Selecting a Potential Evapotranspitration (PET) method in the absence of essential climatic input data

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Background

- many methods available for estimating potential evapotranspiration (PET)

  -past 50 years, almost 700 registered empirical methods
- PET methods developed for specific tasks and climatic regions

Why estimate PET

- Direct measurement of ETo is
  - difficult,
  - time consuming, and
  - costly
- Most common procedure is to estimate ETo from climatic variables, such as
  - solar radiation,
  - air temperature,
  - wind speed, and
  - relative humidity

SWAT PET methods

- Hargreaves (HG) as temperature-based methods
- Priestley-Taylor (P-T) as radiation-based methods
- Penman-Monteith (P-M) as combination methods

Soil & Water Assessment Tool | SWAT

Penman-Monteith method

- Inputs; solar radiation, air temperature, relative humidity and wind speed
- Attributes

➢ commonly used (Migliaccio and Srivastava, 2007),

➢ universally accurate (Wang et al 2009),

➢ the best method when a full complement of weather data is available (Allen et al 1998).

- Has two advantages in comparison with other methods

➢ well documented method in comparison to using lysimeters under a wide range of climate conditions,

➢ it can yield good results under a variety of climate scenarios.

Drooger and Allen, 2002, Saghravani et al 2009,

Hargreaves method

Input: air temperature both maximum and minimum

- the wide-spread availability of temperatures records in many weather stations has increased the usage Droogers and Allen 2002, Saghravani et al 2009,
- good estimation results Jensen et al 1990, Itenfisu et al 2003, and Allen et al
- shown to overpredict PET in humid climates
- underestimate it in very dry regions (Jensen et al., 1990; Amatya, 1995; Droogers and Allen, 2002)
- should only be used with a 5-day or longer time step (Hargreaves and Allen, 2003).

Priestley-Taylor method

Input: Solar radiation

- Use for wet surface area

➢ the energy component is replaced by a coefficient in SWAT.

➢ perform better than the PenmanMonteith and the Hargreaves for wet and humid surfaces. Amatya et al. 1995, Lu et al. 2005

- Underestimates PET in arid and semi arid areas

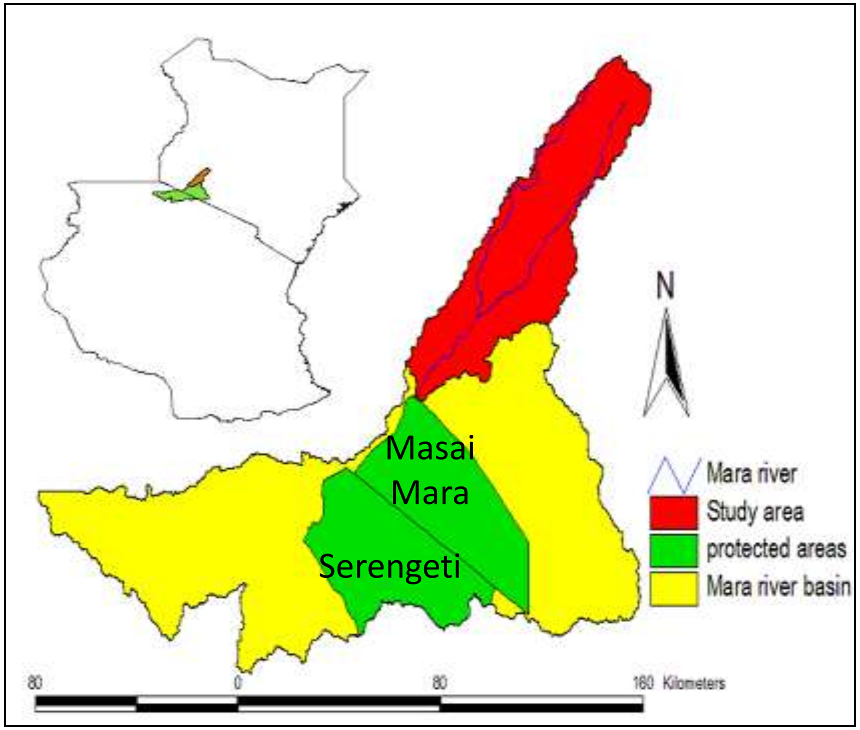
objective

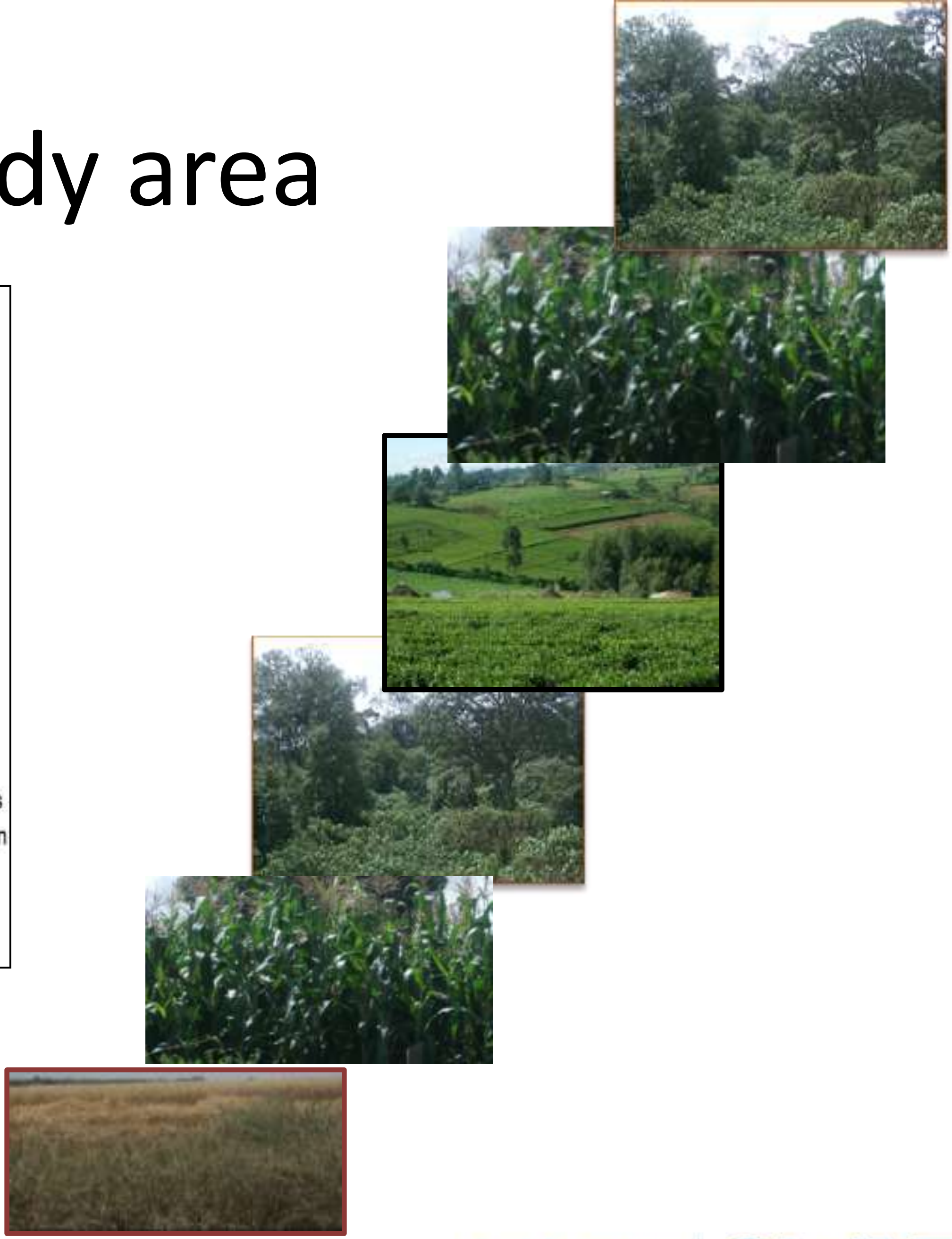
- Evaluate the behaviour of the algorithms used in SWAT for the estimation of the PET
- Selection of one method using simple assessment parameters

assumption

- ➢ any uncertainty associated with rainfall data would be propagated through the model calculations equally and would affect the final results equally
- ➢ the uncertainty associated with data would be constant for all predicted PET and the final comparisons would show which model is predicting PET adequately for the study area.

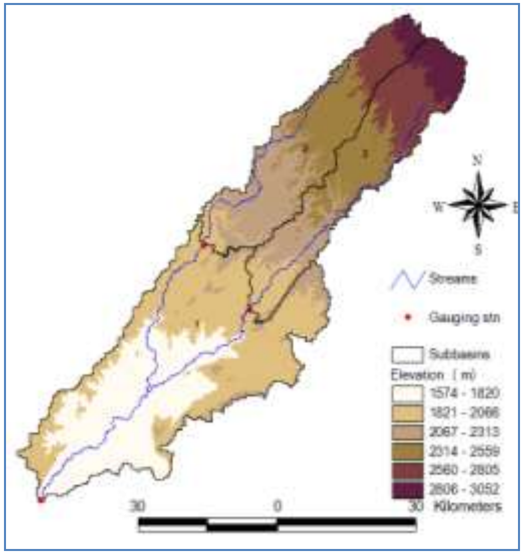
Study area



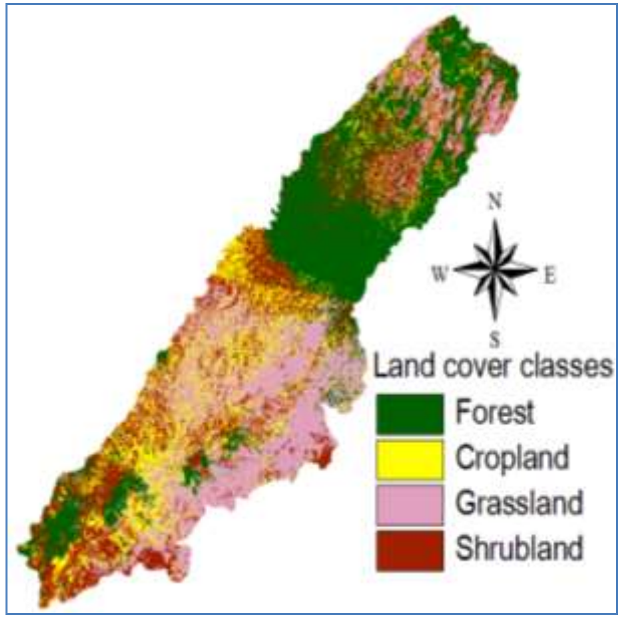


Area: 3000 sq km
Rainfall: Bimodal 800-1800mm
Elevation: 1500-3000

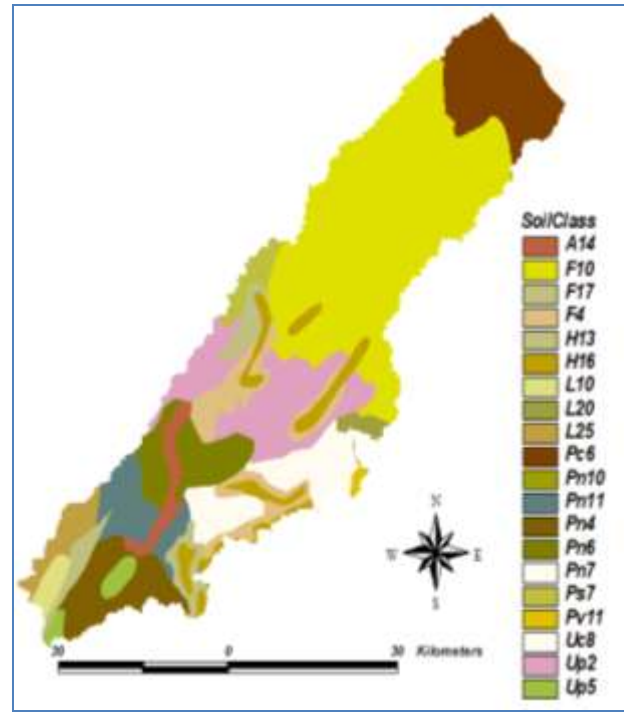
SWAT model inputs



90 X 90M SRTM

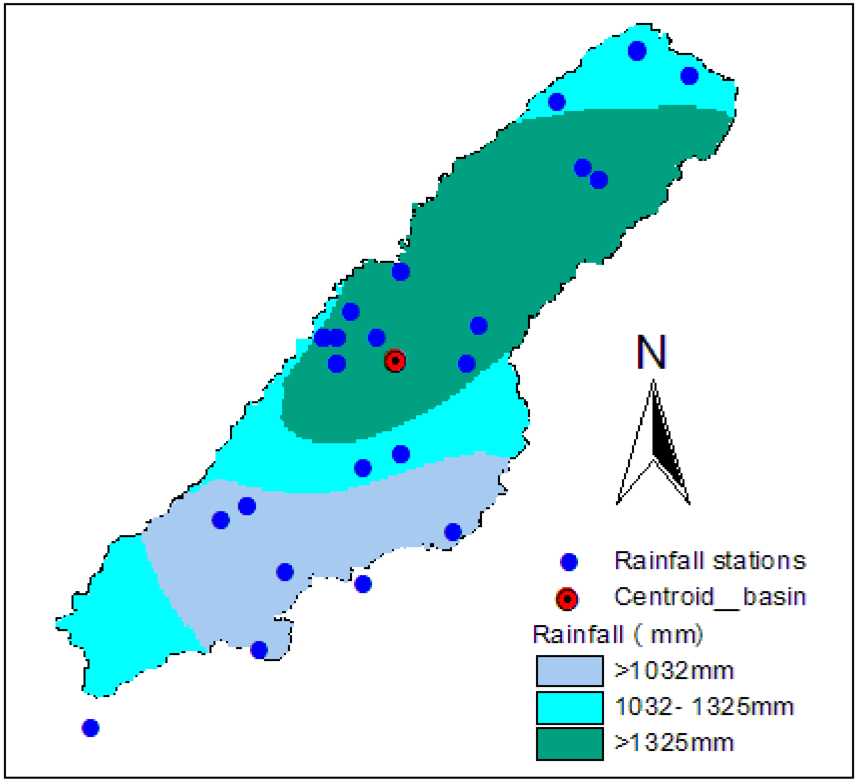


Landsat derived (1976)
30 X 30m

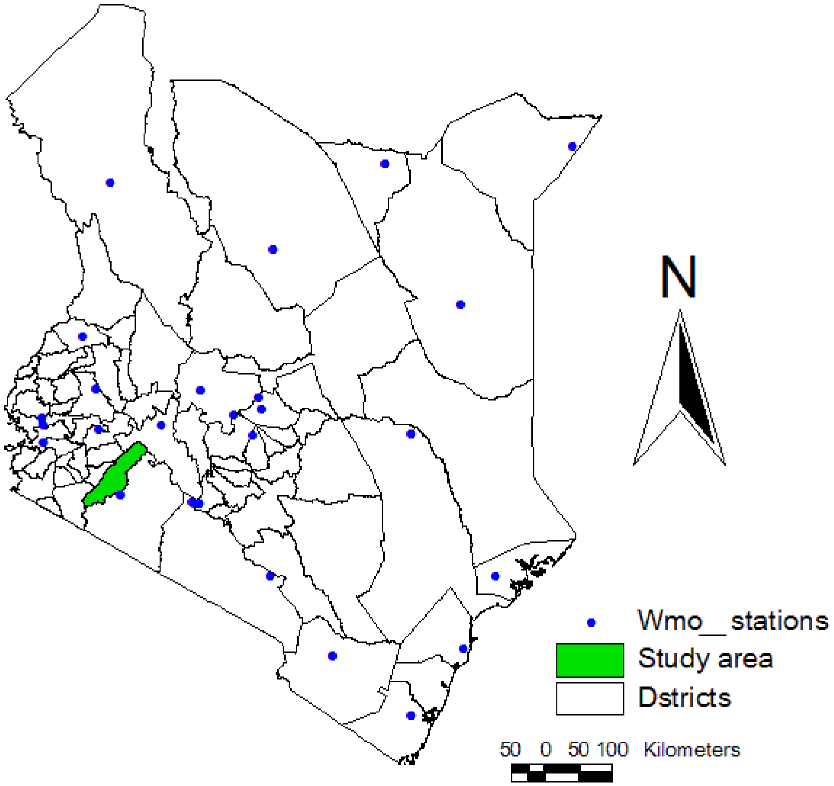


SOTER 1:1000000

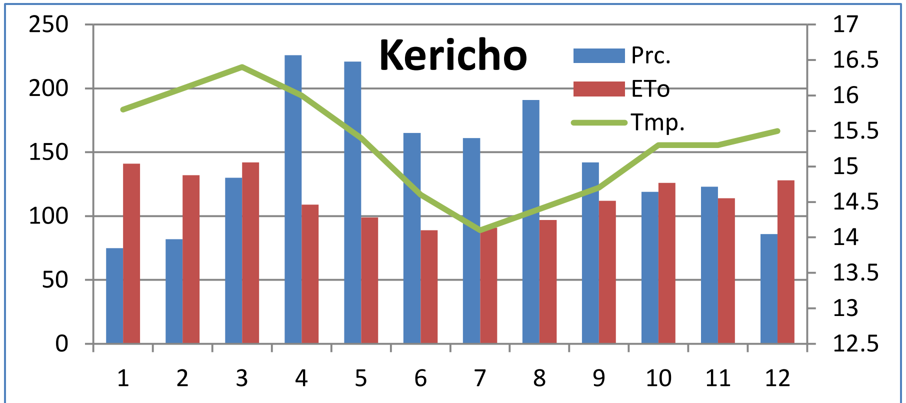
Model inputs -climatic

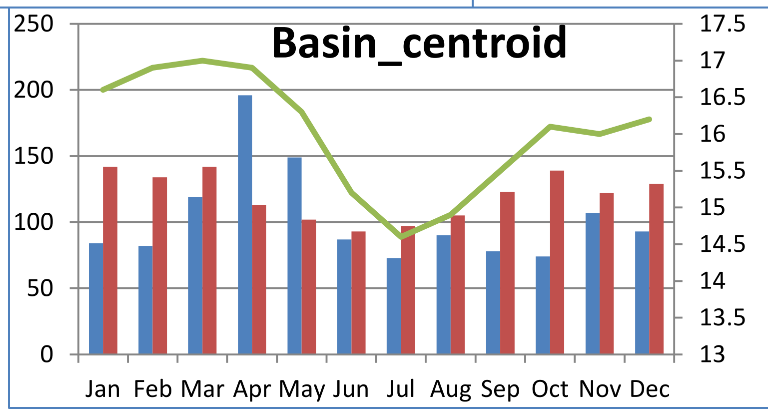


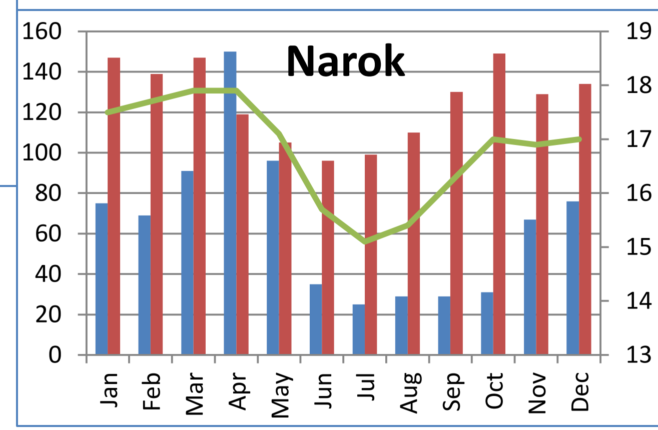
Pcp stns within study area



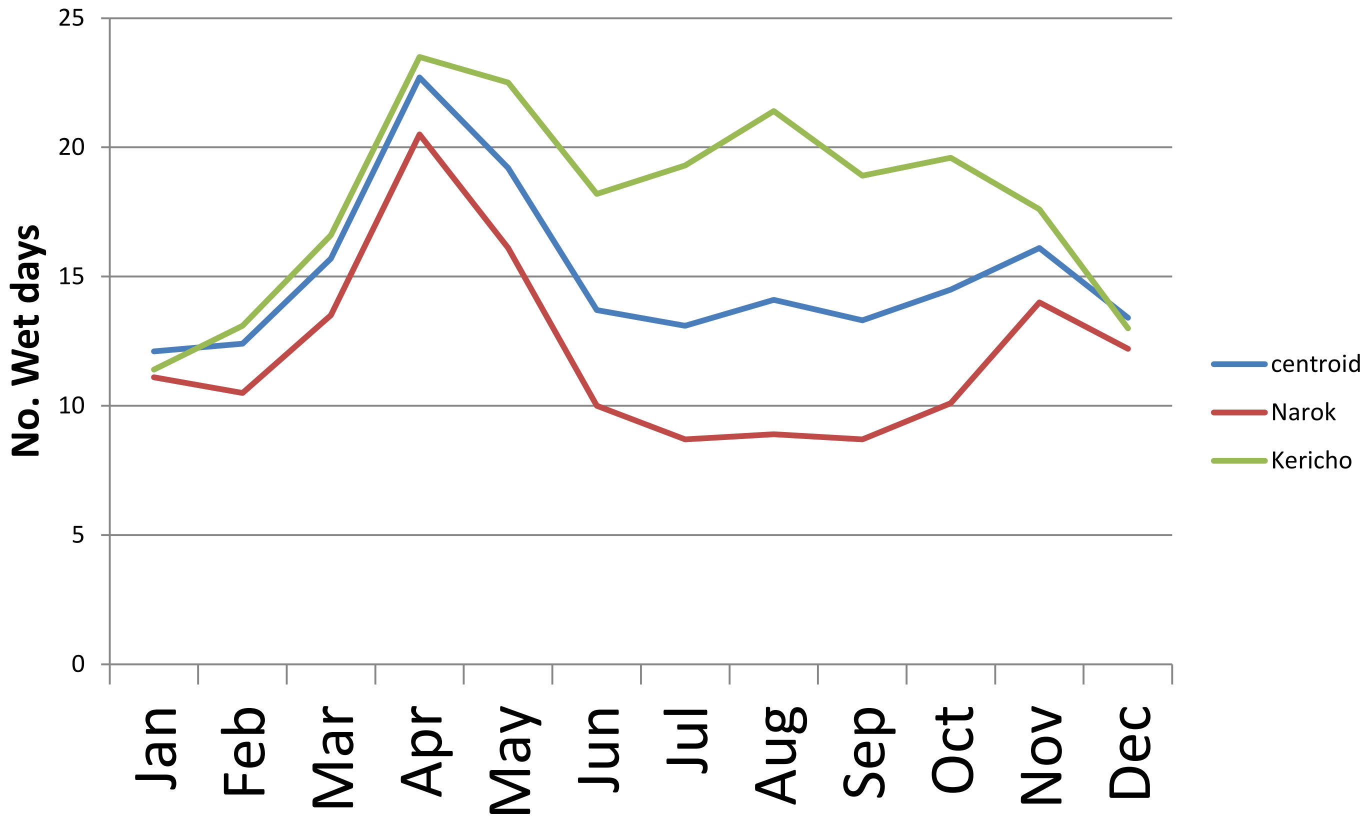
WMO climatic stns in Kenya







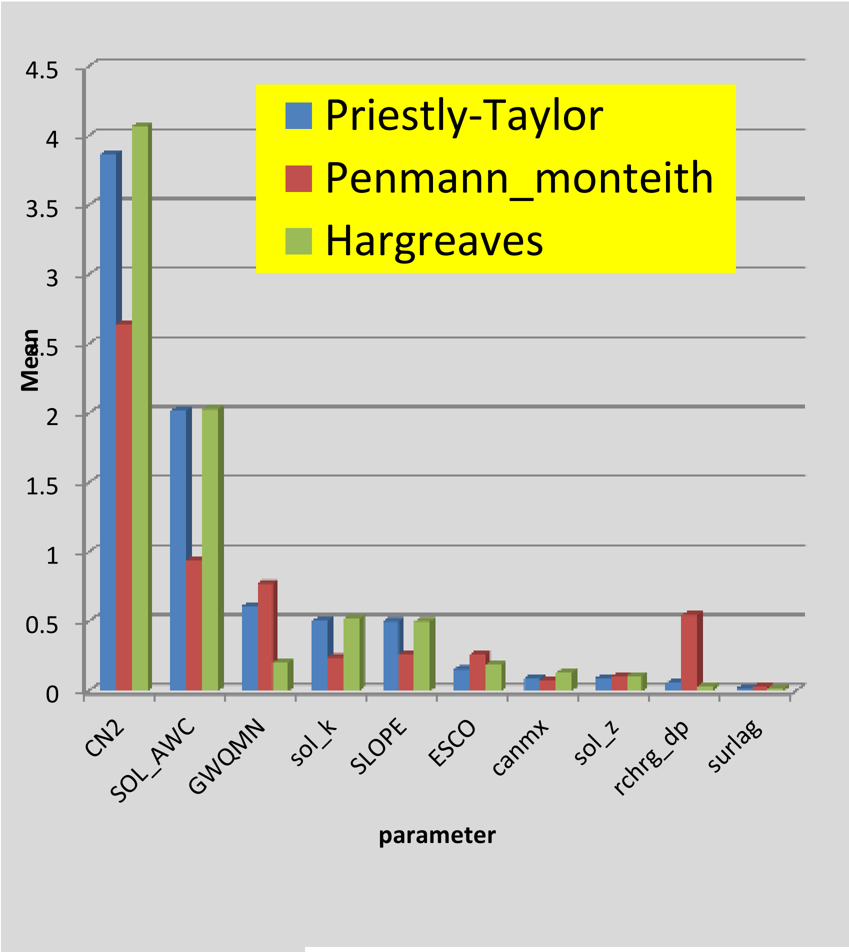
CRU 2.0 data base (1961-1990) , New et al. 2002



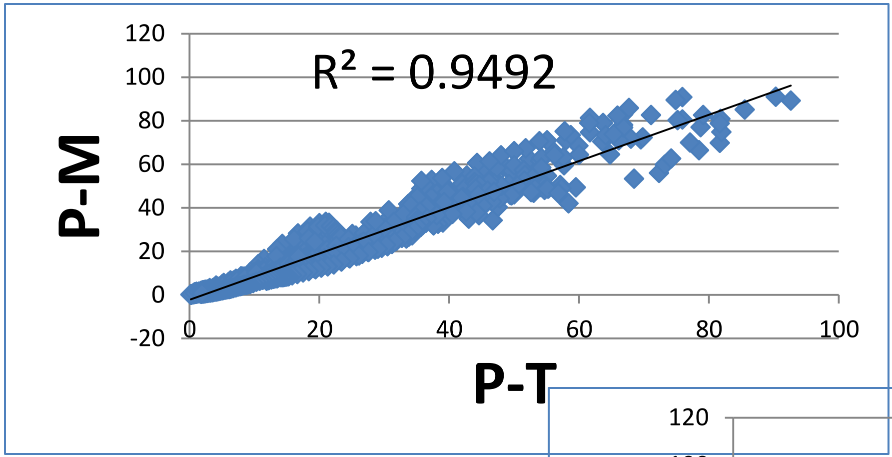
CRU 2.0 data base (1961-1990) , New et al. 2002

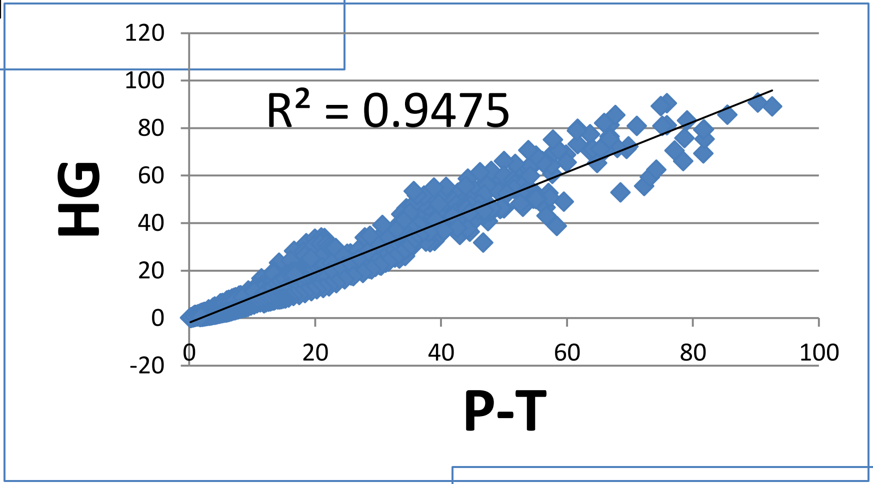
Sensitivity and calibration

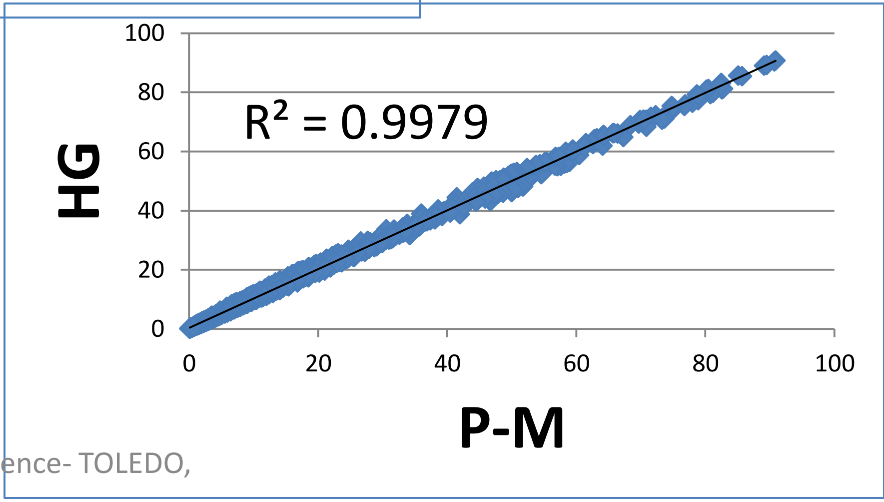
Rank	Sensitivity Parameter			Calibration Best value		
	P-T	P-M	HG	P-T	P-M	HG
1	CN2	CN2	CN2	-46%	1%	3%
2	SOL_AWC	SOL_AWC	SOL_AWC	-41%	43%	43%
3	GWQMN	GWQMN	sol_k	3169	4991	50%
4	sol_k	rchrg_dp	SLOPE	50%	0	14%
5	SLOPE	ALPHA_BF	GWQMN	50%	0.3	4927
6	ESCO	ESCO	ESCO	0.998	1	0.999
10	Surlag	Surlag	Surlag	6.1	0.1	0.1



SCATTERPLOTS FOR SIMULATED FLOW







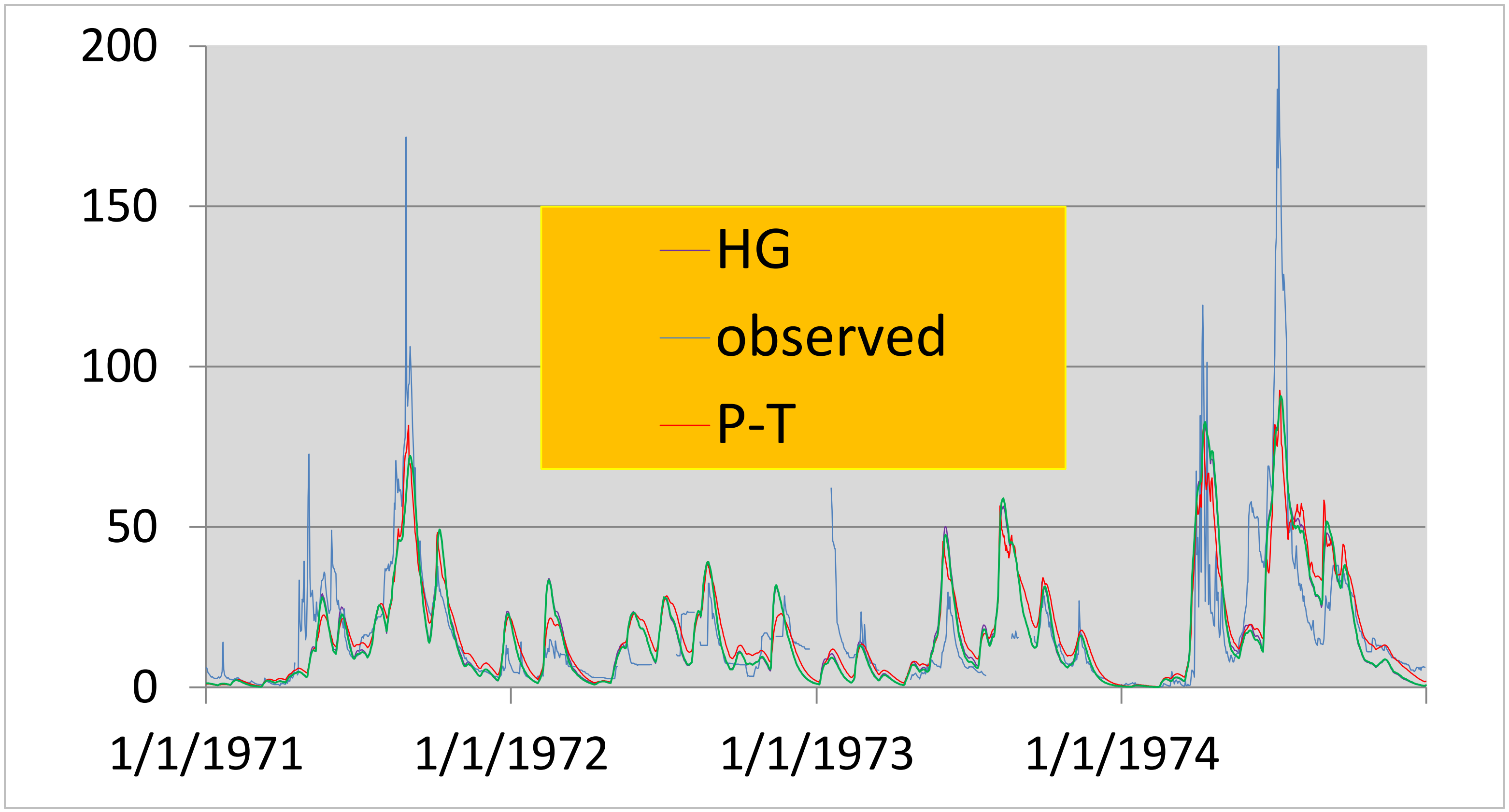
Methods comparison

	Total water yield mm	Lateral water mm	Gw AQ mm	Baseflow mm	Surface runoff mm	Pcp mm	ET mm	PET mm
Observed	***234.3***			***167.0***	***67.3***	***800-1800***		***1400-1800***
Priestly Taylor	183.1	181.6	1.5	183.1	0.0	1155.4	566.1	1346.5
Penman Montheith	170.5	126.2	0.0	126.2	52.4	1155.4	578.2	1846.9
Hargreaves	172.9	122.8	0.0	122.8	58.6	1155.4	643.2	1690.2

Methods comparison

	baseflow fraction %	Precipitation index	NSE
Observed	***0.71***	0.44 - 1.0	
Priestly Taylor	1.00	0.86	0.60
Penman Montheith	0.74	0.63	0.59
Hargreaves	0.71	0.68	0.59

Methods comparison



conclusion

- All 3 methods simulate streamflow and efficiency to similar order of magnitude but with different parameter response.
- Priestly-Taylor underestimates the PET while allocating no water to surface flow.
- The Penman-Montheith and the Hargreaves although having the
  - least correlation in the parameter
  - similar results for stream flow, residual efficiency and baseflow contribution.
- The Penman-Montheith, the RS- Penman-Montheith and the Hargreaves methods have been reported elsewhere in literature to have comparable performance in data challenged areas which was also consistent in this study.
- model calibration results are satisfactory.
- Penman-Montheith is region's PET method by default.

Research

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Parameter	Parameter range	Simulation run1	Simulation run2	Simulation run3
CN2	35 - 98	R_35 - 98	M_±50%	M_±50%
SOL_AWC	0-1	R_0-1	M_±50%	M_±50%
GWQMN	0 - 5000	R_0 - 5000	R_0 - 5000	R_0 - 5000
rchrg_dp	0 - 1	R_0 - 1	R_0 - 0.0505	R_0 - 0.0505
SLOPE	0 - 0.6	R_0 - 0.6	M_±50%	M_±50%
ALPHA_BF	0 - 10	R_0 - 10	R_0 - 10	R_0 - 10
sol_k	0 -100	R_0 -100	M_±50%	M_±50%
ESCO	0 - 1	R_0 - 1	R_0 - 1	R_0.995 - 1
GW_REVAP	0.02-0.2	R_0.02-0.2	R_0.02-0.2	R_0.02-0.205
CH_K2	0 -150	R_0 -150	R_0 -150	R_0 -150
surlag	0 - 1	R_0 - 1	R_0 - 1	R_0 - 1

		total water mm	lateral water (mm)	gw AQ (mm)	baseflow mm	surface mm	Revap	Deep AQ	Total AQ recharge	Percolation out soil	Pcp	ET	PET	baseflow%	NSE
Observed		***234.3***			***167.0***	***67.3***								***0.71***	
Priestly	default	481.5	27.1	394.7	421.8	65.0					1155.4	633.2	1346.5	0.9	
taylor	run1	181.3	113.0	0.0	113.0	74.2	69.8	583.4	720.1	714.7	1155.4	253.3	1346.5	0.6	0.62
	run2	152.5	152.3	0.0	152.3	0.3	175.8	11.1	376.0	376.0	1155.4	620.8	1346.5	1.0	0.58
	run3	183.10	181.60	1.50	183.1	0.02	24.80	17.54	401.48	402.46	1155.4	566.1	1346.5	1.0	0.60
Penman	default	596.97	30.54	438.29	468.8	133.75					1342.1	675.6	1751.6	0.8	
montheith	run1	171.4	171.44	0.0	171.4	0.08	15.68	85	194.37	195	1155.4	775.6	1846.9	1.0	0.61
	run2	143.57	92.02	0.0	92.0	59.47	199.14	3.77	324.88	317	1155.4	678.9	1846.9	0.6	0.45
	run3	170.54	126.22	0.0		52.35	26.72	0.40	397.04	390.05	1155.4	578.2	1846.9	0.74	0.59
Hagreaves	default	519.0	27.9	362.5	390.4	134.1					1342.1	760.7	1660.5	0.8	
	run1	173.5	172.6	0.0	172.6	1.2	19.6	71.8	129.6	129.5	1155.4	839.5	1690.2	1.0	0.62
	run2	153.74	153.74	0.0	153.74	0.0	195.11	0.62	307.3	308.06	1155.4	685.1	1690.2	1	0.46
	run3	172.92	122.86	0.00		58.62	26.07	13.12	329.50	321.85	1155.4	643.2	1690.2	0.71	0.59