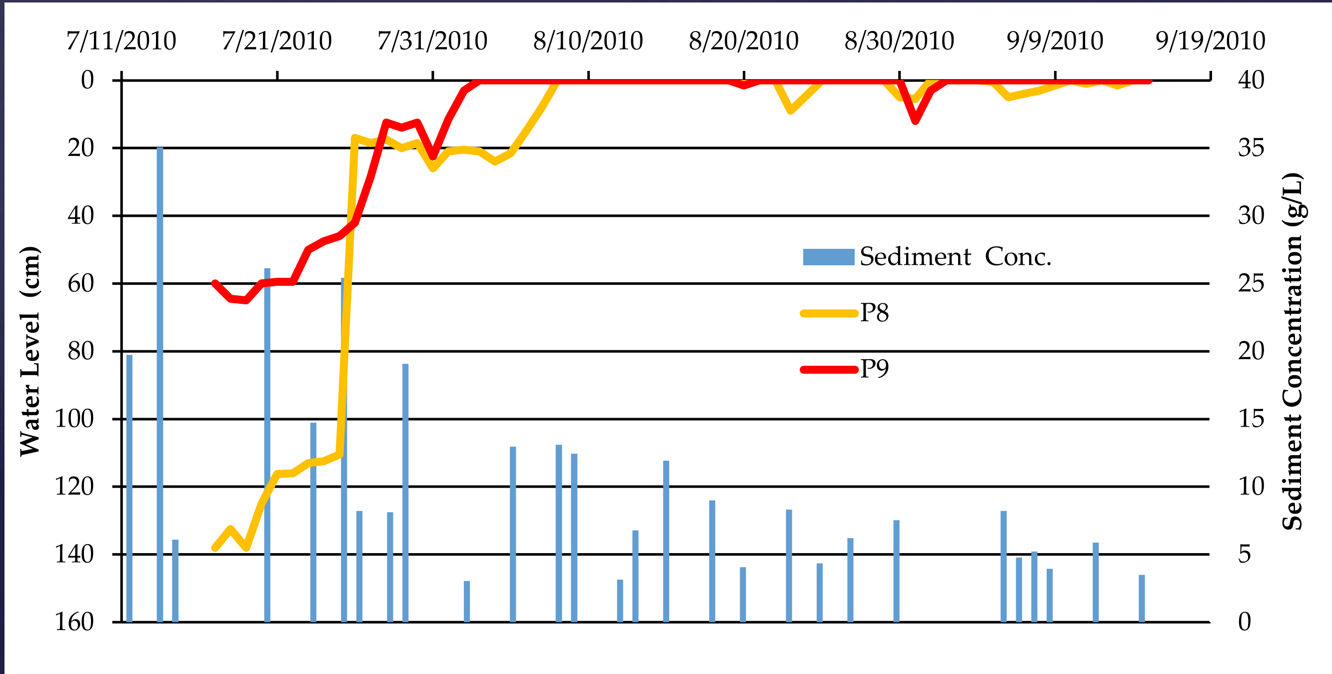
Nash Sutcliff
0.95 for
10-day runoff

SUMMARY HYDROLOGY MODEL

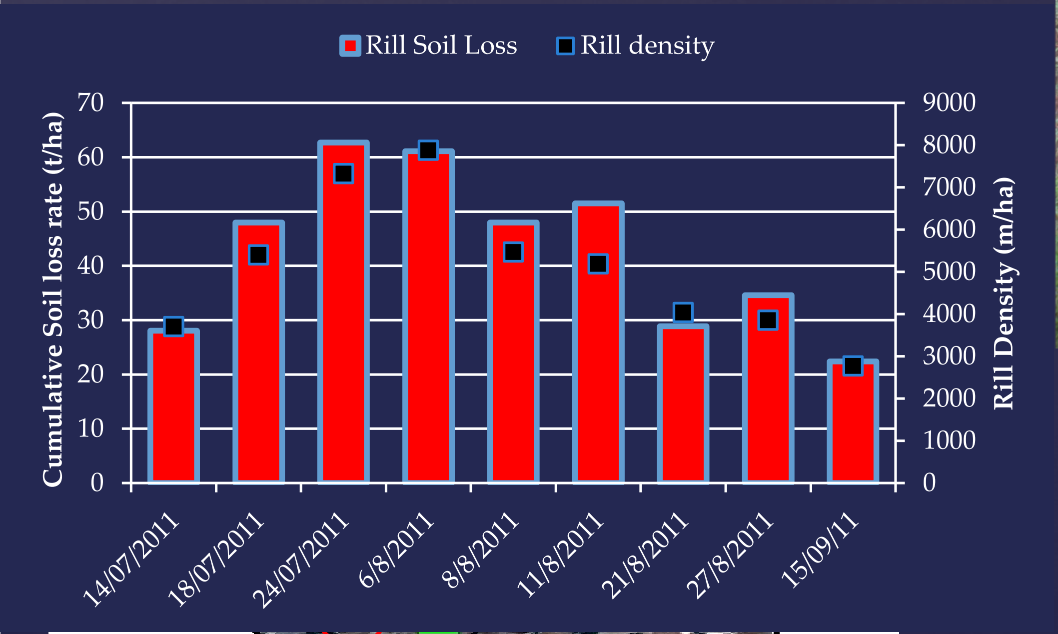
- Predicting runoff for vegetated and sloping watershed with rainfall in excess of 600 mm/year can be accomplished with a distributed model with two areas that represent the shallow soils and potentially saturated soil that produce runoff, In the remaining part of the watershed where water that infiltrates and that flows out slowly.
- Other biological processes and implementation of Soil and water conservation practices will require smaller scales that can be superimposed. SWAT with HRU's that can account for topography can be empoyed for these smaller scales


Erosion

Sediment Concentration: Debre Mawi



Rill & Gully erosion Debre Mawi



– 120 ton ha^{-1} yr^{-1} in 2010

EROSION PREDICTION
MODELED AFTER HAIRSHINE AND ROSE

- Concentration C_r in overland flow is proportional to velocity V,

$$C_r = a V$$

Rectantangular channel with discharge q (per unit area)

$$C_r = a\, q_r^{\,0.4}$$

EROSION PREDICTION

MODELED AFTER HAIRSHINE AND ROSE

$$C_r = a\,V$$

- Transport limiting (rill formation) – $a=a_T$

  Surface runoff carries all the sediment it can -----

- Source limiting (splash erosion) – $a = a_S$

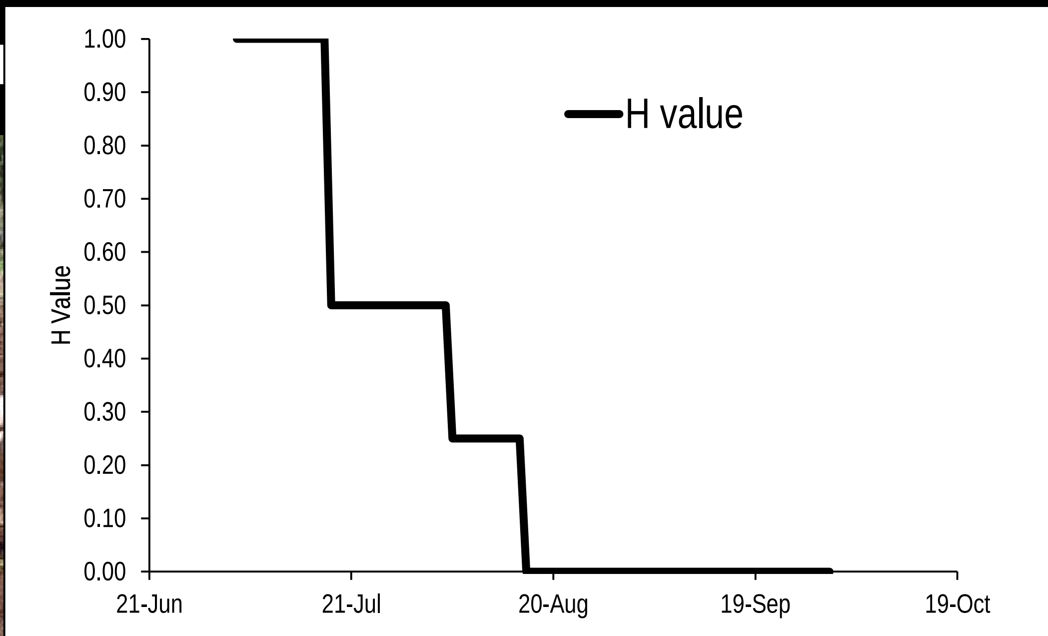
  Concentration is limited by sediment delivered to rill

- Transport limited after plowing and source limited after soils are permanently wet around August 1

$$C_o = \frac{\sum\{[a_s + H(a_t - a_s)]\; q_r^{\;0.4}\}}{q_{total}}$$

INPUT DATA FOR SEDIMENT MODELING

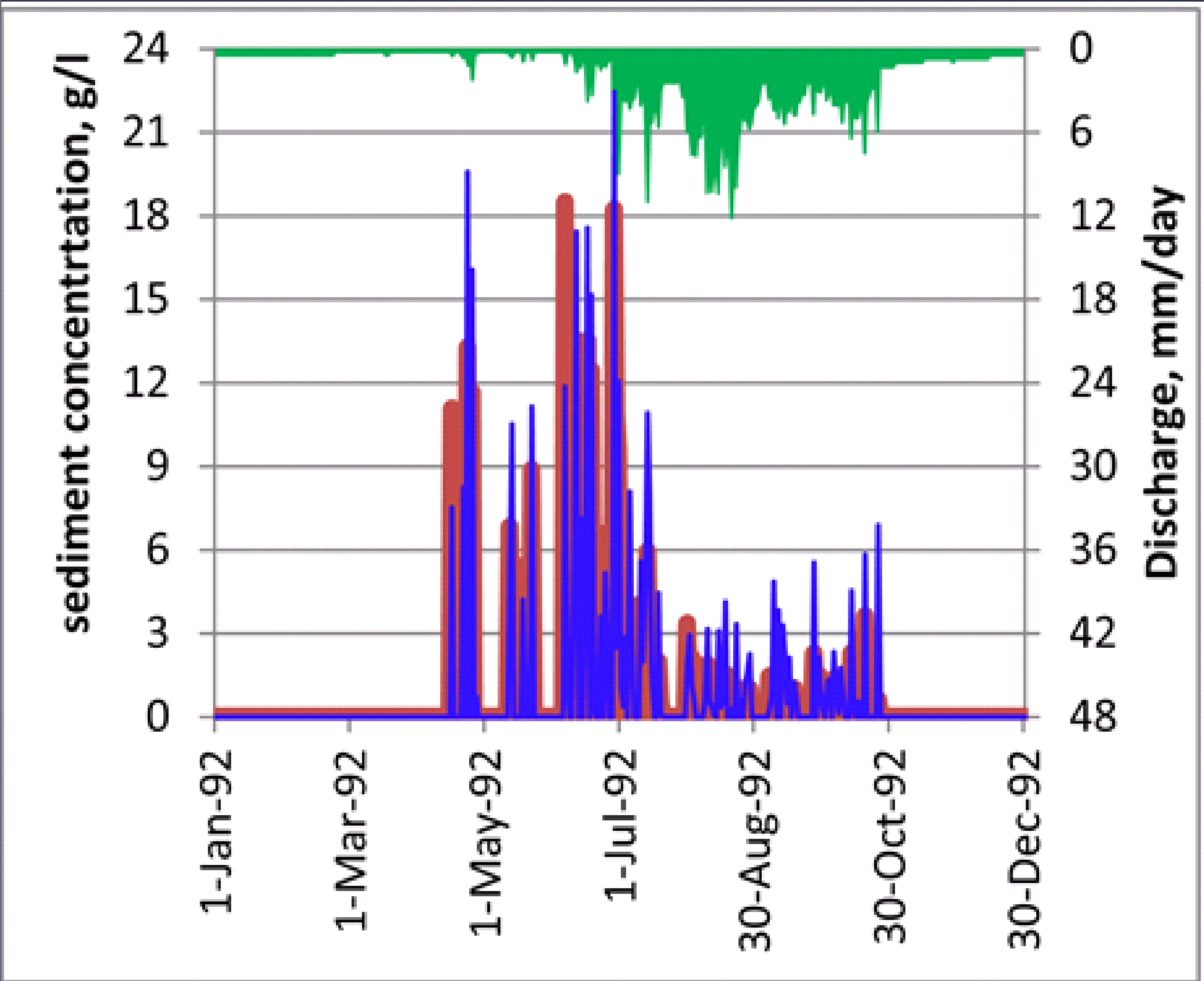
Surface ru … e areas from model



<30 days;	30 - 60 days	>60 days
H = 1	H decreases 1→0	H=0

Component	Description	parameters	Unit	Calibrated Values			
				Anjeni	Enkulal	Blue Nile	Debre Mawi
Hydrology	Saturated area	Area A_1	fraction	0	0.1	0.2	0.15
		S_{max} in A_1	mm	-	50	200	80
	Degraded area	Area A_2	fraction	0.15	0.2	0.2	0.30
		S_{max} in A_2	mm	10	10	25	30
	Hillside	Area A_3	fraction	0.5	0.3	0.6	0.55
		S_{max} in A_3	mm	100	50	250	60
	Subsurface	$t_{½}$	days	70	120	80	70
		τ^*	days	10	100	200	5
Sediment transport limit		a_t	see text	4.5	17	1.2	14
Sediment Source limit		a_s	see text	3	5	0.5	3
Nash Sutcliffe Efficiencies	Time step		days	1	7	10	1
	Hydrology	calibration	none	0.84	0.75	0.95	0.82
		validation	none	0.80		0.92	-
	Erosion	calibration	none	0.70	0.76	0.86	0.75
		validation	none	0.75		0.72	

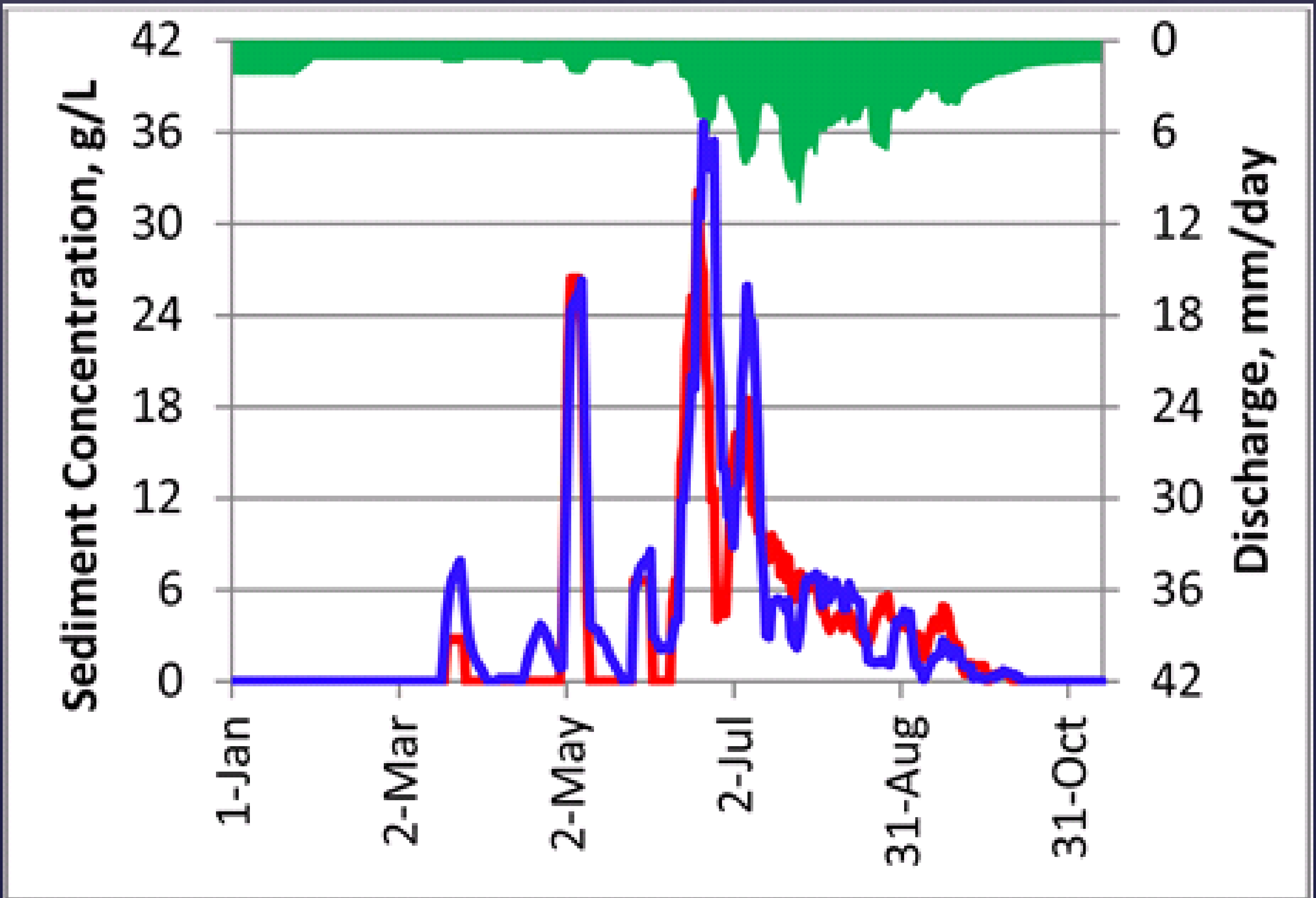
Sediment predictions ANJENI 113 ha



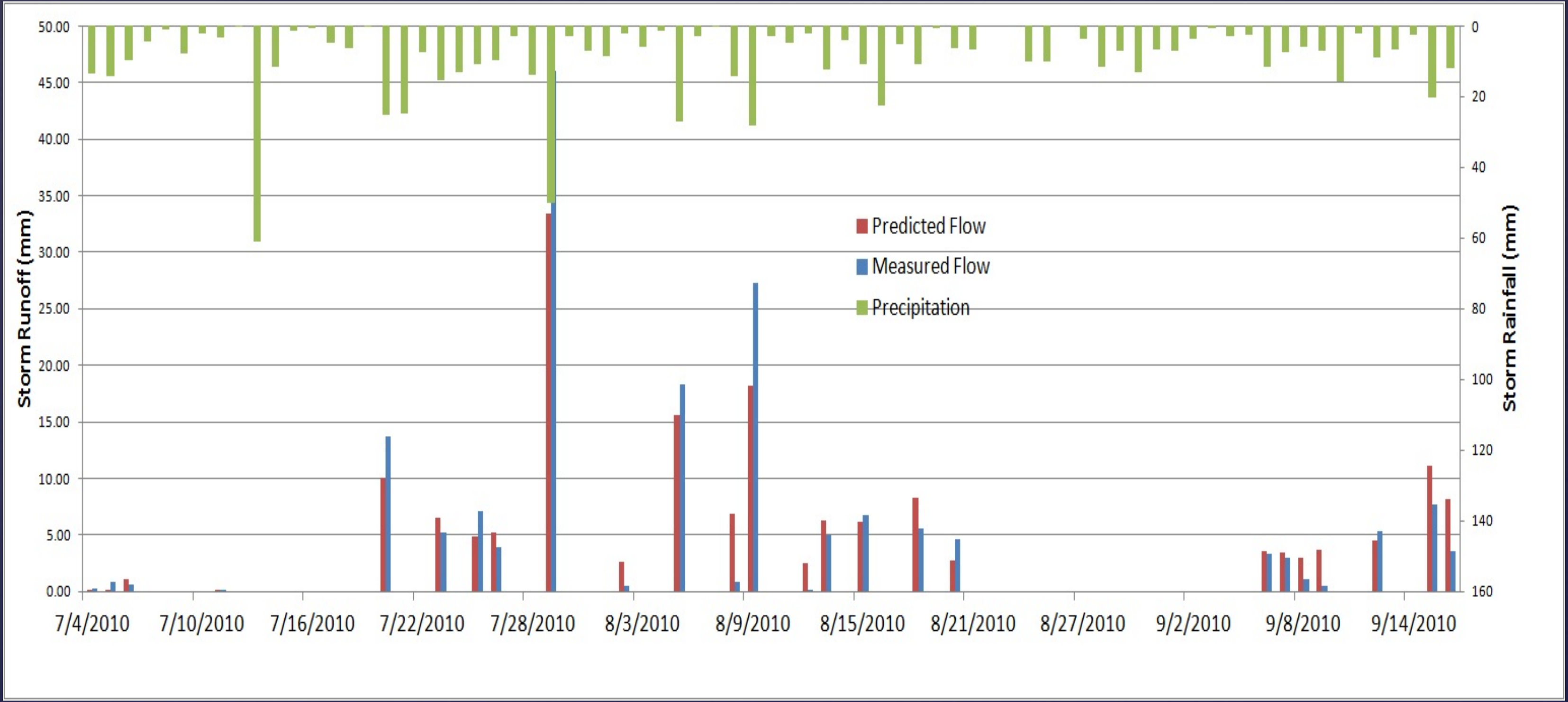
Nash Sutcli
0.75 on daily
values

Sediment concentration Enkulal watershed, 400 ha

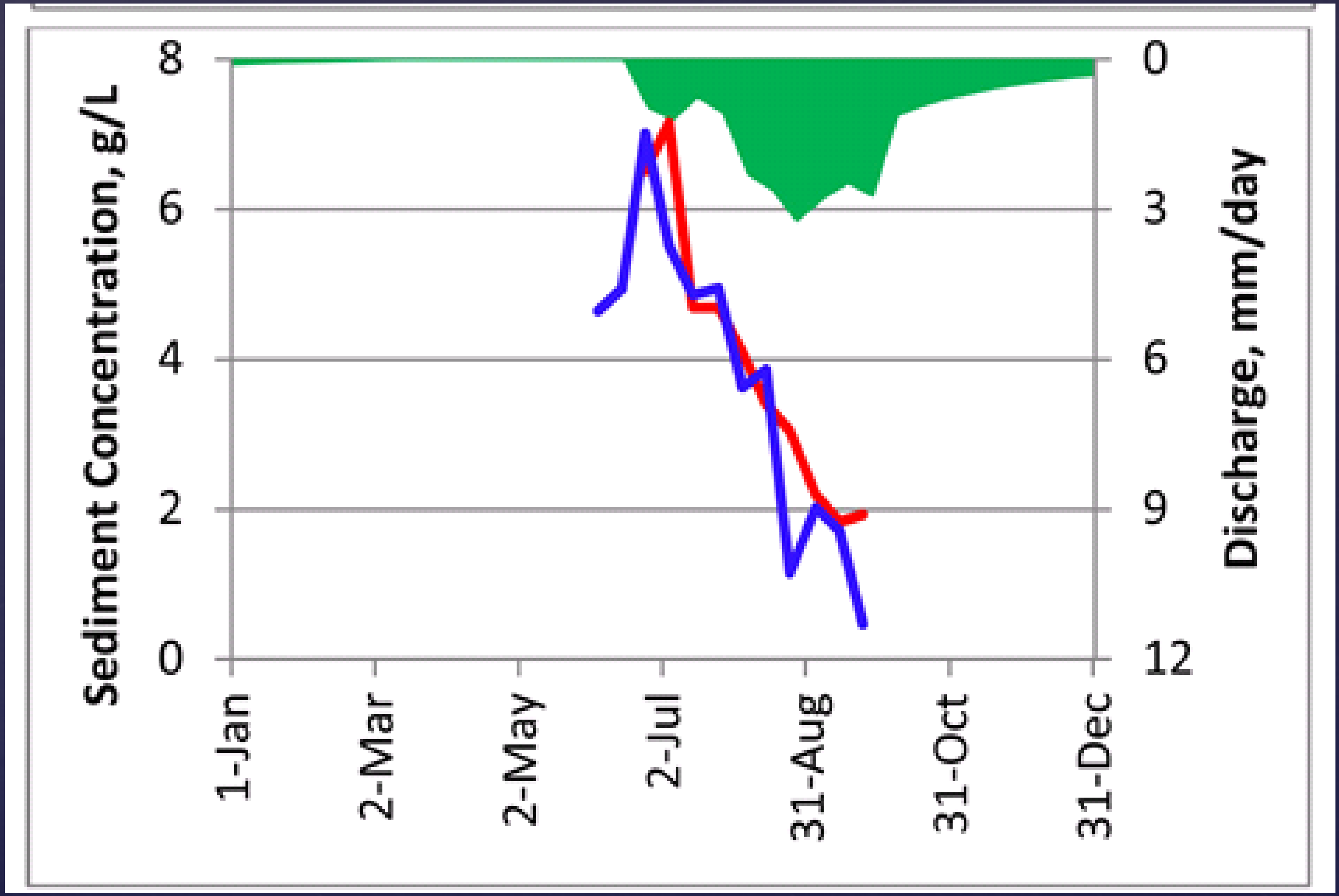
Nash Sutcliff = 0.76



Sediment Concentration Debre Mawi 95 ha



Blue Nile Basin 180,000 km²



WHAT ABOUT WATERSHED MANAGEMENT?

Runoff from

- degraded areas,
- farmland that saturate,
- saturated bottom lands


Plant Elephant grass
GULLY


Fall Bottom land

Keeping saturation below the gully bottom is important

Conclusion

- Most effective best management take climate and lands ape position in to account
- Saturation excess models for (semi) humid areas perform better than infiltration excess models

Many publications are at

http://soilandwater.bee.cornell.edu/

or

google: soil and water cornell ethiopia

Thank You!!