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Estimation of Surface Run off by Swat Model for a Watershed in Punpun Basin

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Abstract: **The Soil and Water Assessment Tool (SWAT) having an interface with QGIS software (QSWAT 1.3) was selected for the estimation of surface runoff from an area of Punpun basin near Patna an intermediate watershed of Punpun river, located in southern Bihar region. The model was run and validated with the observed runoff for the years 2005-2010. The performance of the model was evaluated using statistical and graphical methods to assess the capability of the model in simulating the surface runoff from the study area. According to the model, the value for the surface runoff was maximum for the year 2007 as 710 mm/yr and was minimum for the year 2005 with about 185 mm/yr. As per the observed values of discharge from the CWC and the calculated values for surface runoff by SWAT for these years were different by about 10 to 11%.**

Index terms:-- **SWAT RS, QGIS,DEM, HRUs, Rainfall- Runoff.**

I. INTRODUCTION

There are various rainfall-runoff models developed for accounting of hydrological processes. They are classified as physical, empirical and conceptual models. Mathematical models are much more popular for runoff assessment as these are less data driven, simpler and cheaper. Different types of Physical models have been developed for the purpose of water resources management and planning such as ANSWERS, WEPP, GUEST, EUROSEM and LISEM are now widely accepted models for simulating runoff and soil erosion. The Soil and water Assessment Tool (SWAT) was developed to predict the effects of different management practices on water quality, sediment yield and pollution load in watersheds. Various researchers have been evaluated SWAT model and their findings indicated that SWAT is capable of simulating hydrological processes with reasonable accuracy and can be applied to all types of ungauged basins. Therefore, to test the capability of the model in determining the runoff of the watershed, SWAT 2005 model with QGIS 1.3 interface was selected for the present study. Study area is selected Punpun basin near Patna an intermediate watershed of Punpun river, located in southern Bihar region. Problem of surface drainage congestion due to inadequate passage of monsoon flow is a common phenomenon. Basin of Punpun River contributes huge amount of water in river Ganga during monsoon but remaining season lives dry. Some Part of this basin is inundated during monsoon, which creates lot of problems to the people who live nearby.

II. MODEL DISCRIPTION

In SWAT, the watershed is divided into multiple subwatersheds, which are then further subdivided into hydrologic response units (HRUs) that consist of homogeneous land use, management, topographical and soil characteristics. The HRUs are represented as percentage of the sub watershed area and may not be contiguous or spatially identified within a SWAT simulation. SWAT Flow diagram shows in Figure 1.

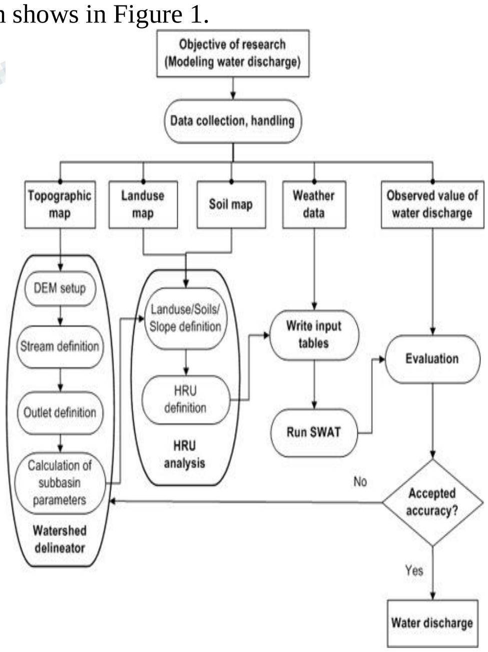

Figure 1: Swat Simulation Flow Diagram

III STUDY AREA

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A watershed has been selected near the Patna district and the surface runoff modeling has been done for the same. The watershed no.24 is selected for SWAT modeling. The area of the watershed is 720 sq kilometers and extension is:

South Latitude: 25.28464 degrees N
West Longitude: 84.76438 degrees E
North Latitude: 25.559372 degrees N
East Longitude: 85.304751 degrees E

The Punpun often causes heavy flood damages on the eastern side of Patna city. The basin is roughly trapezoidal in shape. The length of the catchment is about 180 km and average widths in the upper and lower reaches are 60 km and 25 km respectively. The total catchment area of the basin is about 8,530 km^2. This is 1% of the total area of Ganga basin in the country.

***Dem of Study Area*:**

A **digital elevation model** (**DEM**) is a digital model or 3D representation of a terrain's surface commonly for a planet (including Earth), moon, or asteroid created from terrain elevation data. SRTM is developed for the study area. SRTM (Shuttle Radar Tomography Mission) is a good source of DEM data for almost anywhere in the world. The Figure 2 depicts the DEM map for the study region.

Maximum elevation: 78
Mean elevation: 41.62
Soil data:

The soil map for the area was obtained from the BIRSAC (Bihar Remote Sensing Application centre) for the area to be worked on for SWAT modeling.

The geology of the area varies from granite, gneiss, and charnokites in the hills to the recent alluvium in the plains. The broad soil groups are calcium and non calcium, recent and old alluvium and brown forest soils, red soil podzowe, lateritic soils with cover being very deep in plains and deep to shallow in hills shows in Table 1.

In Figure 3 presenting different type of soil at different area of the study area.

Landuse Data

As for soil data, this information was also obtained with the help of BIRSAC. The land use pattern of the watershed shows that out of the total area of 720 km^2, about 658 km^2 is under agriculture, 48 km^2 is under urban occupation, and the remaining area of 14 km^2 is under wastelands and waterbodies. The pattern for landuse is depicted in Table No.2 and the map for Landuse is shown in Figure 4. The length of the main channel of Punpun basin is 232 km. Drainage density (total length of channels of all order to the total area of the basin) is 0.377 km/km^2.

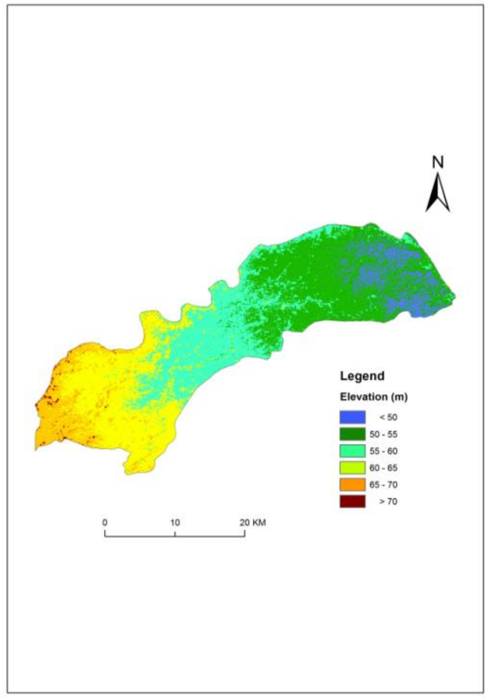

Figure 2: DEM map

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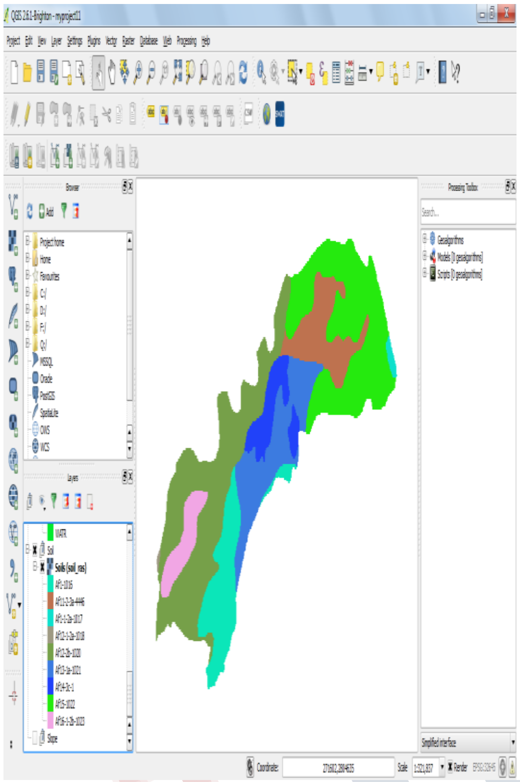

Figure 3: Soil Map

Table 1: Soil Data

SOILS	AREA (KM²)	AREA (%)
Fine,Vertic Ustochrepts,Coarse-loamy,Typic Ustifluvents	83.41	11.59
Coarse-loamy,Typic Ustifluvents,Coarse-loamy,AericHaplaquents	70.06	9.74
Fine-loamy, Fluventic Ustochrepts,Fine-loamy, Typic Ustifluvents	4.10	0.57
Fine-loamy,Typic Haplaquepts,Fine,Typic Fluvaquents	0.80	0.11
Fine,Aeric Haplaquepts,Very-fine,Vertic Ustochrepts	209.83	29.16
Fine,Aeric Ochraqualfs,Fine-loamy,Typic Ustochrepts	94.33	13.11
Fine,Vertic Ustochrepts,Coarse-loamy,Typic Ustifluvents	39.78	5.53
Fine,Vertic Ustochrepts,Fine-loamy,Typic Ustochrepts	186.30	25.89
Very-fine,Vertic Ustochrepts,Very-fine,Udic Chromusterts	31.06	4.32

Total	**719.67**	**100.00**

IV. WEATHER DATA

The weather data was taken for the Patna weather station with the help of data from the IMD (Indian meteorological department).

The data comprises of the following:
1. Maximum temperature (In degree Celsius)
2. Minimum temperature (In degree Celsius)
3. Wind speed (In kmph)
4. Relative Humidity (In Percent)
5. Precipitation (In mm)
6. Solar Intensity (kw/m^2)

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LAND USE/LAND COVER	Area (km^2)	Area (%)
Agricultural Land-Crop Land-Rabi Crop(AGRL)	91.01	12.65
Agricultural Land-Crop Land-Two crop area(AGRL)	534.72	74.30
Agricultural Land-Fallow-Current Fallow(AGRL)	31.47	4.37
Agricultural Land-Plantation-Horticulture Plant(AGRL)	1.22	0.17
Built Up-Built Up (Urban)-Mixed Built Up area(URMD)	26.57	3.69
Built Up-Built Up (Urban)-Recreational(URMD)	0.06	0.01
Built Up-Built Up(Urban)-Rural - Built Up area (Rural)(URMD)	21.82	3.03
Built Up-Built Up(Urban)-Transportation(URMD)	0.11	0.02
Wastelands-Scrub land-Open scrub(WEHB)	1.22	0.17
Waterbodies-Canal/Drain-Lined(WATR)	1.11	0.15
Waterbodies-Lakes/ponds-Dry(WATR)	0.03	0.00
Waterbodies-Lakes/ponds-Perennial(WATR)	0.06	0.01
Waterbodies-River/Stream-Dry(WATR)	0.42	0.06
Waterbodies-River/Stream-Perennial(WATR)	6.90	0.96
Wetlands-Inland Manmade(WEHB)	2.87	0.40
Wetlands-Inland Natural(WEHB)	0.09	0.01
	719.67	100.00

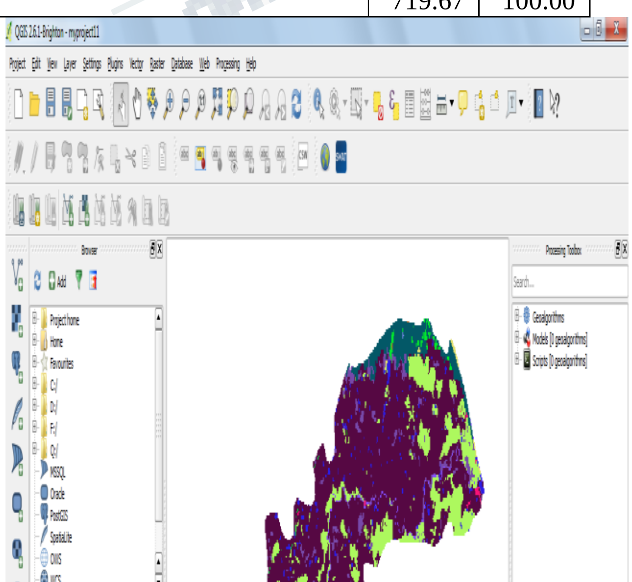

Figure 4 Land Use Map

V. SWAT MODEL:

The SWAT (Soil and Water Assessment Tool) is one of the most recent models developed jointly by the United States Department of Agriculture - Agricultural Research Services (USDA-ARS) and Agricultural Experiment Station in Temple, Texas. It is a physically based, continuous time, long-term simulation, lumped parameter, deterministic, and originated from agricultural models. The computational components of SWAT can be placed into eight major divisions: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management. The SWAT model uses physically based inputs such as weather variables, soil properties, topography, and vegetation and land management practices occurring in the catchment.

Table 2: Landuse Map

The hydrological cycle based on SWAT is based on the water balance equation:

$$SW_t = SW_o + \sum_{i=1}^{n} (R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

SWo is the initial soil water content (mm H_2O), *t* is time in days, R_{day} is amount of precipitation on day *i* (mm H2O), Q_{surf} is the amount of surface runoff on day *i* (mm H2O), E_a is the amount of evapotranspiration on day *i* (mm H_2O), W_{seep} is the amount of percolation and bypass exiting the soil profile bottom on day *i* (mm H_2O)

The **Hydrology** window in SWAT-Check summarizes the water balance both graphically and numerically. It can be accessed by clicking the **Hydrology** tab at the top of the SWAT-Check window, the check for the year 2009 is showing in the Figure 5.

As hydrology is the basis for the landscape processes, particular attention should be given to modeling the hydrology right. Therefore, SWAT-Check will be a vital tool in providing a quick summary of the hydrological components and as such aids easy understanding of the system. For example, it provides the ratios of different water balance components. Users can, therefore, compare these values with published literature values, or measured estimates, and have an idea how to improve the model performance in subsequent model calibration processes.

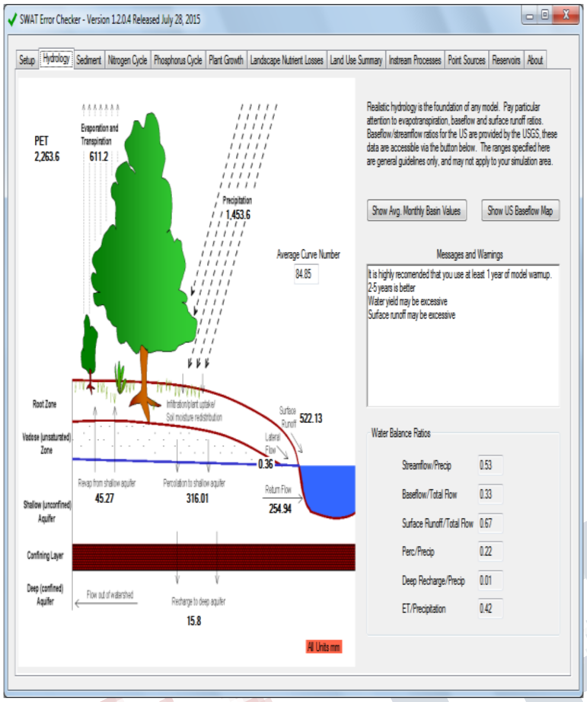

Figure 5: Swat Error Checker

VI. SIMULATIONS AND EXPERIMENTAL RESULTS

The time interval chosen for SWAT run was 1/01/2005 to 1/01/2010 Here we run swat for intervals of one year for each of the five years and the resultant output was generated for runoff per year of SWAT simulation.

For the year 2009:

Ave Annual Basin Values

Precip = 1429.0 Mm
Snow Fall = 0.00 Mm
Snow Melt = 0.00 Mm
Sublimation = 0.00 Mm

Surface Runoff Q = 521.76 Mm
Lateral Soil Q = 0.26 Mm
Tile Q = 0.00 Mm
Groundwater (Shal Aq) Q = 212.80 Mm
Groundwater (Deep Aq) Q = 8.30 Mm
Revap (Shal Aq => Soil/Plants) = 48.36Mm
Deep Aq Recharge = 13.75 Mm
Total Aq Recharge = 274.91 Mm
Total Water Yld = 743.12 Mm
Percolation Out Of Soil = 281.46 Mm
Et = 612.4 Mm
Pet = 2417.9mm
Transmission Losses = 0.00 Mm
Septic Inflow = 0.00 Mm
Total Sediment Loading = 8.884 T/Ha
Tile From Impounded Water = 0.00(Mm)
Evaporation From Impounded Water =0.00(Mm)
Seepage Into Soil From Impounded Water =0.0
Overflow From Impounded Water = 0.000 (Mm)

As per the reports the surface runoff for each year can be summarized as:

Table 3: Surface Runoff by SWAT Model

Year	Surface Runoff (mm/yr)
2005	185.01
2006	479.54
2007	710.05
2008	694.73
2009	521.76

VII. COMPARISON OF RESULTS WITH OBSERVED DATA:

The observed discharge data for the watershed at the outlet of Sripalpur as given by the CWC is as below:

Table 4: Observed Discharge at Sripalpur.

Year	Discharge (Cumecs)
2005	16865.12

2006	44642.86
2007	67460.36
2008	59523.81
2009	47571.43

Alternatively, discharge may be expressed as a depth in millimeters over the catchment or the runoff which we will use to compare our SWAT results with. Runoff depth is the volume expressed as depth over the specified catchment area with a constant to adjust units to millimeters; i.e. for daily runoff:

$$R_d\,(mm) = \frac{V_d\,(cum)\,x\,10^3}{Area\,(km^2)\,x\,10^6} = \frac{V_d\,(mm)}{Area\,(km^2)\,x\,10^3} = \frac{86.4\,Q_d}{Area\,(km^2)}$$

The Area for the entire basin is 8530 sq Kilometres while the area for the selected watershed is about 720 sq Kilometres. Therefore to get discharge for the watershed we need to multiply the annual discharge with the ratio of area of watershed to the area of the basin.

Area Ratio=720/8530=0.084

Table 5: Observed and Computed runoff of the study area.

VIII. CONCLUSION

The SWAT model was applied to a small watershed of area 720 sq kilometers in Punpun Basin, Bihar for the estimation of Surface Runoff. The average value for the observed runoff calculated through discharge data for the basin was 457 mm/yr and the calculated value through SWAT was 518 mm/yr and were different by 10.84%. The comparison of observed and computed runoff shown in Figure 6. It shows the computed runoff and observed runoff is more and less same for each year. According to the model, the value for the surface runoff was maximum for the year 2007 as 710 mm/yr and was minimum for the year 2005 as 185 mm/yr. This shows that SWAT model is valid for small watersheds in predicting surface runoff for a shorter span and can be used further in estimation of runoff for a longer period.

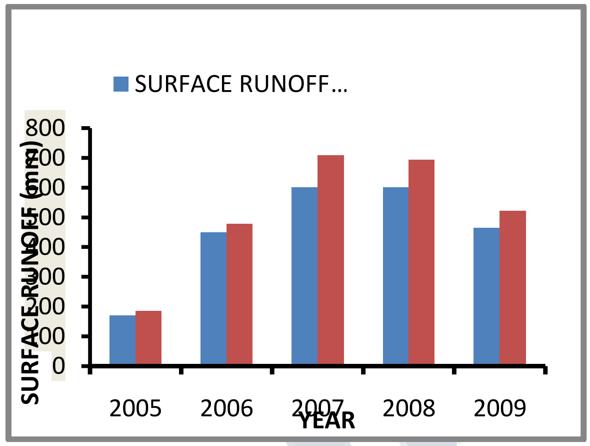

Figure 6: Comparison of Simulated and Observed values of Surface Runoff

Prediction of runoff and soil loss is important for assessing soil erosion hazards, and for determining suitable land uses and soil conservation measures for a catchment. In turn, this can help in deriving optimum benefit from the use of the land whilst minimizing the negative impacts of land degradation and other environmental problems. As there are limited data available from the region of study, the model developed herein could help assess different land management options and in studying the effect of climate change on soil erosion.

Year	Observed Discharge (Cumecs)	Observed Surface Runoff (mm)	Computed Surface Runoff (SWAT) (mm)	Variation in Runoff (%)
2005	1416.67	170.2	185.01	8.89
2006	3750	450	479.54	7.50
2007	5666.67	602.4	710.05	11.76
2008	5000	600.82	694.70	15.67
2009	3996	465	521.76	10.40

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