Modelling Stream Flow Rate and Sediment Concentration for Seonath Sub-basin using ArcSWAT Model

By

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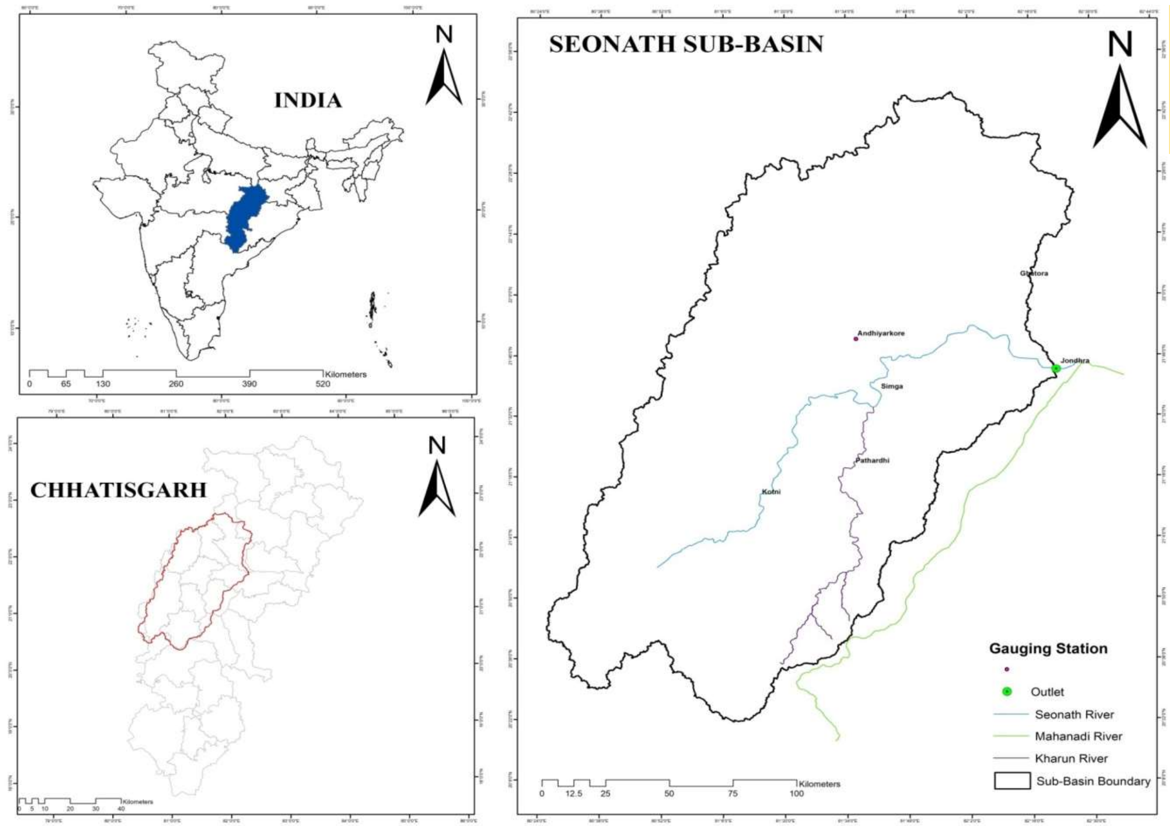
- **Hydrological modeling is necessary for design of conservation measure to reduce the ill effects of sedimentation and to identify critical watershed for implanting watershed management programmes with limited financial resources.**

- **Numerous models including ANSWERS, CREAMS, EPIC, SHE, AGNPS, SWRRB, SWMM, ROTO, SWIM and SWAT have been developed to predict runoff, erosion, sediment yield and nutrient losses from agricultural watersheds under various management regimes.**

- **Among these models, the Soil and Water Assessment Tool (SWAT) is one of the most recently developed distributed parameter hydrologic model used successfully for simulating runoff, sediment yield and water quality of small watershed.**



Location map of the Study Area

- The Seonath sub-basin is the part of upper Mahanadi basin.
- The Seonath river is the longest tributary of the Mahanadi basin.
- The main tributaries of Seonath river basin are Tandula, Kharun, Arpa, Hamp, Agar and Maniyari rivers.

Originate: near village Markaskasa of Maharashtra State near Chhattisgarh Border	
Longitude and Latitude	**80° 25’ to 82° 35’ E and 20° 16’ to 22° 41’ N**
Length of Seonath Sub-Basin (Km)	**380**
Catchment Area (km^2)	**29,638.9 km^2 (25 % of Mahanadi basin)**
Average Annual Rainfall (mm)	**1005 - 1255**
Average Elevation (m) from MSL	**201 to 1140**
No. of Hydrological Observation Stations	**15**
No. of Sediment Observation Stations	**6**

Districts covered under Seonath sub-basin

S.No.	Name of the District	State	Area (km^2)	% Area
1	Balod	*Chhattisgarh*	3,342.49	11.3
2	Balodabazar		1,794.59	6.1
3	Bemetra		2,864.44	9.7
4	Bilaspur		3,651.69	12.3
5	Dhamtari		554.02	1.9
6	Durg		2,271.42	7.7
7	***Kanker***		***85.86***	***0.3***
8	Kawardha		3,590.50	12.1
9	Korba		620.29	2.1
10	Mungeli		2,775.79	9.4
11	Raipur		2,006.52	6.8
12	***Rajnandgaon***		***5,705.42***	***19.2***
13	Gondia	*Maharashtra*	3,75.90	1.3
Total Area			29,638.9	100

ArcSWAT - SOIL AND WATER ASSESSMENT TOOL

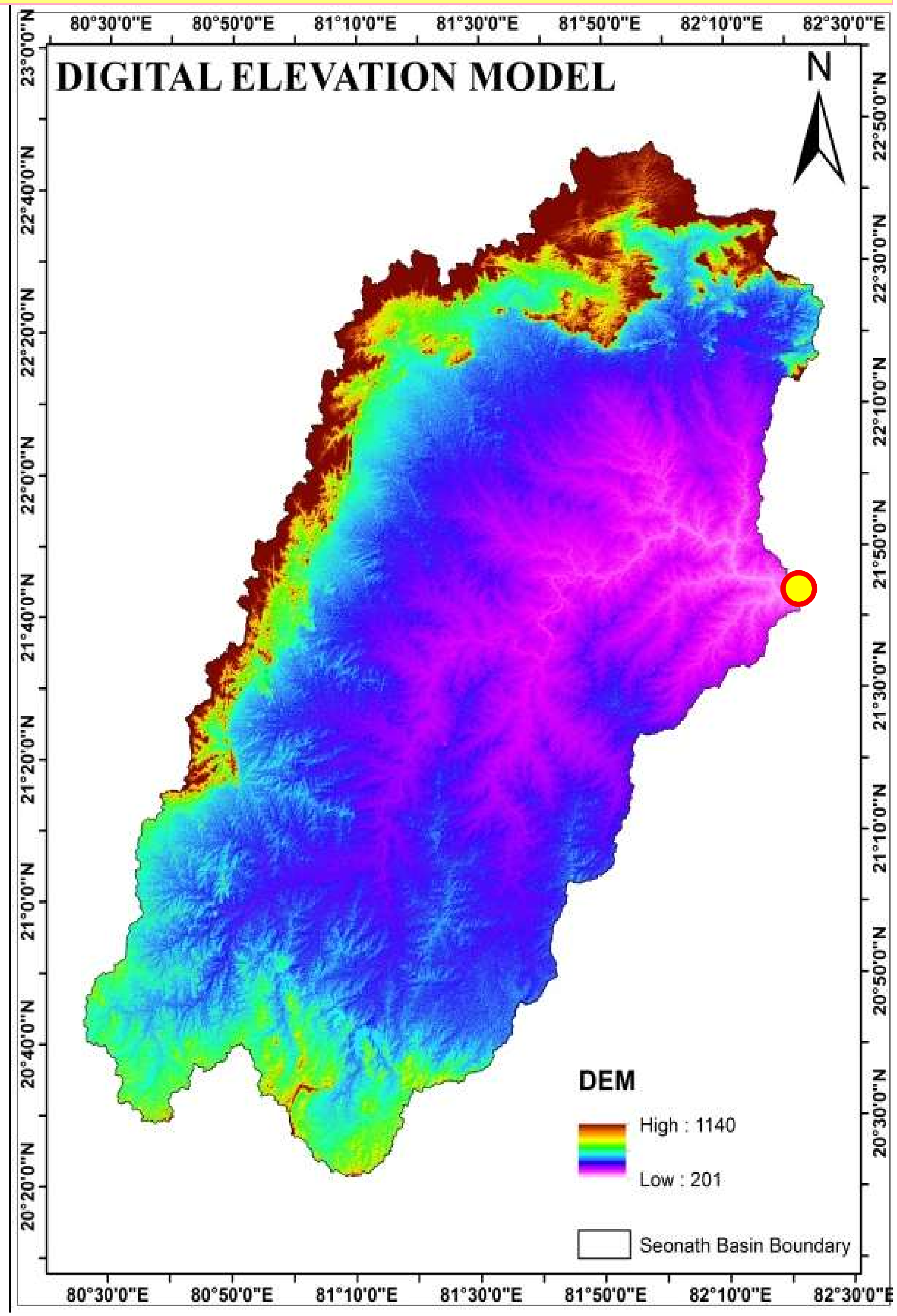
- The Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998) is a continuous time, hydrological model used for river basin, catchments or watershed modelling. ArcSWAT is the interface of Arc GIS and SWAT

- A model was developed by merging SWRRB and ROTO into one basin scale model called SWAT. This is one of the most widely used distributed parameter hydrologic models for large scale basin.

- The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. are directly modelled by ArcSWAT.

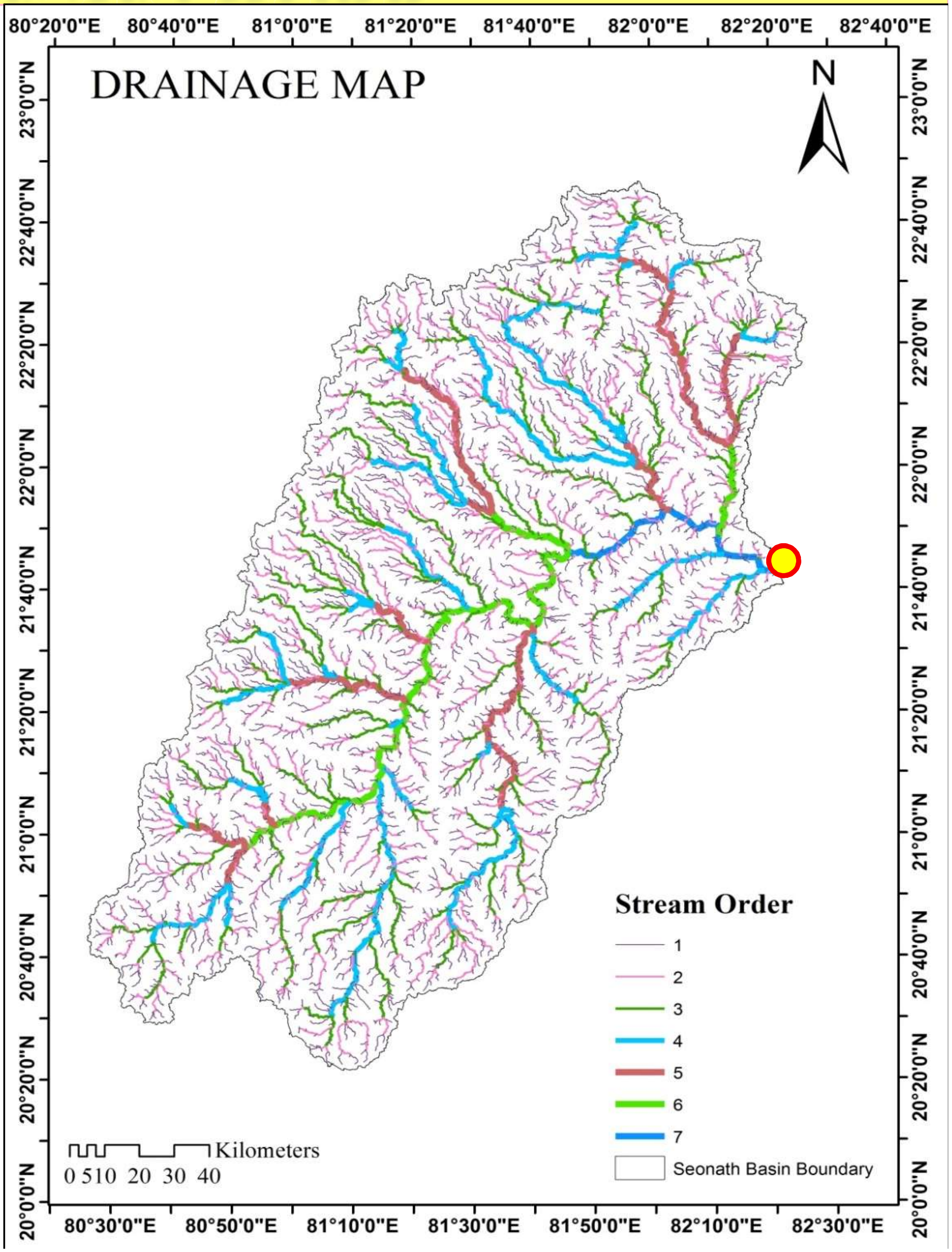
DIGITAL ELEVATION MODEL (DEM)

Product specifications	
Projection	Geographic
Horizontal Datum	WGS84 (World Geodetic System)
vertical Datum	EGM96 (Earth Gravitational model 1996)
Vertical Units	Meter
Spatial Resolution	SRTM 1 arc-second for global coverage (30 m)
Raster Size	1 degree tiles



DRAINAGE NETWORK

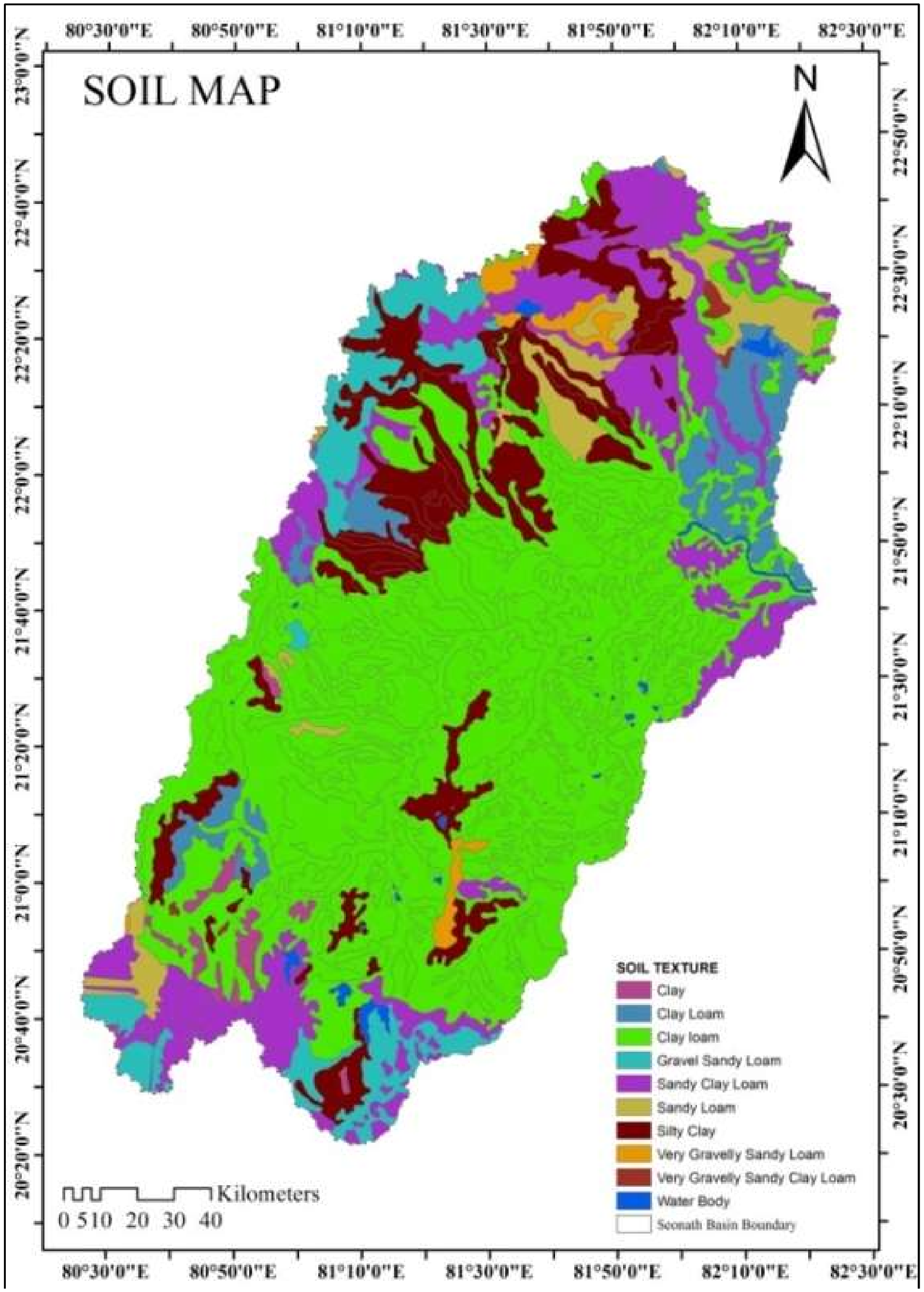
Stream Order	Number of Streams
1	3245
2	1498
3	863
4	457
5	216
6	147
7	60
Total	6486



SOIL MAP OF SEONATH SUB-BASIN

Data procured from the **10 Km²** grids from National Bureau of Soil Survey and Land Use Planning **(NBSS and LUP), Nagpur..**

The shape files of the soil data were also collected from the, State Level **Nodal Agency (SLNA), Government of Chhattisgarh**



Physio-chemical properties of the soils in Seonath sub-basin

Soil texture	Soil description	Hydrologic Soil Group	Soil layer (mm)	Bulk density (gm cc^{-1})	Avail. water holding capacity (mm H_2O per mm soil)	Saturated hydraulic conductivity (mm hr^{-1})	Organic Carbon (%)	Clay (%)	Silt (%)	Sand (%)	Rock (%)	USLE K
Clay (CLAY)	Clay, Mixed, Hyperthermic, Lithic Ustochrepts	C	300	1.665	0.252	2.032	0.71	54.9	31.8	13.3	0	0.163
			900	1.71	0.2755	1.778	0.62	58.7	31.5	9.8	0	0.1775
			1750	1.765	0.3	2.286	0.46	63.45	28.35	8.2	0	0.202
Very Gravelly Sandy Loam (SYLM)	Loamy, Mixed, Hyperthermic , Lithic Ustochrepts	B	13	1.56	0.299	65.486	1.05	32.8	25.9	41.3	46	0.322
Gravelly Sandy Loam (GSCL)	Loamy-Skeletal, Kaolinitic, Hyperthermic, Typic Ustorthents	B	130	1.66	0.2	75.552	0.66	47.2	26.5	26.3	34	0.201
			400	1.7	0.18	42.809	0.46	51.3	24	24.7	36	0.198
Clay Loam (CYLM)	Fine-Loamy, Mixed, Hyperthermic, Typic Haplustalfs	C	250	1.575	0.171	1.778	0.55	47.15	29.75	23.1	0	0.1088
			900	1.665	0.204	1.27	0.35	50.35	27	22.65	0	0.1148
			1550	1.7	0.236	1.016	0.29	53.4	26	20.6	0	0.136
Silty Clay (SYCY)	Fine, Montmorillonitic, Hyperthermic, Typic Haplusterts	C	180	1.62	0.194	3.597	0.79	49.3	30.5	20.2	0	0.111
			620	1.65	0.215	3.551	0.51	52.5	30	17.6	0	0.103
			1000	1.7	0.226	3.505	0.41	55.3	30	14.7	0	0.094
Very Gravelly Sandy Clay Loam (VGSL)	Loamy-Skeletal, Kaolinitic, Hyperthermic, Typic Ustorthents	B	90	1.6	0.184	13.952	1.25	21.5	8.6	69.9	35	0.245
			350	1.62	0.182	8.001	0.95	24.9	9.2	65.9	0	0.235
Sandy Clay Loam (GSLM)	Fine-Loamy, Kaolinitic, Hyperthermic, Typic Haplustalfs	B	150	1.61	0.164	19.903	0.45	26.4	10	63.6	0	0.188
			750	1.625	0.185	10.9765	0.32	31.4	14.25	53.3	0	0.195
			1200	1.66	0.214	3.901	0.29	34.5	14	51.5	0	0.221
Sandy Loam (SCLM)	Fine, Mixed, Hyperthermic, Typic Ustochrepts	A	160	1.55	0.164	108.295	0.68	18.5	8.4	73.1	0	0.516
			750	1.595	0.175	59.1805	0.57	26	10.3	63.7	0	0.4365
			1350	1.61	0.224	22.667	0.45	30.2	9.6	60.2	0	0.446

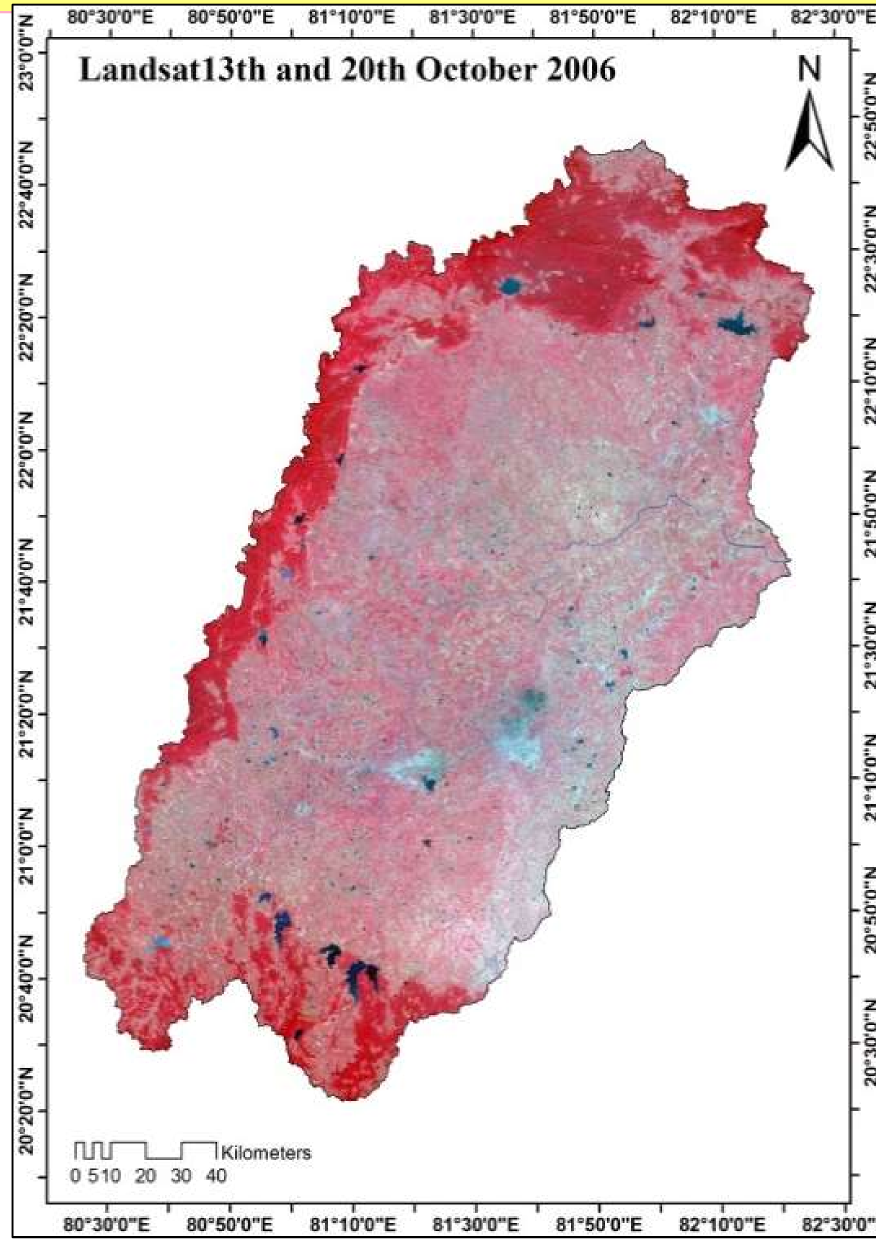
LANDSAT 7 IMAGERY

Features of Landsat 7

Launch Date	**15 April 1999, at Vandenberg Air Force Base in California**
Spatial Resolution	30 meters
Orbit	705 ± 5 km (at the equator) sun-synchronous
Orbit Inclination	98.2 ± 0.15
Orbit Period	98.9 minutes
Grounding Track Repeat Cycle	16 days (233 orbits)
Resolution	15 to 90 meter
Date of Image	13th October 2006 and 20th October 2006

Resolution of bands of Landsat 7

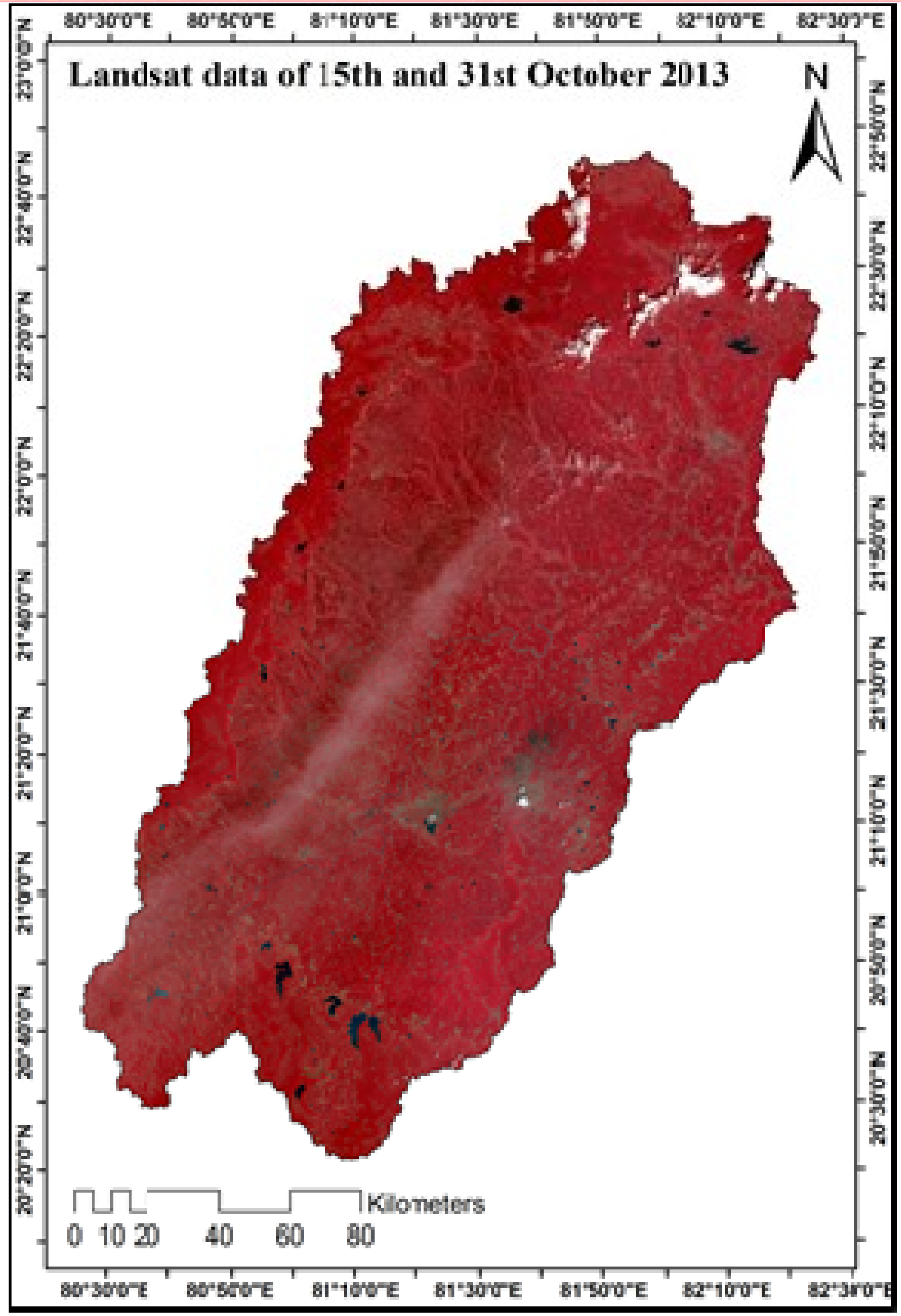
Landsat-7	Wavelength, micrometres	Resolution (m)
Band 1 (Blue)	0.45-0.52	30
Band 2 (Green)	0.52-0.60	30
Band 3 (Red)	0.63-0.69	30
Band 4 Near Infrared (NIR)	0.77-0.90	30
Band 5 Shortwave Infrared (SWIR) 1	1.55-1.75	30
Band 6 Thermal	10.40-12.50	60 * (30)
Band 7 Shortwave Infrared (SWIR) 2	2.09-2.35	30
Band 8 (Panchromatic)	0.52-0.90	15



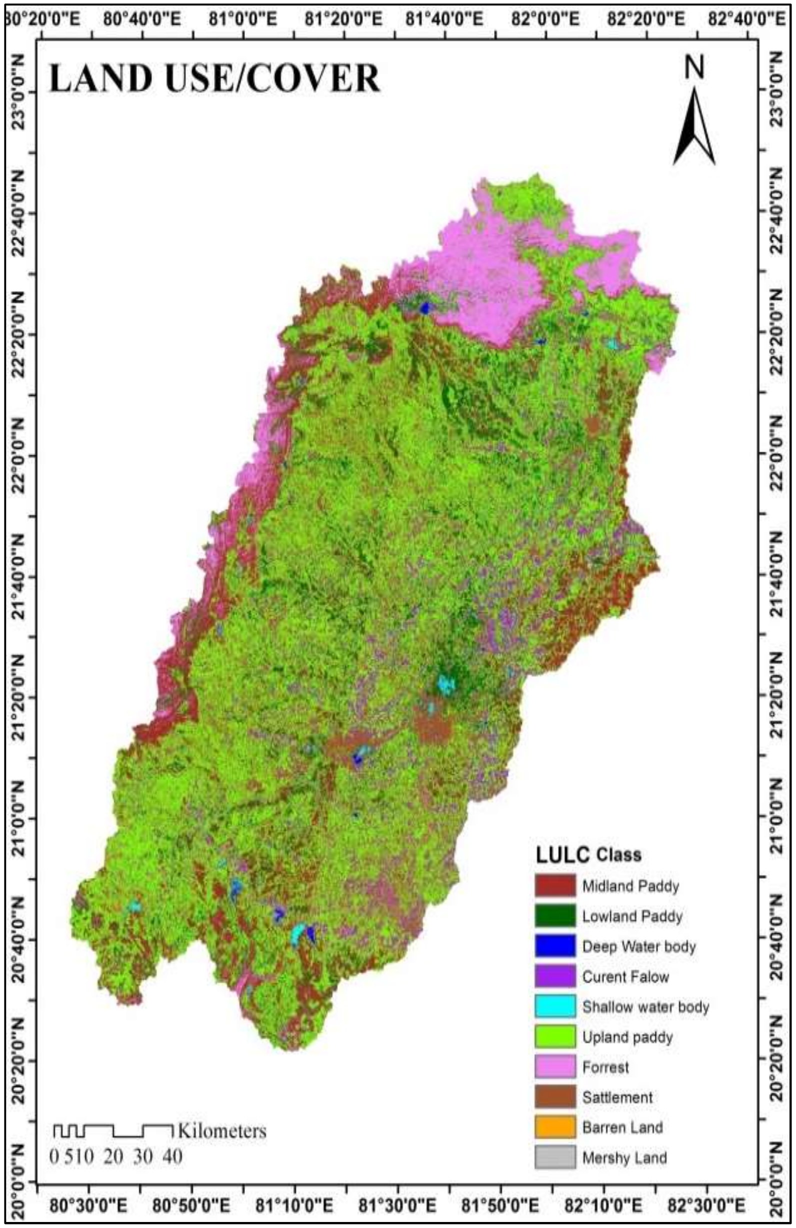
LANDSAT 8 OPERATIONAL LAND IMAGER (OLI) AND THERMAL INFRARED SENSOR (TIRS)

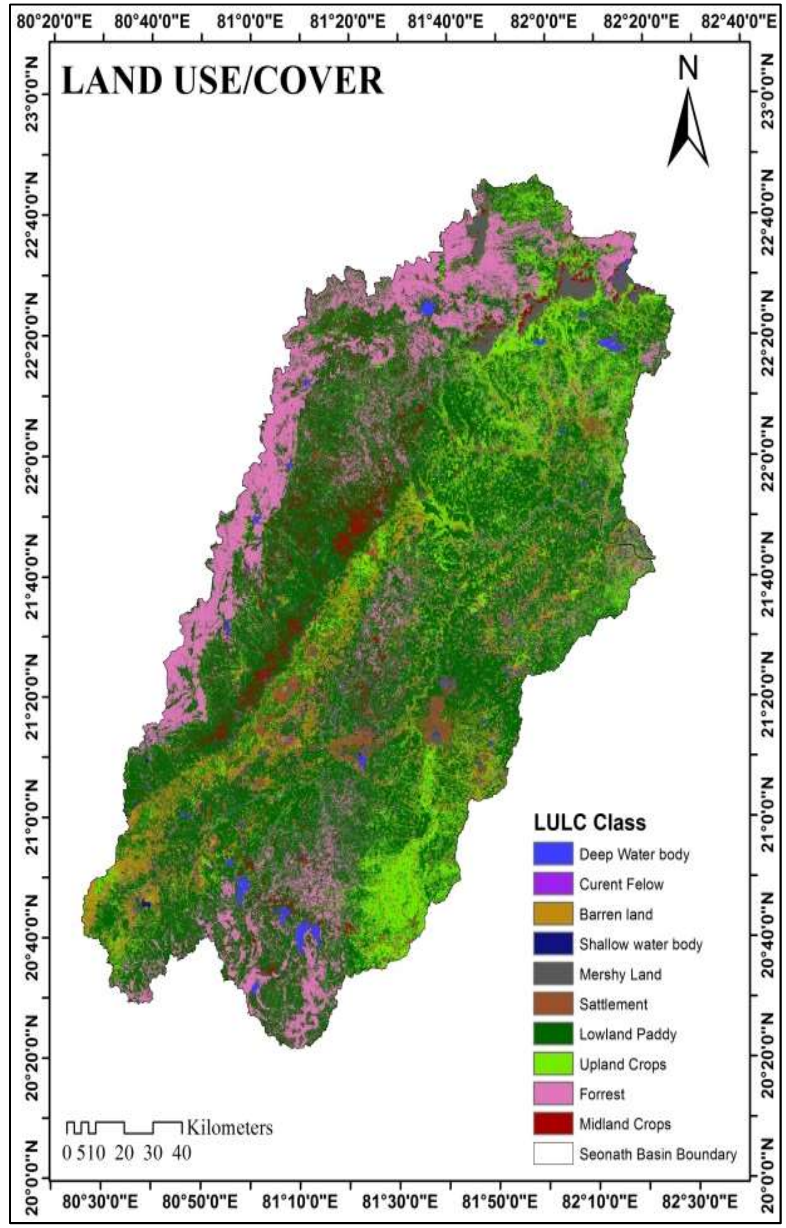
Date of Image :
15th October 2013 and 31st October 2013

Landsat-8	Wavelength (micrometres)	Resolution (m)
Band 1 (Ultra blue)	0.45-0.52	30
Band 2 (Blue)	0.52-0.60	30
Band 3 (Green)	0.63-0.69	30
Band 4 (Red)	0.77-0.90	30
Band 5 Near Infrared (NIR)	1.55-1.75	30
Band 6 Shortwave Infrared (SWIR) 1	10.40-12.50	60
Band 7 Shortwave Infrared (SWIR) 2	2.09-2.35	30
Band 8 (Panchromatic)	0.52-0.90	15
Band 9 (Cirrus)	1.36 - 1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)



LAND USE/COVER (LULC) MAP (2006 and 2013)





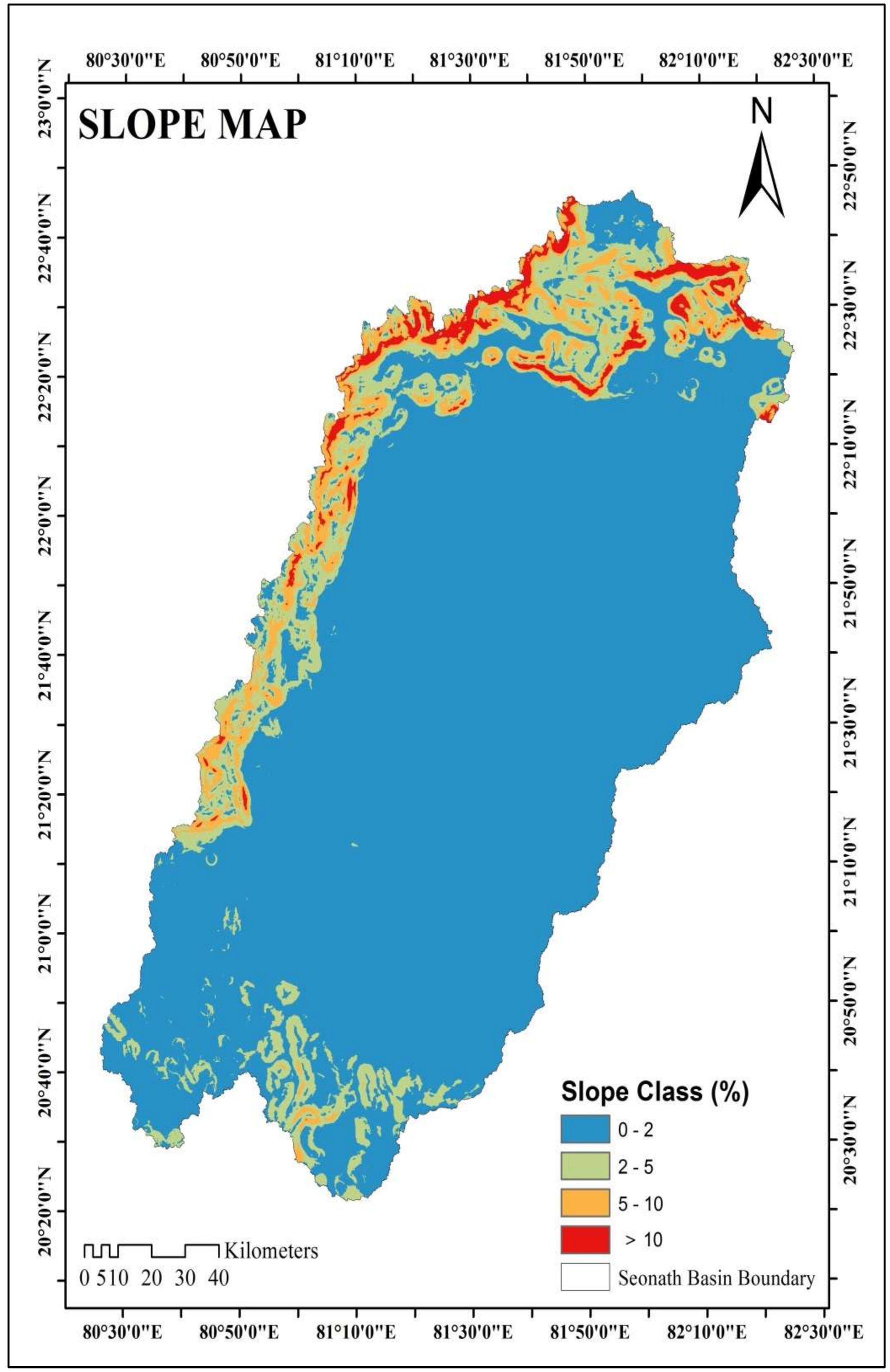
Pixel based land use/cover classification of False Colour Composite (FCC) of Landsat satellite

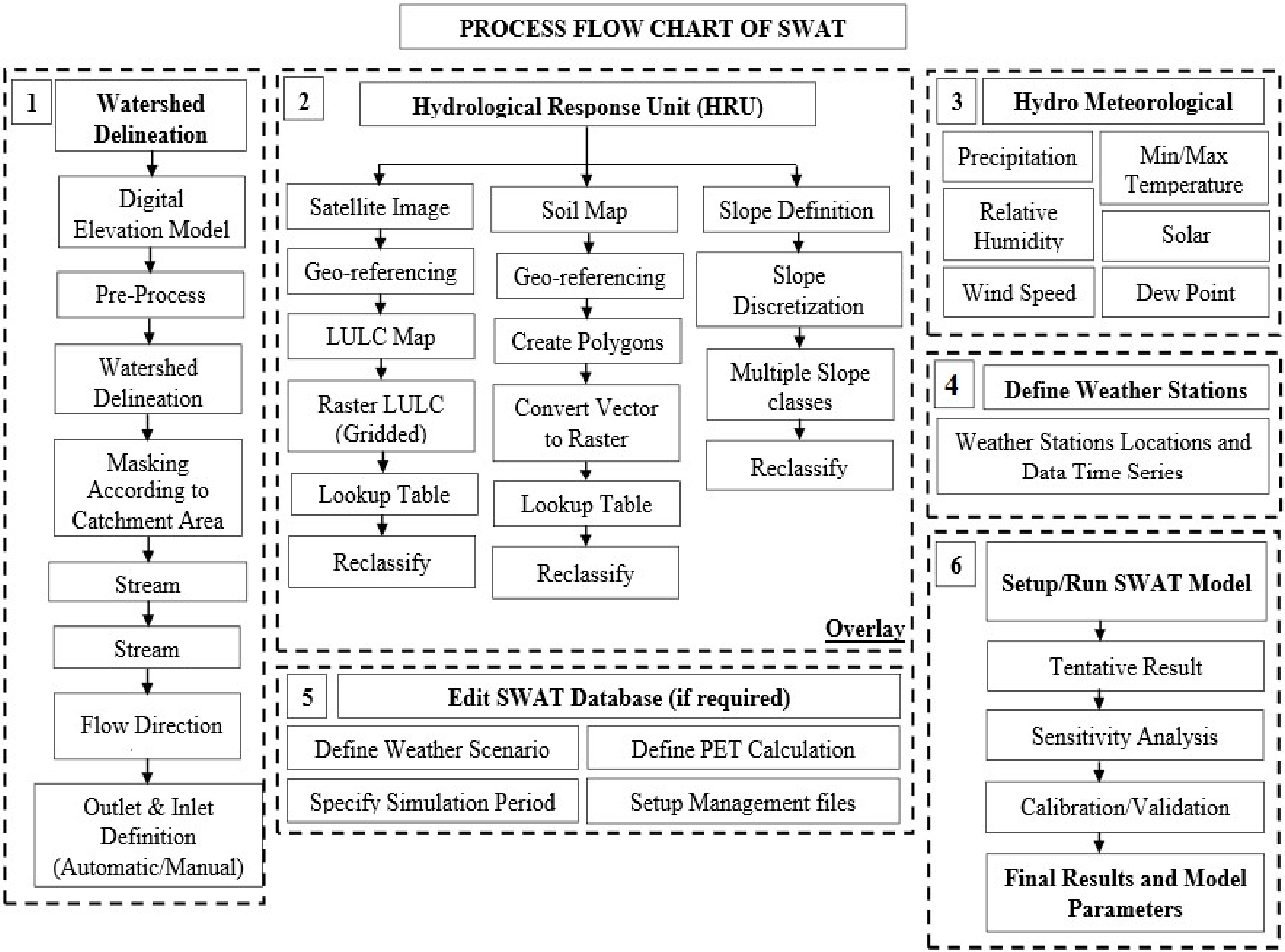
Pixel Based classification					
Land Use Classes	**2006**		**2013**		**% Change**
	Area (ha)	% Area	Area (ha)	% Area	
Barren Land	20054.3	0.68	38530.1	1.30	0.62
Current Fallow	208291.7	7.03	87730.0	2.96	-4.07
Deep Water body	8409.8	0.28	35566.2	1.20	0.92
Forrest	***234802.6***	***7.92***	***198577.9***	***6.70***	***-1.22***
Lowland Paddy	313663.6	10.58	355662.0	12.00	1.42
Marshy Land	1815.7	0.06	1185.5	0.04	-0.02
Midland Paddy	497876.8	16.80	385300.5	13.00	-3.80
Settlement	***418760.4***	***14.13***	***563131.5***	***19.00***	***4.87***
Shallow Water body	30755.2	1.04	53349.3	1.80	0.76
Upland Paddy	1229420.1	41.48	1244817.0	42.00	0.52

Mean Monthly (2003 - 13) Observed Weather Data of Seonath Sub-basin

Climatic parameters	Statistical variables	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	Mean	3.98	2.4	2.82	2.52	2.1	26.1	56.7	48.2	32.4	7.33	3.1	0.8
	Standard deviation	2.78	2.3	2.17	2.33	2.3	14.9	19.4	18.4	13.1	4.81	1.7	1.1
	Skewness	2.64	3.1	3.43	3.69	3.4	3.08	2.31	2.86	2.88	3.86	2.5	1.8
Maximum temperature (°C)	Mean	26.6	30	35.2	39.1	40	35.0	29.9	29.0	29.6	29.6	28	26
	Standard deviation	2.40	3.0	3.07	3.28	3.3	4.49	1.82	1.50	1.44	1.62	1.4	1.8
Minimum Temperature (°C)	Mean	12.3	15	20.3	24.3	27	26.1	24.2	23.7	23.2	19.8	16	13
	Standard deviation	2.58	2.6	2.50	2.21	1.9	2.13	1.17	1.23	1.09	2.43	2.5	2.3
Average number of rainy days		1.83	2.3	2.46	2.45	3.3	11.7	19.6	18.8	12.5	3.99	1.2	0.9
Average wind velocity (m/s)		1.84	2.0	2.23	2.62	3.0	3.52	3.29	2.89	2.23	1.65	1.5	1.6
Average solar radiation ($MJ/m^2/day$)		16.9	19	22.7	24.5	24.	18.3	14.3	13.9	17.1	18.5	17	16

Slope (%)	Area (ha)	Area (ac)	% area
0-2	528187.2	1305177.1	41.6
2 - 5	1232811.5	3046338.8	26.5
5 - 10	786381.8	1943188.7	17.8
>10	416516.6	1029233.4	14.1




PROCESS FLOW CHART OF SWAT
1
Watershed Delineation
Digital Elevation Model
Pre-Process
Watershed Delineation
Masking According to Catchment Area
Stream
Stream
Flow Direction
Outlet & Inlet Definition (Automatic/Manual)
2
Hydrological Response Unit (HRU)
Satellite Image
Geo-referencing
LULC Map
Raster LULC (Gridded)
Lookup Table
Reclassify
Soil Map
Geo-referencing
Create Polygons
Convert Vector to Raster
Lookup Table
Reclassify
Slope Definition
Slope Discretization
Multiple Slope classes
Reclassify
Overlay
3
Hydro Meteorological
Precipitation
Min/Max Temperature
Relative Humidity
Solar
Wind Speed
Dew Point
4
Define Weather Stations
Weather Stations Locations and Data Time Series
5
Edit SWAT Database (if required)
Define Weather Scenario
Define PET Calculation
Specify Simulation Period
Setup Management files
6
Setup/Run SWAT Model
Tentative Result
Sensitivity Analysis
Calibration/Validation
Final Results and Model Parameters

The SWAT model is based on the water balance equation

$$SW_t = SW_o + \sum_{i=1}^{t} \left(R_{day} - Q_{surf} - ET_a - P_{seep} - QR_{gw} \right)$$

Where,

SW_t = Final soil water content, mm

SW_o = Initial soil water content, mm

t = time (days)

R_{day} = Precipitation on day i, mm

Q_{surf} = Surface runoff on day i, mm

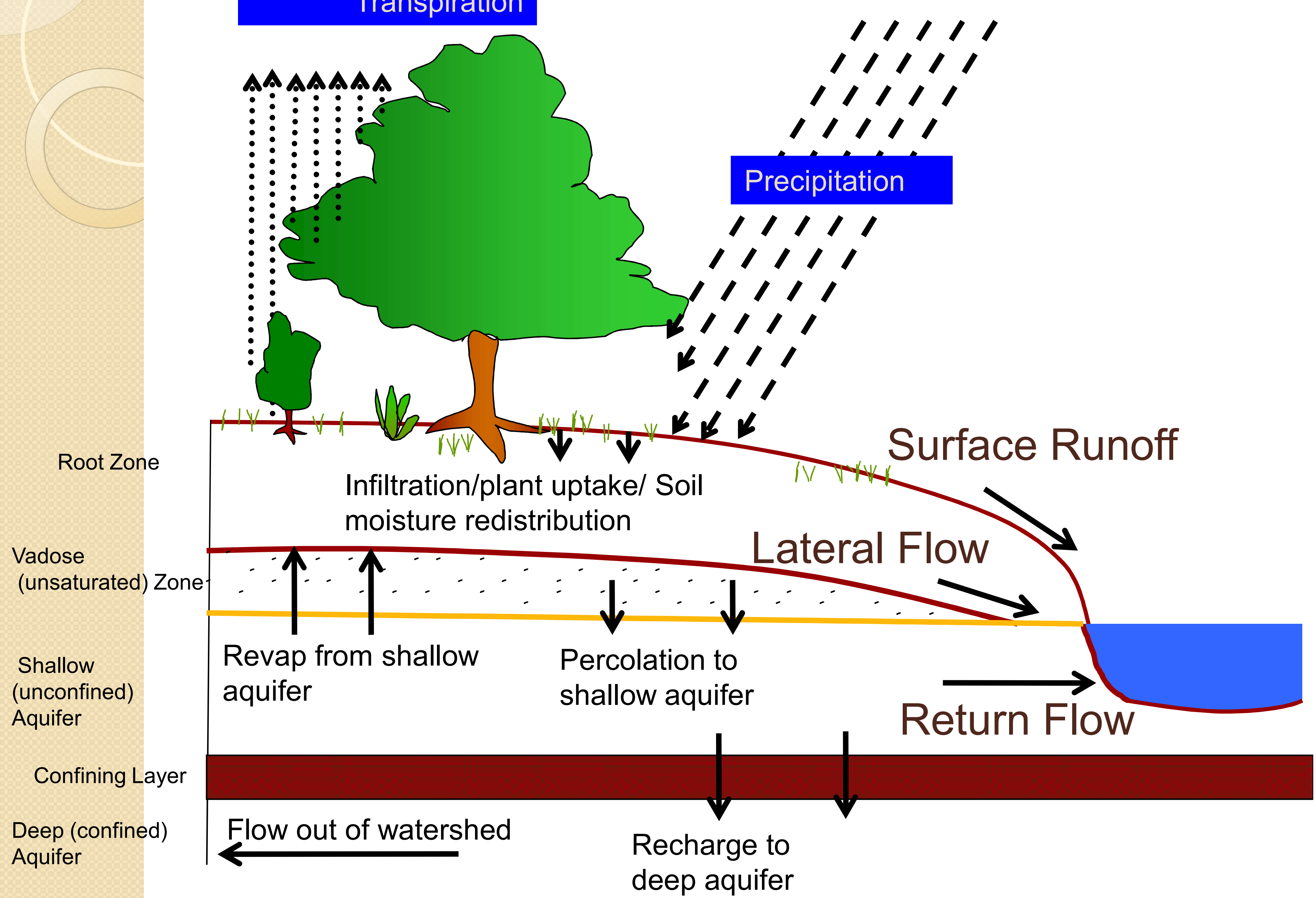
ET_a = Evapotranspiration on day i, mm

P_{seep} = amount of water entering vadose zone on day i, mm

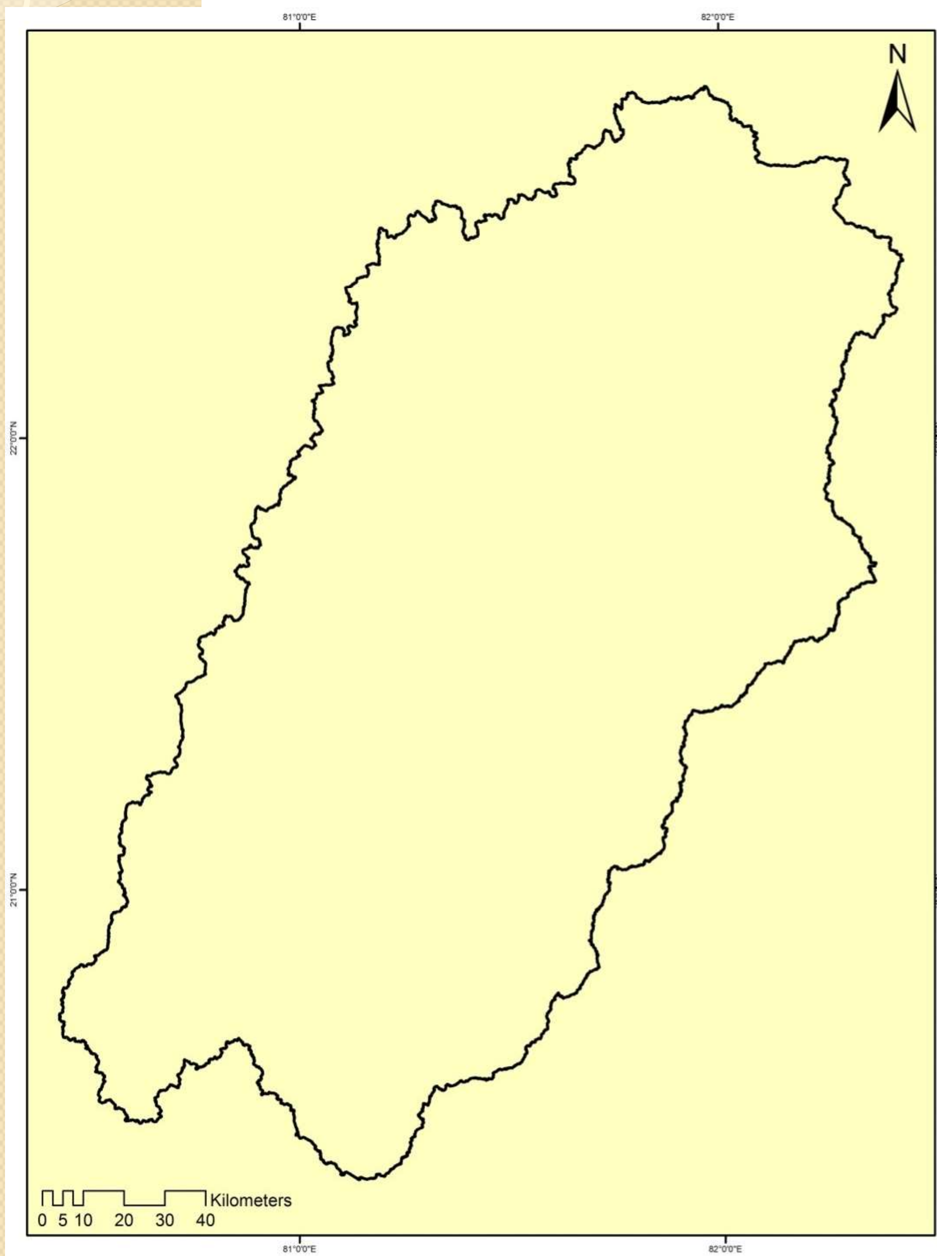
QR_{gw} = Return flow on day i, mm

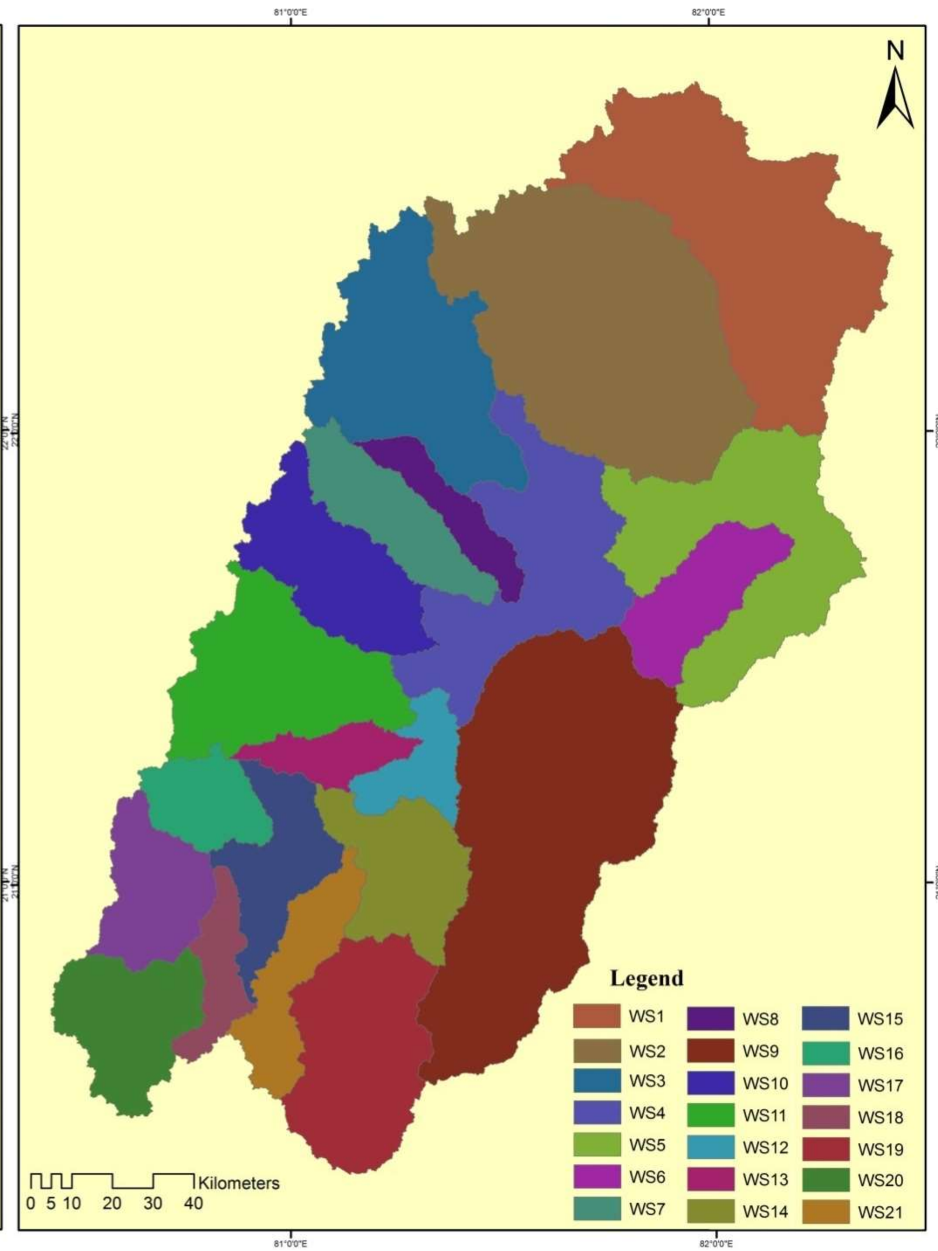
ArcSWAT

Hydrologic Balance



SEONATH SUB-BASIN AND WATERSHED DELINEATION





WATERSHED WISE INFORMATION OF SEONATH SUB-BASIN

Watersheds	Area (km^2)	Perimeter (km)	Elevation (m)			Total Relief (m)
			Max	Min	Avg	
WS1	3154.6	561.9	1140.0	211.0	675.5	929.0
WS2	3832.9	533.2	1031.0	232.0	631.5	799.0
WS3	2002.7	432.6	977.0	259.0	618	718.0
WS4	1871.3	583.4	325.0	218.0	271.5	107.0
WS5	2009.7	589.8	329.0	201.0	265	128.0
WS6	786.1	245.8	323.0	225.0	274	98.0
WS7	813.4	275.5	887.0	254.0	570.5	633.0
WS8	444.6	236.6	415.0	252.0	333.5	163.0
WS9	***4148.6***	***582.0***	***453.0***	***212.0***	***332.5***	***241.0***
WS10	1177.7	330.5	813.0	263.0	538	550.0
WS11	1627.5	365.9	811.0	268.0	539.5	543.0
WS12	463.9	238.0	345.0	243.0	294	102.0
WS13	***408.2***	***204.5***	***456.0***	***268.0***	***362***	***188.0***
WS14	966.7	299.1	358.0	268.0	313	90.0
WS15	806.2	322.9	488.0	275.0	381.5	213.0
WS16	563.1	182.5	761.0	285.0	523	476.0
WS17	818.1	235.1	523.0	301.0	412	222.0
WS18	418.5	228.8	493.0	292.0	392.5	201.0
WS19	1595.3	313.9	701.0	289.0	495	412.0
WS20	988.5	261.4	594.0	306.0	450	288.0
WS21	741.5	306.2	646.0	284.0	465	362.0

Criteria for Model Evaluation

1. The Coefficient of Determination (r^2)

$$r^2 = \left\{ \frac{\sum_{i=1}^{N} \left(Y_i^{obs} - Y_{mean}^{obs}\right)\left(Y_i^{sim} - Y_{mean}^{sim}\right)}{\left[\sum_{i=1}^{N} \left(Y_i^{obs} - Y_{mean}^{obs}\right)\right]0.5 \left[\sum_{i=1}^{N} \left(Y_i^{sim} - Y_{mean}^{sim}\right)2\right]0.5} \right\}^2$$

2. Nash-Sutcliffe Efficiency (E_{NS})

$$E_{NS} = 1 - \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_{mean}^{obs}\right)^2} \right]$$

3. Index of Agreement (d)

$$d = 1 - \frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(IY_i^{sim} - Y_{mean}^{obs} I + IY_i^{obs} - Y_{mean}^{obs} I\right)^2}$$

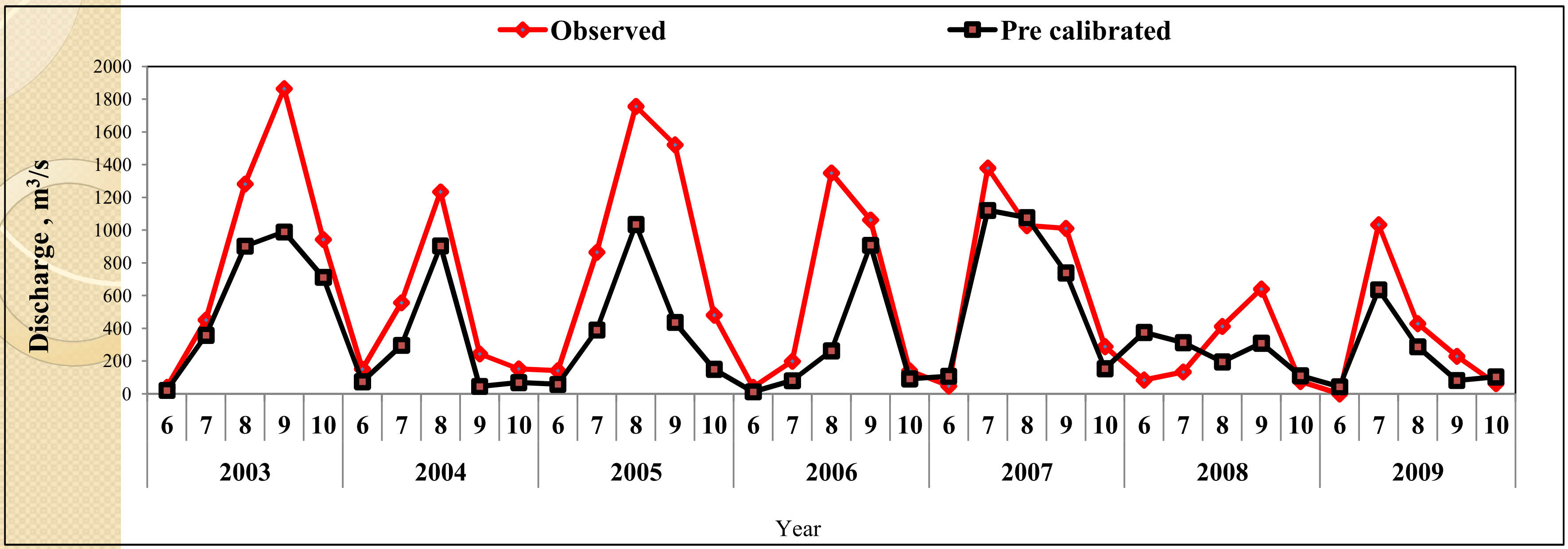
4. Modified Nash-Sutcliffe Coefficient (E_{NS}) and Index of Agreement (d)

$$E_j = 1 - \frac{\sum_{i=1}^{n} \left|Y_i^{obs} - Y_i^{sim}\right|^i}{\sum_{i=1}^{n} \left|Y_i^{obs} - Y_{mean}^{obs}\right|^i} \quad with\ j \in N$$

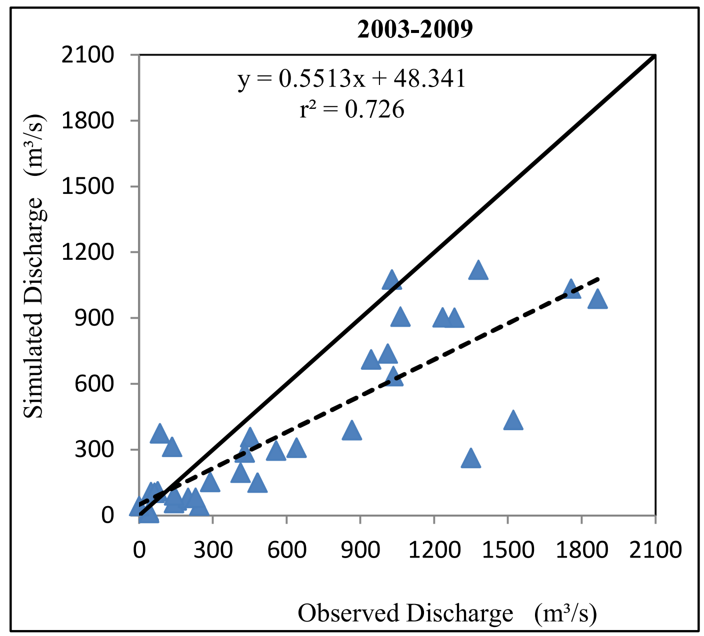
$$d_j = 1 - \frac{\sum_{i=1}^{n} \left|Y_i^{obs} - Y_i^{sim}\right|^i}{\sum_{j=1}^{n} \left(\left|Y_i^{obs} - Y_{mean}^{obs}\right| + \left|Y_i^{obs} - Y_{mean}^{obs}\right|\right)^i} \quad with\ j \in N$$

5. Percent Bias

$$PBIAS = \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right) \times 100}{\sum_{i=1}^{n} \left(Y_i^{obs}\right)} \right]$$



Statistical parameters	2003 - 2009	
	Observed	Simulated
Mean	609.61	384.44
Maximum	1864.74	1121.00
SD	556.92	360.29
Count	35	35
r^2	0.726	
Nass-Sutclif Efficency (E_{NS})	0.540	
Index of Agreement (d)	0.862	
PBIAS	36	
Modified E_{NS}	0.480	
Modified Index of Agreement (d)	0.730	



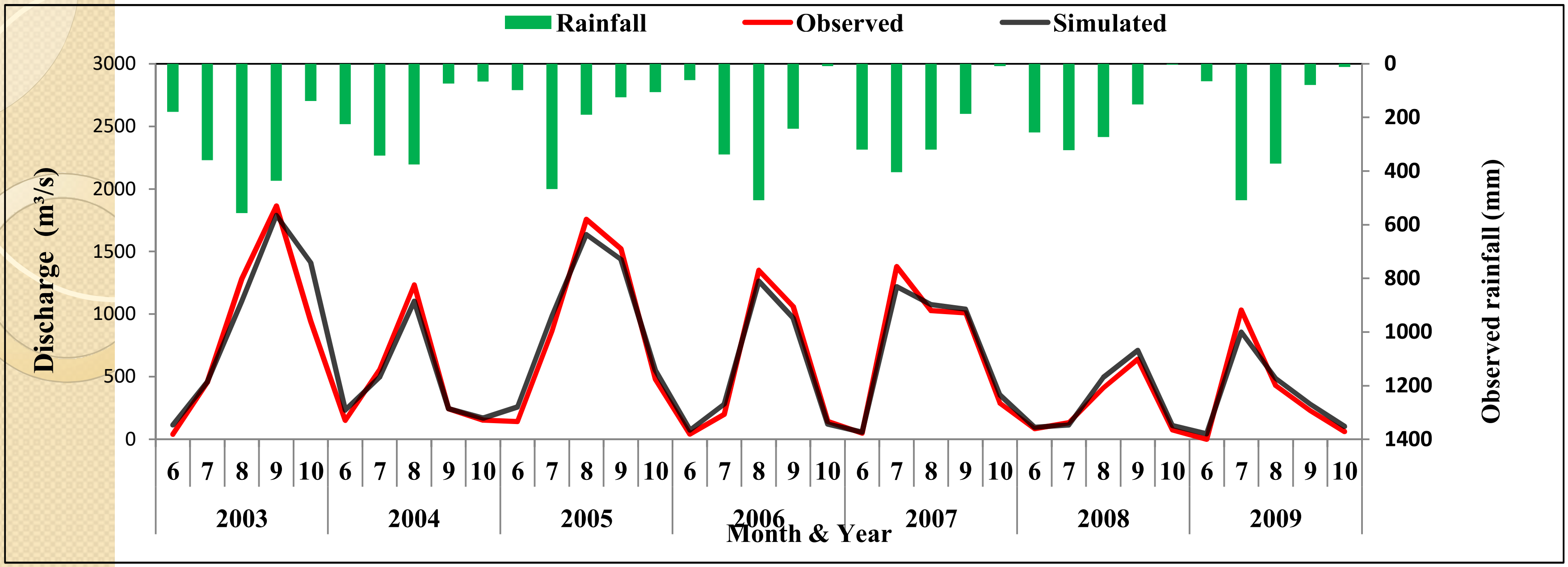
Statistical analysis of observed and Pre-calibrated simulated monthly discharge (m^3/s)

Results of sensitivity analysis

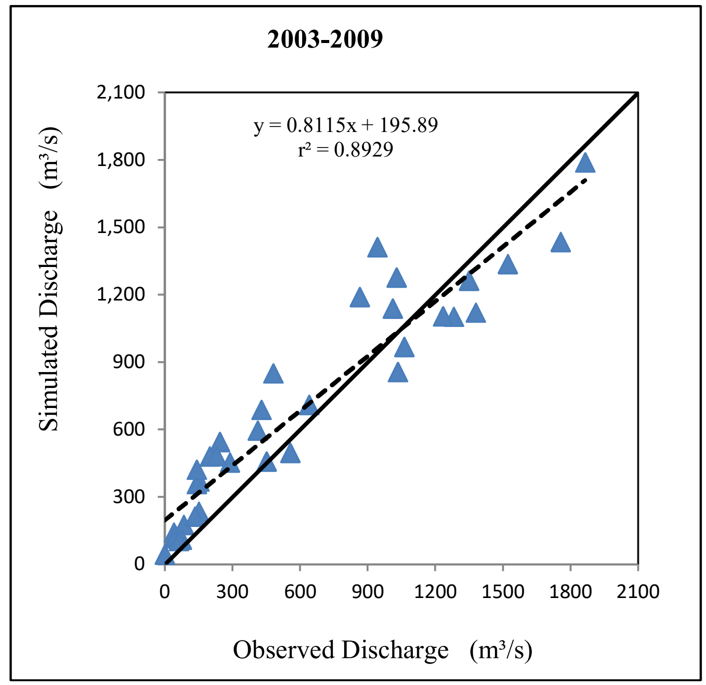
Rank	Name	Description	Lower Bound	Upper Bound	Process
1.	CN	SCS discharge CN for moisture condition II	25	98	Discharge
2.	ALPHA_BF	Base flow alpha factor (days)	0	1	Groundwater
3.	GW_ DELAY	Groundwater delay (days)	-30	90	Groundwater
4.	GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	-1000	1000	Groundwater
5.	ESCO	Soil evaporation compensation factor.	0	1	Flow
6.	EPCO	Plant evaporation compensation factor	0	1	Evaporation
7.	GW_ REVAP	Groundwater-revap coefficient	0	1	Flow
8	CH_N2	Manning coefficient for main channel	0	1	Channel
9	SOL_AWC	Available water capacity of the soil layer (mm/mm soil)	-25	25	Soil
10	RCHRG_DP	Deep aquifer percolation fraction	0	1	Groundwater
11	CH_K2	Hydraulic conductivity in main channel (mm/hrs)	1	150	Channel
12	OV_N	Manning "n" value for overland flow.	0.01	0.6	Discharge
13	SOL_Z	Soil depth	-25	25	Soil
14	SURLAG	Surface discharge lag time	0.05	24	Discharge
15	CANMX	Maximum canopy storage (mm)	0	10	Soil
16	BLAI	Maximum potential leaf area index	0	1	Crop
17	CH_K1	hydraulic conductivity for tributary	0	1	Soil
18	USLE_P	Support practice factor	0	1	Sediment
19	CH_COV	channel cover factor	0	1	Sediment
20	CH_EROD	Channel erodibility factor	0	1	Sediment
21	SPEXP	Exponent parameter for calculating sediment restrained in channel sediment routing.	1	1.5	Basin
22	BIOMIX	Biological mixing efficiency	0	1	Management
23	SOL_ALB	Soil albedo	-25	25	Evaporation

Calibrated parameter values

SI. No.	Parameter	Default values	Calibrated values
1	CN	Varies	6 % decrease for agricultural cover and 8 % decrease for forest and settlements
2	Alpha bf	0.0482	0.285
3	GW Delay	41	82
4	GWQMN	0	179
5	ESCO	0.85	0.61
6	EPCO	1	0.644
7	GWREVAP	0.02	0.034
8	CH_N2	0.014	0.024
9	SOL_AWC	Varies	8.95% increase
10	RCHRG_DP	0.05	0.41
11	CH_K2	0	32
12	OV_N	0.14	0.132



Statistical parameters	2003 - 2009	
	Observed	Simulated
Mean	609.61	690.57
Maximum	1864.74	1789.25
Std Dev	556.92	478.27
Count	35	35
r^2	0.893	
Nash-Sutcliffe coefficient (E_{NS})	0.870	
Index of Agreement (d)	0.961	
PBIAS	13.28	
Modified Nash-Sutcliffe coefficient (E)	0.67	
Modified Index of Agreement (d1)	0.82	



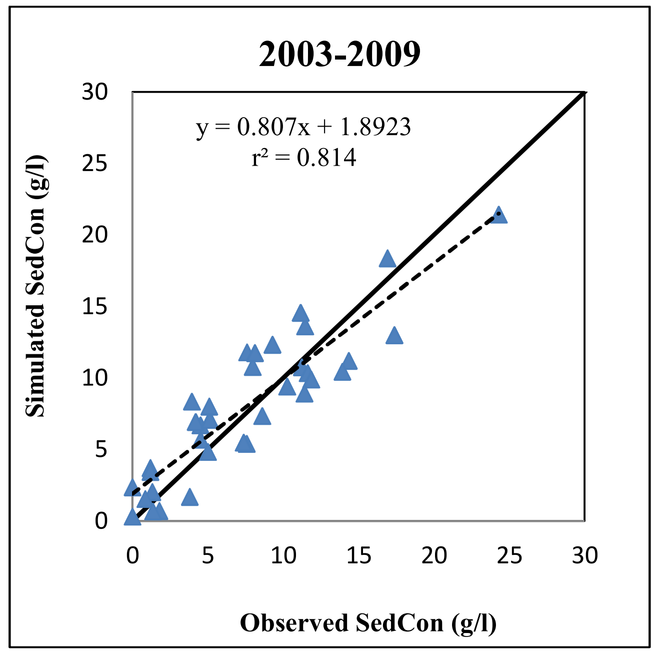
Simulation of monthly discharge m^3/s

Statistical analysis of observed and simulated monthly discharge (m^3/s) for model calibration (2003 – 2009)

Year	Observed			Simulated			Calibration					
	Mean	Max	Std	Mean	Max	SD	E_{NS}	d	PBIAS	E	d1	r^2
2003	916.15	1864.7	710.44	975.43	1789.2	684.87	0.879	0.968	6.471	0.718	0.862	0.879
2004	467.8	1233.4	459.36	548.92	1104.2	332.56	0.862	0.952	17.55	0.661	0.802	0.894
2005	953.15	1756.1	681.33	1034	1435	438.04	0.796	0.932	8.484	0.491	0.719	0.873
2006	558.79	1349.3	602.05	655.15	1262.9	451.44	0.885	0.960	17.24	0.695	0.820	0.957
2007	751.13	1379.6	558.32	823.70	1276.9	503.62	0.857	0.959	9.663	0.624	0.807	0.879
2008	269.32	640.23	249.01	361.09	709.89	271.78	0.959	0.988	34.07	0.803	0.890	0.962
2009	350.89	1033.8	416.42	434.68	856.3	355.86	0.884	0.964	23.87	0.692	0.818	0.813

Year	Observed			Simulated			Calibration					
	Mean	Max	SD	Mean	Max	SD	E_{NS}	d	PBIAS	E	d1	r^2
2003	5.767	11.23	3.77	7.645	11.80	3.87	0.829	0.889	32.577	0.837	0.898	0.789
2004	7.636	16.91	6.45	9.299	18.38	5.67	0.848	0.869	21.772	0.857	0.798	0.902
2005	8.516	14.34	5.13	7.770	11.21	4.17	0.901	0.898	8.759	0.915	0.896	0.777
2006	6.620	13.92	5.49	6.202	10.45	4.00	0.882	0.846	6.323	0.876	0.786	0.839
2007	6.639	11.45	4.99	6.437	13.62	5.00	0.872	0.891	3.043	0.821	0.831	0.817
2008	12.692	24.30	8.64	12.405	21.44	7.48	0.926	0.935	2.260	0.931	0.853	0.841
2009	5.366	8.60	3.43	6.452	11.75	4.23	0.922	0.921	20.23	0.905	0.858	0.759

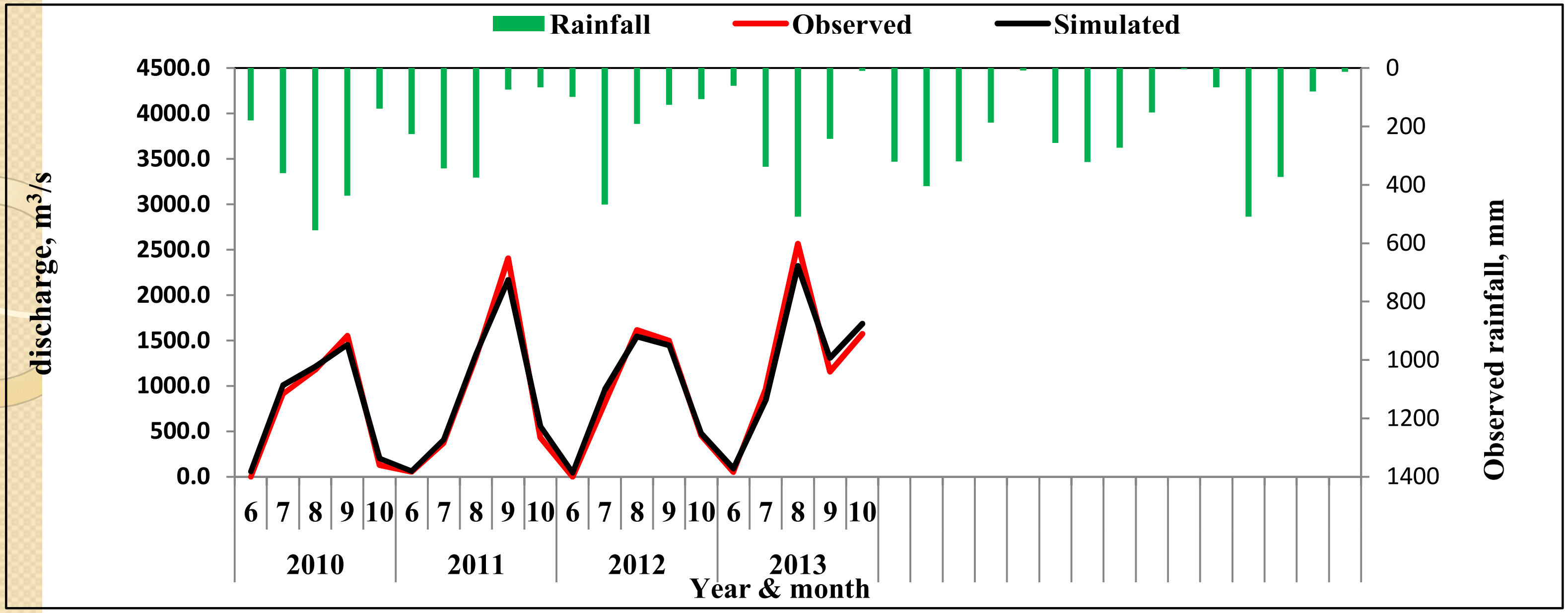
Statistical parameters	2003 - 2009	
	Observed	Simulated
Mean	7.605	8.030
Maximum	24.297	21.437
Std Dev	5.64	5.04
Count	35	35
r^2	0.814	
Nash-Sutcliffe coefficient (E_{NS})	0.889	
Index of Agreement (d)	0.829	
PBIAS	5.586	
Modified Nash-Sutcliffe coefficient (E)	0.897	
Modified Index of Agreement (d1)	0.942	

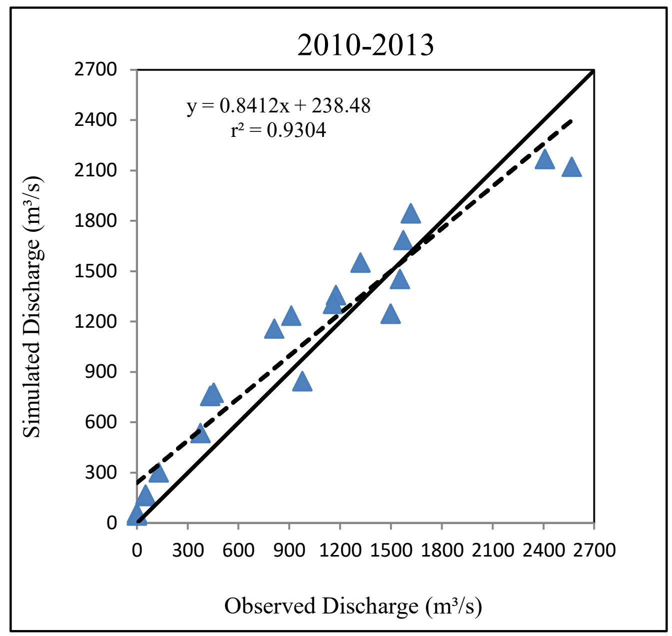


Simulation of monthly sediment concentration

Validation of the Model

- Validation is the essential part of a model testing after calibration.
- Model should be validated properly to know the model performance without any changes in the input file except climatic parameters.
- Validation for daily as well as for monthly runoff and sediment yield from the both watersheds.



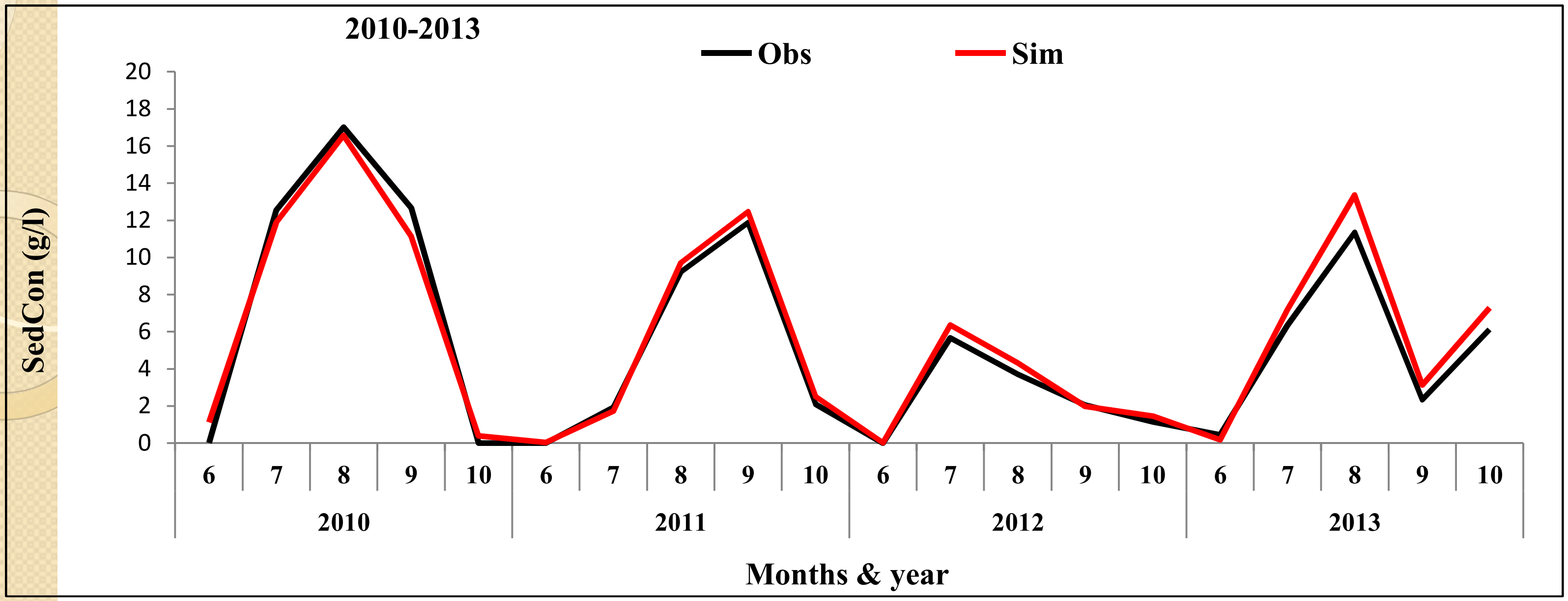


Statistical parameters	2010 - 2013	
	Observed	Simulated
Mean	952.67	1039.83
Maximum	2565.95	2169.7
Std Dev	775.13	675.97
Count	20	20
r^2	0.93	
Nash-Sutcliffe coefficient (E_{NS})	0.91	
Index of Agreement (d)	0.97	
PBIAS	9.14	
Modified Nash-Sutcliffe coefficient (E)	0.69	
Modified Index of Agreement (d1)	0.84	

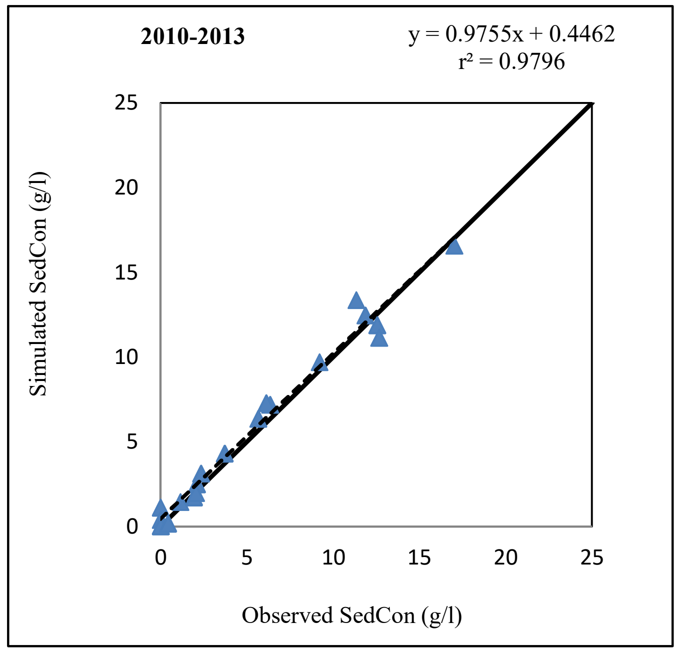
Validation of monthly discharge m^3/s

Statistical analysis of year wise observed and simulated monthly discharge (m^3/s) for the year 2010 – 2013 for model validation

Year	Observed			Simulated			Evaluation criteria					
	Mean	Max	SD	Mean	Max	SD	E_{NS}	d	PBIAS	E	d1	r^2
2010	753.27	1552.31	670.47	882.3	1454.3	650.31	0.898	0.974	17.1	0.697	0.853	0.944
2011	917.59	2407.34	955.92	1035.8	2169.7	812.84	0.933	0.981	12.9	0.703	0.839	0.967
2012	875.53	1616.12	686.40	1014.8	1845.8	663.72	0.827	0.957	15.9	0.563	0.783	0.870
2013	1264.3	2565.95	916.20	1226.4	2123.05	755.61	0.945	0.983	2.99	0.762	0.874	0.870



Statistical parameters	2010 - 2013	
	Observed	Simulated
Mean	5.327	5.642
Maximum	17.02	16.58
Std Dev	5.32	5.24
Count	20	20
r^2	0.98	
Nash-Sutcliffe coefficient (E_{NS})	0.92	
Index of Agreement (d)	0.91	
PBIAS	5.9	
Modified Nash-Sutcliffe coefficient (E)	0.89	
Modified Index of Agreement (d1)	0.90	



Validation of monthly sediment concentration (g/l)

Statistical analysis of year wise observed and simulated monthly sediment yield (t/ha) for the year 2010 – 2013 for model validation

Year	Observed			Simulated			Evaluation criteria					
	Mean	Max	SD	Mean	Max	SD	E_{NS}	d	PBIAS	E	d1	r^2
2010	8.448	17.019	7.92	8.23	16.58	7.13	0.91	0.90	2.62	0.89	0.91	0.971
2011	5.026	11.873	5.19	5.23	12.46	5.45	0.89	0.91	5.16	0.90	0.93	0.983
2012	2.515	5.659	2.22	2.83	6.364	2.51	0.90	0.94	12.38	0.91	0.96	0.981
2013	5.320	11.340	4.20	6.23	13.37	4.98	0.91	0.92	17.17	0.93	0.93	0.974

Identification and Prioritisation of Critical Sub-watersheds

1. On the basis of average annual sediment and nutrient losses.
2. Identified critical watersheds are arranged in descending order and then priorities were fixed for their management.

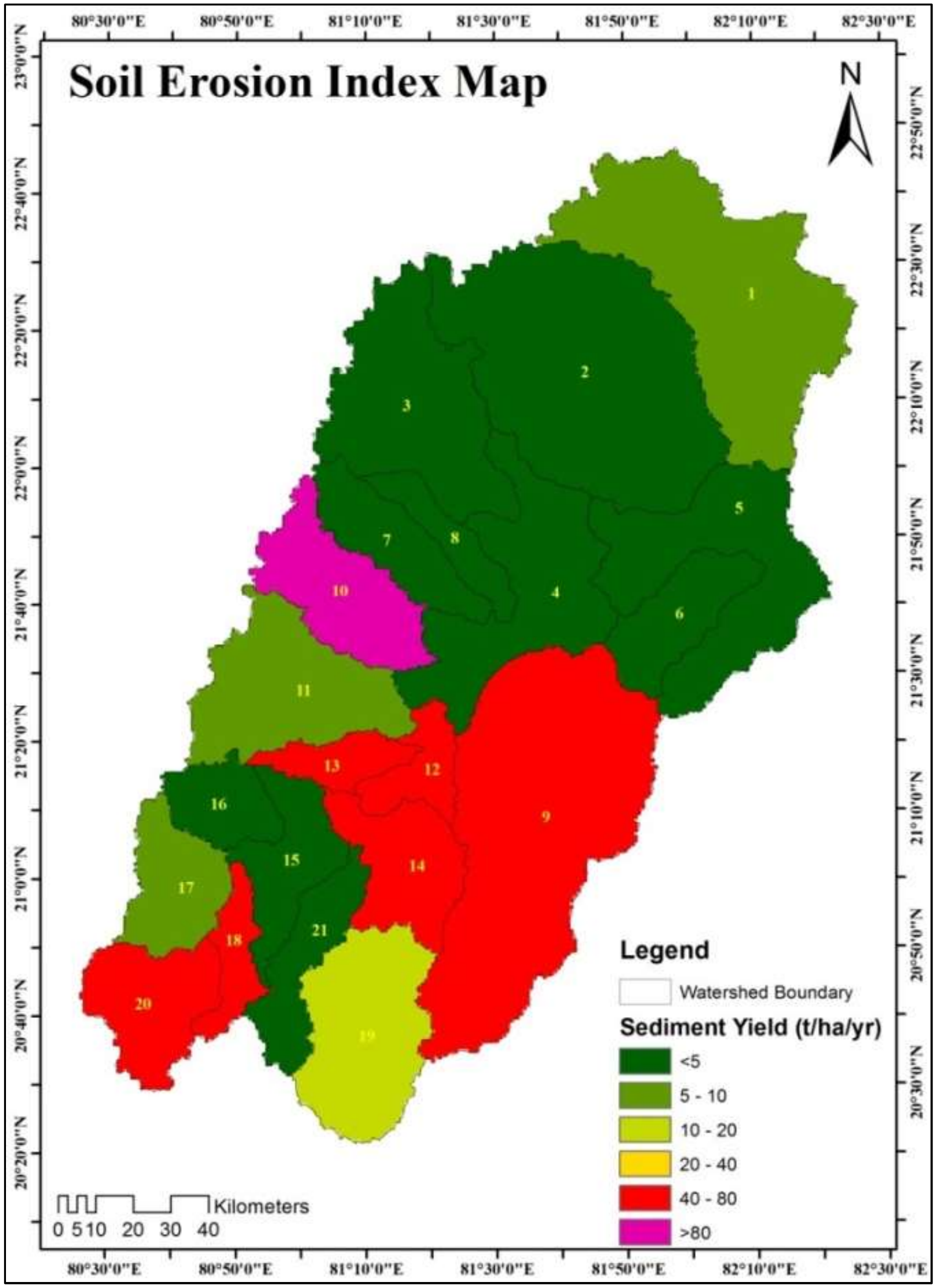
Soil erosion classes	Slight	Moderate	High	Very high	Severe	Very severe
Soil erosion range (t/ha/yr)	0-5	5-10	10-20	20-40	40-80	>80

Source : Singh *et al*., 1992

Identification and Prioritization of Critical Watersheds (2010-2013)

WS	Area, km^2	Rainfall(mm)	Runoff (mm)	Sediment Yield (t/ha)	Area under agriculture (ha)	% slope	Priority
1	3154.6	805.9	132.3	9.74	92097.9	8.1	9
2	3832.9	1007.5	130.6	2.90	128653.2	6.3	13
3	2002.7	749.1	62.2	0.06	106569.2	9.7	21
4	1871.3	780.1	66.3	0.66	74779.9	3.8	18
5	2009.7	902.8	129.1	1.61	84880.7	3.7	14
6	768.1	806.2	110.0	0.87	30400.5	3.7	16
7	813.4	1005.3	149.5	0.48	31459.9	3.8	20
8	444.6	1001.3	224.9	0.53	18859.5	3.8	19
9	***4148.6***	***1033.3***	***515.9***	***66.46***	***67089.8***	***4.6***	***2***
10	***1177.7***	***1047.8***	***609.6***	***92.37***	***76996.4***	***5.7***	***1***
11	1627.5	682.8	216.0	5.99	100205.9	6.1	11
12	463.9	818.9	210.1	44.01	28366.1	3.8	7
13	408.2	918.9	473.6	61.54	21763.1	3.6	5
14	966.7	1085.5	433.7	63.29	65884.2	3.6	4
15	806.2	682.1	89.7	1.60	59890.5	3.7	15
16	563.1	631.0	68.0	5.12	36393.2	3.8	12
17	818.1	730.1	80.8	9.39	51293.3	3.8	10
18	418.5	776.9	419.8	49.73	27392.5	3.6	6
19	1595.3	1081.8	416.6	11.59	88215.8	4.8	8
20	988.5	972.1	492.0	65.89	35098.2	5.9	3
					[illegible]	[illegible]	

Sediment Yield for Identification of Critical Watersheds



Conclusions

1. The ArcSWAT model accurately simulates monthly discharge and sediment concentration from Seonath sub-basin.
2. Manning's 'n' values for overland flow and channel flow are 0.132 and 0.024, respectively for the Seonath sub-basin.
3. Sensitivity analysis of the model input parameters shows that the stream flow rate and sediment concentration are more sensitive to Soil Conservation Service (SCS) curve number (CN) followed by Manning roughness coefficient for overland flow (OV_N), Surface runoff lag time (SURLAG) and Support practice factor (USLE_ P).
4. The Arc-SWAT model accurately simulates stream discharge and sediment concentration from the Seonath sub-basin on monthly basis.
5. The Arc-SWAT model can successfully be used for identifying critical watersheds for the management purpose.
6. Watershed (WS10) was found to be most critical followed by WS9, hence recommended for effective management.

THANKS