Localised variations in water scarcity: a hydrologic assessment using SWAT and spatial techniques

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Water scarcity is universal

- Demand increases
- Availability decreases, mainly due to the decrease in natural water conservation
- Quality deteriorates

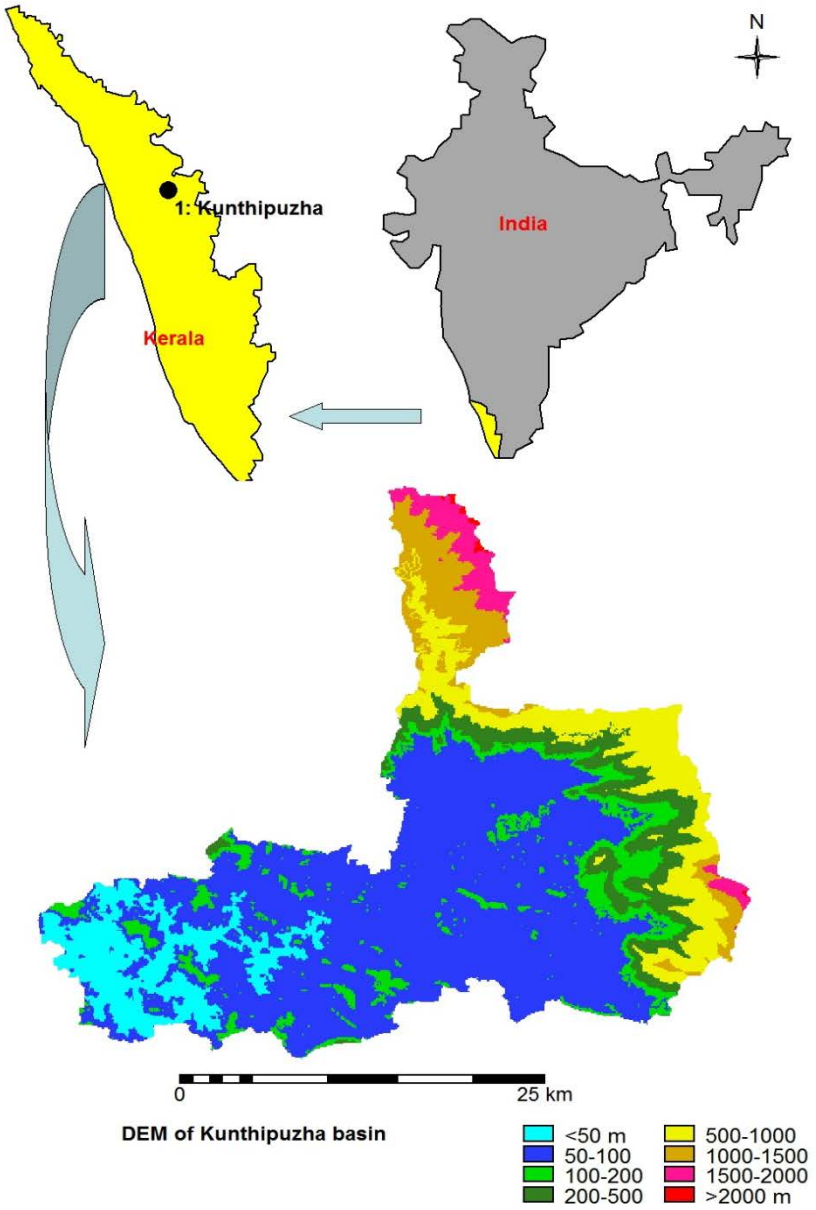
Objectives

- To quantify the water balance of the basin at basin level and at micro watershed level
- To quantify the water scarcity at micro watershed level

Study area

Kunthipuzha subbasin

1. Contributing area – 822 km^2
2. Stream order - 6
3. Mean annual rainfall – 2300 mm
4. Mean annual temperature – 27.3 ^0c
5. Mean annual flow – 53.1 m^3/s
6. Flow range – 0.1 to 1020 m^3/s
7. Simulation period – 7yrs (1996 to 2002)



Source of Data used

- Contour & drainage: Survey of India Dept.
- Soil: NBSS & LUP of ICAR and Rubber Board
- Satellite Imagery: NRSA
- Rainfall: Water Resources Dept, Govt of Kerala and KAU
- Temperature, Humidity, Wind velocity and Solar radiation: KAU
- Runoff: CWC

Tools and techniques used

1. GIS software: ILWIS
   - Integrated Land and Water Information System
   - All functions required for the spatial analysis of land and water available
   - Developed by International Institute for Geo- Information science and Earth Observation (ITC)
   - It is freeware

Tools and techniques used

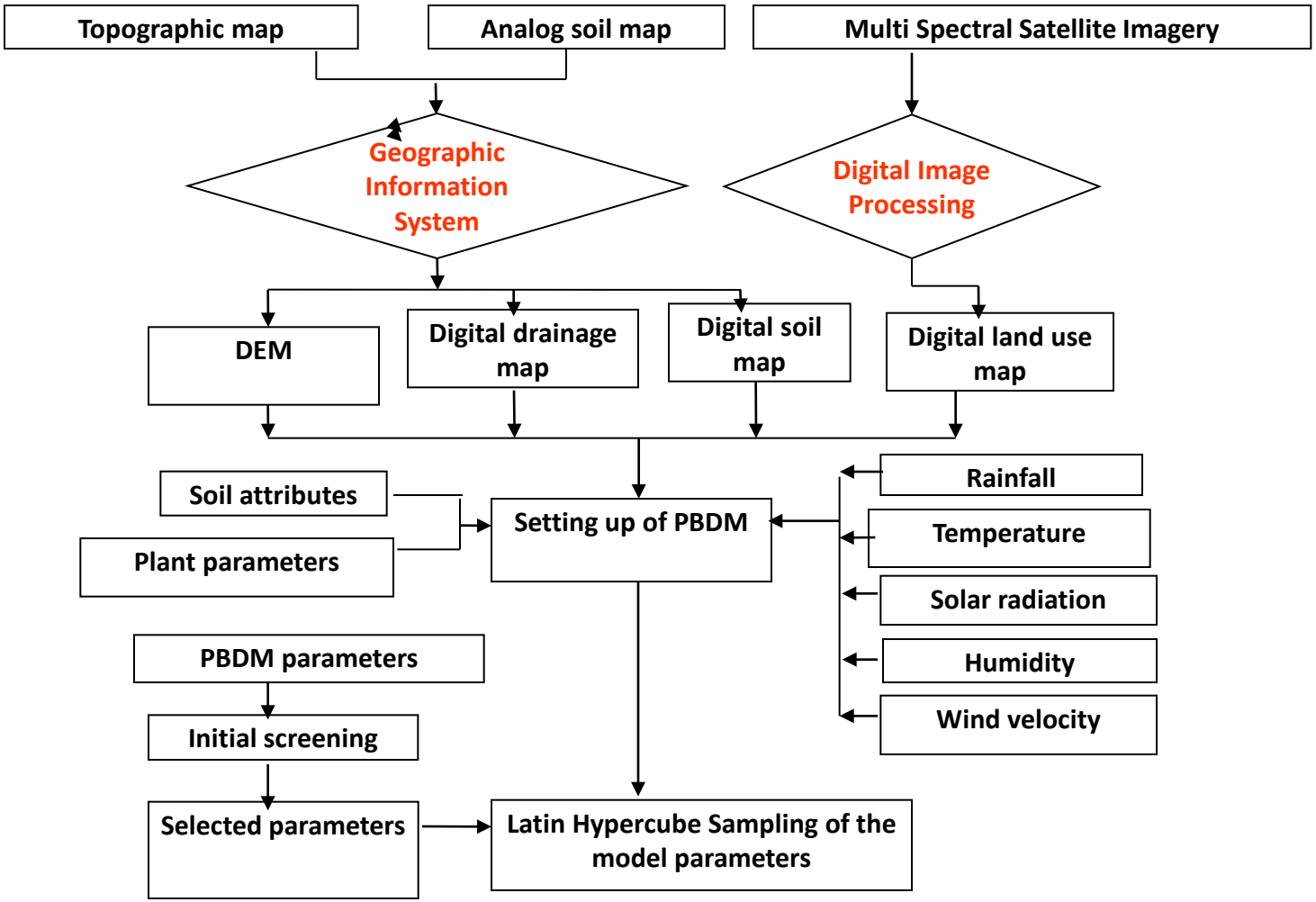
2. Digital image processing: ILWIS

- The software has got good capability for landuse classification from multispectral satellite imagery, comparable to the costly high end packages in the area
- Image enhancement possible
- Image fusion capability for spatial resolution improvement is also available

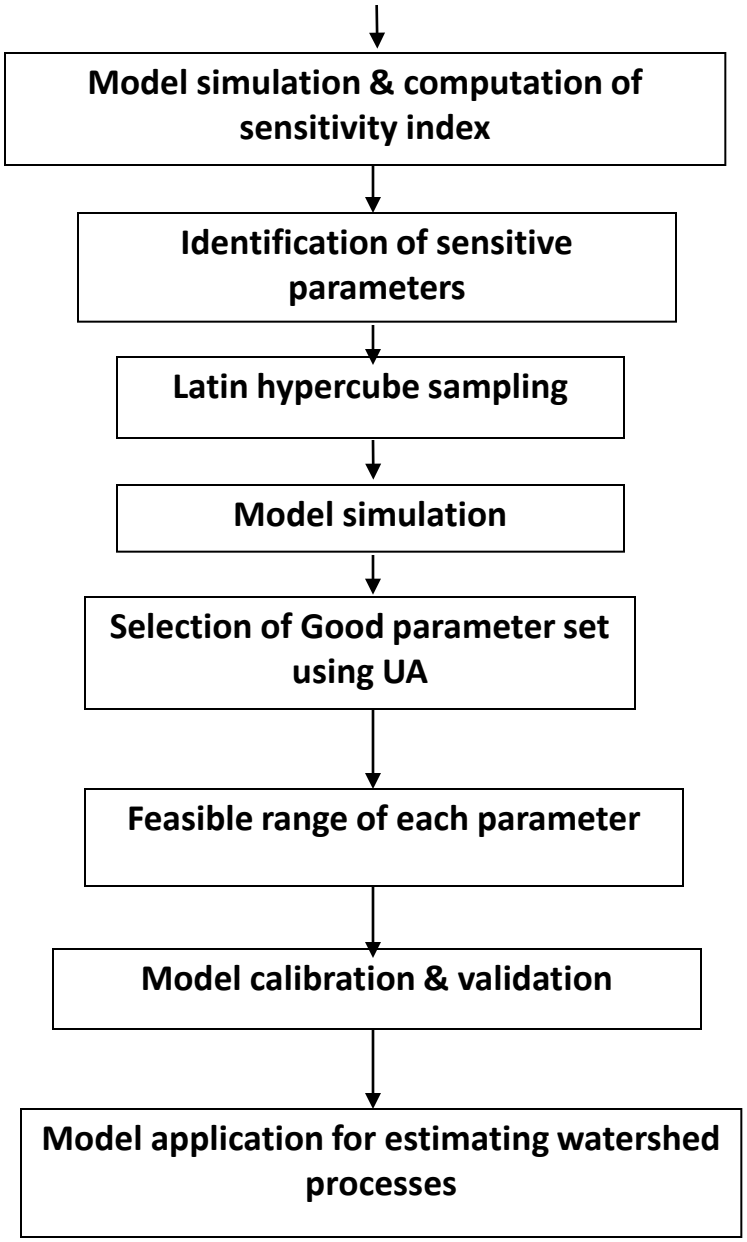
Tools and techniques used

3. Physically Based Distributed Model: SWAT
   - Soil and Water Assessment Tool
   - Physical process based, spatially distributed, integrated and large basin scale watershed model
   - Integrated hydrological model capable of predicting
     - Runoff
     - Sediment flow
     - Water quality

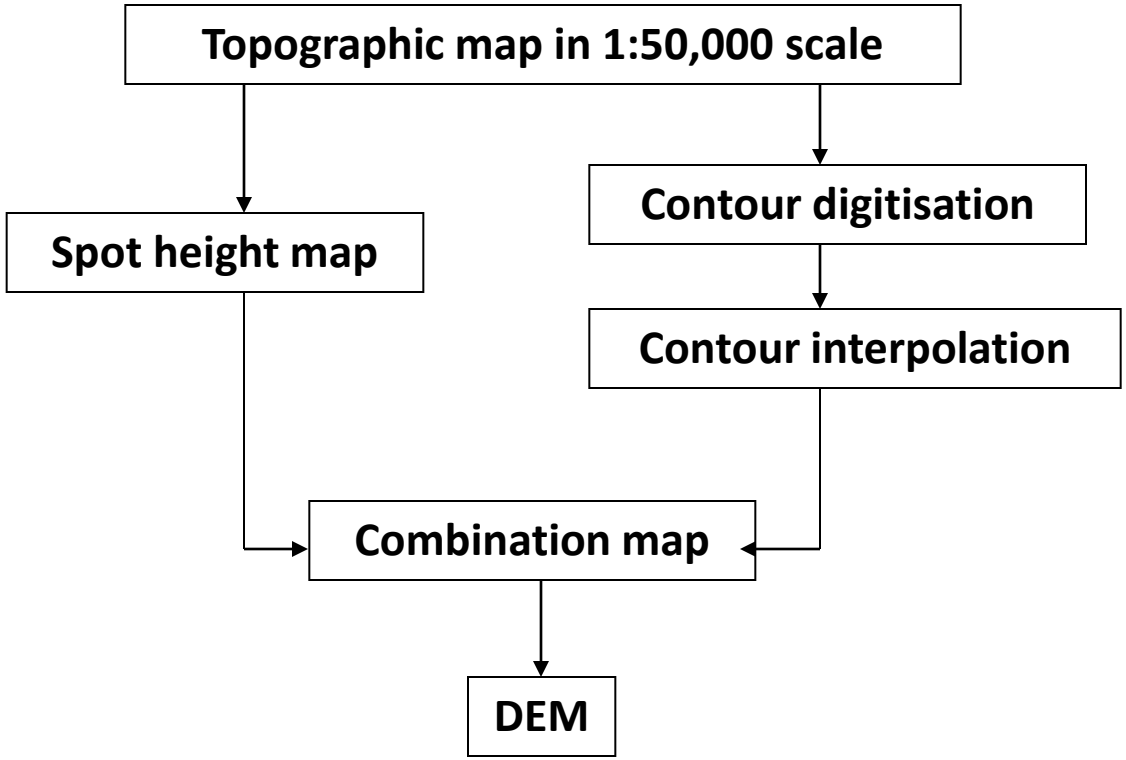
Flow diagram of Methodology



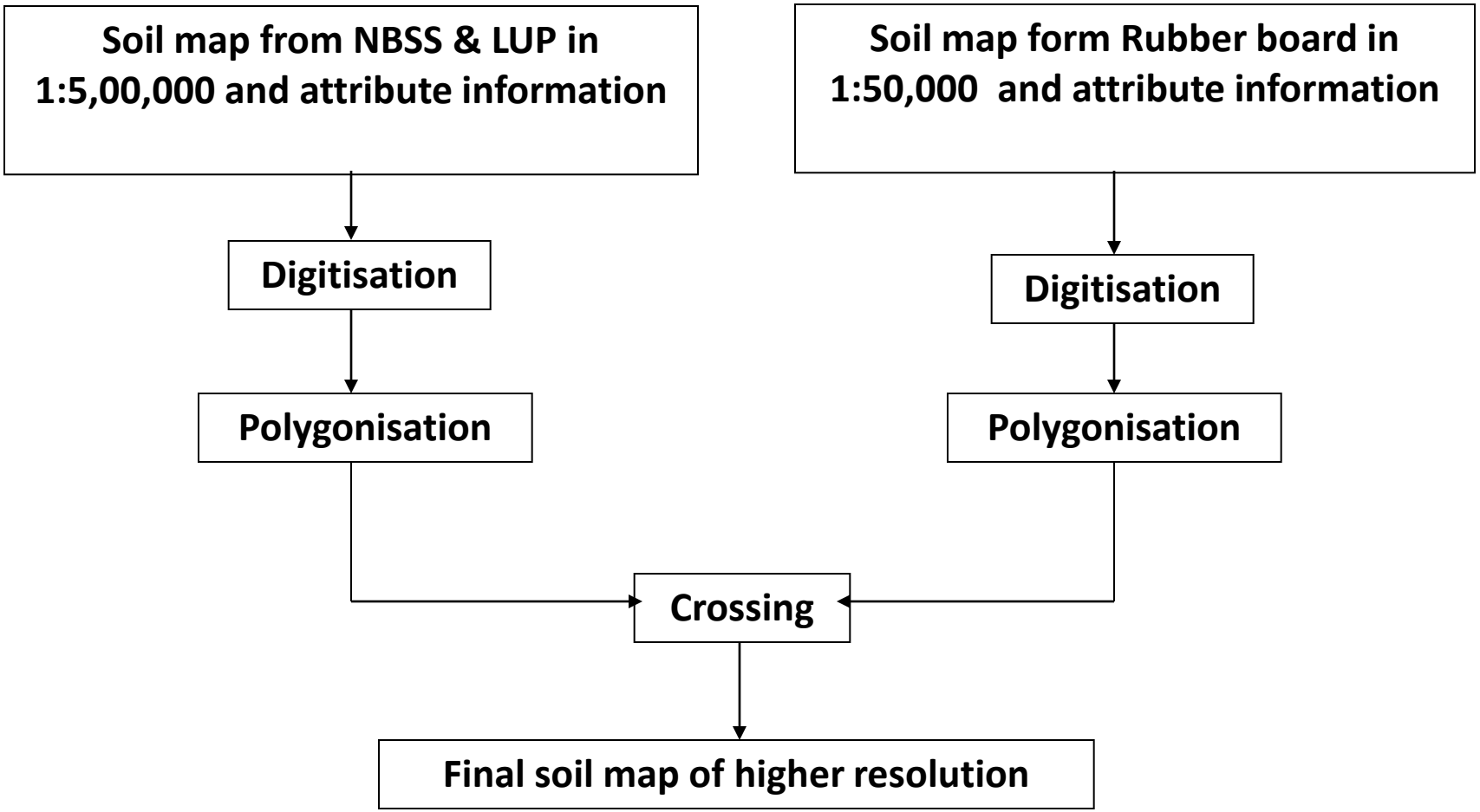
Flow diagram of Methodology (contd)



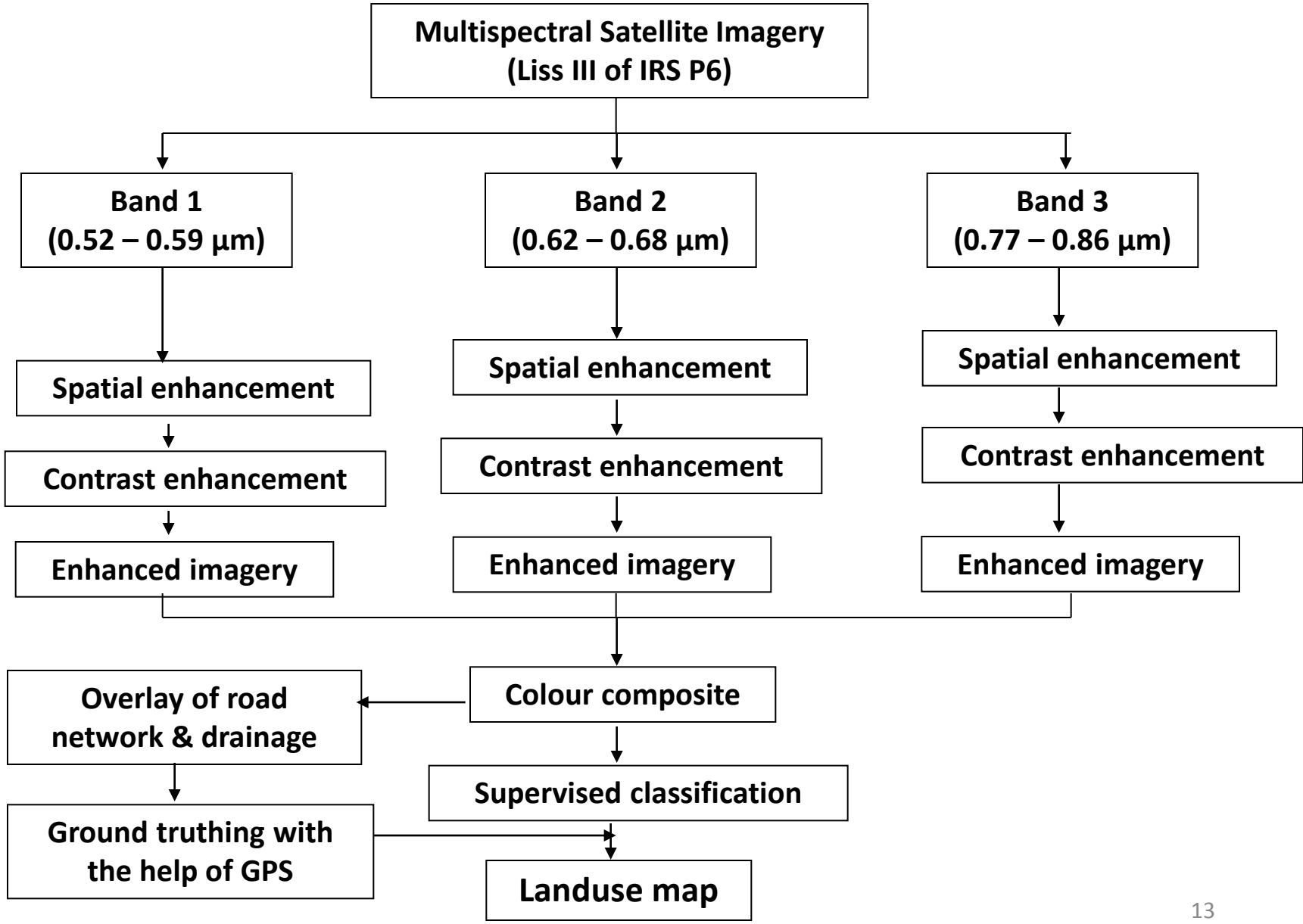
Digital Elevation Model (DEM)



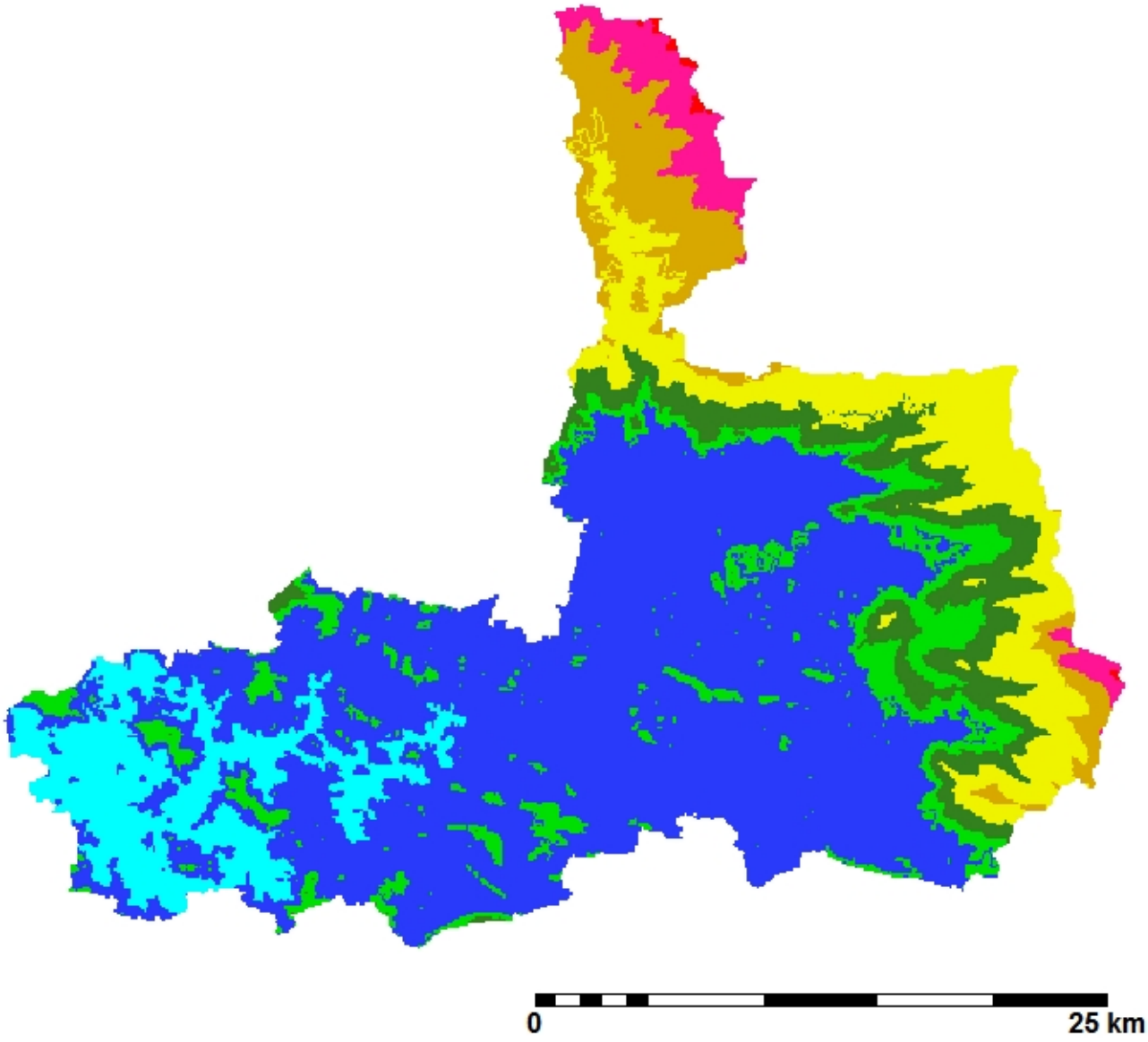
Soil map


Soil map from NBSS & LUP in 1:5,00,000 and attribute information
Soil map form Rubber board in 1:50,000 and attribute information
Digitisation
Digitisation
Polygonisation
Polygonisation
Crossing
Final soil map of higher resolution

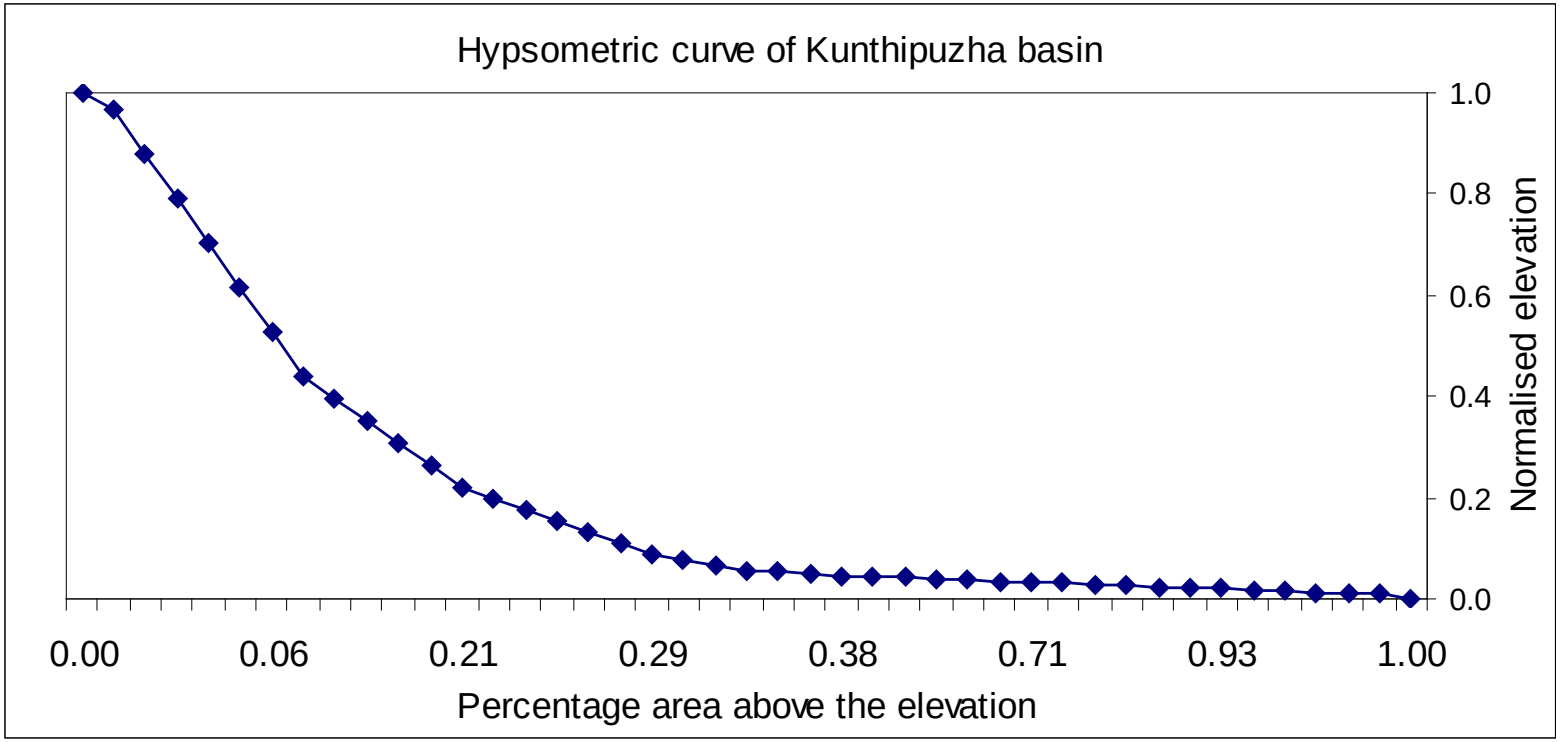
Landuse map


Multispectral Satellite Imagery
(Liss III of IRS P6)
Band 1
(0.52 – 0.59 µm)
Band 2
(0.62 – 0.68 µm)
Band 3
(0.77 – 0.86 µm)
Spatial enhancement
Contrast enhancement
Enhanced imagery
Spatial enhancement
Contrast enhancement
Enhanced imagery
Spatial enhancement
Contrast enhancement
Enhanced imagery
Colour composite
Overlay of road
network & drainage
Supervised classification
Ground truthing with
the help of GPS
Landuse map

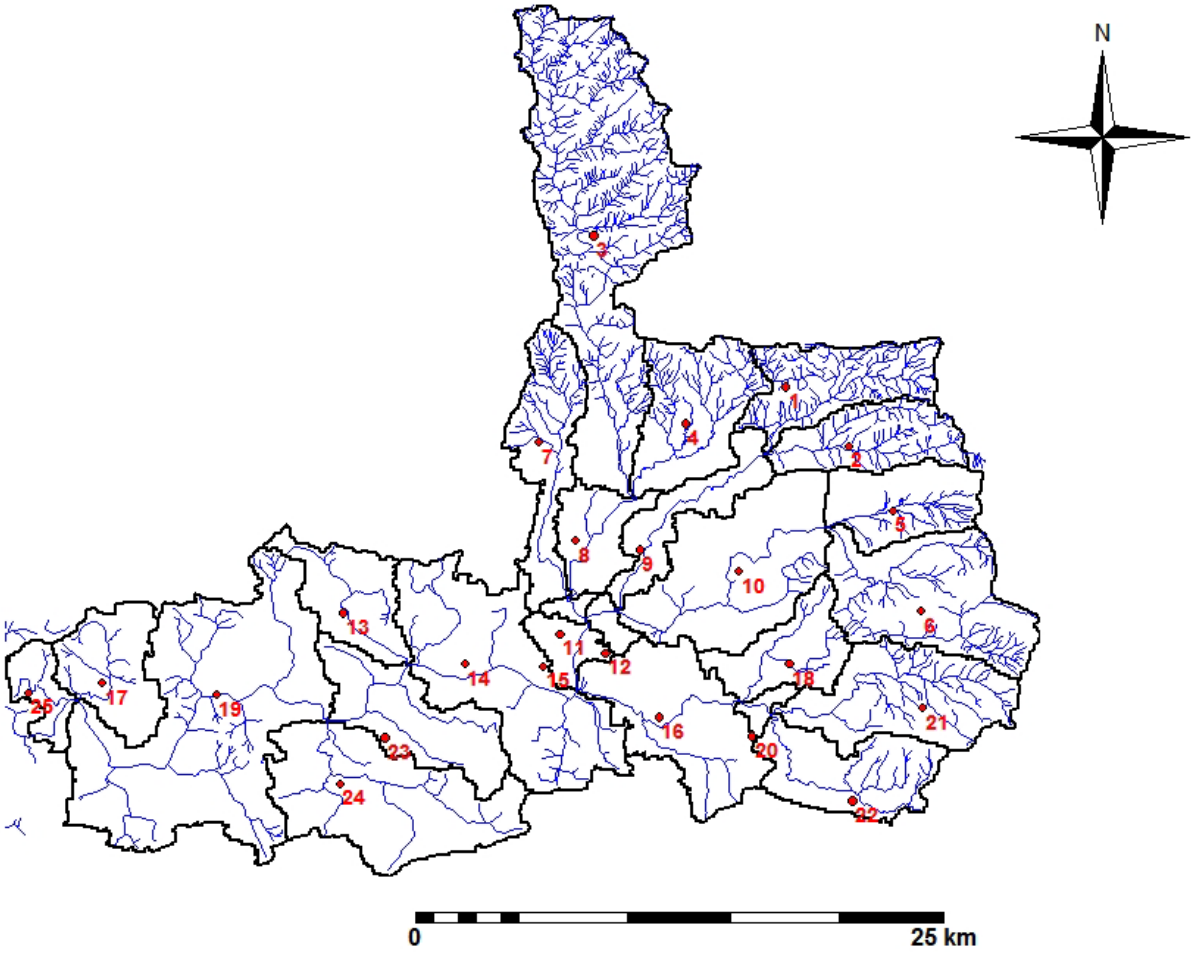
DEM of Kunthipuzha basin



Hypsometric Curve of the Watershed



Subbasins of Kunthipuzha with drainage network



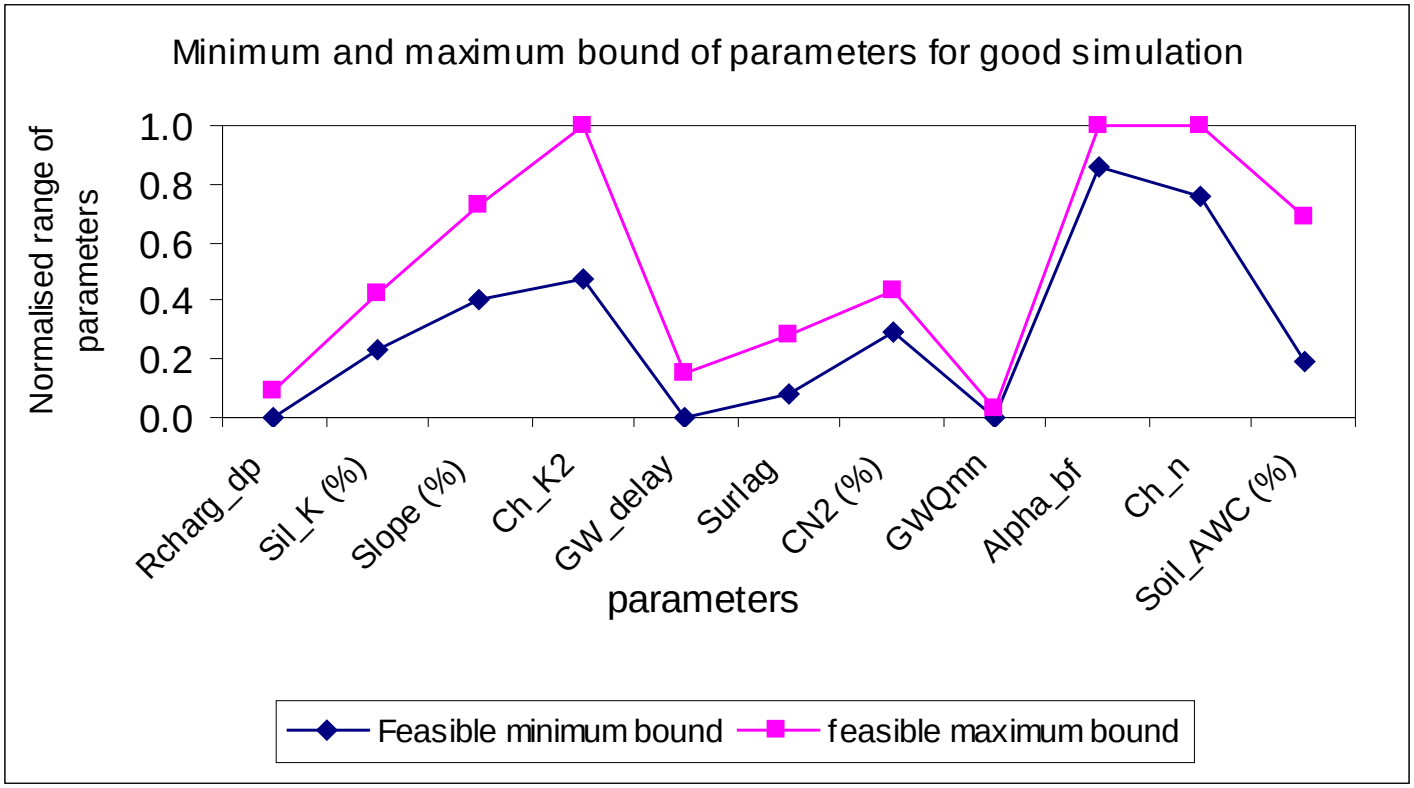
Landuse and soil of Kunthipuzha watershed and their area coverage

Landuse			Soil		
Class	Area (km^2)	% area of the watershed	Series	Area (km^2)	% area of the watershed
Barren land	24.06	2.94	Chelikkuzhi	20.30	2.48
Dense mixed forest	42.72	5.22	Kairad	1.93	0.24
Evergreen forest	152.24	18.61	Kalladikkode	168.34	20.56
Garden land	307.27	37.56	Kanchirappuzha	17.53	2.14
Mixed forest	90.88	11.11	Kongad	15.7	1.92
Open scrubs	53.74	6.57	Kottappadi	28.33	3.46
Paddy	41.75	5.10	Manjallor	91.01	11.11
River bed	2.26	0.28	Pallippadi	371.56	45.38
Rubber	99.65	12.18	Perambra	104.11	12.71
Water	3.4	0.42			
Total	817.97	100.00	Total	818.81	100.00

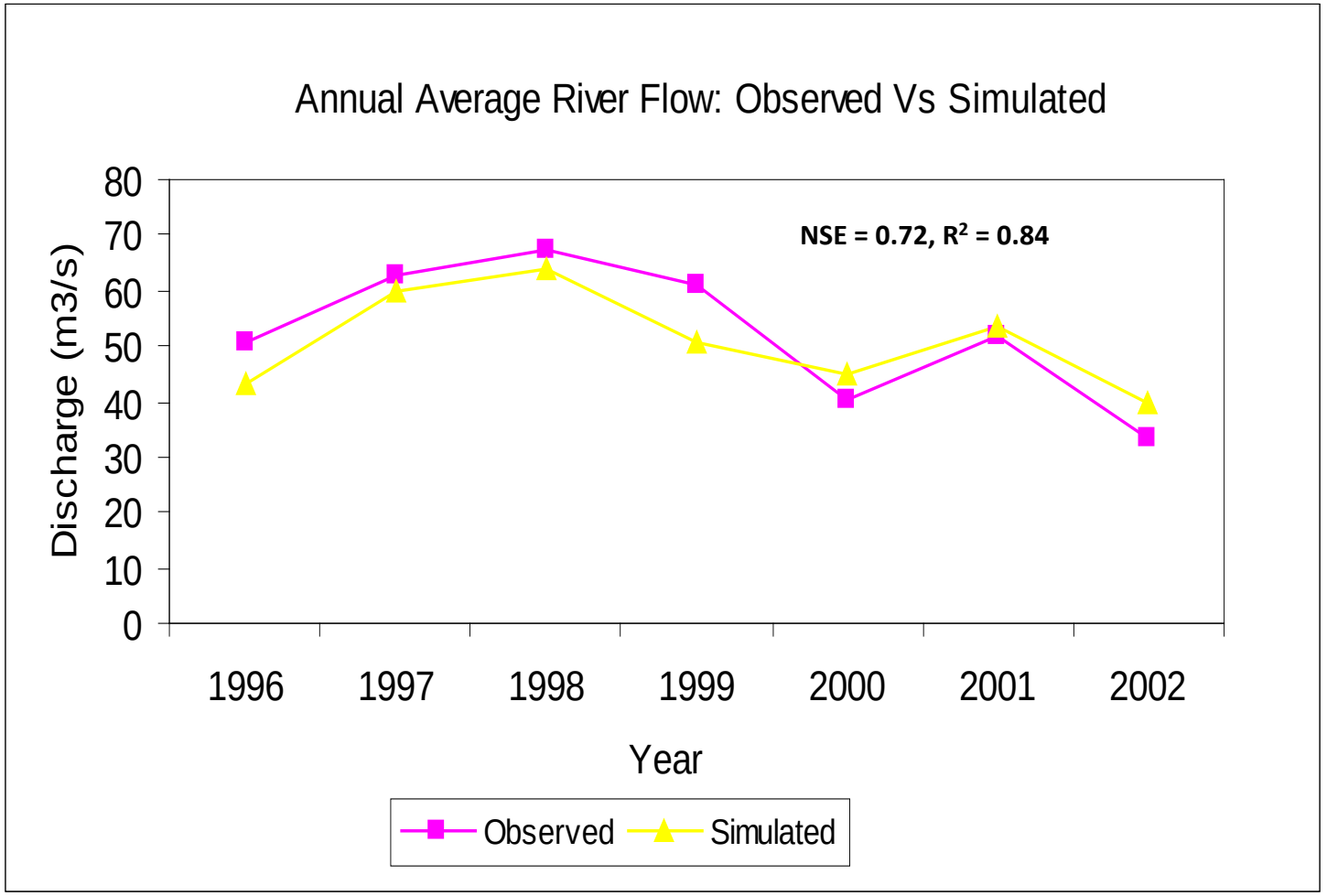
Parameter description of the PBDM and the sensitivity ranking

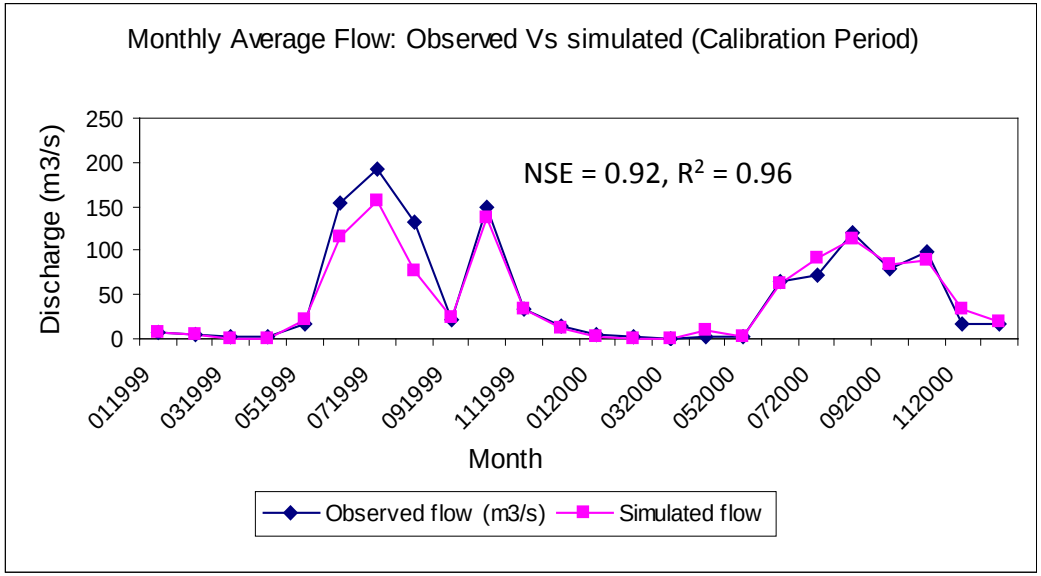
Sl No	Name	Description	Sensitivity Rank
1	ALPHA_BF	Baseflow alpha factor (days)	1
2	GWQMN	Threshold minimum depth of water in the shallow aquifer for the baseflow initiation (mm)	4
3	ESCO	Soil evaporation compensation factor	12
4	SLOPE	Average slope steepness (m / m)	6
5	SLSUBBSN	Average slope length (m)	14
6	CH_K2	Channel effective hydraulic conductivity (mm / h)	2
7	CN2	Initial curve number (II) value	3
8	SOL_AWC	Available water capacity (mm water / mm soil)	11
9	SURLAG	Surface runoff lag time (days)	5
10	GW_DELAY	Groundwater Delay (days)	13
11	RCHRG_DP	Deep aquifer percolation fraction	10
12	CANMAX	Maximum canopy storage (mm)	15
13	SOL_K	Saturated hydraulic conductivity (mm/h)	7
14	SOL_Z	Soil depth (mm)	9
15	EPCO	Plant uptake compensation factor	18
16	CH_N	Manning's n value for main channel	8
17	BLAI	Maximum potential leaf area index	20
18	BIOMIX	Biological mixing efficiency	19
19	SOL_ALB	Soil albedo fraction	16
20	GW_REVAP	Groundwater revaporation factor	17

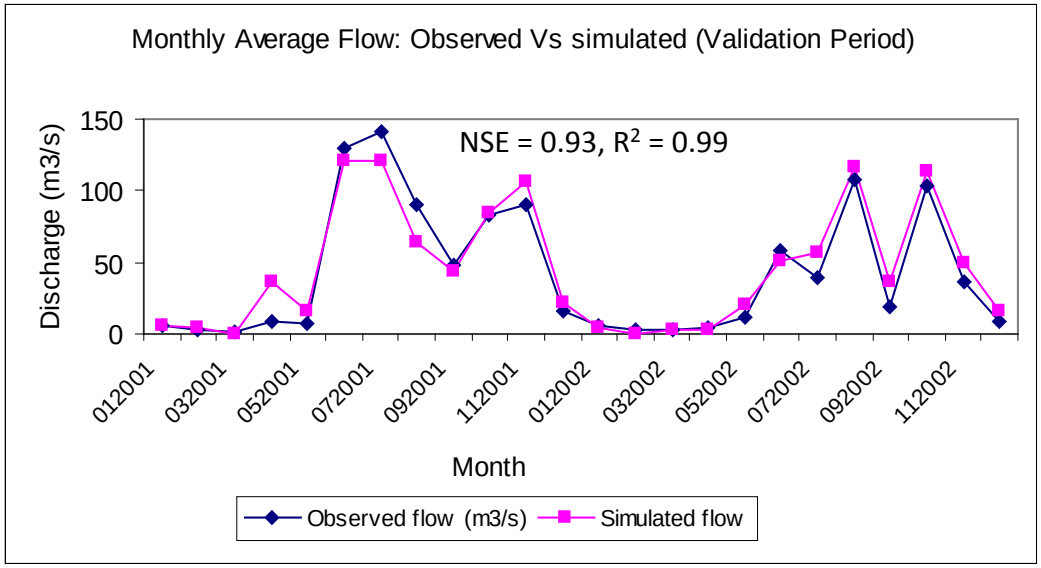
Normalised parameter range for good simulations

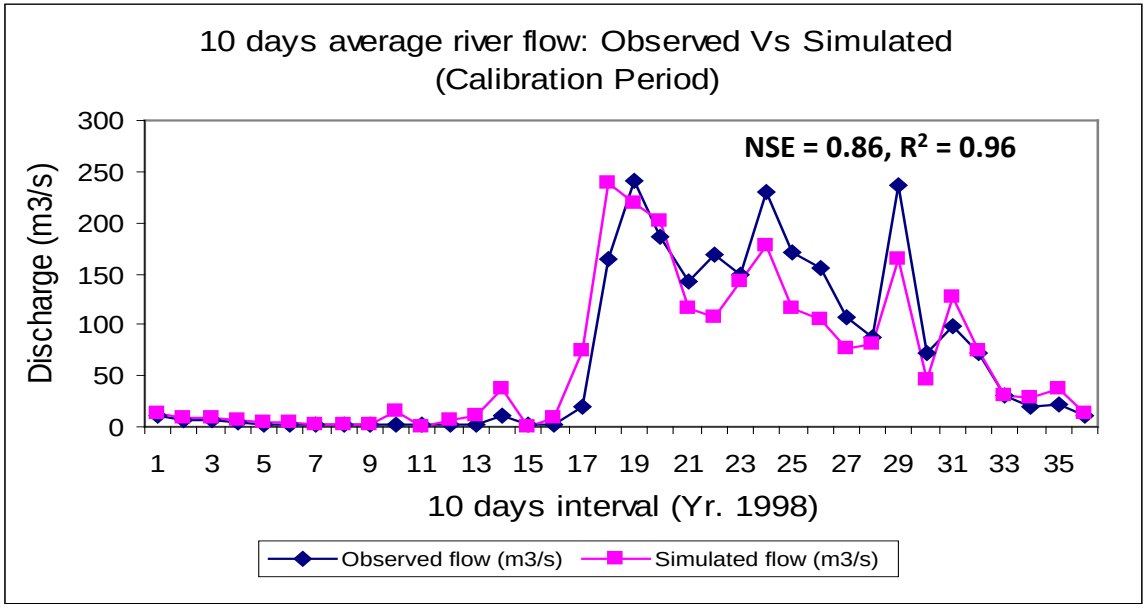


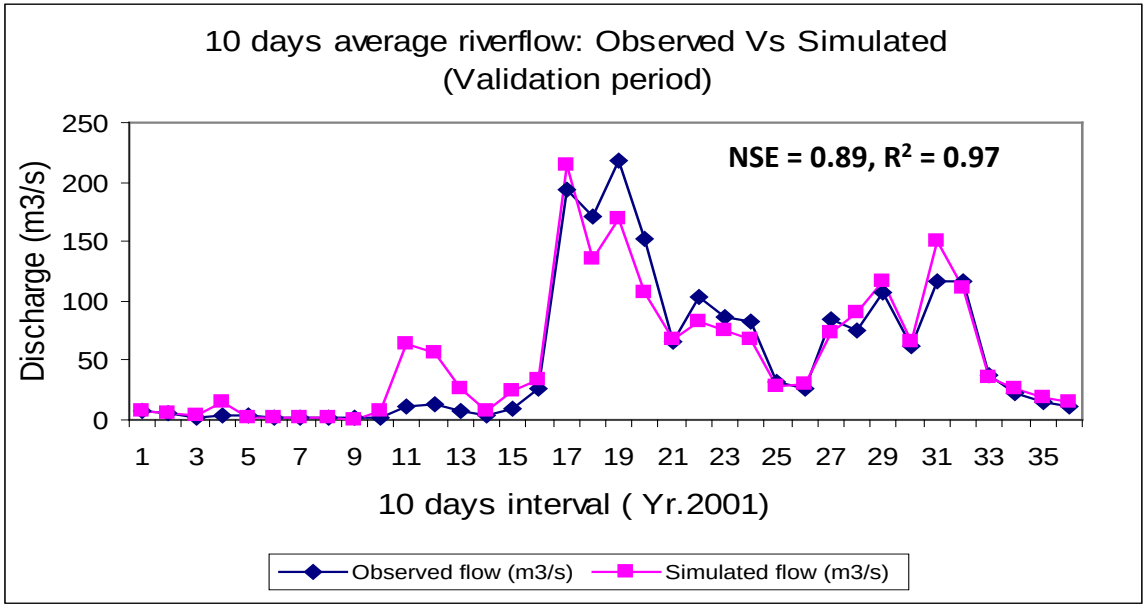
Results : Calibration and Validation

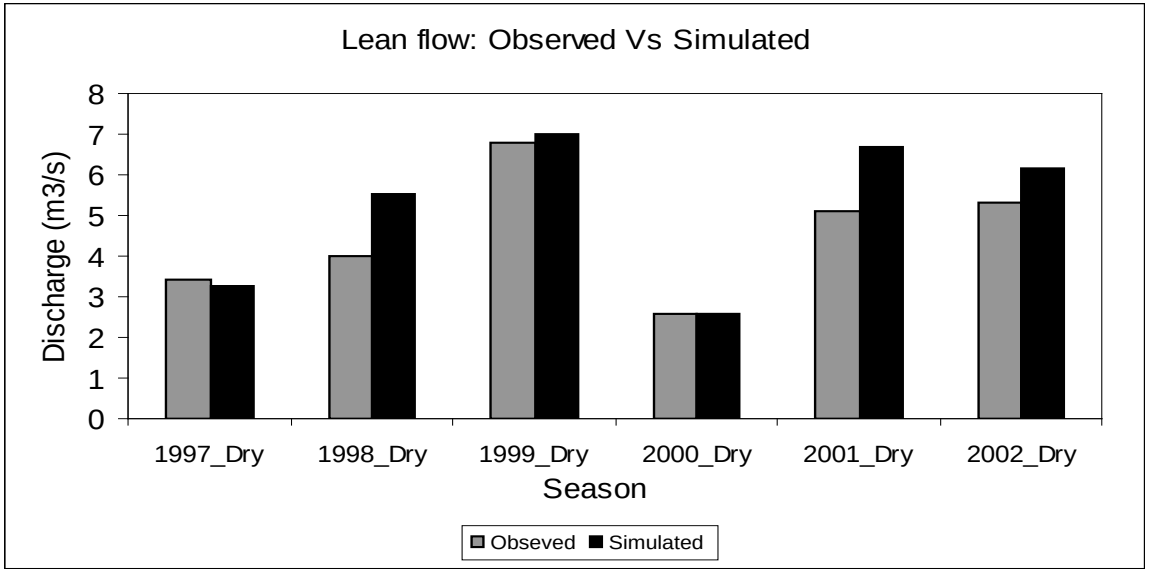


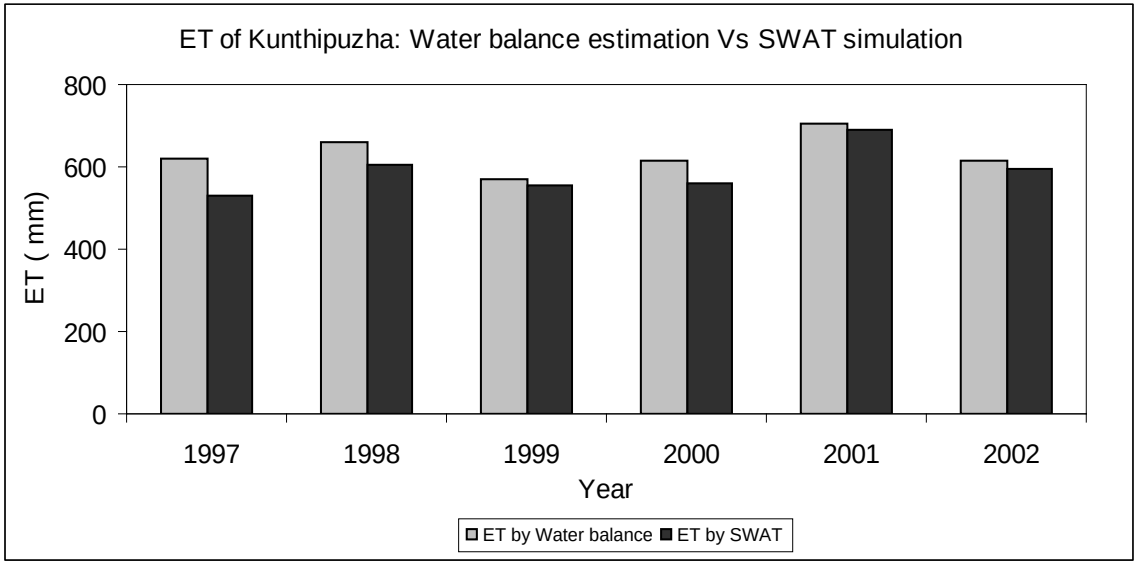

Monthly Average Flow: Observed Vs simulated (Calibration Period)
Discharge (m3/s)
250
200
150
100
50
0
NSE = 0.92, R2 = 0.96
011999
031999
051999
071999
091999
111999
012000
032000
052000
072000
092000
112000
Month
Observed flow (m3/s)
Simulated flow


Monthly Average Flow: Observed Vs simulated (Validation Period)
Discharge (m3/s)
150
100
50
0
NSE = 0.93, R2 = 0.99
012001
032001
052001
072001
092001
112001
012002
032002
052002
072002
092002
112002
Month
Observed flow (m3/s)
Simulated flow

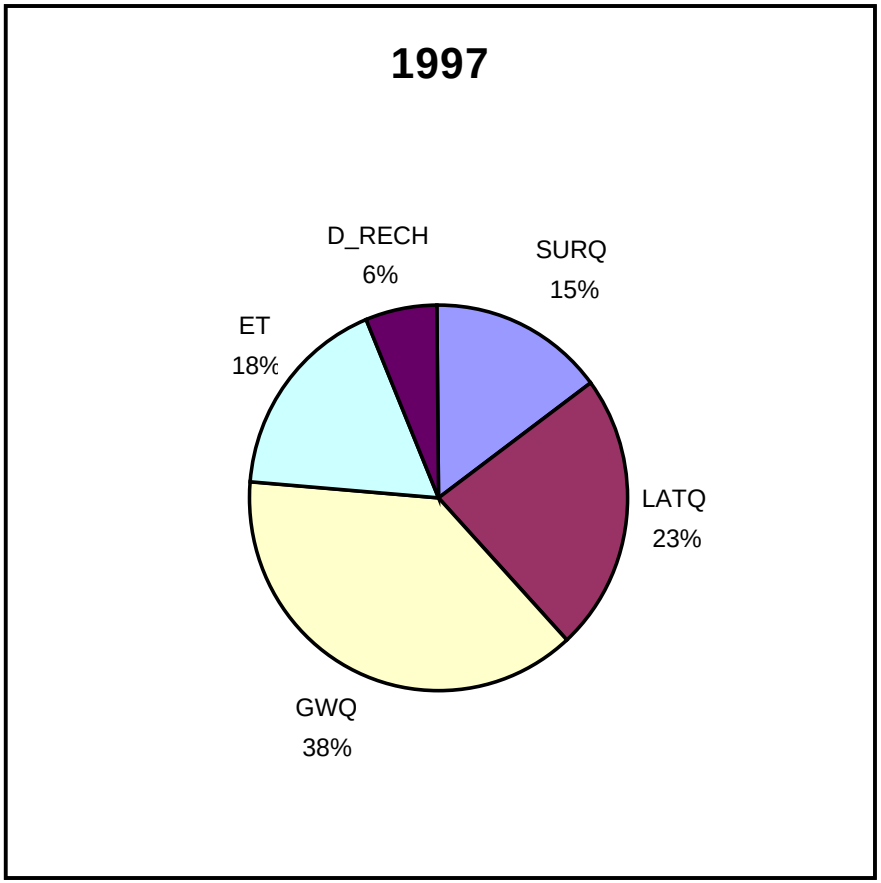

10 days average river flow: Observed Vs Simulated
(Calibration Period)
NSE = 0.86, R² = 0.96
Discharge (m3/s)
300
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
10 days interval (Yr. 1998)
Observed flow (m3/s)
Simulated flow (m3/s)

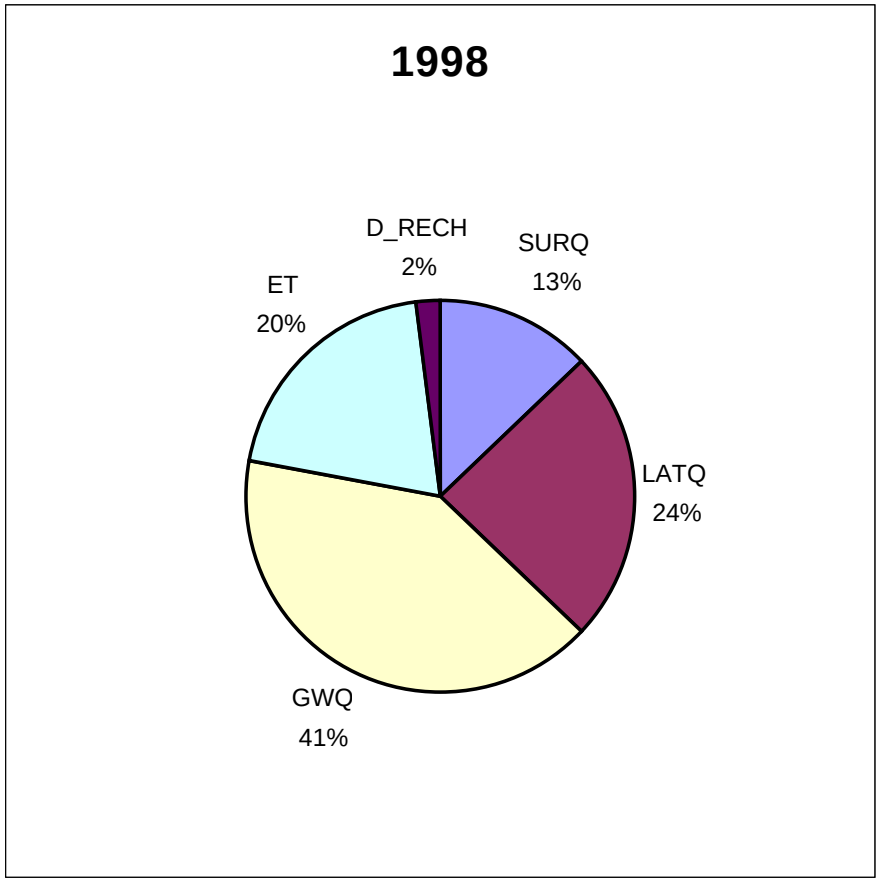

10 days average riverflow: Observed Vs Simulated
(Validation period)
NSE = 0.89, R² = 0.97
Discharge (m3/s)
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
10 days interval (Yr.2001)
Observed flow (m3/s)
Simulated flow (m3/s)


Lean flow: Observed Vs Simulated
Discharge (m3/s)
0
1
2
3
4
5
6
7
8
1997_Dry
1998_Dry
1999_Dry
2000_Dry
2001_Dry
2002_Dry
Season
Obseved
Simulated

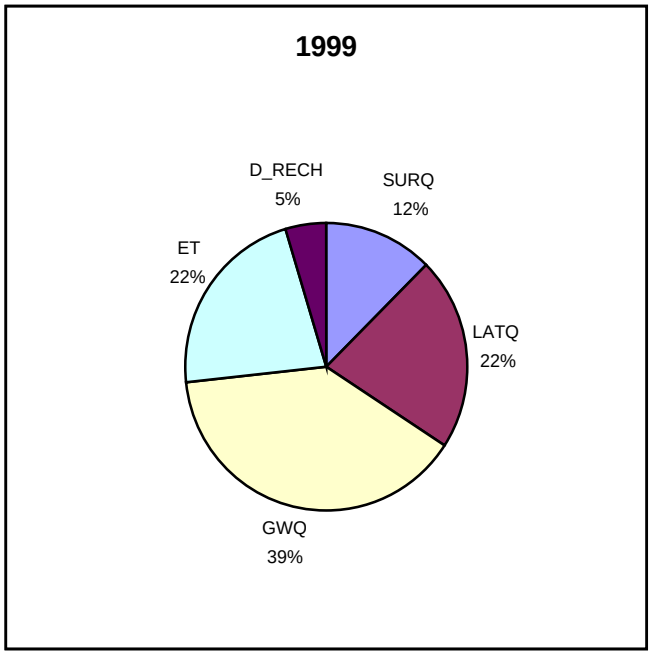

ET of Kunthipuzha: Water balance estimation Vs SWAT simulation
ET (mm)
0
200
400
600
800
1997
1998
1999
2000
2001
2002
Year
ET by Water balance
ET by SWAT

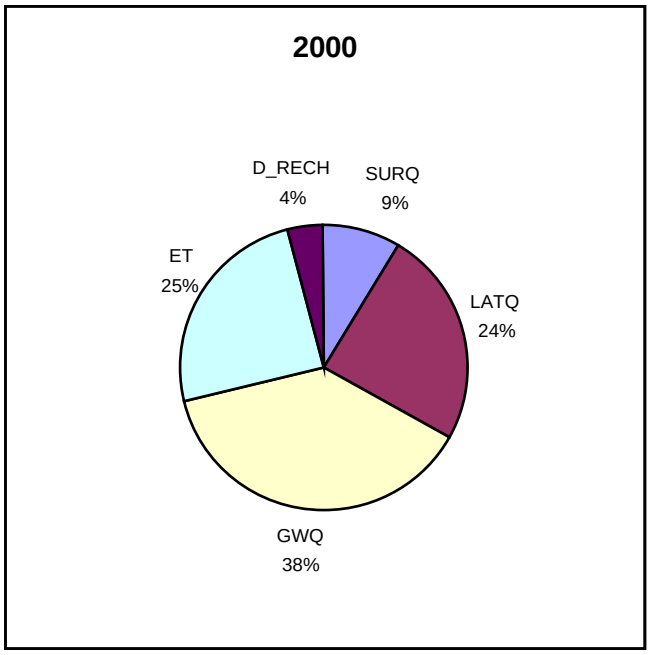
Application of the PBDM for basin level Water balance estimation

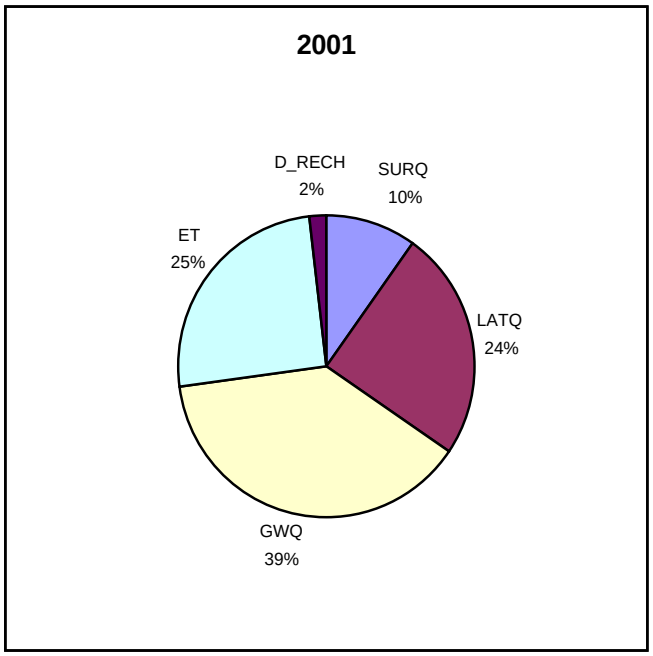


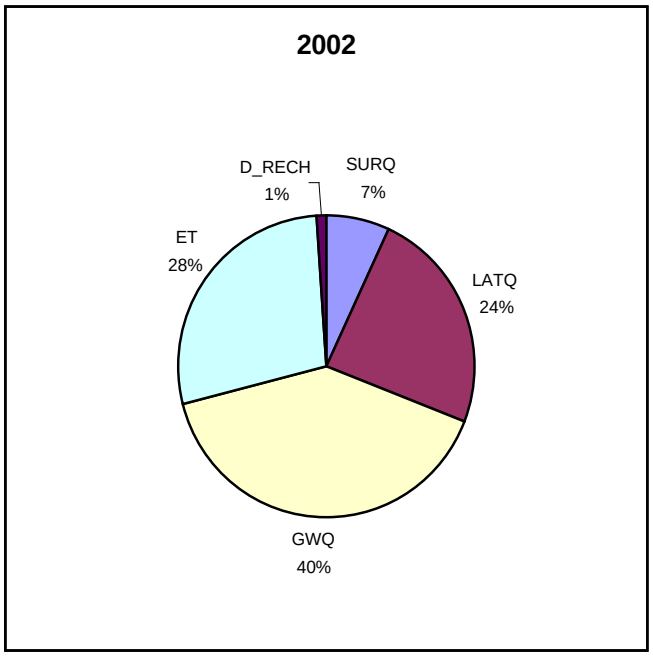


Application of the PBDM for basin level Water balance estimation









PBDM Applications: Physical characteristics of the sub watersheds

Subwater-shed No	Area (km2)	Mean elevation (m)	Mean slope (m/m)	Channel length (km)	Channel slope (m/m)
1	27.99	420.00	0.272	11.327	0.067
2	24.62	600.00	0.339	11.095	0.066
3	104.4	963.00	0.330	31.466	0.068
4	32.54	80.00	0.220	12.549	0.083
5	23.7	120.00	0.314	9.028	0.119
6	46.07	850.00	0.425	17.619	0.114
7	28.37	80.00	0.162	15.494	0.063
8	15.98	82.00	0.030	10.216	0.004
9	18.98	80.00	0.049	13.161	0.001
10	52.72	81.00	0.075	16.898	0.025
11	2.26	62.00	0.042	2.905	0.017
12	3.78	120.00	0.068	3.664	0.023
13	21.74	120.00	0.085	11.140	0.034
14	61.01	62.00	0.047	15.251	0.007
15	8.11	62.00	0.057	6.891	0.003
16	39.93	60.00	0.048	12.243	0.002
17	23.32	35.00	0.079	10.633	0.006
18	20.55	90.00	0.109	8.714	0.046
19	102.31	40.00	0.080	22.956	0.006
20	30.5	60.00	0.038	3.377	0.012

Water demand Vs availability during the 5 summer months

Sub watershed no	Total_demand (m3)	Availability (m3)	Water shortage as % of demand
1	419620	0	-100
2	367750	0	-100
3	3292095	0	-100
4	597370	1012684	70
5	1768505	0	-100
6	5579685	0	-100
7	1257650	1443761	15
8	1205670	766151	-36
9	1026330	980219.2	-4
10	2258955	2651683	17

Conclusions

1. For Kunthipuzha basin, the major river flow component is base flow which amounts to 40% of annual average rainfall and 52% of the total river flow
   - High baseflow is resulting from the high infiltration rates and the large amount of shallow aquifer recharge.
   - inference match with experience and infiltration studies with infiltrometers (IR > 15 to 25 cm/h)
2. The second major flow component is lateral flow with a rainfall fraction of 23% and a river flow fraction of 30%
   - High infiltration rate and high land slope will lead to high lateral flow
3. Surface runoff fraction is 12% and 16% respectively
   - It matches with the observation; from vegetated area SUR_Q is very less
4. Deep aquifer recharge is very less
   - It is justified by the nature of impervious layer seen in Kerala
   - It gives an insight to Kerala's poor potential of deep groundwater
5. 20 to 25% of annual rainfall is lost as ET
   - It shows the state has enough surplus to meet various requirements, provided the resources is conserved and utilised properly

Conclusions (contd)

6. Between the years, there is marked variation in surface runoff and evapotranspiration
   - This may be mainly due to the variations in rainfall pattern
   - High rainfall can increase SUR_Q and ET, and it is observed so.
7. Base flow remains more or less uniform between the years
   - Slow response of the base flow may be the reason for its uniform behaviour
8. Watershed has good potential of shallow groundwater
9. Availability of shallow groundwater can be prolonged by subsiding the flow rate of baseflow through appropriate interventions
10. Total water yield from subbasins and HRUs are not varying significantly

Conclusions (contd)

11. There is significant variations for the water balance components between the subbasins and between the HRUs.
12. Hence, insitu and semi exsitu water conservation measures should look into micro level water balance.