Incorporation of GIUH into the SWAT model

N. Sajikumar & I. Iskender
Government Engineering College
Trichur, Kerala India-680009
saji@gectcr.ac.in

Motivation for the study

- SWAT - a continuous distributed (physically based?) watershed model
- SWAT –can use of the sub daily rainfall data
- If so; is it possible to use as an event model?

Motivation for the study

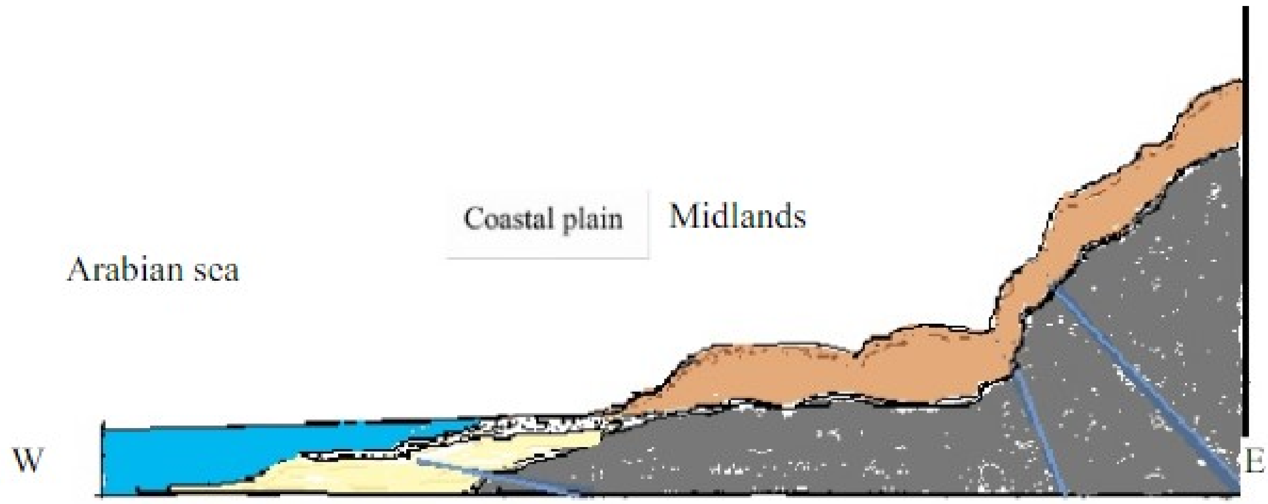
- Internal engine computes at the daily time step
- Lag in surface runoff is being represented by

$$Q_{ch,i} = (Q_{surf,i} + Q_{stor,i-1}) \cdot [1 - e^{(-surlag/t_{conc})}]$$

- Peak by the rational formula

Motivation for the study

- Event model
  - Effect of surface slope
  - Peculiar nature of Kerala
  - Effect of Geo-morphological factors
  - Drainage pattern



Event modelling

- Interested in peak flow
- Continuous model : total volume
- Hence several cases of mismatching peak
- Hourly input without matching peaks may induce a notion of wrong output

literature

- Borah et al.2005
  - Strom event model for Little Wabash River Watershed
  - Predicted one event correctly
- Borah et al.2007
  - Compared two models :SWAT and DWSM
  - Daily peak flows were not estimated
  - Need for comprehensive continuous and event model

literature

- Boithias et al.2017
  - Compared sub daily SWAT and MARINE models for event modelling
  - MARINE model performed better
- Yu et al.2017
  - Improvement of the SWAT model for event-based flood forecasting
  - Synthetic parametric UH

NECESSITY OF THE STUDY

- SWAT model – a continuous model
- There is an option for running the model using hourly rainfall
- Generally, the accuracy of the SWAT model –daily Vs monthly
- Flood simulation in small basins -hourly
- Essential to incorporate hourly flood computation methodologies in SWAT model
  - For small basins

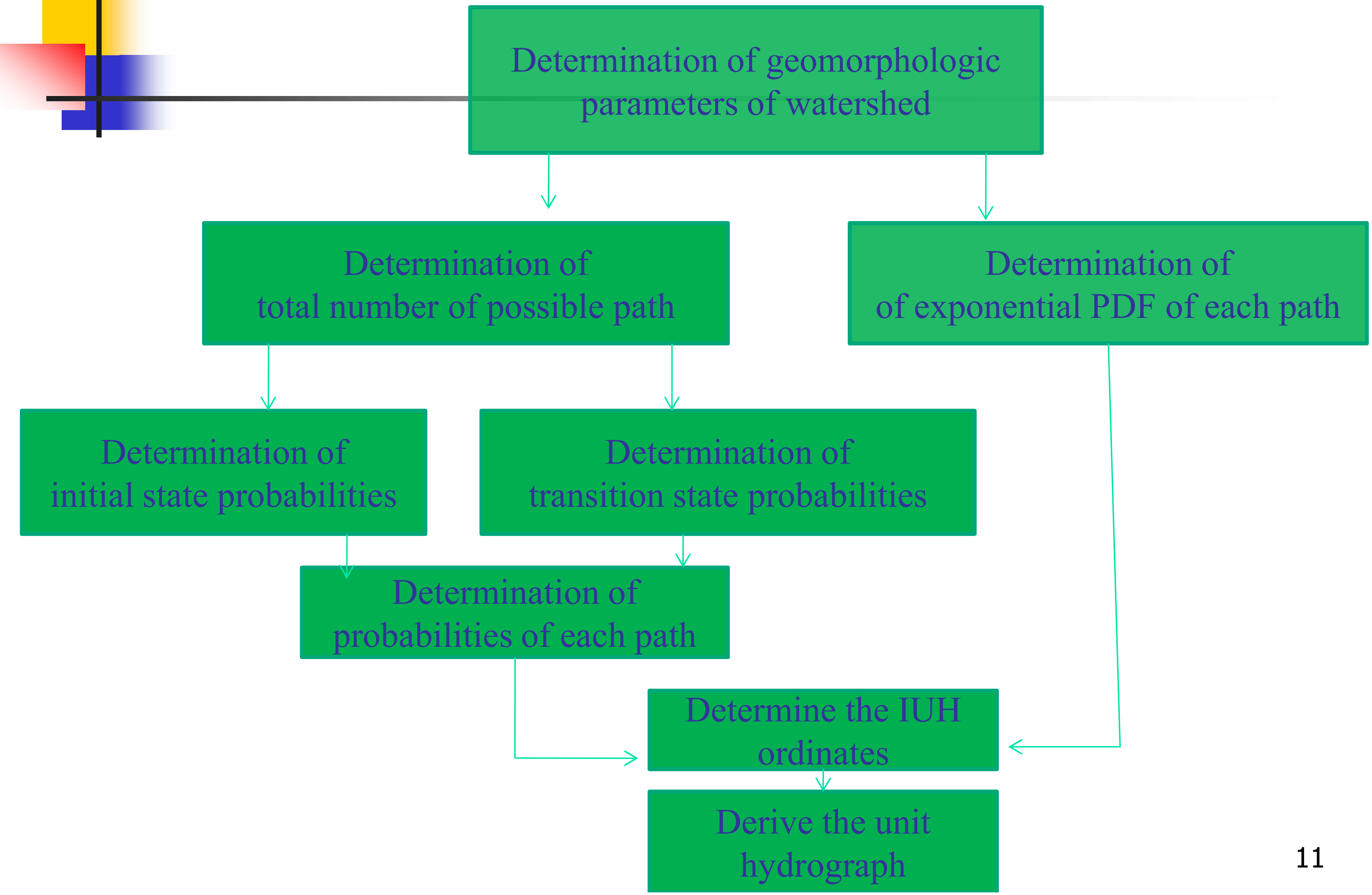
OBJECTIVES

- Incorporation of Geomorphologic Instantaneous Unit Hydrograph(GIUH) into SWAT model by modifying the source code of SWAT model
- Assessing the efficiency of SWAT in event modelling using GIUH and sub daily modelling.

GIUH

- Rodriguez-Iturbe and Juan B.Valdes, (1979)
- Basic idea: The equivalence between the IUH and the probability density function of holding time (T_B)
- Hence very much depend drainage pattern and hence the slope of terrain

DEVELOPMENT OF GIUH



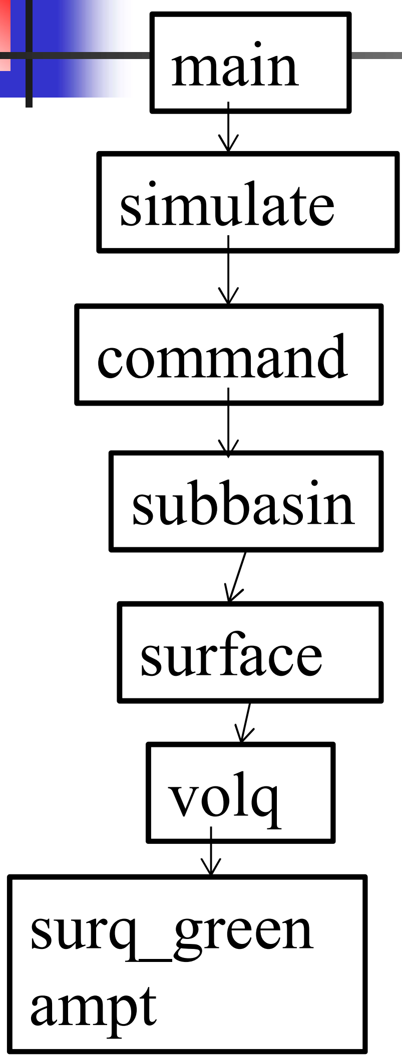
GIUH TOOL

- Tool box in ArcGIS (Anju &Sajikumar 2014)
  1. Bifurcation ratio $R_B = N_i / N_{i+1}$
  2. Length ratio $R_L = L_{i+1} / L_i$
  3. Area ratio $R_A = A_{i+1} / A_i$
  4. Path probability
  5. Travel time parameters
  6. IUH
  7. Unit Hydrograph
  8. Runoff

SWAT SOURCE CODE

- The SWAT source code -FORTRAN 90
- The source code for SWAT model from the site http://swat.tamu.edu.
- Source code consists of various 302 subroutines.
- Three key files of SWAT are as follows
  - a main program file (main.f) to control all main process
  - a module file (modparm.f) containing a parmamter module declaring variables and arrays
  - a dynamic allocation routine (allocate_parms.f) to allocate memory for variables.

HIERARCHY OF SWAT SUBROUTINES TO FIND SURFACE RUNOFF (f files)



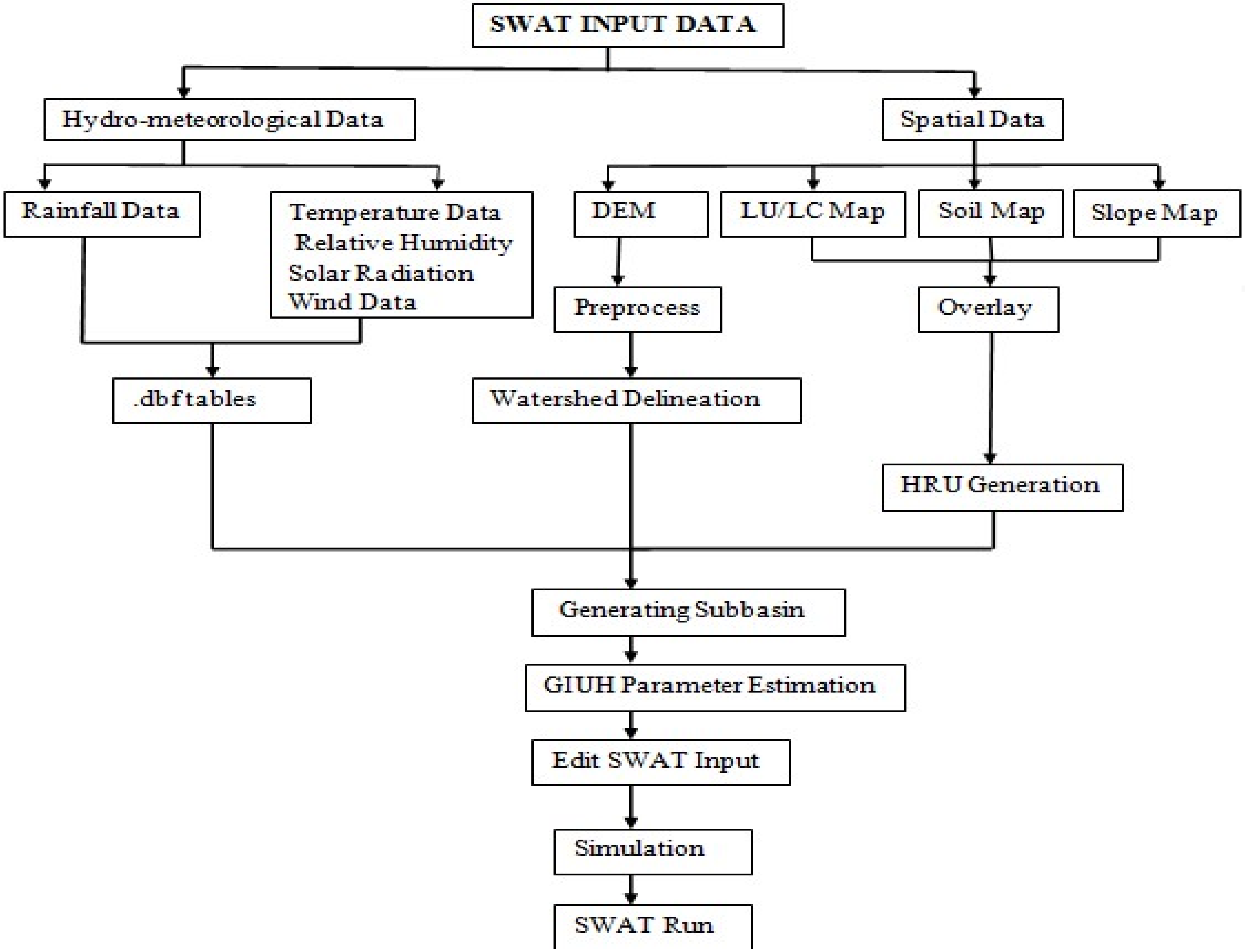
- **main** - main program that reads input, calls the main simulation model, and writes output.
- **simulate** -contains the loops governing the modeling of processes in the watershed
- **command** - for every day of simulation, this subroutine steps through the command lines in the watershed configuration (.fig) file.
- **subbasin** - controls the simulation of the land phase of the hydrologic cycle
- **surface** - models surface hydrology at any desired time step
- **volq** - Call subroutines to calculate the current day's CN for the HRU and to calculate surface runoff
- **surq_green ampt** - Predicts daily runoff given breakpoint precipitation and snow melt using the Green & Ampt technique

NEWLY ADDED VARIABLES IN SWAT CODE

- **no_giuh** – number of ordinates in giuh
- **giuh_ord** –unit hydrograph ordinates obtained from giuh
- **exrain_ddt** -excess rainfall for 24 hours for all HRUs
- **surfq_hr** - surface runoff generated in the basin in 24 hour
- **exr_act_giuh**- excess rainfall which active for the giuh computation in the current hour
- **exr_24** - excess rainfall 24 ordinates for each hour in a day
- **latq_ddt –** lateral flow for 24 hours for all HRUs
- **exr_ddt** - runoff for the 24 hour in HRUS

ADDED SUBROUTINE IN SWAT SOURCE CODE

- Additional subroutines are added to the SWAT source code:
  - **readgiuh**- subroutine open the giuh file and reads GIUH ordinates
  - **exrain_act_hr**
    - Stores the hourly excess rainfall (computed using Green & Ampt method) in each HRU
    - Calculate area weighted average of hourly rainfall excess at basin level.
  - **conv_giuh** - subroutine convolutes the hourly excess rainfall with unit hydrograph ordinates on hourly basis (inorder to cope up with the daily time step 24 ordinates are prepared in each daily step)



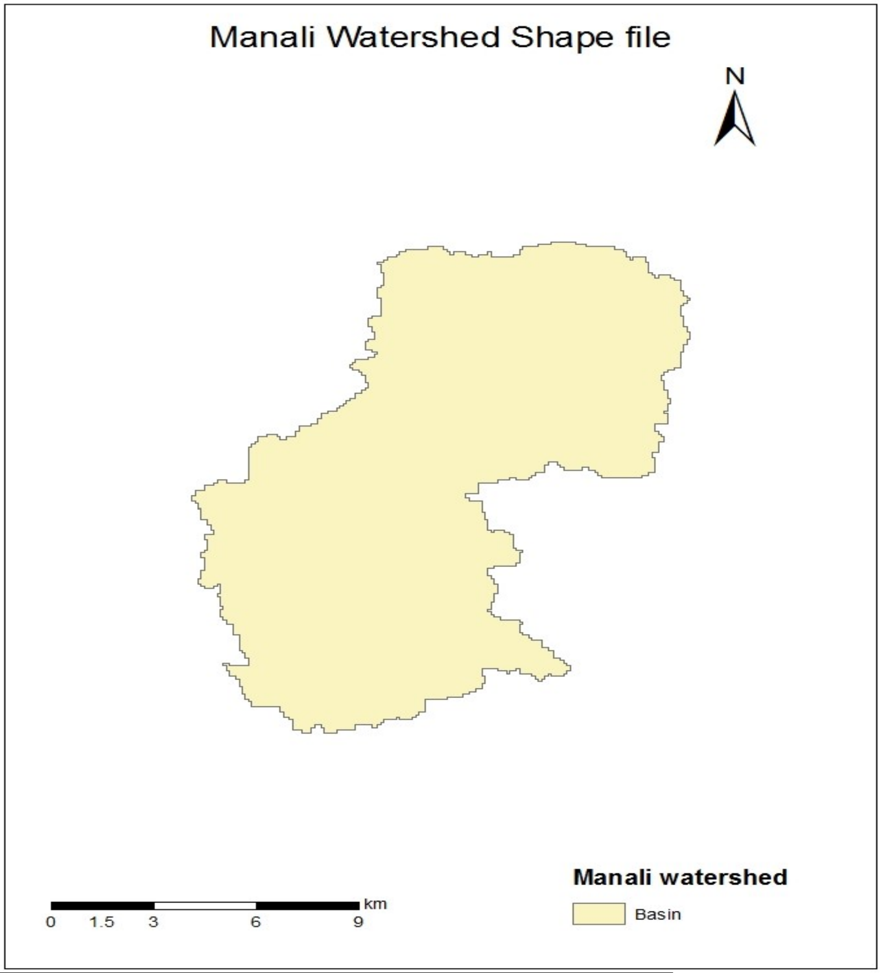
Flow chart showing the methodology for Surface Runoff modeling using Arc SWAT incorpating GIUH

STUDY AREA

Manali Watershed

- The watershed is located in Thrissur district

- **Two events**
  - June- August,2009
  - August-October,2009



WATERSHED	**LATITUDE**	**LONGITUDE**	**AREA (km^2)**
Manali	$10^0$26'30.76"	$76^0$16'2.30"	148

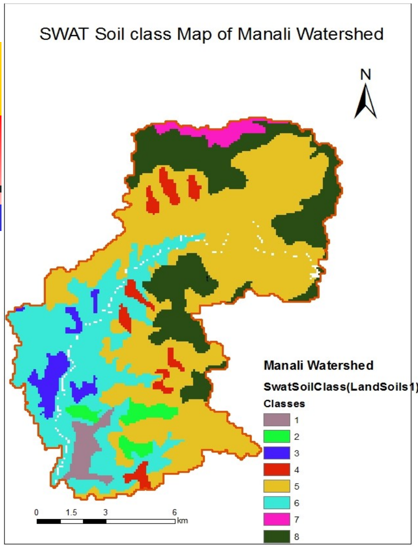
DATA COLLECTED

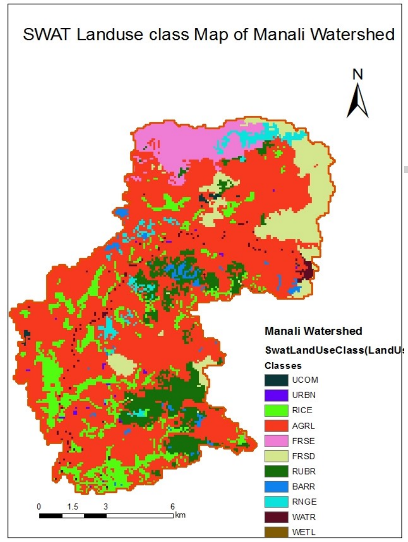
INPUT DATA	SOURCES
DEM	DEM = 90m SRTM (srtm.csi.cgiar.org)
Local Landuse map	Kerala Forest Research Institute (KFRI)
Local Rainfall Data	Hydrology Department,thrissur
Local Soil data	Soil Survey Department, Thrissur
Local Weather data	Kerala Agricultural University, Vellanikkara
SWAT Source Code	http://swat.tamu.edu

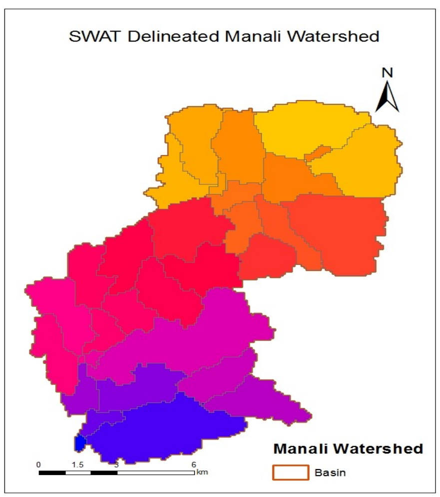
RUNOFF VOLUME ESTIMATION IN SWAT

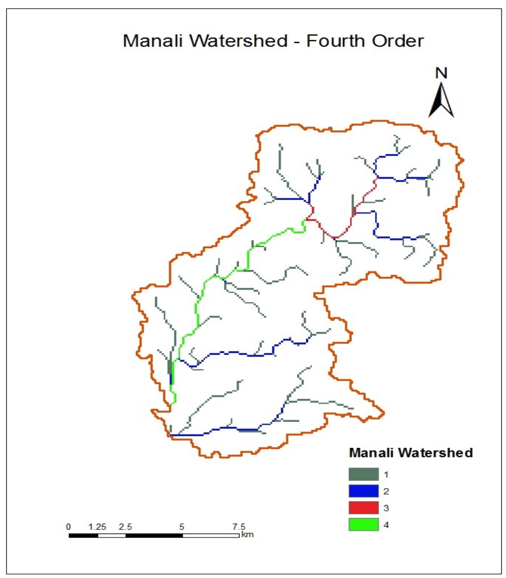
- Four main data files that SWAT requires:
  - ✓ Digital Elevation Model (DEM) data
  - ✓ Landuse data
  - ✓ Soil data
  - ✓ Weather data (Rainfall data, Temperature data, Relative Humidity, Solar Radiation, Wind Data)
- Steps
  - ✓ Swat Project Setup
  - ✓ Watershed Delineation
  - ✓ HRU Analysis
  - ✓ Write Input Tables
  - ✓ Edit Swat Input
  - ✓ SWAT Simulation

SWAT Delineated Manali Watershed









Landuse	% Area
Built up(commercial ,UCOM)	0.26
Built up(Rural ,URLD)	0.22
Rice(RICE)	10.5
Agricultural land (AGRL)	60.38
Forest-Evergreen (FRSE)	6.16
Forest-Deciduous (FRSD)	8.86
Rubber(RUBR)	8.91
Barren(BARR)	1.32
Range(RNGE)	2.46
Water(WATR)	0.91
Wetland(WETL)	0.02
TOTAL	100
Area	**148km^2**

DEVELOPMENT OF GIUH ORDINATES

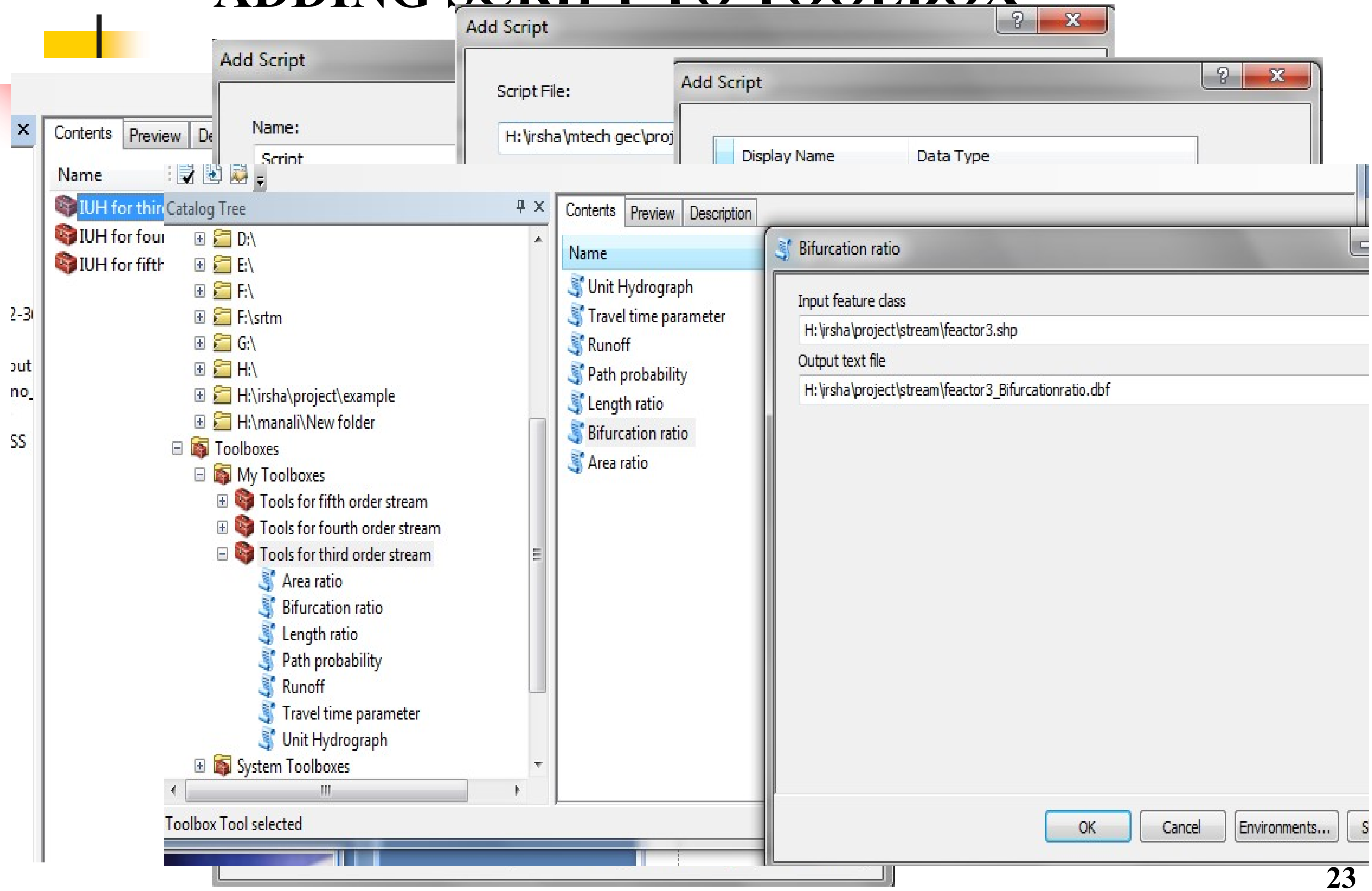
- Toolbox using Python script in Arc tool box

(Anju and Sajikumar 2014)

- Tools were created for finding out
  1. Bifurcation ratio
  2. Length ratio
  3. Area ratio
  4. Path probability
  5. Travel time parameters
  6. GIUH
  7. Unit Hydrograph

Transfer these 1 hour UH ordinates to the textinout folder of swat project

ADDING SCRIPT TO TOOLBOX



Morphological parameters

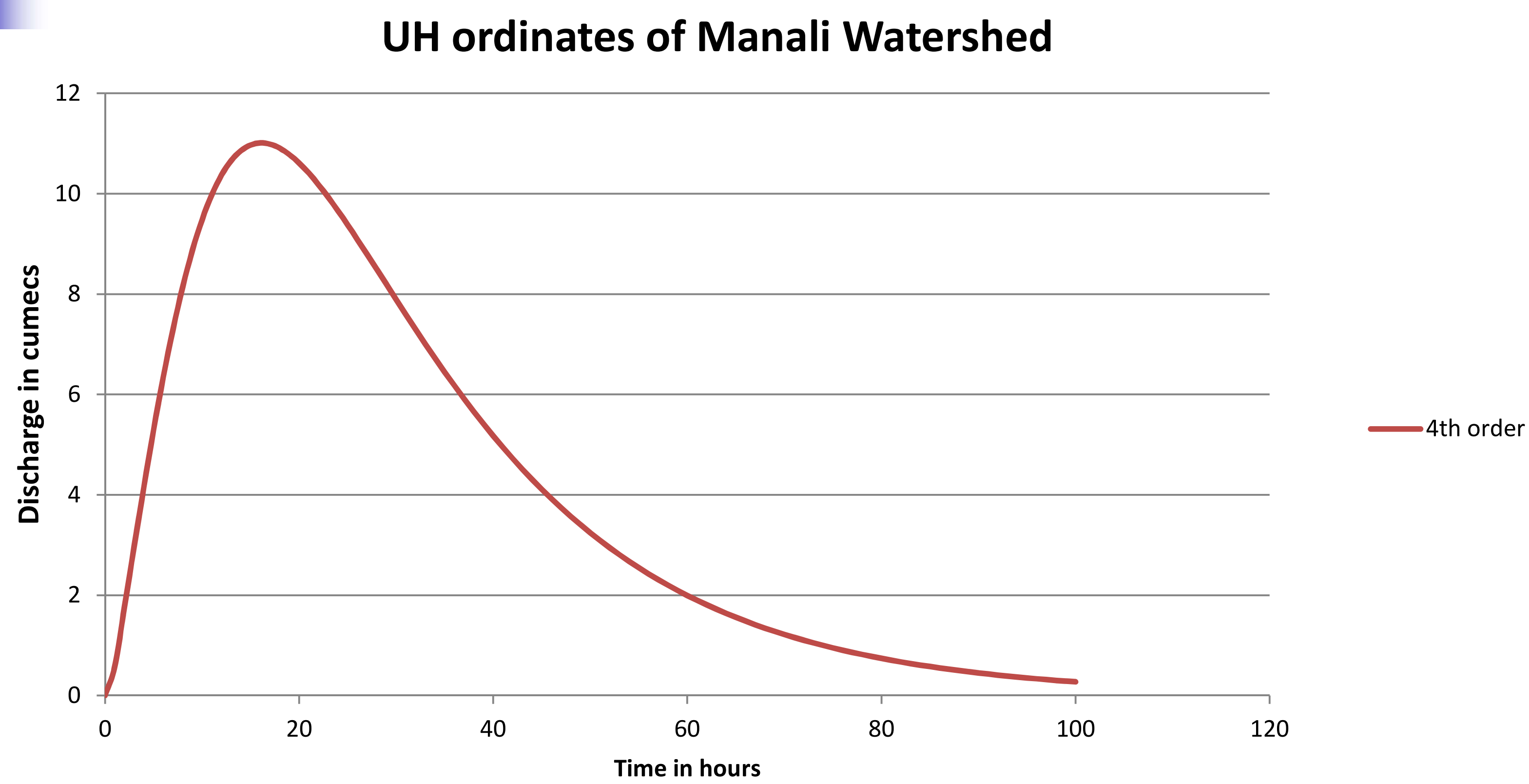
Watershed	Area(km2)	Threshold	Stream Order	Bifurcation Ratio	Length Ratio	Area Ratio
Manali	148	100	4	3.767	2.661	5.144

Initial probability	Manali
	Fourth Order Stream
θ_1	0.372
θ_2	0.231
θ_3	0.222
θ_4	0.173
θ_5	-

Transitional Probability	Manali
	Fourth Order Stream
P_{12}	0.774
P_{13}	0.204
P_{14}	0.094
P_{15}	-
P_{23}	0.801
P_{24}	0.198
P_{25}	-
P_{34}	1
P_{35}	

Parameters	Manali
	Fourth Order Stream
α	0.316
$\lambda1$	0.950
$\lambda2$	0.357
$\lambda3$	0.134
$\lambda4$	0.050
$\lambda5$	-

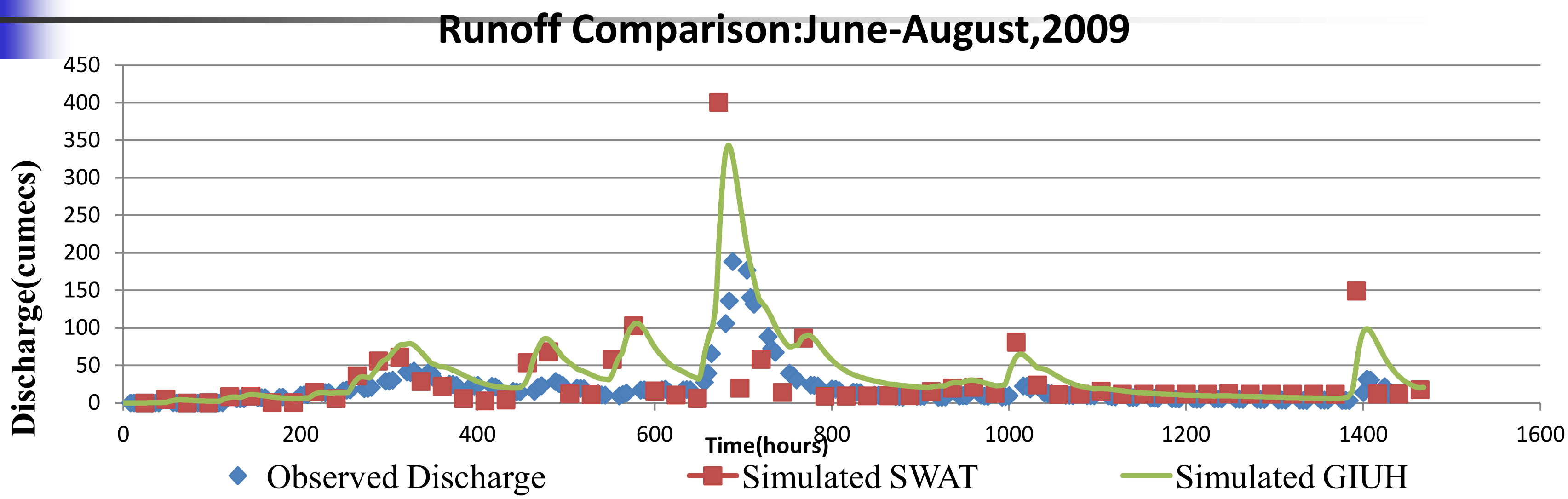
Typical GIUHydrograph : Manali Watershed

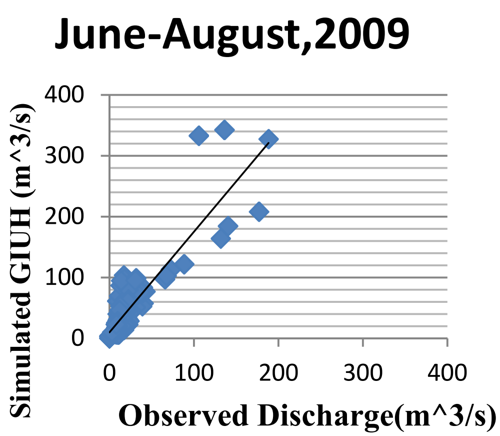


RUNOFF ESTIMATION USING GIUH IN SWAT MODEL

- Unit hydrograph ordinates of GIUH are read using code of SWAT
- Runoff are estimated by running the edited SWAT code
- Runoff were computed for two event.s
  - For Manali Watershed:
    - June- August, 2009
    - August-October, 2009

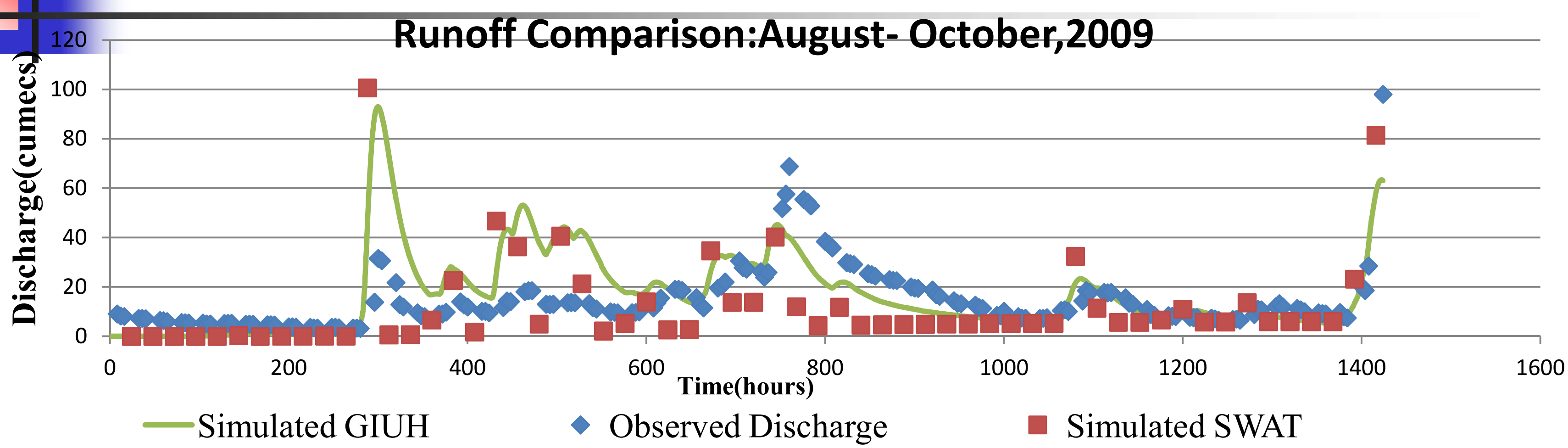
RUNOFF COMPARISON: Manali Watershed

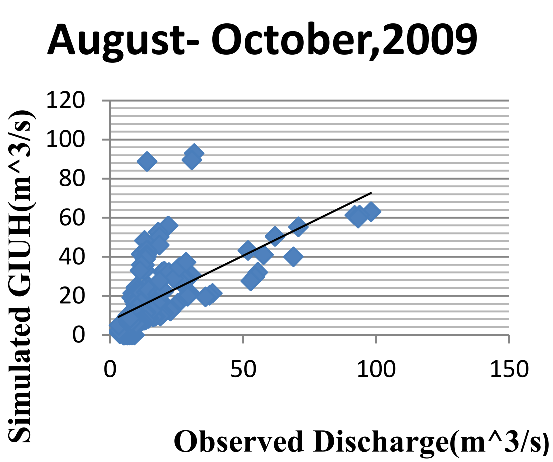




R^2=0.79

RUNOFF COMPARISON: Manali Watershed





R^2=0.4

CONCLUSION

- GIUH tool is incorporated into the SWAT model in the basin level.
- The performance of the GIUH method in the simulations of runoff for the manali watershed are better than that from the original SWAT.
- Hence the model may be utilized as an event model. However refinements are obtained such that the GIUH is computed at the subbasin level.

CONCLUSION

- There are some external factors reasons less accurate performance for watersheds
  - Need distributed rainfall for the GIUH computation
  - GIUH computation should be done in the subbasin level.
  - Hourly runoff details of the station are not available
- Further scope of the study
  - Incoperation of the GIUH into the SWAT at the subbasin level


THANK
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