

HYDROLOGICAL ASSESSMENT OF GRIDHAMAL BASIN AND SENSITIVITY ANALYSIS USING SWAT

1

By
V Kumar

Madurai

PROBLEM FORMULATION

2

- Urban water usage/management and Food production has to be addressed in the perspective of **sustainable approach** but there is a lagging of this approach in our present scenario.
- **WATER CRISES at GRIDHAMAL Basin.**
- No Irrigation (crop production) & Groundwater depletion
- Increasing of urban water stress and Inefficient usage of treated wastewater.



Tamil Nadu Worst North East Monsoons in 150 years	
Years	October 1st - December 31st Rainfall in mm
1876	163.5
2016	168.4
1892	186.2
1938	194.5
1897	197.2
1878	220.6
1904	229.9
1974	233.4
1988	234.6
1949	235.4
1909	239.1
1947	239.1
1995	260.0
1950	275.9
1889	277.6
1927	287.5
1986	289.2
1886	293.0
1952	302.6
1879	303.3



AIM: To establish the treated wastewater as an reliable source for Crop production, Groundwater Recharge.

OBJECTIVES :

- To study the treated wastewater along with surface runoff respect to different crops
- To establish a model that would generate framework in different scenario using **SWAT**.
- To generate the output as CROP GROWTH, GW Recharge, SOCIO-ECONOMIC Benefits.

SWAT

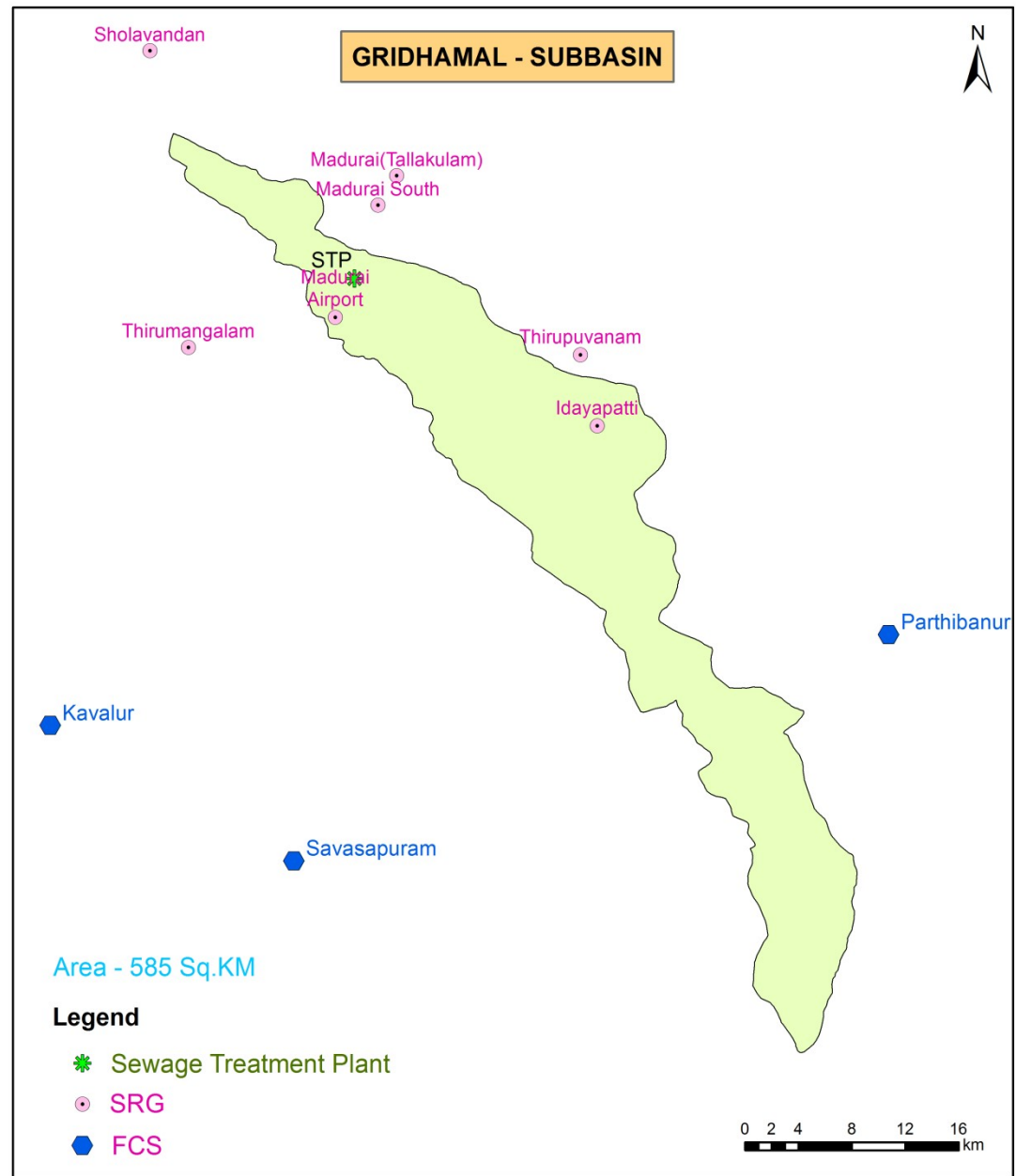
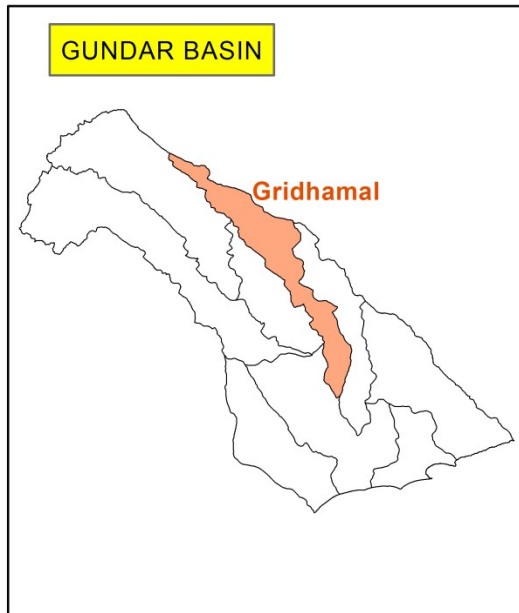
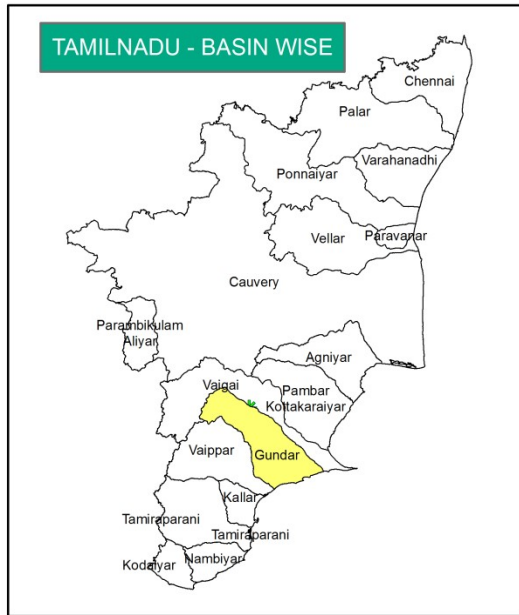
5

- **SWAT** (Soil and Water Assessment Tool)

- A Semi-Distributed hydrological model with world wide acceptance for watershed projects.

SWAT is developed to predict the impact of land management practices on **hydrologic components, crop growth, sediment load** and **water quality** including **Total nitrogen (TN)** in large complex watersheds over long periods of time.

STUDY AREA



METHODOLOGY

PRIMARY WORK

- INVENTORY STUDY ON STP (Quality and Quantity Parameter)
- INVENTORY ON WATERBODIES (Ayyacuts, Capacity and Position)
- CROPPING PATTERN by TNAU
- CLIMATIC & WEATHER DATA (Precipitation, max-min Temp)

SECONDARY WORK

- DIGITAL ELEVATION MODEL
- LANDUSE & LANDCOVER MAP
- SOIL MAP

- WATERSHED DELINATION
- HRU PREPARATION
- WEATHER INPUT using PCP-STAT

SIMULATION

MODEL CALIBRATION

VALIDATION

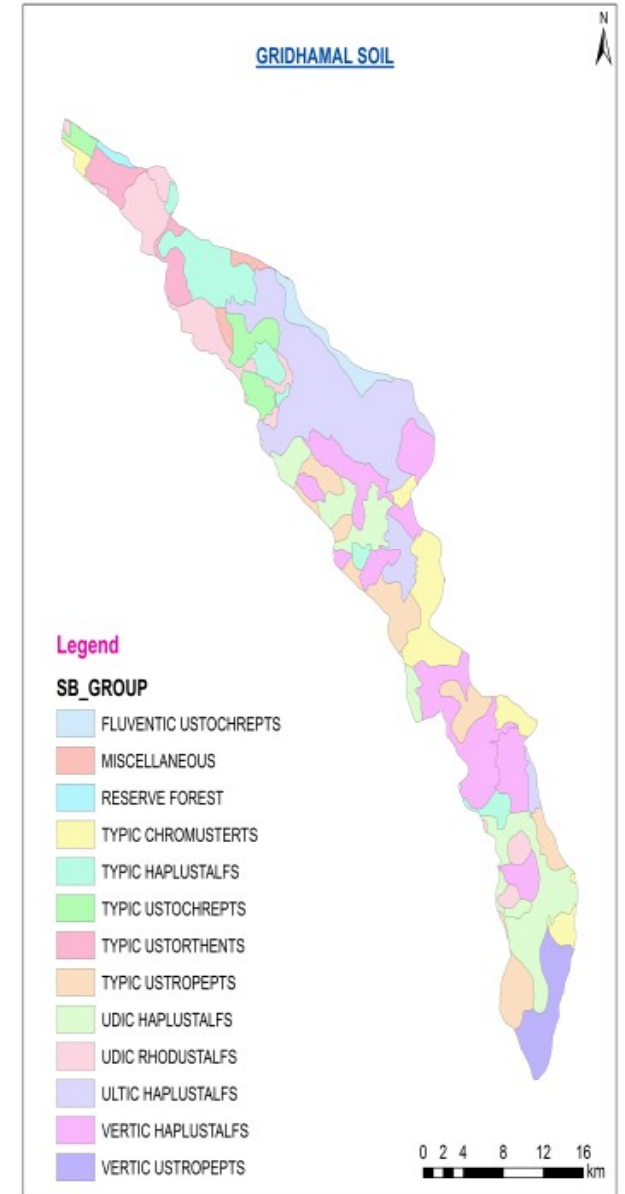
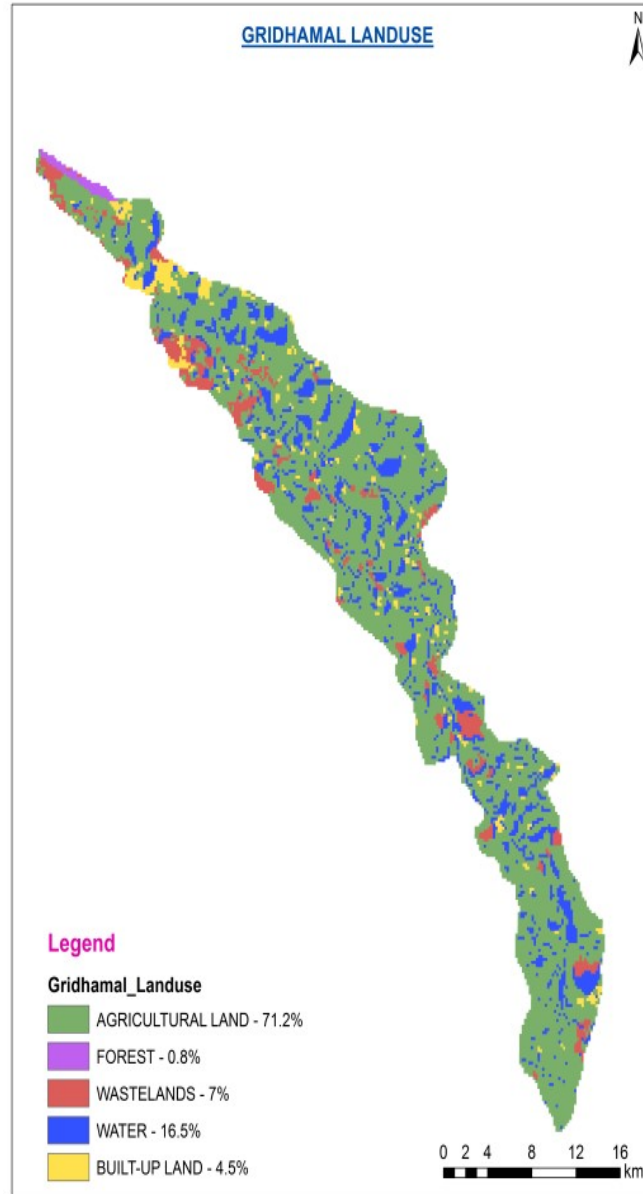
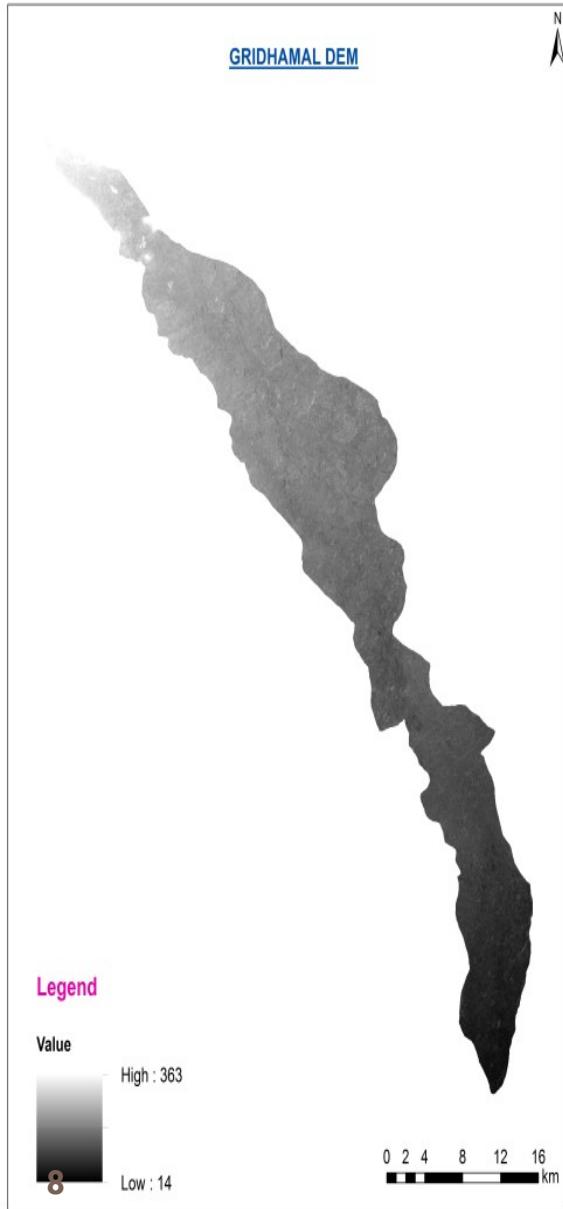
SWAT-CUP SUFI2

CROP GROWTH

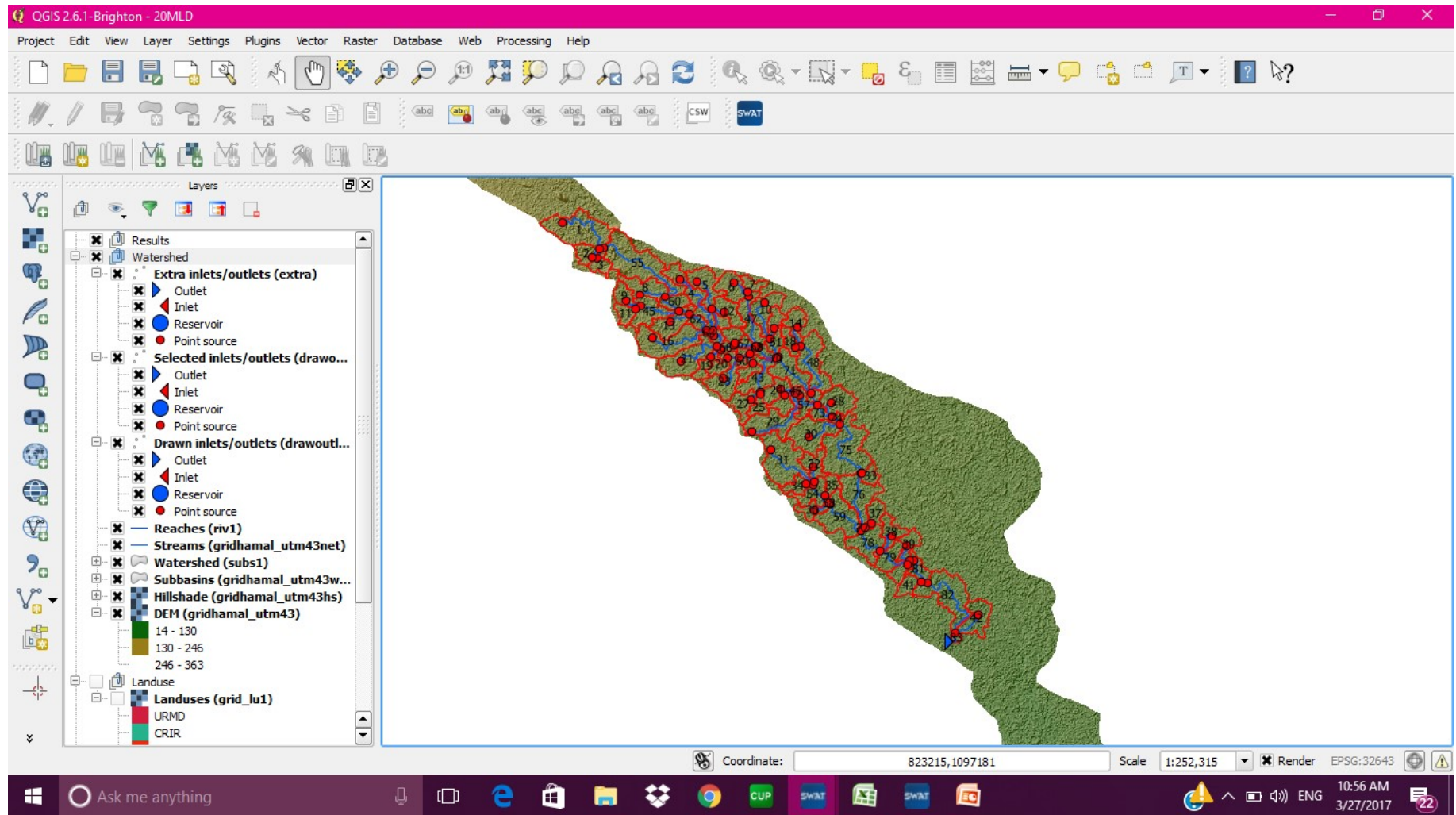
GROUNDWATER RECHARGE

SOIL CHARACTERISTICS CHANGES

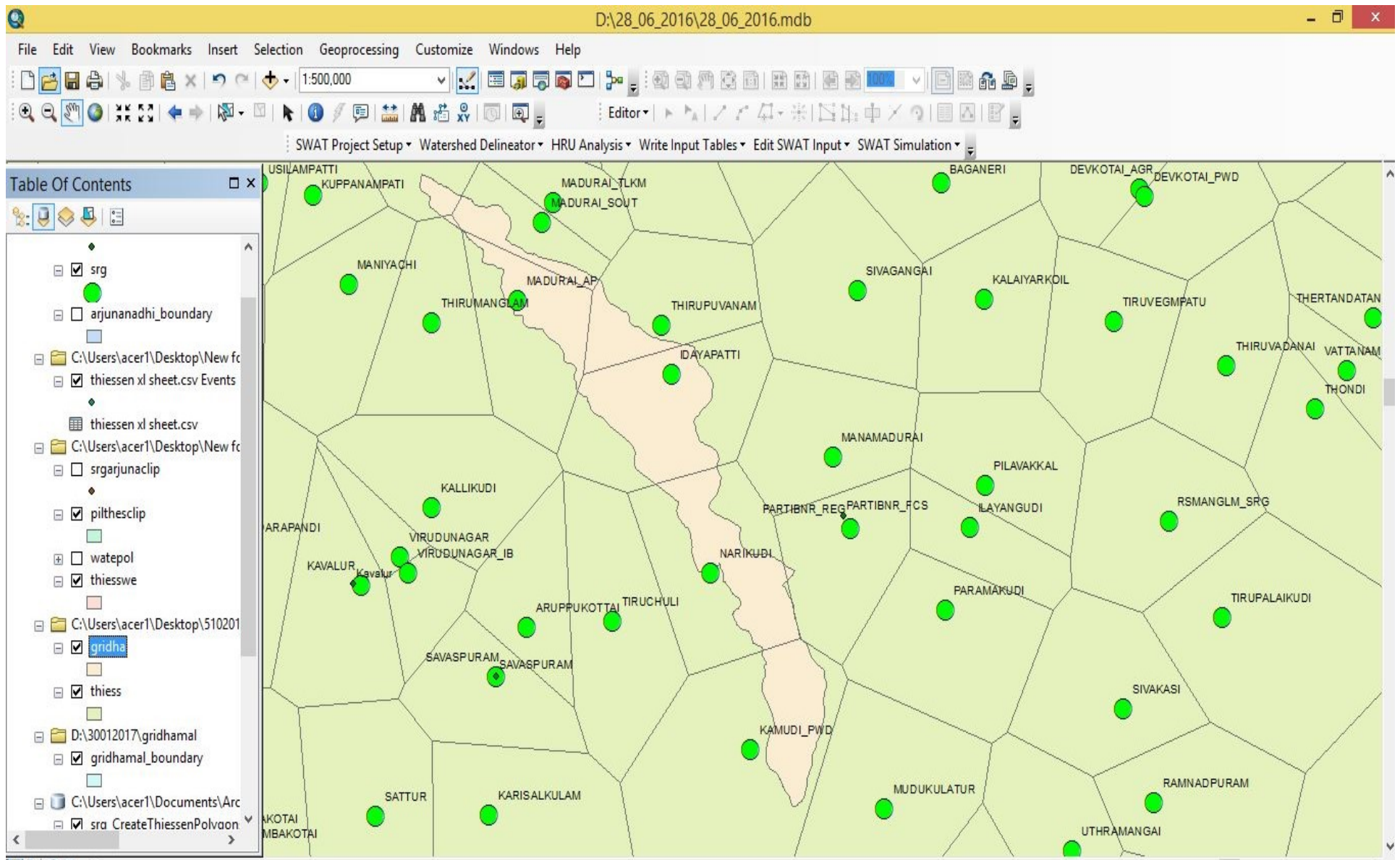
SOCIO-ECONOMIC BENIFITS



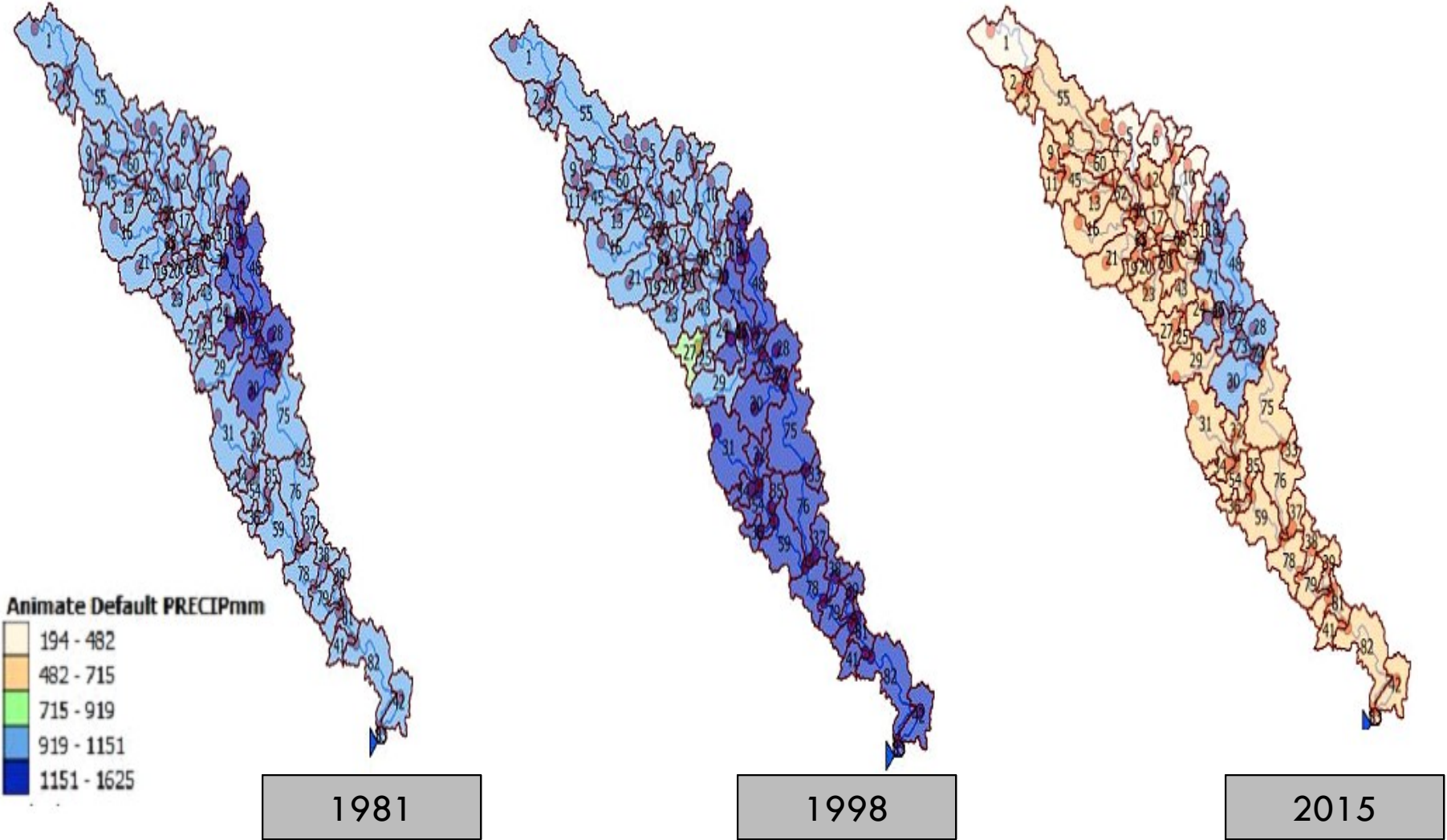
WATERSHED DELINEATION and HRU COMPLETION



THISSION POLYGON

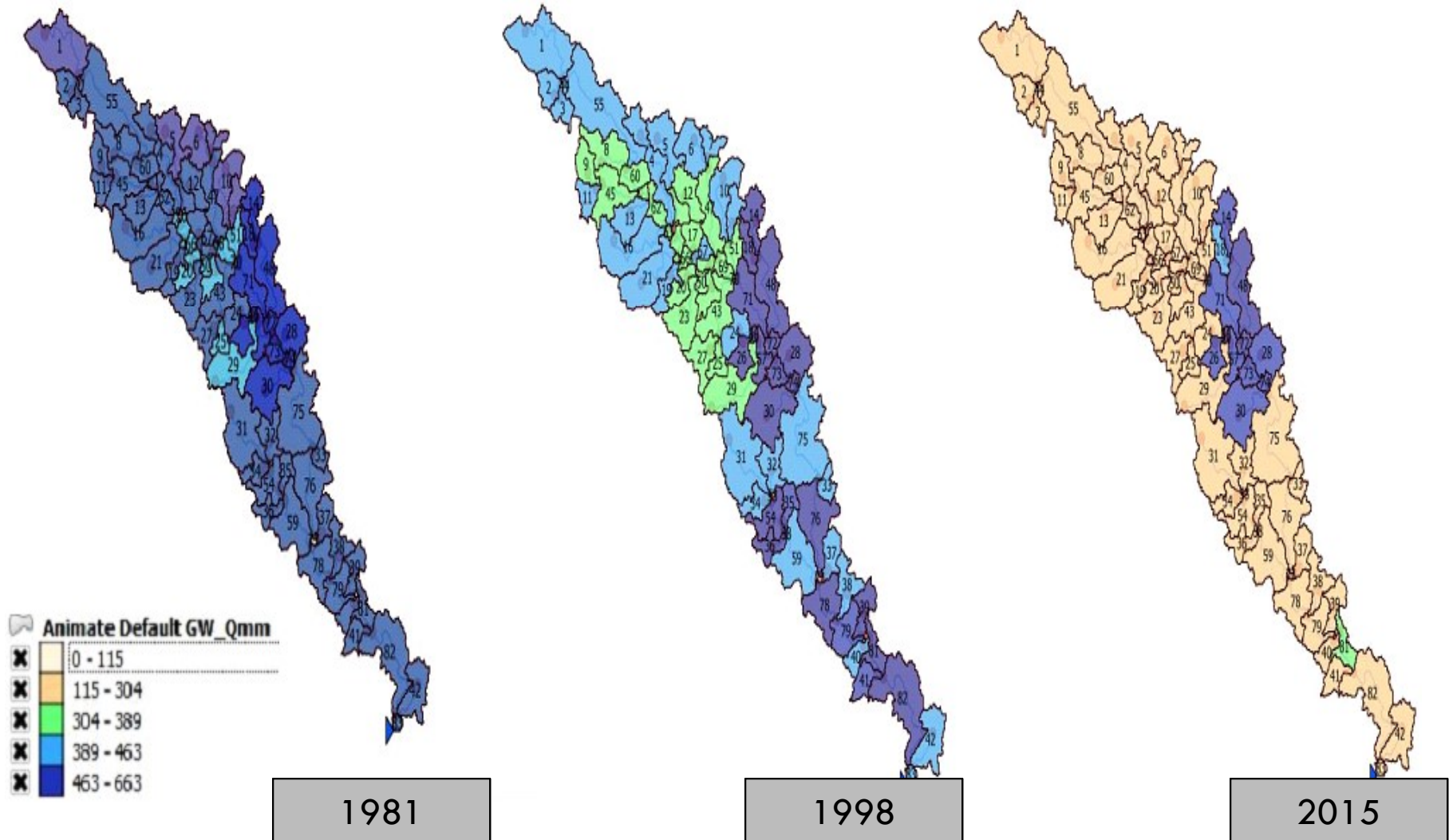


Variations in Precipitation



Variations in Ground water Recharge

12

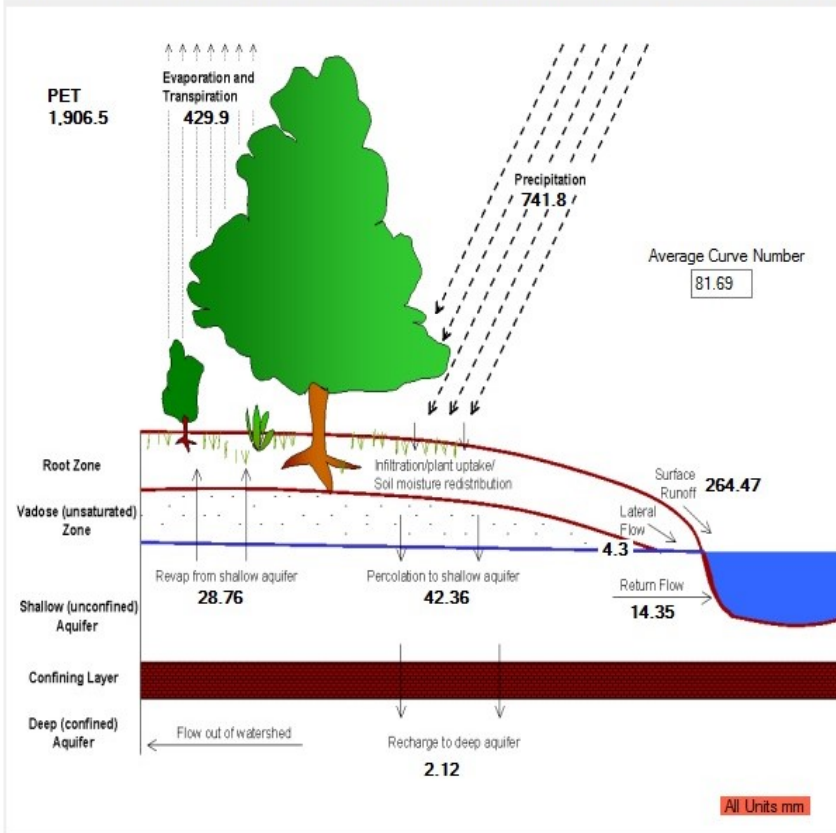


Results

13

SWAT Error Checker - Version 1.2.0.4 Released July 28, 2015

Setup Hydrology Sediment Nitrogen Cycle Phosphorus Cycle Plant Growth Landscape Nutrient Losses Land Use Summary Instream Processes Point Sources Reservoirs About



Realistic hydrology is the foundation of any model. Pay particular attention to evapotranspiration, baseflow and surface runoff ratios. Baseflow/streamflow ratios for the US are provided by the USGS, these data are accessible via the button below. The ranges specified here are general guidelines only, and may not apply to your simulation area.

Show Avg. Monthly Basin Values

Show US Baseflow Map

Messages and Warnings

Surface runoff ratio may be high (> 0.8)
Groundwater ratio may be low
Surface runoff may be excessive

Water Balance Ratios

Streamflow/Precip	0.38
Baseflow/Total Flow	0.07
Surface Runoff/Total Flow	0.93
Perc/Precip	0.06
Deep Recharge/Precip	0
ET/Precipitation	0.58

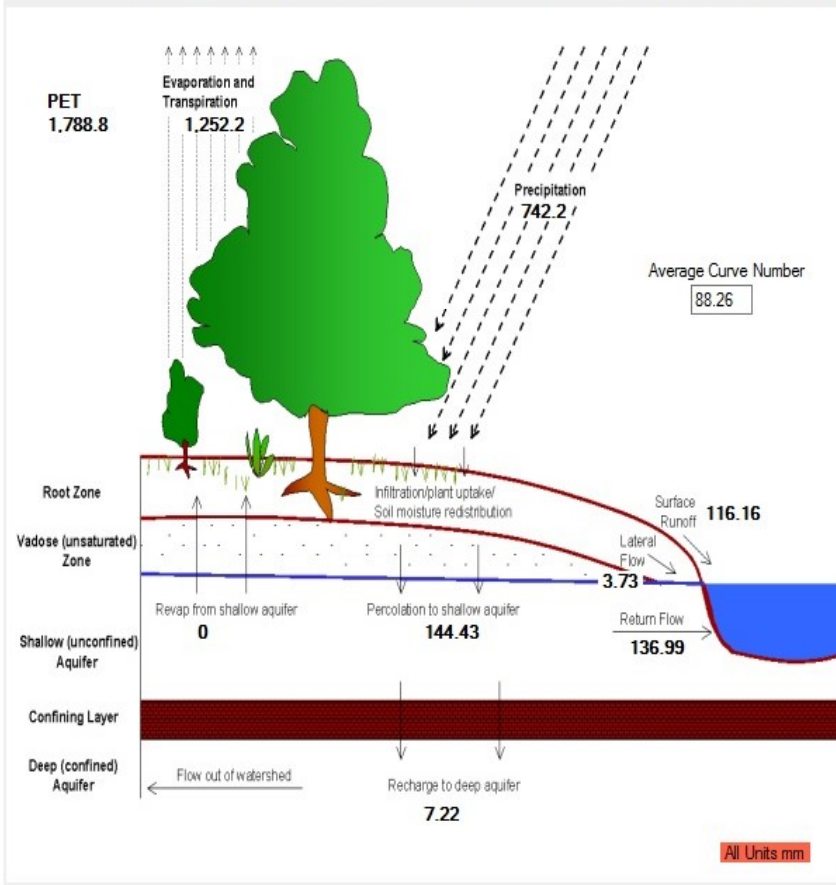
Infiltration
42.36 mm

2nd Scenario

14

SWAT Error Checker - Version 1.2.0.4 Released July 28, 2015

Setup Hydrology Sediment Nitrogen Cycle Phosphorus Cycle Plant Growth Landscape Nutrient Losses Land Use Summary Instream Processes Point Sources Reservoirs About



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Show Avg. Monthly Basin Values

Show US Baseflow Map

Messages and Warnings

ET Greater than precip, may indicate a problem unless irrigated

Water Balance Ratios

Streamflow/Precip	0.35
Baseflow/Total Flow	0.55
Surface Runoff/Total Flow	0.45
Perc/Precip	0.19
Deep Recharge/Precip	0.01
ET/Precipitation	1.69

Infiltration
144.43 mm

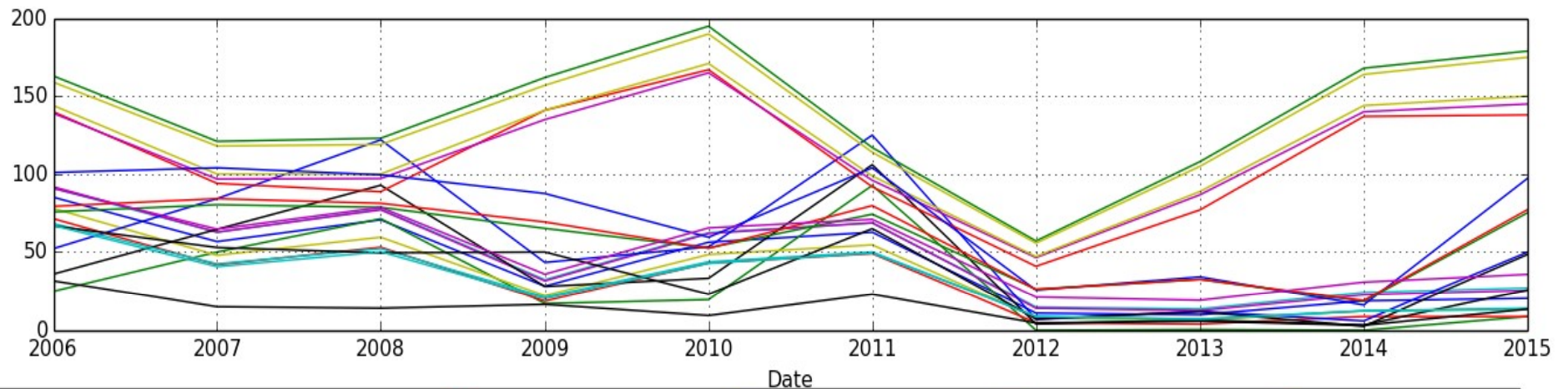
Increases as
3.4 times

Characteristics of Treated wastewater

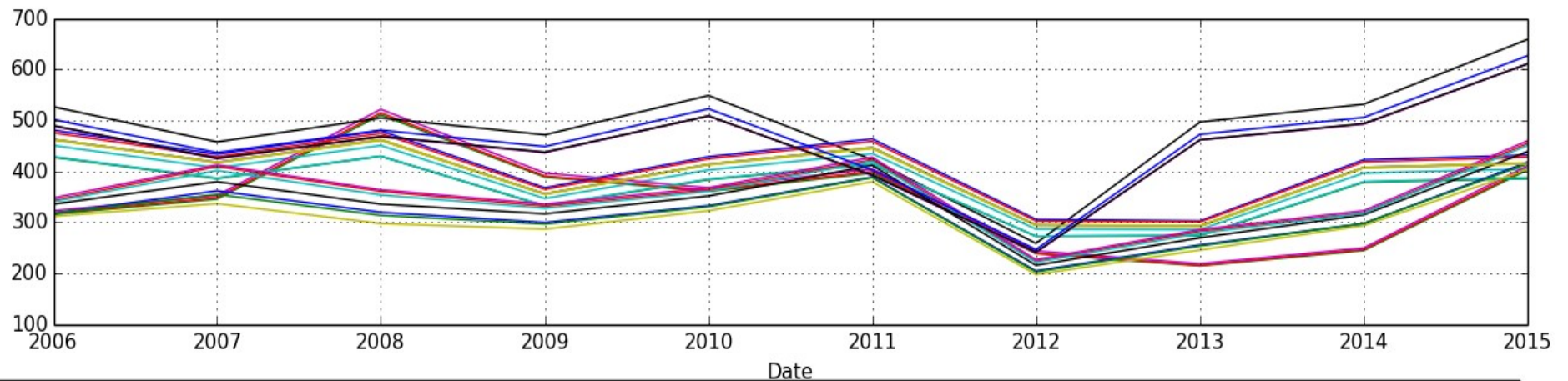
S.No	PARAMETER	CONCENTRATION (ACTUAL)	UNITS	STANDARD LEVEL
1	BOD	8	mg/l	< 30
2	COD	24	mg/l	< 250
3	TSS	6	mg/l	50-100
4	PH	7.3	---	6.5 – 8.4
5	OIL & GREASE	0.7	mg/l	< 10
6	POTASSIUM	31	mg/l	5 to 20
7	SODIUM	391	mg/l	115-230 mg/l for Sensitive crops. 230-460 mg/l Tolerant crops.
8	PHOSPHORUS	1.24	mg/l	0.1 to 0.4
9	NITROGEN	7.85	mg/l	>10

PERCOLATION Changes

Comparison of 22 Sub-basins



ault-sub-12-PERCmm Default-sub-7-PERCmm Default-sub-48-PERCmm Default-sub-30-PERCmm Default-sub-38-PERCmm Default-sub-54-PERCmm
 ault-sub-24-PERCmm Default-sub-10-PERCmm Default-sub-20-PERCmm Default-sub-31-PERCmm Default-sub-42-PERCmm Default-sub-76-PERCmm



ault-sub-10-PERCmm Default-sub-19-PERCmm Default-sub-25-PERCmm Default-sub-34-PERCmm Default-sub-54-PERCmm Default-sub-47-PERCmm
 ault-sub-13-PERCmm Default-sub-20-PERCmm Default-sub-28-PERCmm Default-sub-38-PERCmm Default-sub-76-PERCmm Default-sub-49-PERCmm

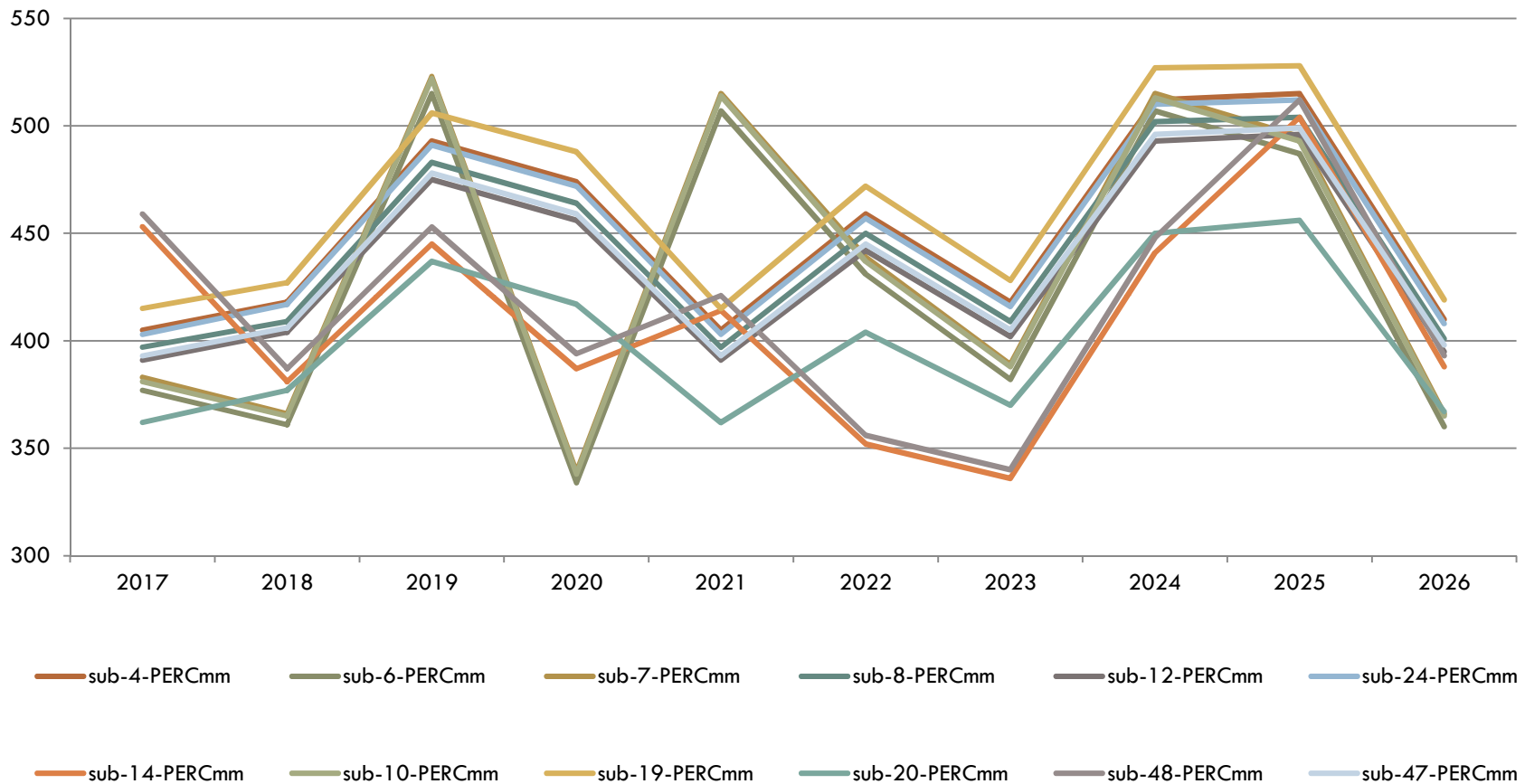
Prediction of 6 Sub-basins Percolation with 20 MLD Flow

PREDICTED PERCOLATION



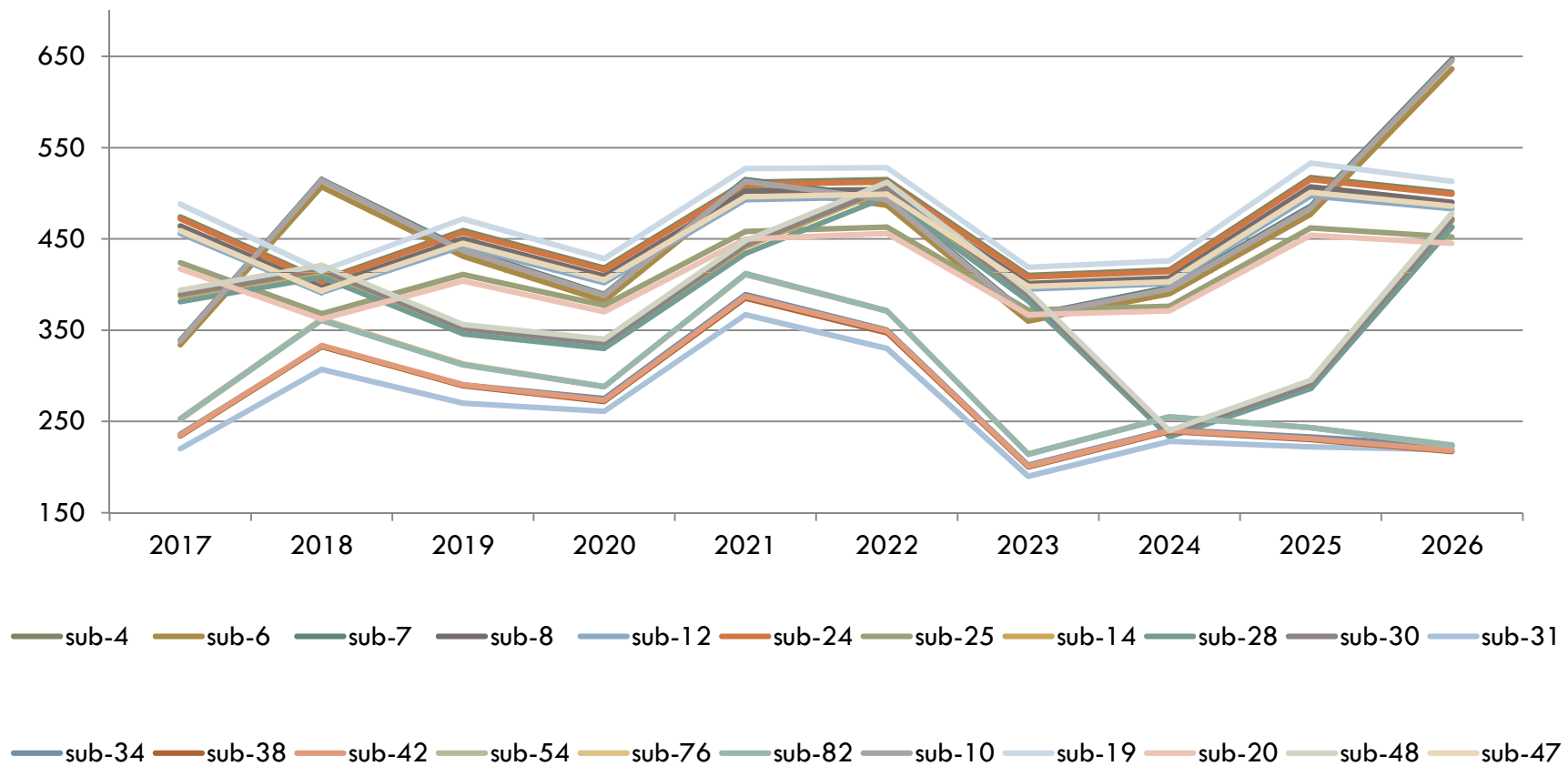
- Area of 1st 6 sub-basins was 1622 ha.
- Average recharge would be 404.2 mm

Prediction of 12 Sub-basins Percolation with 60 MLD Flow



- Area of 1st 12 sub-basins was 2988 ha.
- Average recharge would be 422.5 mm

Prediction of 22 Sub-basins Percolation with 100 MLD Flow



- Area of 1st 22 sub-basins was 6489 ha.
- Average recharge would be 373.6 mm

CROP GROWTH

SWAT Error Checker - Version 1.2.0.4 Released July 28, 2015

Setup Hydrology Sediment Nitrogen Cycle Phosphorus Cycle Plant Growth Landscape Nutrient Losses Land Use Summary Instream Processes Point Sources Reservoirs About

Proper plant growth is key to accurate runoff and sediment predictions. Problems in plant growth are often related to excessive stress due to temperature or the lack of water/nutrients. The data presented here are basin averages, and may not reflect problems with individual land uses. Carefully review the land use summary tab.

Average Biomass (Mg/ha) All Units kg/ha
 Average Yield (Mg/ha)

N Removed in Yield
 P Removed in Yield

Temperature Stress Days
 Water Stress Days
 Nitrogen Stress Days
 Phosphorus Stress Days

Messages and Warnings
 Unusually low phosphorus stress

Total Fertilizer N
 Total Fertilizer P

Plant Uptake N
 Plant Uptake P

SWAT Error Checker - Version 1.2.0.4 Released July 28, 2015

Setup Hydrology Sediment Nitrogen Cycle Phosphorus Cycle Plant Growth Landscape Nutrient Losses Land Use Summary Instream Processes Point Sources Reservoirs About

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Average Biomass (Mg/ha) All Units kg/ha
 Average Yield (Mg/ha)

N Removed in Yield
 P Removed in Yield

Temperature Stress Days
 Water Stress Days
 Nitrogen Stress Days
 Phosphorus Stress Days

Messages and Warnings
 Unusually low phosphorus stress

Total Fertilizer N
 Total Fertilizer P

Plant Uptake N
 Plant Uptake P

Average Biomass (Mg/ha)
 Average Yield (Mg/ha)

Average Biomass (Mg/ha)
 Average Yield (Mg/ha)

Average Biomass (Mg/ha)
 Average Yield (Mg/ha)

Management File – Schedule

QSWAT 1.3

Edit Management Parameters: Subbasin 1, Land Use CRGR, Soil Af17-1-2a-2, Slope 0-2.0

General Parameters | Operations | HRU Info

Add Year
Delete Year
Add Operation
Delete Operation
Edit Operation

Current Management Operations					
Year	Month	Day	Operation	Crop	
1	1	11	Plant/begin. growing se	CORN	
1	1	20	Auto fertilization initializ		
1	1	25	Auto irrigation initializati		
1	5	10	Harvest and kill operati		
1	5	30	Tillage operation		
1	6	15	Plant/begin. growing se	RICE	
1	6	25	Auto fertilization initializ		
1	7	5	Auto irrigation initializati		
1	11	15	Harvest and kill operati		

Load Schedule
Save Schedule

Operation Parameters

Schedule by Date
 Schedule By Heat Units

OP NUM Year of Rotation : 1

Cancel OK

Edit Values
Cancel Edits
Save Edits
Exit

Extend Parameter Edits

Extend ALL MGT General Parameters
 Extend Management Operations
 Extend Edits to Current HRU
 Extend Edits to All HRUS
 Extend Edits to Selected HRUS

Selected HRUs

Subbasins Land Use Soils
Slope

watershed (subs1)
Subbasins (gridhamal utmwsh...)

Coordinate 842973, 1096138 Scale 1:203,240 Magnifier 100% Rotation 0.0 Render EPSG:32643 (OTF)

Ask me anything 2:49 PM 3/25/2017

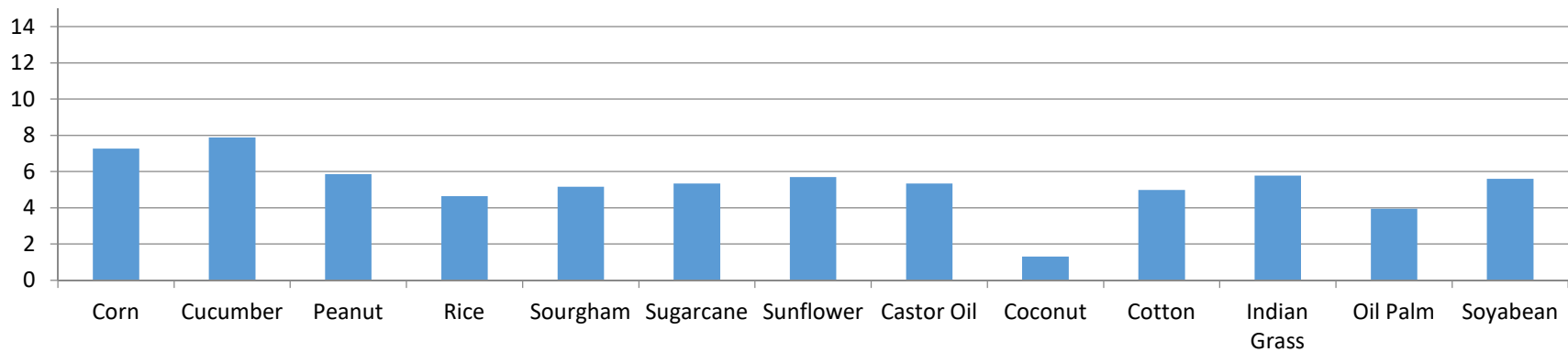
Comparison of Simulated yield with average by TNAU

Crop Growth						
Sl.No	Crop Name	Model Simulated Yield Kg/Hec	Avg. Range by TNAU	Average Yield by TNAU	Deviation	Suitability
1	Rice	3200	3000-3500	3200	0	Highly Suitable (A)
2	Corn	4900	4000-5000	4800	-2.083	Highly Suitable (A)
3	Cucumber	6200	6000-8000	7000	11.42	Highly Suitable (A)
4	Peanut	1600	1800-2200	2000	20	Highly Suitable (A)
5	Sunflower	1000	1100-1400	1200	16.67	Highly Suitable
6	Sugarcane	110	100-120	110	0	Highly Suitable (A)
7	Sorghum	1800	1600-1900	1800	0	Highly Suitable (A)
8	Coconut	9500	12000-15000	13500	29.6	Suitable
9	Oil Palm	500	300-400	350	-42.8	Suitable
10	Castor Oil	180	200-300	250	28	Suitable
11	Soyabean	550	600-900	700	21.42	Suitable
12	Spinach	5100	6000-8000	7000	27.2	Suitable (A)
13	Cotton	400	500-700	600	33.33	Suitable
14	Indian Grass	8100	10000-16000	13500	40	Suitable
15	Banana	6000	35000-40000	36000	83.3	Not Suitable
16	Papaya	3600	30000-36000	32000	88.75	Not Suitable
17	Cabbage	1000	45000-55000	55000	98.18	Not Suitable
18	Orange	600	1600-2100	1800	66.67	Not Suitable
19	Pine Apple	5000	30000-36000	32000	84.3	Not Suitable
20	Potato	3000	12000-16000	14000	78.5	Not Suitable
21	Tomato	1600	11500-14000	12500	87.2	Not Suitable
22	Sweet Potato	500	11000-15000	12000	95.83	Not Suitable
23	Tobacco	100	300-500	350	71.42	Not Suitable
24	Onion	3200	7000-8000	7200	55.55	Not Suitable
25	Water Melon	4400	25000-30000	27000	83.7	Not Suitable
26	Green Beans	2600	8000-10000	8700	70.1	Not Suitable

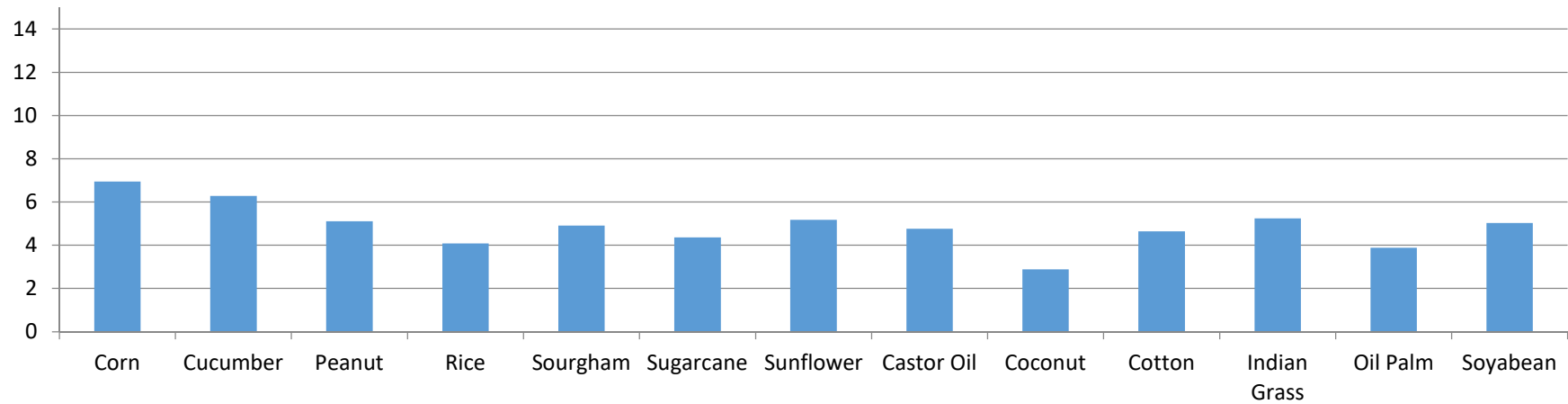
A – Crops having this mark are already an usual crop in our study area

NUTRIENT CHANGES

■ % change in ORG P



■ % change in ORG N



Calibration

Parameterization twocalibration.Sufi2 - SWAT-CUP

Home Parallel Processing Utility Programs Layout Parameterization

Paste Cut Copy Delete Undo Redo Find Next Bookmark Previous Bookmark Clear Bookmarks Save Save All Add a new parameter Insert a new parameter Import New Parameters

Project Explorer

- Iter14
- Iter15
- Iter16
- Iter17
- Iter18
 - Calibration Inputs
 - Par_inf.txt
 - SUF12_swEdit.def
 - File.Cio
 - Absolute_SWAT_Val.
 - Observation
 - Extraction
 - Objective Function
 - No Observation

Par_inf.txt
Contains input parameters to be optimized. After a complete iteration, review the suggested new parameters in the "Calibration Outputs \new_pars.txt", (change if necessary) and copy them to par_inf.txt and

Iter18 - Par_inf.txt x

Iter18 - Par_inf.txt
Contains input parameters to be optimized. After a complete iteration, review the suggested new parameters in the "Calibration Outputs \new_pars.txt", (change if necessary) and copy them to ...

Number Of Parameters: 11 [1] [All] Number Of Simulations: 250

Parameters:

#	Basic Information			Value			Filter Conditions (optional)						
	Par Name	File Name	File Ext.	Method	Min	Max	Hydro Grp	Soil Texture	Landuse	Subbasins	Slope	Condition..Filt	Layers/C
1	CN2		.mgt	I' Relative	-0.2	0.2				(All)			
2	ESCO		.hru	V Replace	0.8	1				(All)			
3	SOL_AWC		.sol	I' Relative	-0.2	0.1				(All)			(All)
4	ALPHA_BF		.gw	V Replace	0	1				(All)			
5	GW_DELAY		.gw	V Replace	30	450				(All)			
6	GWQMN		.gw	A Absolute	0	25				(All)			
7	GW_REVAP		.gw	A Absolute	-0.1	0				(All)			
8	EPCO		.hru	V Replace	0.8	1				(All)			
9	SOL_K		.sol	I' Relative	-0.8	0.8				(All)			(All)
10	SOL_BD		.sol	I' Relative	-0.5	0.6				(All)			(All)

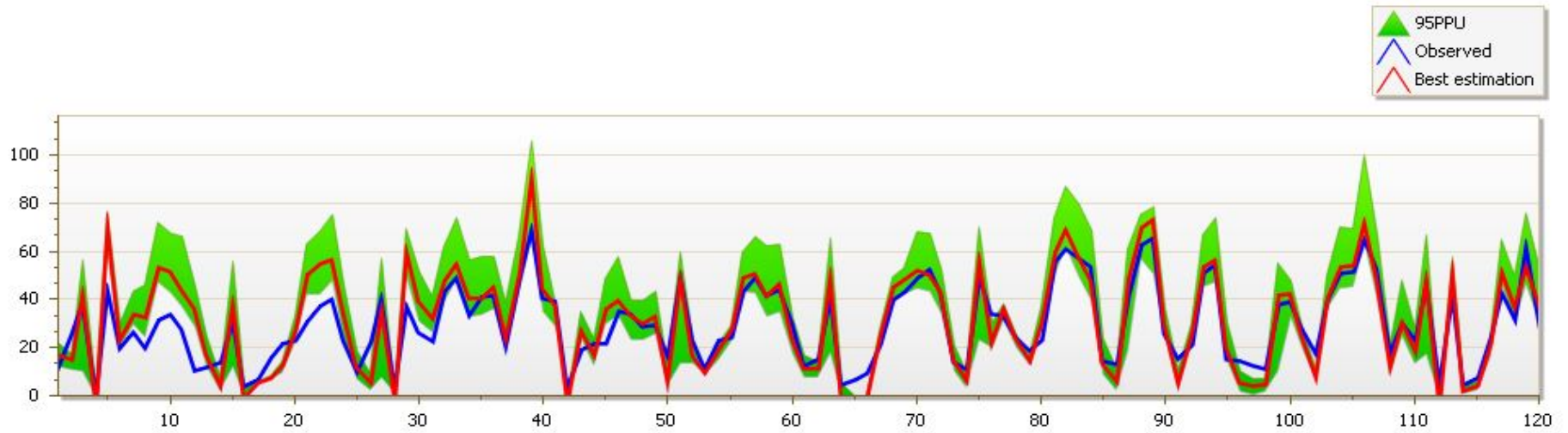
Parallel Processing License Status: Limited | SWAT Version: 2012, Processor Architecture: 64-bit

100%

Type here to search

11:39 AM 4/30/2017

ET_10



Iter18 - Summary_Stat.txt

This file has the statistics comparing observed data with the simulation band through p-factor and r-factor and the best simulation of the current iteration by using R2, NS, bR2, MSE, and SSQR

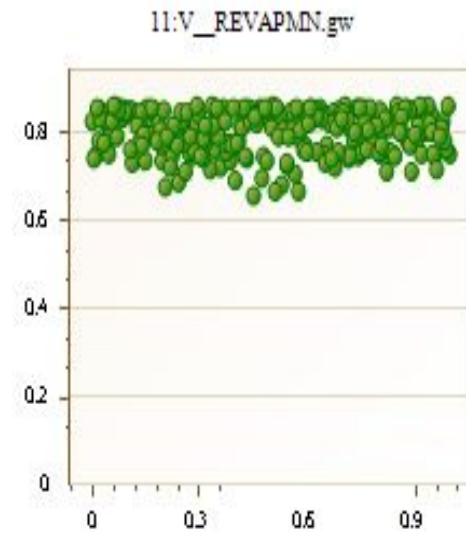
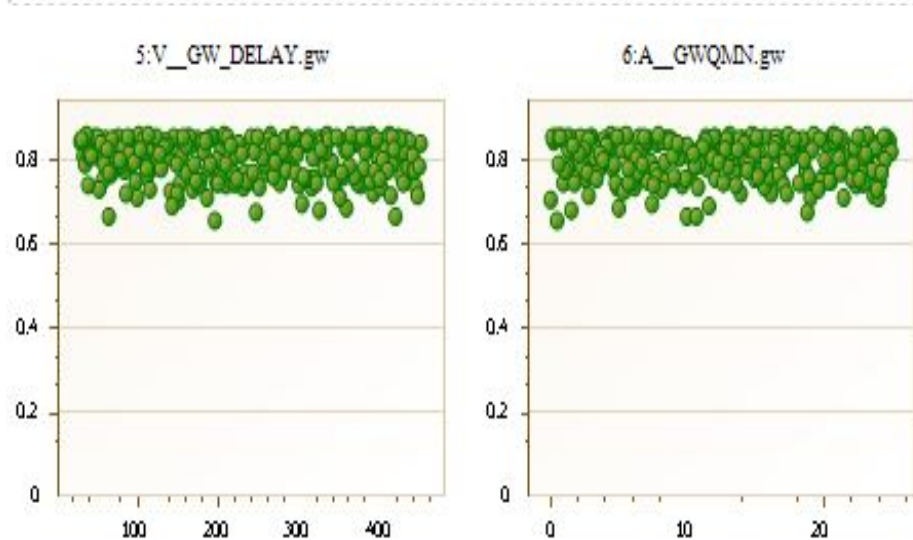
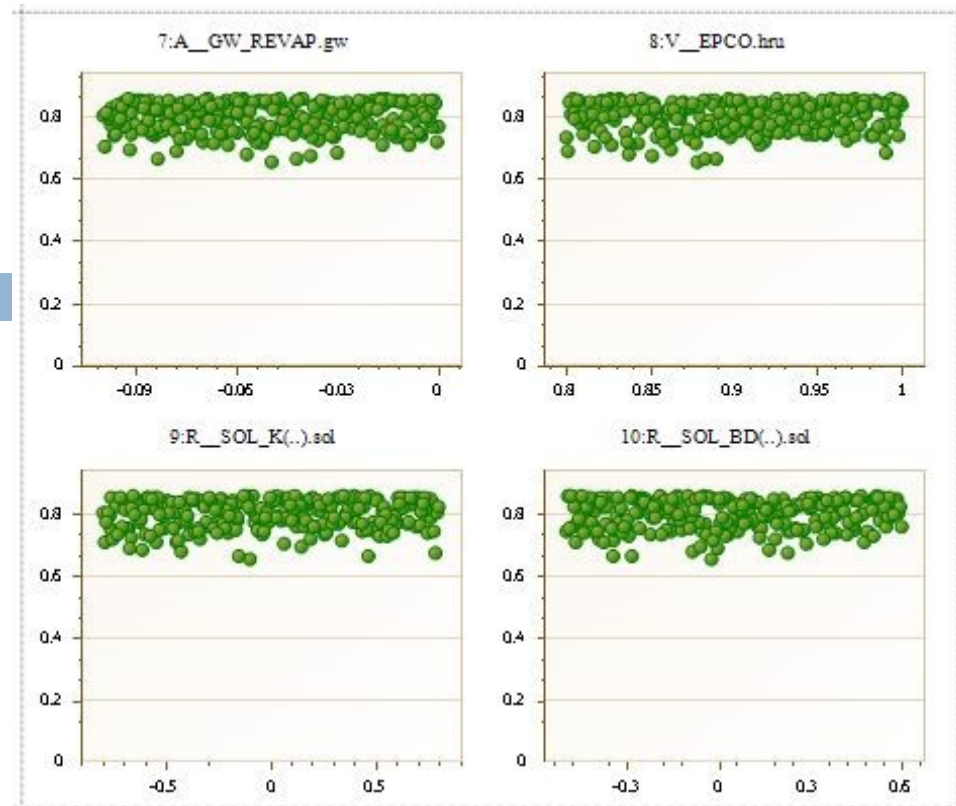
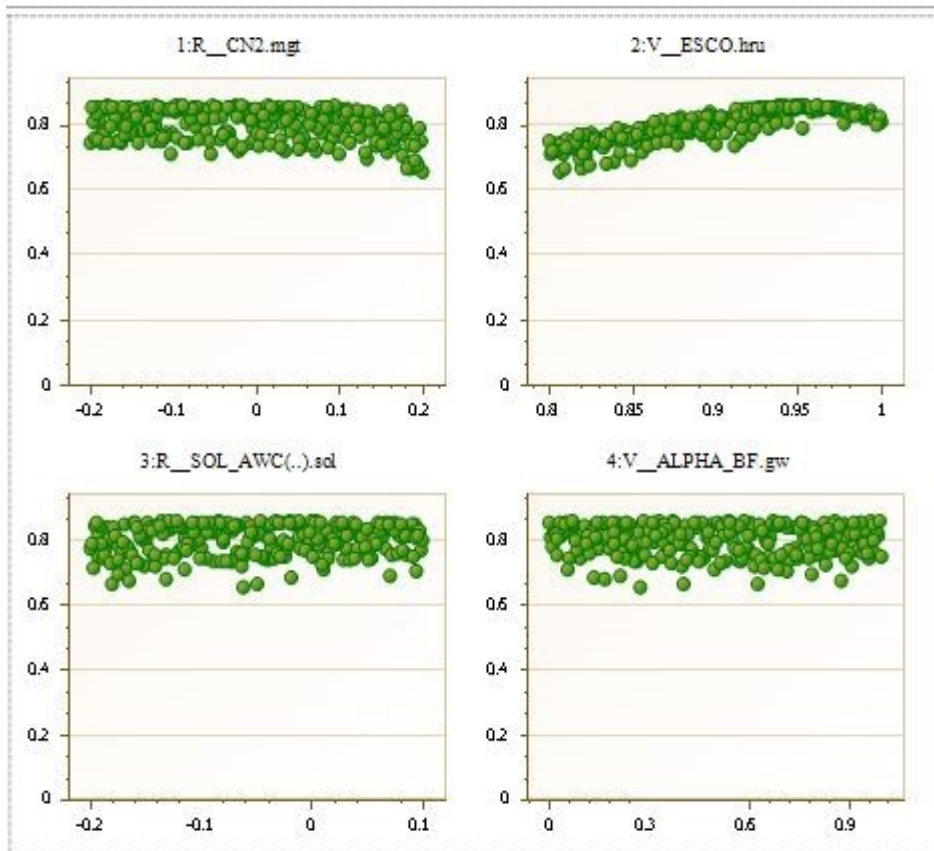
```

Goal_type= R2 ···· No_sims= 250 ···· Best_sim_no= 54 ···· Best_goal = 8.577751e-001

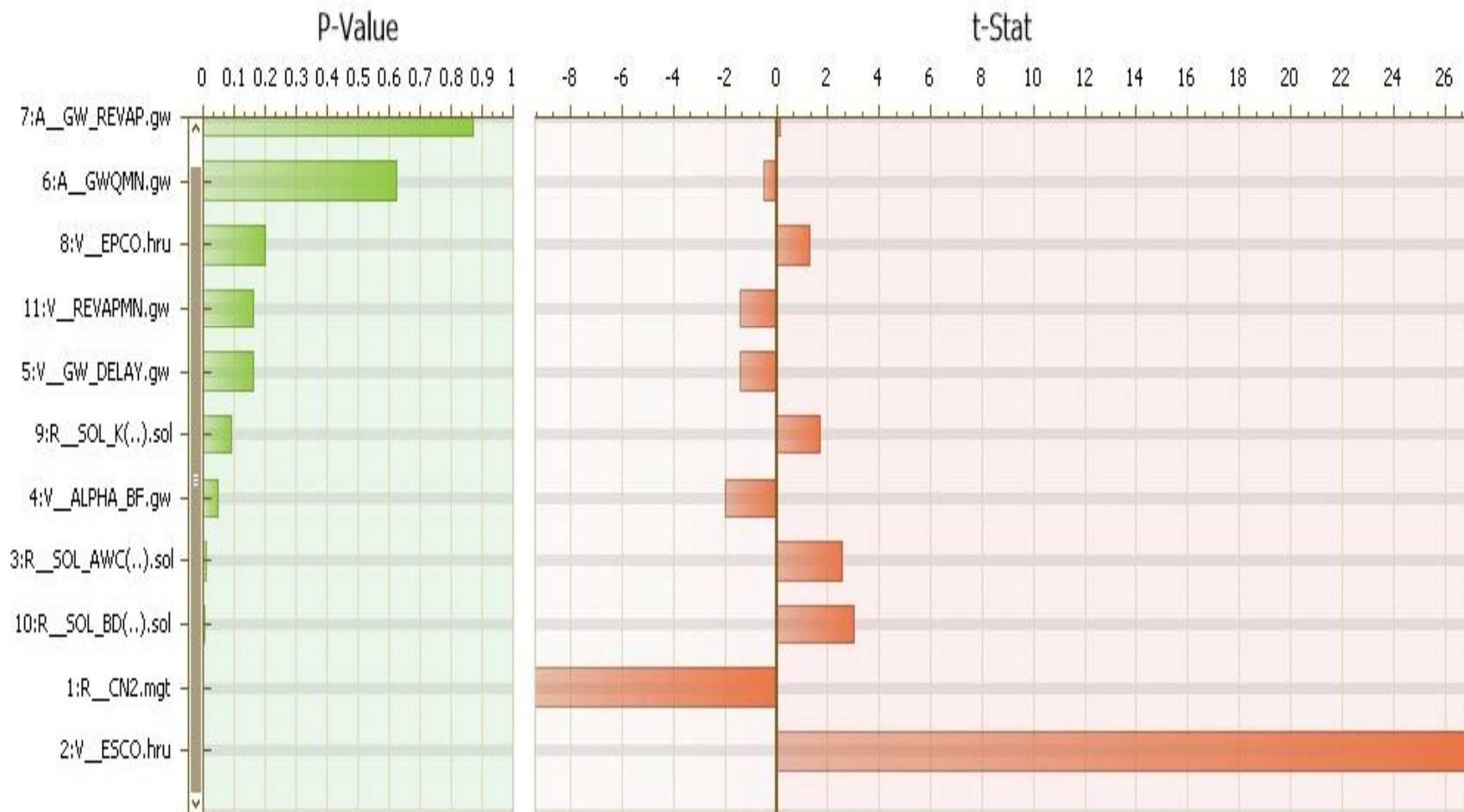
Variable ····· p-factor · r-factor · R2 ··· NS ···· bR2 ····· MSE ····· SSQR ····· PBIAS · KGE · RSR ··· MNS ··· VOL_FR ····· |
ET_10 ····· 0.68 ····· 1.06 ····· 0.86 · 0.72 ···· 0.7307 ···· 7.4e+001 · 3.0e+001 ···· -7.2 · 0.71 · 0.53 · 0.53 · 0.93 ····· |

---- Results for behavioral parameters ----
Behavioral threshold= 0.600000
Number of behavioral simulations = 250

Variable ····· p-factor · r-factor · R2 ··· NS ···· bR2 ····· MSE ····· SSQR ····· PBIAS · KGE · RSR ··· MNS ··· VOL_FR ····· |
ET_10 ····· 0.68 ····· 1.06 ····· 0.86 · 0.72 ···· 0.7307 ···· 7.4e+001 · 3.0e+001 ···· -7.2 · 0.71 · 0.53 · 0.00 · 0.93 ····· |
    
```



Sensitivity Analysis



New set of values

Par_No	Par_Name	Rank	t-Stat	p-value	Description
1	CN2.mgt	11	-9.3825295	0.0000000	curve number
2	ESCO.hru	1	26.9988940	0.0000000	Soil evaporation compensation factor
3	SOL_AWC().sol	3	2.5714094	0.0107371	Available water capacity of soil layer
4	ALPHA_BF.gw	10	-1.9755991	0.0493554	Baseflow factor
5	GW_DELAY.gw	9	-1.4008556	0.1625597	Groundwater delay
6	GWQMN.gw	7	-0.4943307	0.6215285	Threshold water in shallow aquifer required for return flow to occur (mm)

					to occur (mm)
7	GW_REVAP.gw	6	0.1646679	0.8693451	GW "revap" coefficient
8	EPCO.hru	5	1.2904292	0.1981538	Plant uptake compensation factor
9	SOL_K().sol	4	1.7003348	0.0903742	Saturated hydraulic conductivity.
10	SOL_BD().sol	2	3.0291082	0.0027232	Moist bulk density
11	REVAPMN.gw	8	-1.397088	0.1636881	Threshold water in shallow aquifer for "revap" to occur (mm)

par_no	par_name	new_min	new_max
1	r_CN2.mgt	-0.240519	0.053319
2	v_ESCO.hru	0.876490	1.029910
3	r_SOL_AWC().sol	-0.253785	-0.017815
4	v_ALPHA_BF.gw	0.482727	1.449273
5	v_GW_DELAY.gw	147.063324	381.656647
6	a_GWQMN.gw	-5.831972	14.731972
7	a_GW_REVAP.gw	-0.087327	-0.029073
8	v_EPCO.hru	0.886143	1.058657
9	r_SOL_K().sol	-0.200442	1.000442
10	r_SOL_BD().sol	-1.040403	0.053602
11	v_REVAPMN.gw	0.252721	0.759279

Validation

```

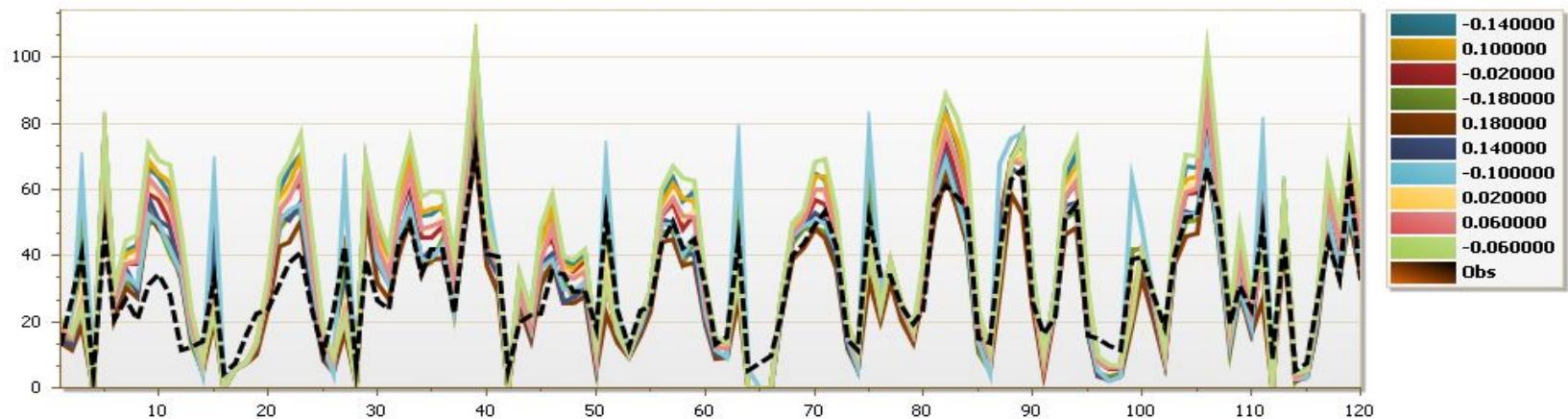
Goal_type=R2···No_sims=10···Best_sim_no=3···Best_goal=8.534294e-001

Variable·····p-factor··r-factor··R2···NS···bR2····MSE····SSQR····PBIAS··KGE··RSR··MNS··VOL_FR··---
ET_10·····0.63····0.89····0.85··0.61··0.6932··1.0e+002··5.7e+001··-14.6··0.63··0.63··0.42··0.87······

----·Results·for·behavioral·parameters·----
Behavioral·threshold=0.600000
Number·of·behavioral·simulations=10

Variable·····p-factor··r-factor··R2···NS···bR2····MSE····SSQR····PBIAS··KGE··RSR··MNS··VOL_FR··---
ET_10·····0.63····0.89····0.85··0.61··0.6932··1.0e+002··5.7e+001··-14.6··0.63··0.63··0.00··0.87······
    
```

ET_10



Summary



- Model is first simulated with Scenario 1 and for this calibration and validation was done with ET values
- Then the corrected model was used for future predictions.
- Outputs are focused on CROP GROWTH, GW RECHARGE, SOIL NUTRIENT CHANGES and ECONOMICAL ASPECTS.

Conclusion and Recommendations

- The results of Calibration and Validation for ET value with objective functions of **R² and NS** were **0.86 & 0.72** and **0.85 & 0.61**
- As an average of more than **300 mm** will be percolated every year in these 22 sub-basins. These sub-basins has an area of 6500 hectares and approximately **19.5 Mm³** of water will gets percolated.
- If we properly utilize the treated wastewater as per this study, the Peri Urban will get lot of benefits in the form of CROP PRODUCTION, GW RECHARGE.

Thank
You