Evaluation and focusing of Soil and Water Conservation measures using SWAT model in Krishnagiri Reservoir Catchment area, South India

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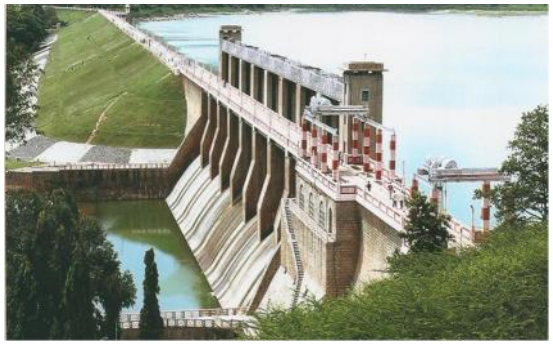
Krishnagiri Reservoir project



– **Reservoir**

- Original Capacity – 68.2 Mm^3 (1958)
- Sedimentation survey 2007 – Loss of Capacity 42% (IHH, 2007)
- Bathymetric survey 2012 – Loss of capacity 52% (Arunbabu et al, 2014)

– **Watershed**

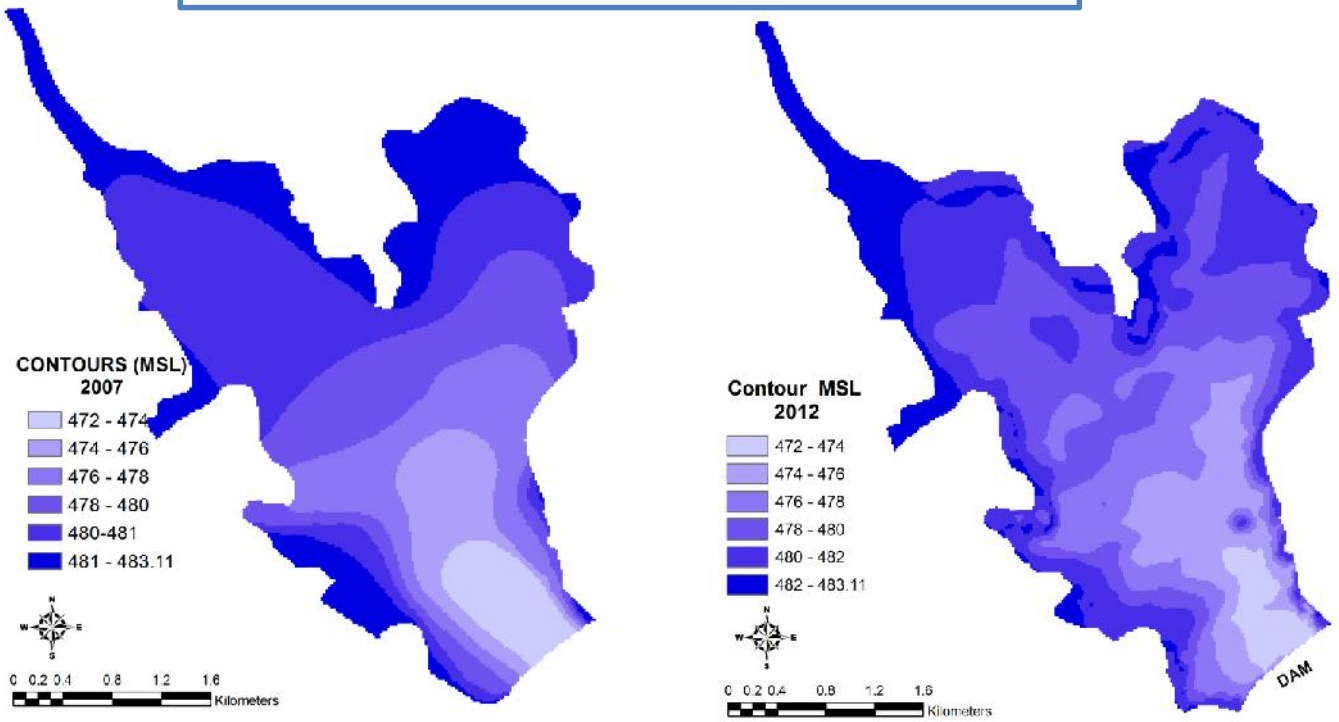
- Soil loss – 25 t/ha/year (Ismail & Ravichandran, 2008)

- Vepanapalli and
- Shoolagiri (Sub watersheds) – highly eroding areas

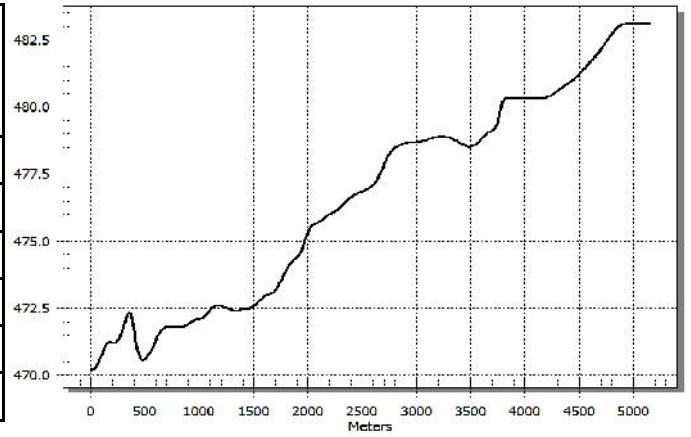
Hence conservation practices should be implemented in the watershed effectively.

Background

Bathymetry of the reservoir 2007 and 2012



Year of Survey	Survey details	Capacity of the reservoir (Mm^3)	Loss in capacity (%)
1957	Preliminary Survey	68.20	0.00
1976	First Capacity Survey	50.47	26.00
1981	Second Capacity Survey	47.78	29.94
1983	Third Capacity Survey	47.18	30.82
2007	Fourth Capacity Survey	39.70	41.79
2012	**Present Study**	**35.57**	**52.16**

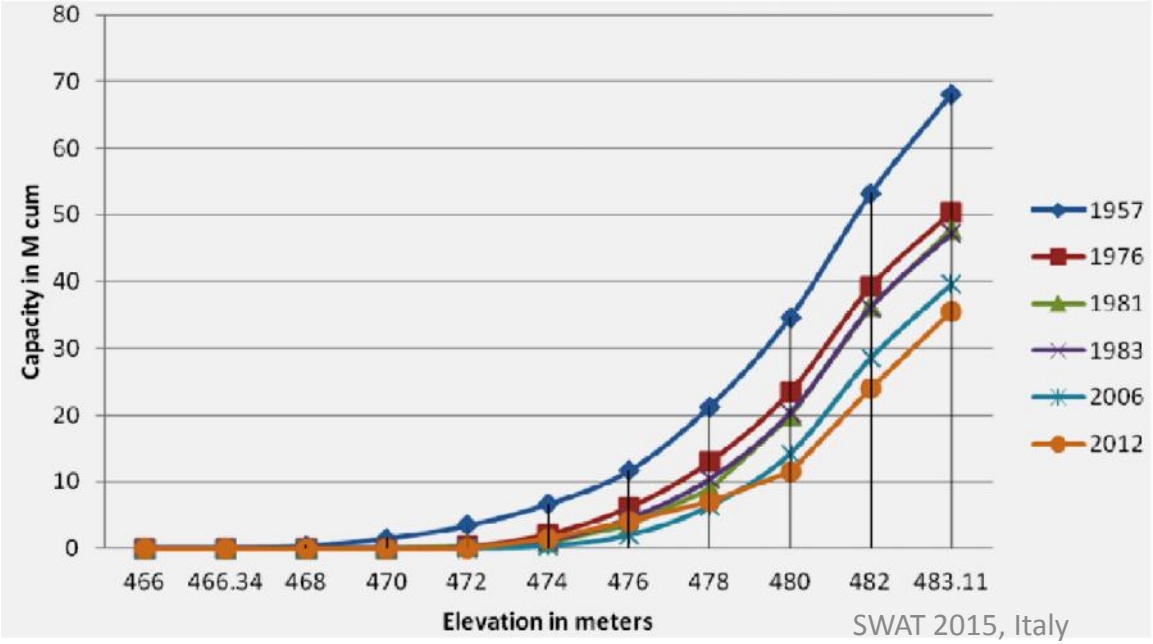


Arunbabu, E, Ravichandran, S & Sreeja, P 2014, 'Sedimentation and internal phosphorus loads in Krishnagiri Reservoir, India', Lakes & Reservoirs: Research & Management, vol. 19, pp. 161-173. doi:10.1111/lre.12069

Background

Reservoir Capacity and its percentage loss

		Capacity in M.cum					
Level of contours	height in meters	1957	1976	1981	1983	2006	2012
466	0	0	0	0	0	0	0
466.34	0.34	0.0597	0	0	0	0	0
468	2	0.4064	0	0	0	0	0
470	4	1.5042	0	0	0	0	0
472	6	3.4189	0.2562	0.295	0.0902	0	0.053929
474	8	6.6414	2.0619	0.8651	1.1407	0.38899	1.462982
476	10	11.6211	6.0659	3.5631	4.4054	1.9563	4.04831
478	12	21.2445	12.9246	8.9547	10.3167	6.3144	7.03101
480	14	34.6645	23.4639	19.978	20.2327	14.212	11.58556
482	16	53.3061	39.3021	36.2814	36.0756	28.5877	23.93606
483.11	17.11	68.2	50.4756	47.7886	47.1836	39.7034	35.57155

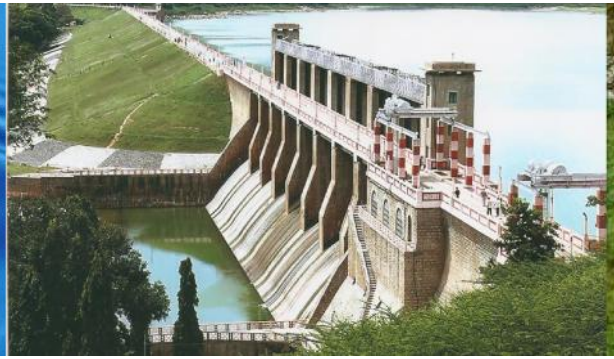


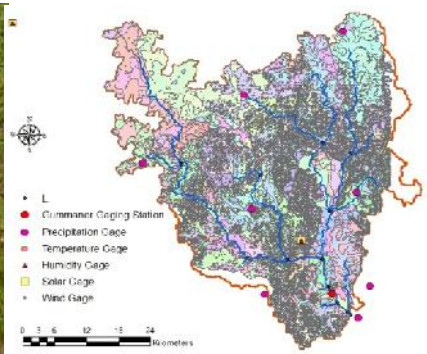
Between the years 1957 and 1976 the capacity loss was found to be 17.73 MCM reveals that the rate of sedimentation was **0.933 MCM/year till 1976.**

During the last five years the sedimentation rate has been increased to **0.828 MCM/year from 0.31 MCM/year.**

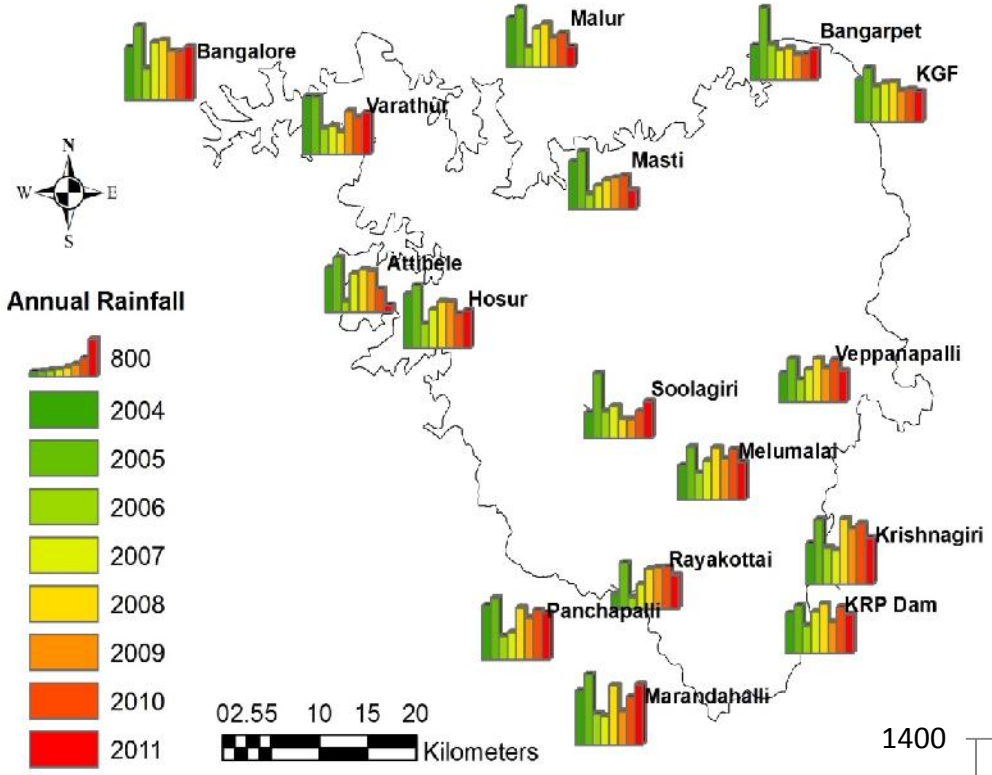
OBJECTIVES

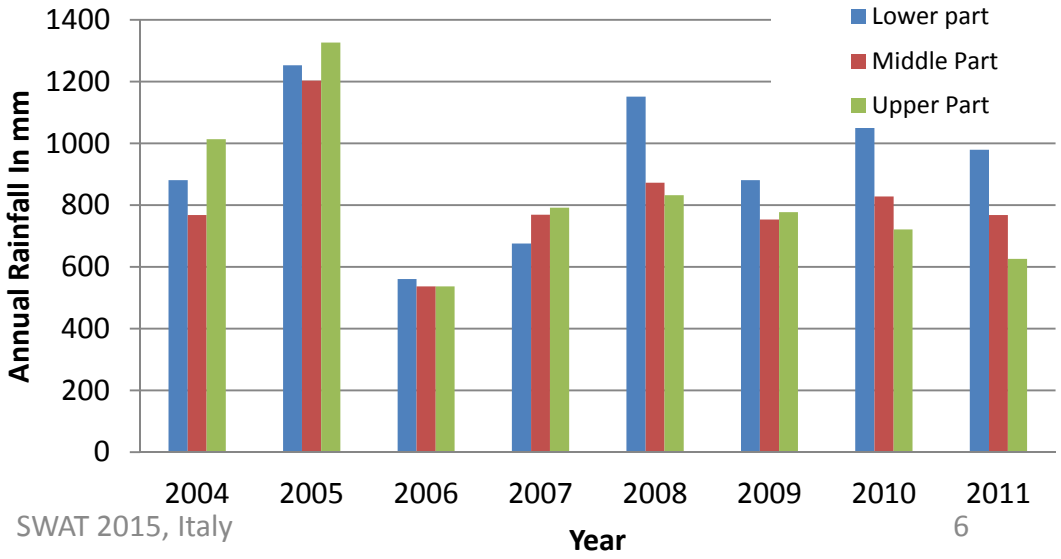
- To Setup a SWAT model for watershed modeling
- Calibrate / Validate for flow and sediment
- To evaluate the effectiveness of Soil and Water Conservation (SWC) measures implemented in the catchment area of Krishnagiri Reservoir



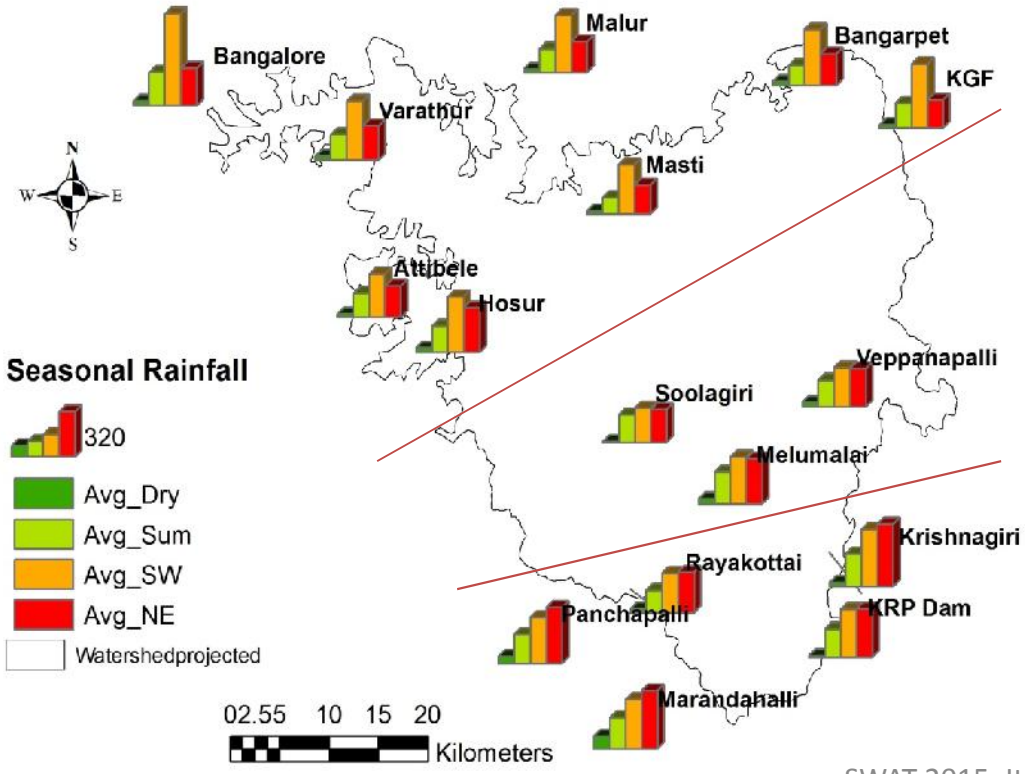
Rainfall distribution in the catchment area





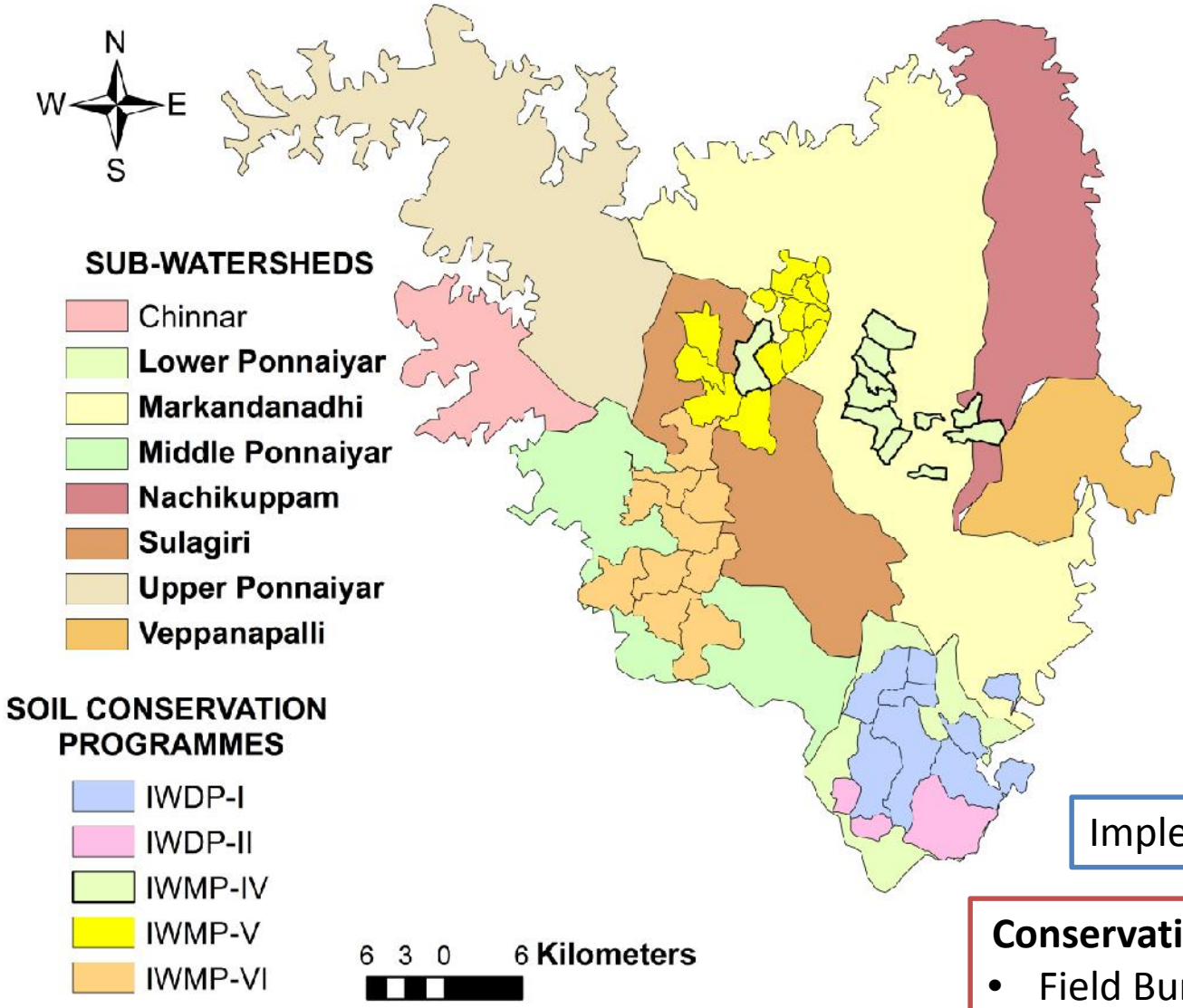
Seasonal distribution of rainfall in the catchment area

- Stations located in the **upper catchment area receive more rainfall** during **Southwest monsoon than the northeast monsoon rainfall.**
- The contribution of rainfall from the **northeast monsoon is less** in the upper catchment area whereas it is almost **equal to southwest monsoon** in the middle part of the catchment area.



- In the lower part of the basin, the contribution of the **north east monsoon is high compared to the south west monsoon.**
- This clearly reveals that at any point of time during the monsoon periods from June to December some part of the catchment area receives rainfall and its seasonal influence is variable.
- **This pattern of rainfall appears unique and may influence the erosivity of the catchment.**

Conservation Practices



Implemented by TAWDEVA

Conservation Practices followed

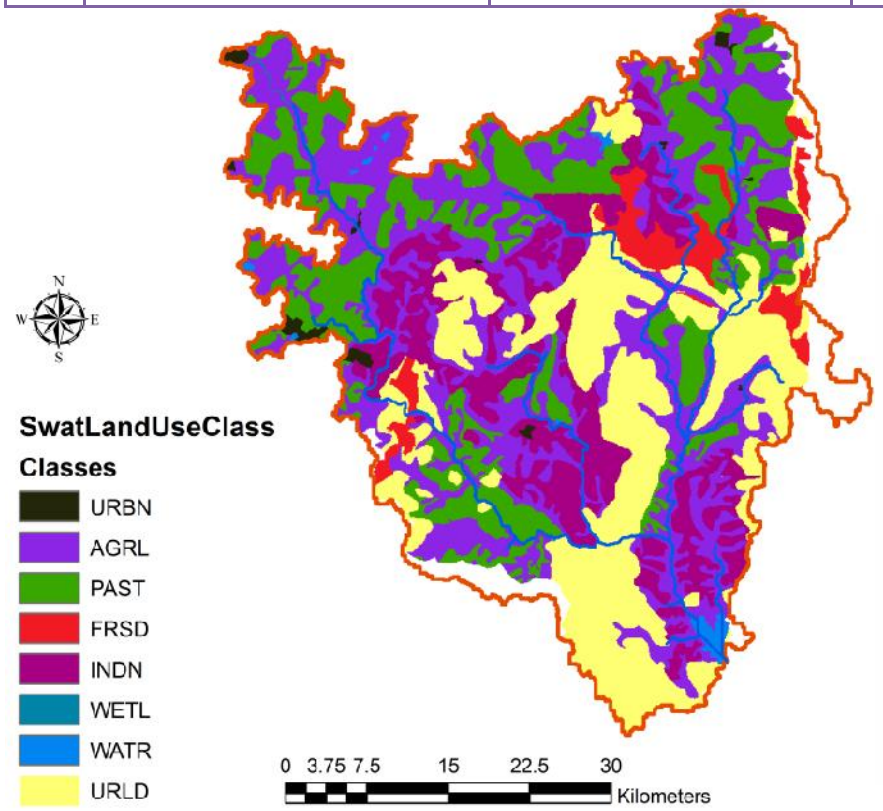
- Field Bunding
- Stone Walls

Preparation of Datasets

• DEM	-	SRTM 90 m resolution
• Landuse	-	Resourcesat Image
• Soil	-	Agricultural Engineering Department + Soil samplings +FAO
• Climate	-	FCS at two locations
• Rainfall	-	Raingauges at eight locations
• Discharge	-	At one location (CWC)
• Sediment	-	At one location (CWC)
• Time line	-	1998 – 2000 (Warmup) 2001 – 2005 (calibration) 2006 – 2011 (validation)

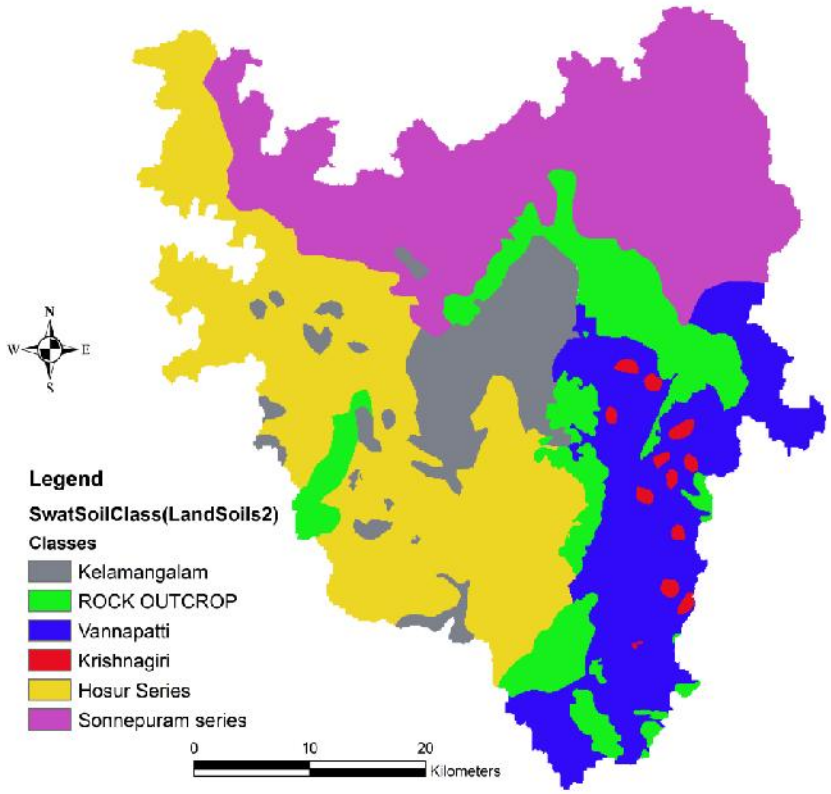
Land use

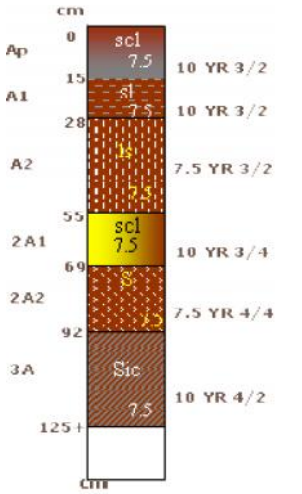
ID	LANDUSE	AREA (km²)	Area (%)	SWAT LANDUSE
1	RESIDENTIAL	68.89	2.90	URBN
4	AGRICUOTURAL	779.88	33.25	AGRL
5	FALLOW LAND	500.27	21.33	PAST
7	FOREST	105.07	4.50	FRSD
8	SCRUB LAND	321.94	13.72	WETL
9	RIVER	14.28	0.62	INDN
11	RESERVOIR /WATERBODY	20.87	0.89	WATR
20	BARREN ROCK	534.56	22.79	URLD

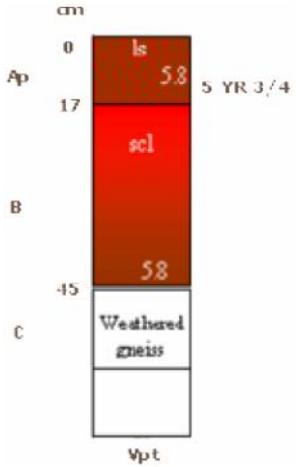


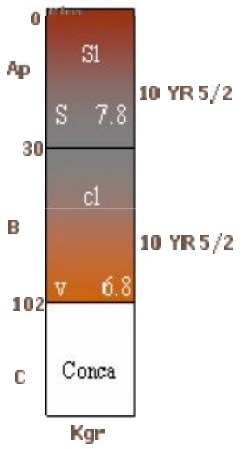
Soil

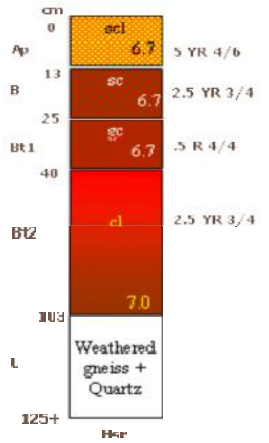
ID	SOIL SERIES	AREA (km^2)	Area (%)	SWAT SOIL CLASSIFICATION (USER SOIL GROUP)
1	KELAMANGALAM SERIES	214	9.49	KELAMANGALAM SERIES
2	ROCKOUTCROP	287	12.60	ROCKOUTCROP
3	VANNAPATTI SERIES	400	17.46	VANNAPATTI SERIES
4	KRISHNAGIRI SERIES	17	0.84	KRISHNAGIRI SERIES
5	HOSUR SERIES	775	29.97	HOSUR SERIES
6	SONEPURAM SERIES	722	29.64	SONEPURAM SERIES

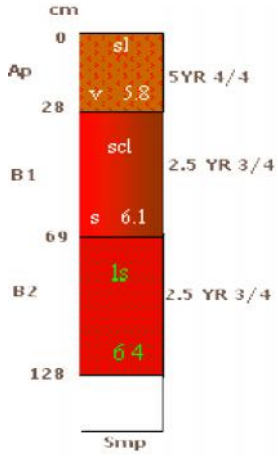


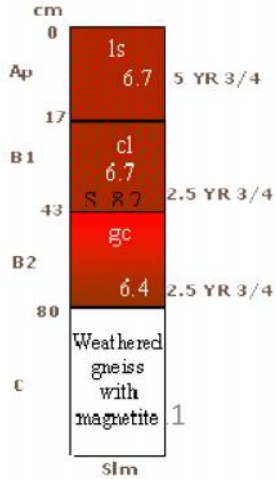




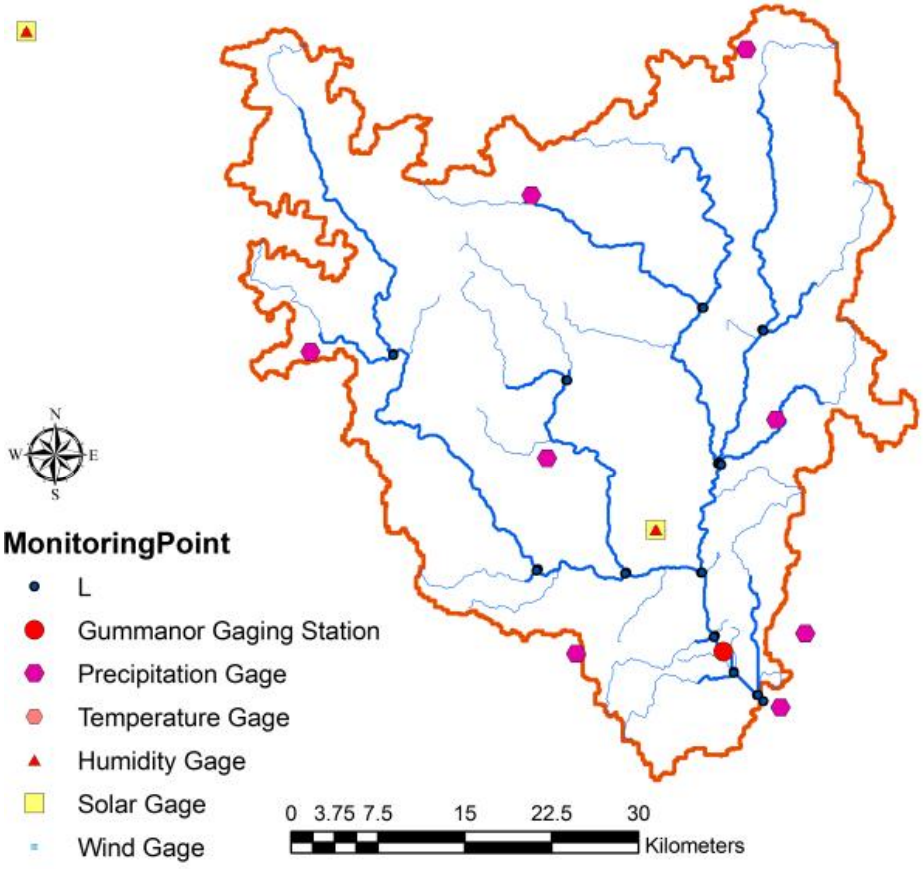








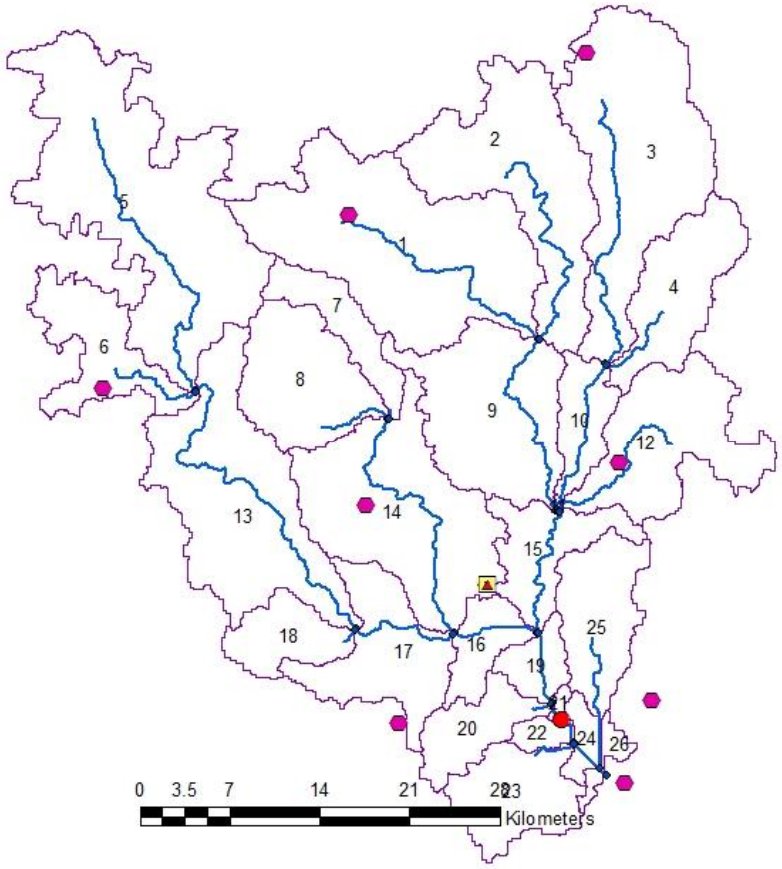
Rain gauge , Flow gauge and Weather station



- 8 Rain gauges
- 1 Flow gauge
- 2 weather station
- Temporal resolution of data: daily measurements

•Preprocessors were used to generate the weather statistics
•User weather database has been created

Model Setup



- Arc SWAT 2009 interfaced with ArcGIS 9.3
- 26 subbasins (using DEM +Gauges)
- 417 HRUS by using multiple Landuse / Soil /Slope (THRESHOLDS : 5 / 5 / 5 [%])
- 8 years data were used to run the model (NYSKIP = 3)

- 1998 – 2000 (Warmup)
- 2001 – 2005 (Calibration)
- 2006 – 2011 (Validation)

SWAT sensitive parameters and fitted values

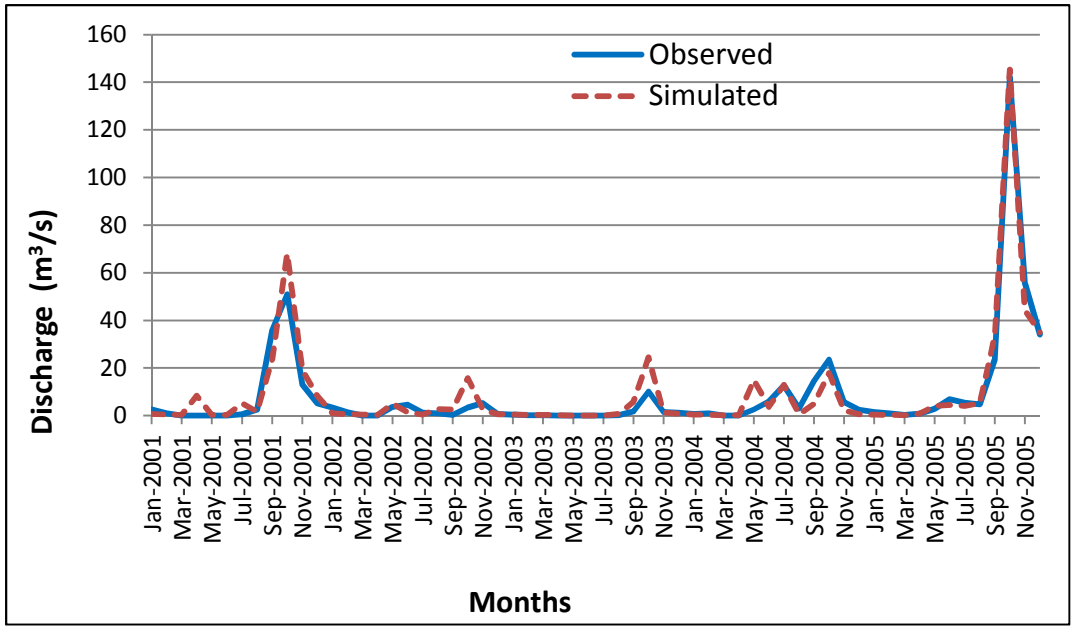
Variable	Parameter Name	Description	t-Stat	P-Value	Fitted Value	Minimum Value	Maximum Value
Flow	r__CN2.mgt	Curve number	-13.386	0.000	-0.102	-0.200	0.200
	v__GWQMN.gw	Threshold water depth in the shallow aquifer	9.954	0.000	167.000	0.000	200.00
	v__GW_REVAP.gw	Ground water revap co-efficient	8.206	0.000	0.178	0.020	0.200
	v__ESCO.hru	Soil evaporation compensation factor	-5.314	0.000	0.630	0.500	0.900
	v__GW_DELAY.gw	Groundwater delay time	5.090	0.000	28.789	5.000	31.000
	v__ALPHA_BF.gw	Baseflow alpha factor	-2.799	0.006	0.745	0.000	1.000
	v__CH_N2.rte	Manning's 'n' value for main channel	1.468	0.146	0.093	0.014	0.300
	r__SOL_AWC(1).sol	Available water capacity	-0.847	0.399	-0.009	-0.020	0.020
	v__CH_K2.rte	Channel effective hydraulic conductivity	-0.046	0.964	6.250	0.000	10.00

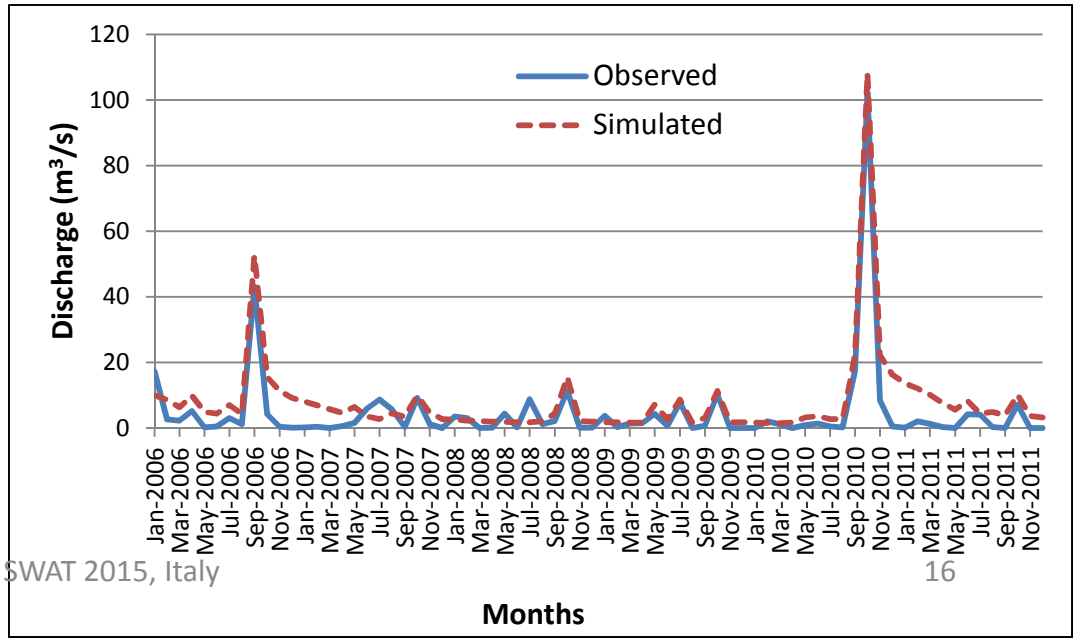
SWAT sensitive parameters and fitted values

Sediment	v__SLSUBBSN.hru	Average Slope length	-13.743	0.005	45.000	10.000	150.00
	v__USLE_P.mgt	USLE support practice factor	-9.175	0.012	0.325	0.100	1.000
	r__CH_EROD.rte	Channel erodibility factor	7.824	0.016	0.030	0.000	0.600
	v__SPEXP.bsn	Exponent of re-entrainment parameter for channel sediment routing	-5.128	0.036	1.225	1.000	1.500
	v__SPCON.bsn	Linear re-entrainment parameter for channel sediment routing	-4.811	0.041	0.006	0.001	0.010
	r__CH_COV.rte	Channel cover factor	-3.515	0.072	0.050	0.000	1.000
	r_RSDCO.bsn	Residue decomposition coefficient	0.835	0.492	0.032	0.020	0.100

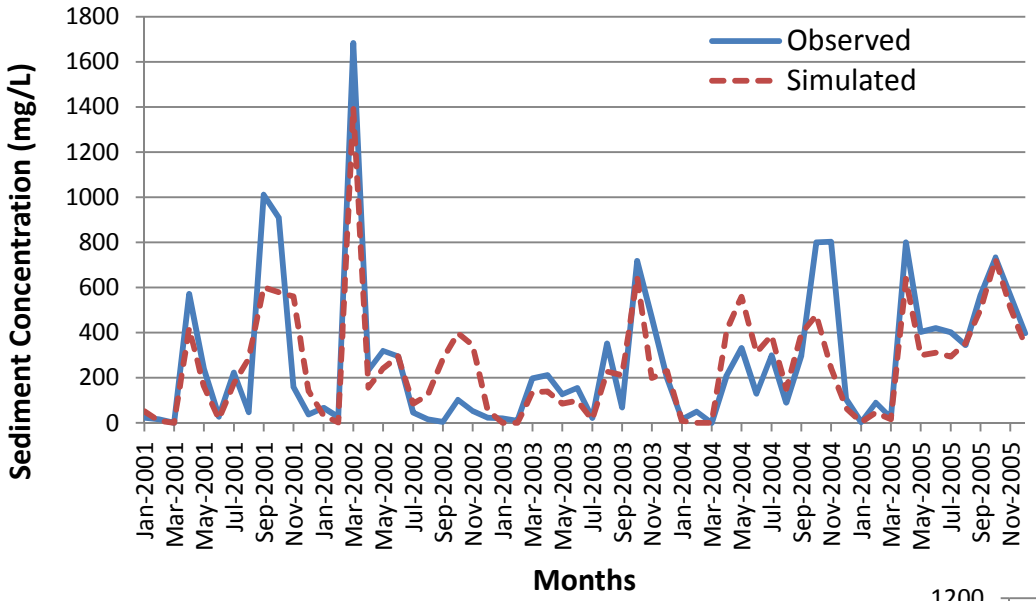
v__ means the existing parameter value is to be replaced by the given value
r__ means the existing parameter value is multiplied by (1+ a given value)

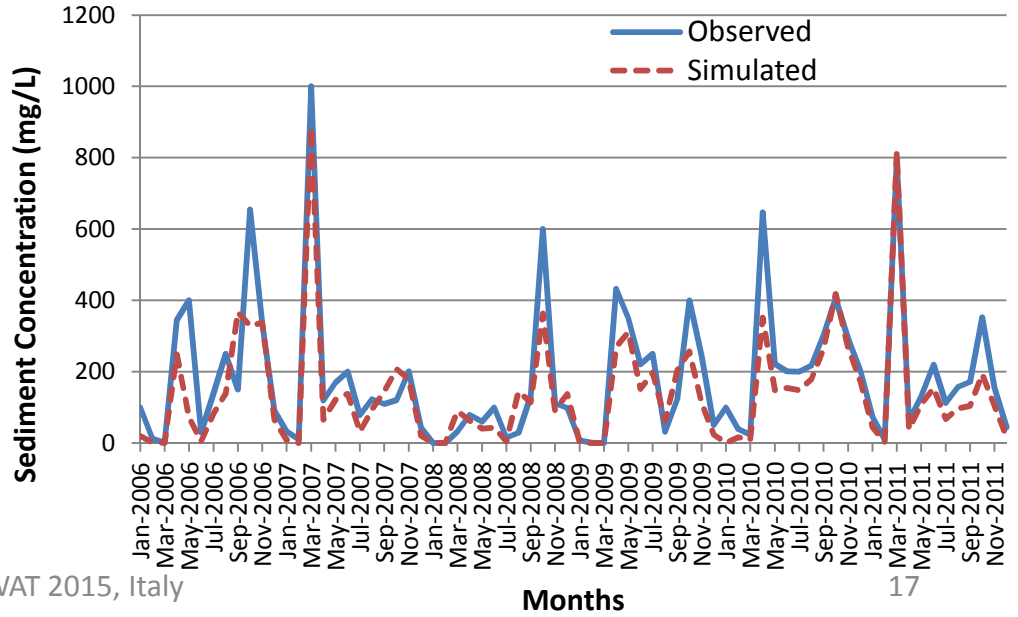
Calibration and Validation for Flow





Calibration and Validation for Sediment





Performance ratings for the model in monthly time step

Station	Variable	Model	NSE	R^2	PBIAS (%)
Gummanur	Flow	Calibration	0.89	0.90	-7.2
		Validation	0.83	0.91	-14.0
	Sediment	Calibration	0.73	0.74	6.6
		Validation	0.76	0.81	23.4

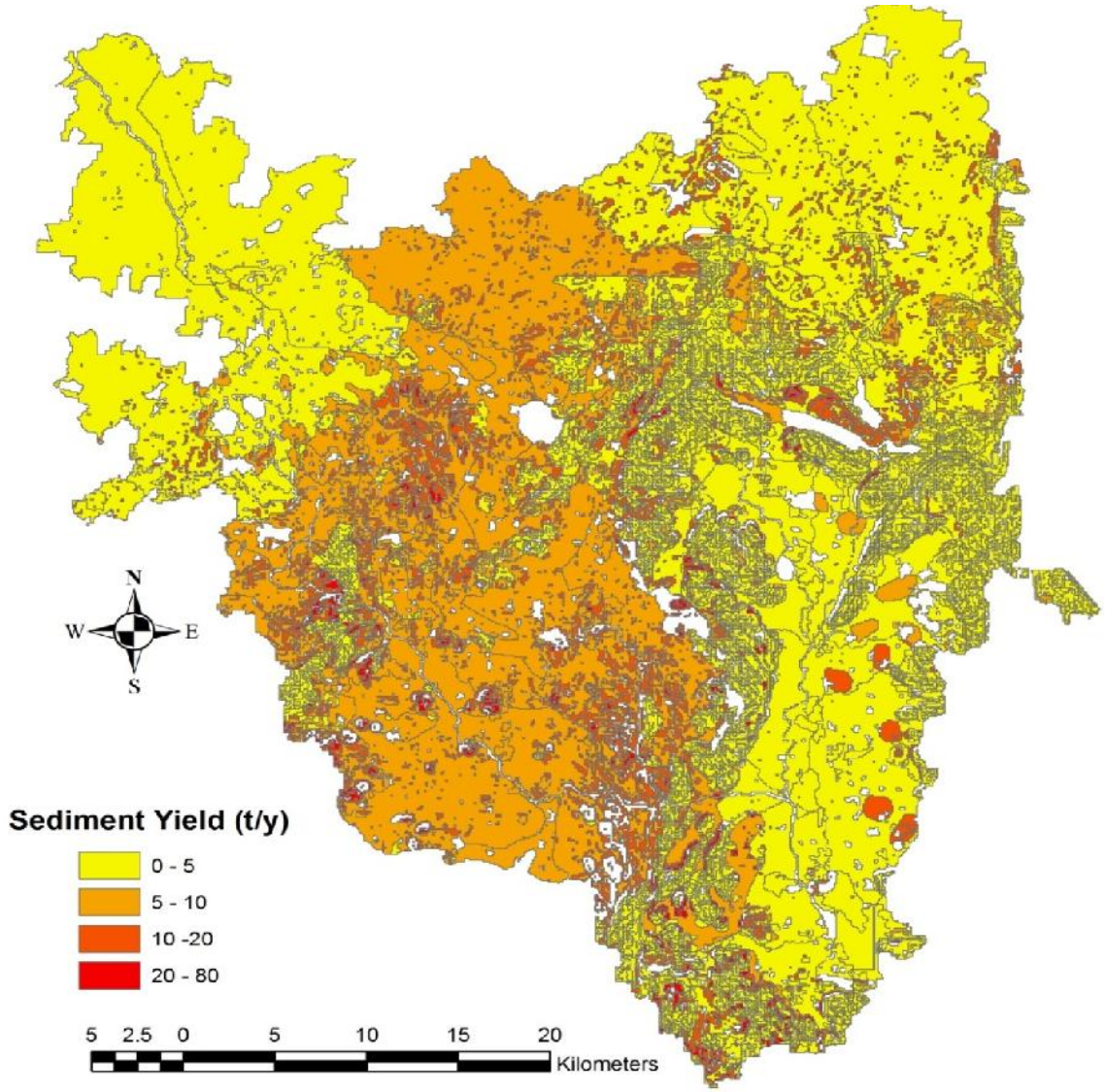
General performance ratings for recommended statistics for a monthly time step (Moriasi et al 2007)

Performance Rating	NSE	PBIAS (%) (Stream Flow)	PBIAS (%) (Sediment)
Very Good	$0.75 < NSE \leq 1.00$	$PBIAS < \pm 10$	$PBIAS < \pm 15$
Good	$0.65 < NSE \leq 0.75$	$\pm 10 \leq PBIAS < \pm 15$	$\pm 15 \leq PBIAS < \pm 30$
Satisfactory	$0.50 < NSE \leq 0.65$	$\pm 15 \leq PBIAS < \pm 25$	$\pm 30 \leq PBIAS < \pm 55$
Unsatisfactory	$NSE \leq 0.50$	$PBIAS \geq \pm 25$	$PBIAS \geq \pm 55$

Erosion prone area, SWC program and area to be covered in Krishnagiri Reservoir catchment area

Subwatersheds	Area (km^2)		Soil Water Conservation Program			Area to be Treated
	Total	Erosion Prone	Number of Villages	Area under SWC Programme (km^2)	Erosion (t/yr)	
Upper Ponnaiyar	358.88	0.45	0	0.00	NA	0.45
Chinnar	89.08	0.12	0	0.00	NA	0.12
Sulagiri	297.37	2.71	8	5.36	2686.19	NA
Markandanadhi	663.21	**11.36**	18	7.12	3476.72	4.24
Middle Ponnaiyar	275.68	5.74	7	5.85	4697.27	NA
Nachikuppam	244.57	3.72	1	**0.33**	118.03	3.39
Veppanapalli	91.30	0.60	1	0.50	68.64	0.60
Lower Ponnaiyar	189.03	10.06	11	13.80	14617.85	NA

Sediment yield from the Krishnagiri Reservoir Catchment area



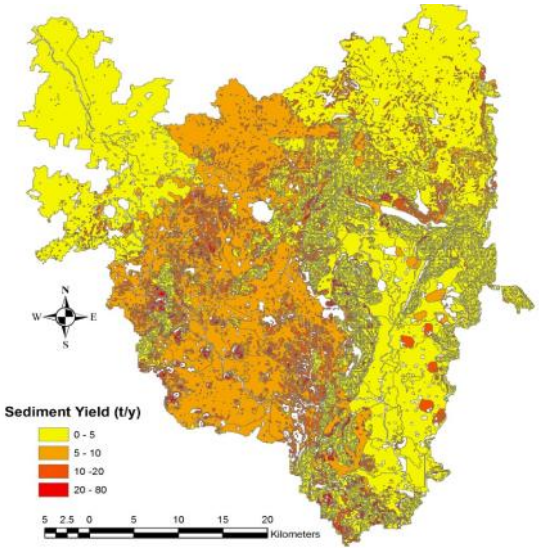
Simulation of Conservation Practices

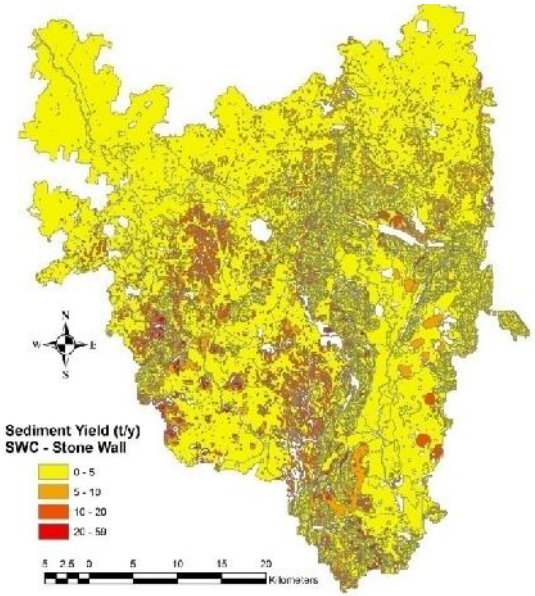
- **Stone wall (SW)** and **Field Bunding (FB)** are the conservation structures implemented by Government of Tamil Nadu in the Krishnagiri catchment **(TAWDEVA 2002)** and hence the effect of these measures on sediment yield was simulated.

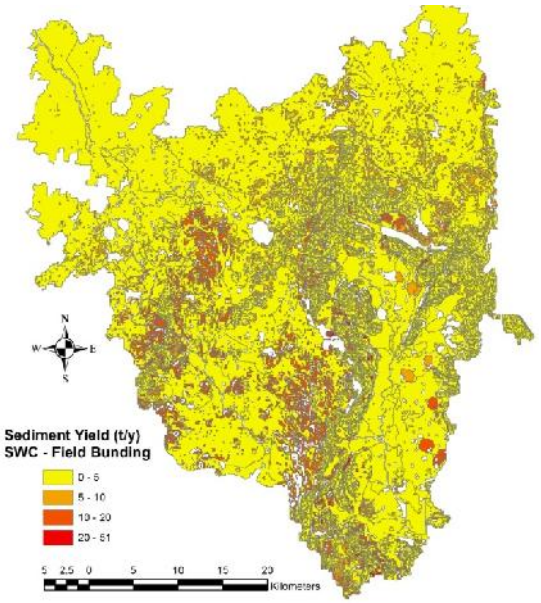
- In addition, the impact of **vegetative metho**ds such as **Mulching and Bio fencing** over mechanical methods was also evaluated as these may be **cost effective** and **local materials** may be favourable.

- Another possible way of reducing soil erosion and sediment yield from the agricultural fields is by **adopting minimum tillage operation** where the disturbance to the soil is minimised.

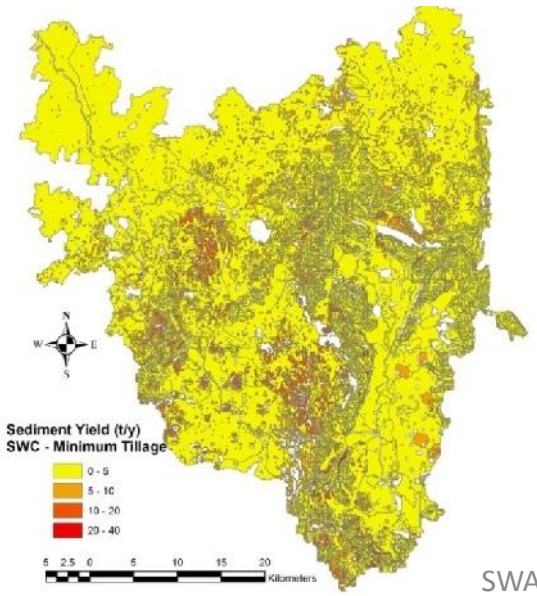
Simulation of Conservation Practices

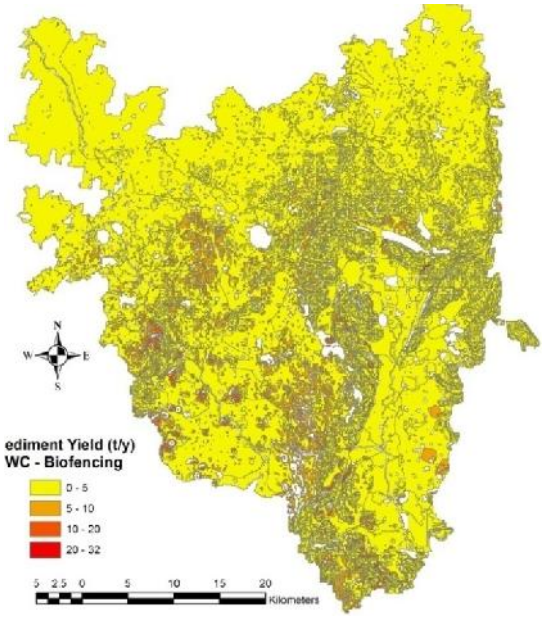






Base Value –No Conservation

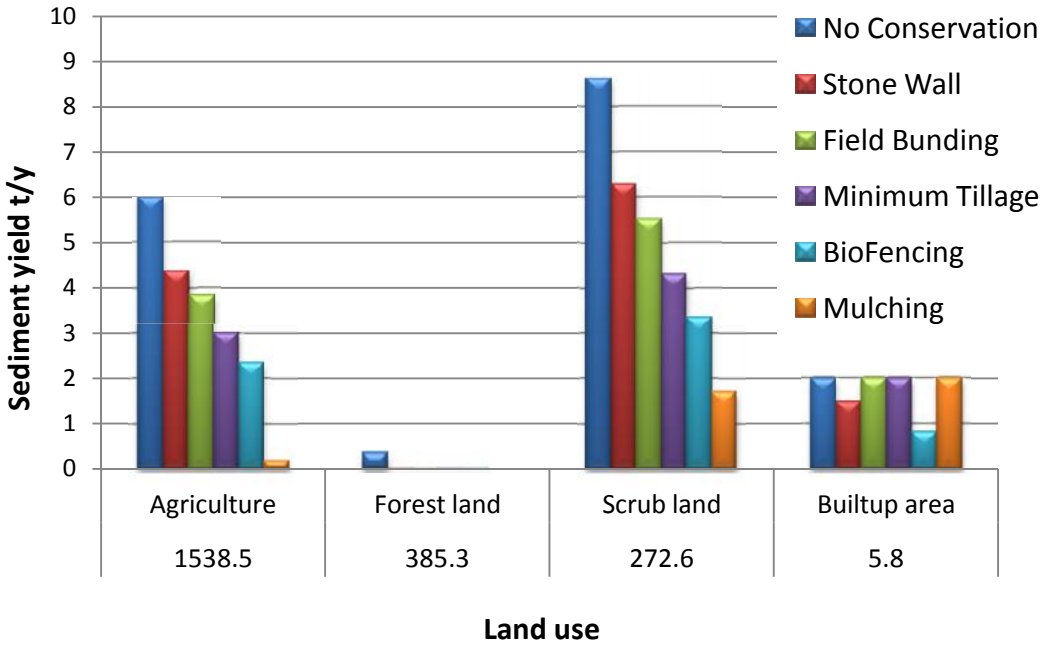




Sediment yield from subwatersheds of Krishnagiri Reservoir catchment under different SWC measures simulated in SWAT

Subwatersheds	Sediment Load (t/y)					
	No Conservation	Stone Wall	Field Bunding	Minimum Tillage	Bio-fencing	Mulching
Upper Ponnaiyar	10259.43	6787.03	6125.37	4787.90	3738.44	1863.90
Chinnar	3165.69	2188.22	1953.68	1504.04	1156.29	574.11
Sulagiri	23065.04	16431.20	14412.22	12260.15	8804.90	4524.42
Markandanadhi	16211.43	11019.98	9706.08	7653.07	5996.57	3170.09
Middle Ponnaiyar	28946.26	20131.86	17898.97	14107.05	11127.35	5877.31
Nachikuppam	5813.19	4016.79	3531.38	2774.53	2149.23	1121.45
Veppanapalli	906.53	623.53	547.96	429.41	334.81	173.20
Lower Ponnaiyar	60523.27	42042.50	37160.07	29320.00	23106.16	12338.16
Total	148890.84	103241.11	91335.73	72836.15	56413.75	29642.64

Sediment yield for Land use



Average Sediment yield from different Land uses categories in Krishnagiri Reservoir Catchment area

- **scrub land** contribute more sediment load and combined with Agricultural lands, it is more than 80% of the total load from the catchment area.
- Average sediment yield from agricultural land was 5.97 t/y without any land treatment
- Even though Bio-fencing and Minimum tillage reduce sediment yield to 2.35 t/y and 3.01 t/y respectively, the possibility of minimum tillage operation in all the field are very less.

Conclusion

- The current practice of **stone wall** and **field bunding** in the agricultural lands reduces sediment yield upto **26%** (4.36 t/y) and **35%** (3.84 t/y) respectively.
- Maximum reduction in the sediment yield feasible in the catchment was 90% in the case of **Mulching** and **61%** in the case of Bio-fencing while all other measures the reduction achieved was less than **50%**.
- The **scrub land** in the catchment area contributes **higher sediment yield** than agricultural lands.
- Among all practices **mulching** and **bio-fencing** are found to be more effective and feasible in the catchment area.
- Therefore the results of the simulation study suggest that Mulching and Bio-fencing can be effective in reducing sediment yield from the catchment area of the Krishnagiri Reservoir and may be considered for implementation.

THANK YOU FOR YOUR KIND ATTENTION