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RAINFALL RUNOFF MODELLING OF IB SUB-BASIN OF MAHANADI RIVER SYSTEM USING SWAT MODEL

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Abstract: - Water is one of the most important sources in our daily lives. We cannot sustain our lives without water on the surface of the earth. The Hydrological modelling is important tool for land and water resources and in the same way of hydrologic behavior of watershed. Proper water management is the only solution to bridge the gap between demand and supply. In order to overcome the related issue, the availability of water and its supply. There are certain standard methods to assess the availability of water resources. Soil and water assessment tool (SWAT) which is a physically distributed parameter model to predict the surface runoff, land use and management conditions over long periods of time. It is also a river basin and continuous- time model. The model uses ArcGIS to integrate the various attribute data to estimate the Rainfall-Runoff of particular catchments at different outlets. The present study area carried out assessment of runoff for IB river basin of Mahanadi River located in Hirakud reservoir catchment area using SWAT model. The IB River flows on left side of the Mahanadi River. Digital Elevation Model (DEM) is used for delineation has been carried out in the catchment area. The slope maps were prepared by using DEM. The land use land cover map was prepared using Landsat-8 data image. The rainfall data from 2016 to 2017 on daily basis had been used to prepare the modelling.

Keywords: Hydrological modelling, Rainfall-Runoff, SWAT model, ArcGIS, DEM, IB Sub-basin.

I. INTRODUCTION

Water is one of the most precious and natural resources for all living beings present on this earth. Without water we cannot sustain our lives. Large quantities of flowing water carries tremendous energy results in floods and related phenomena such as mudslides. In hydrology, it is very important to estimate river runoff for water management operations. Different techniques have been developed to estimate accurate runoff. Mostly, the hydrological process depends upon local physiographic, biotic and climatic factors. The rainfall runoff depends upon different hydrological parameters. They are rainfall intensity, evaporation and it is also plays very important role between surface water and ground water is very difficult to simplify the models. Basically, for watershed delineation in SWAT model there are two methods. They are 1.DEM based method which is based on study area and the other one is pre-defined method which is used to do in manual way. At present many researchers used to do in first method. SWAT is one of the powerful and successful tool used in sediment simulation, runoff yield and water quality in small and large basins. Hence IB sub basin of Mahanadi river system has been taken as study area using SWAT Model.
Mahanadi is one of the major peninsular rivers in the country and it is divided into three sub basins. They are mainly 1. Upper sub basin 2. Middle sub basin 3. Lower sub basin. The present study area is covered under left tributary of Mahanadi River.

Swat stands for soil and water tool and it is a river basin or watershed originally developed by Arnold for the United States Department of Agriculture (USDA). It is a physically distributed parameter model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex varying with soil, water and management conditions over long period of time. In addition to that, to setup a SWAT model, a watershed needs to be sub divided into number of sub watersheds. These are again sub divided into HRU's (Hydrological Response Units) and unique intersection of soil and land use. This model also includes weather data, topography, vegetation and land management practices of the particular basin. It is also used as hydrological tool for the design of larger river basins.

II. STUDY AREA

The study area mainly discuss about IB sub basin of Mahanadi river system using SWAT model. To create SWAT model we need raster or vector files and data files should be in SWAT standard formats. Basically the model requires four types of data sets. They are DEM (Digital Elevation Model), Soil data, LULC (Land Use Land Cover) and meteorological data for evaluating hydrological processes. The present study data was prepared by collecting from various sources. The total area of IB Sub-basin is 7255.31 Sq. km and located partly in the areas of Raigarh, Simdega, Jashpur, Surguja and Sundargarh districts of Odisha and Chattisgarh. IB River is tributary of Mahanadi river in North East Central India and joins in Mahanadi river and flows directly into Hirakud reservoir. The study area lies on Sundargarh and Jashpur districts and it originates in hills near Pandrapet at an elevation of 1116 meters. The IB River is also famous for coal belt, the valley coal field. The major portions of the Mahanadi coal fields are situated on the banks of IB River. Many industries have been flourished on the banks of the river IB. The river runs over a distance of 252 km² and drains an area of 12,447 km².

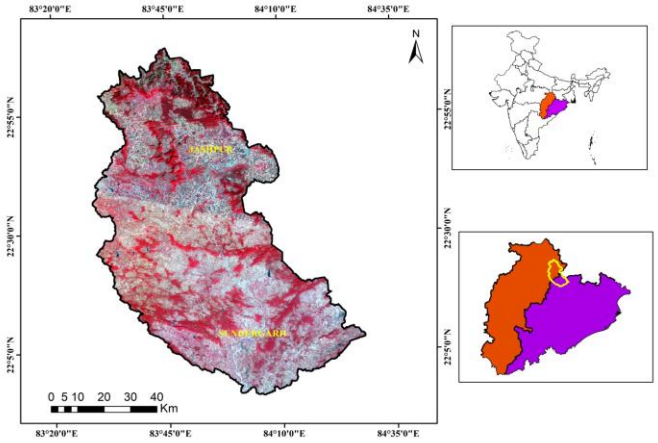

Figure 2.1: Location of the IB Sub-Basin

III. METHODOLOGY

To execute the entire work Arc SWAT 10.4 was used to prepare the data as a input in SWAT. In general there are basic components are required to execute the data. They are 1.Soil data 2. DEM data 3. Land use land cover 4. Weather data of the study area. With the help of ArcGIS 10.4 Location map was generated. Land use/Land Cover was prepared by using ERDAS Imagine software 2014, Soil data obtained from NBSS & LUP Nagpur, Maharashtra. The soil map was prepared and numbering has been given based on the hydrological soil group and provided in the raster format. By using GIS software, the data was converted from rater data to raster data. Finally rainfall data for the years 2016 & 2017 collected from IMD to run the SWAT for simulation.

3.1. Land use Land Cover (LULC)

The LULC map was prepared by using Landsat 8 satellite data using 5, 4, 3 bands having 30 meters resolution. The supervised classification has been done with the help of ERDAS software. The estimation of these parameters are more accurately with space and time plays important role in calculating hydrological parameters on any basin. The satellite remote sensing can provide real time information land use/cover and other kind of map information to estimate hydrological parameter more accurately in spatial environment using distributed hydrology modelling approach. Seven numbers of classes have been taken into consideration to prepare the LULC map. The classes are Built-up area (2.54%), water body (0.63%), deciduous forest (14.94%), mining (2.37%), fallow land (76.78%), crop land (8.9%) & Scrub land (2.94%) as shown in the table: 1and figure: 3.1

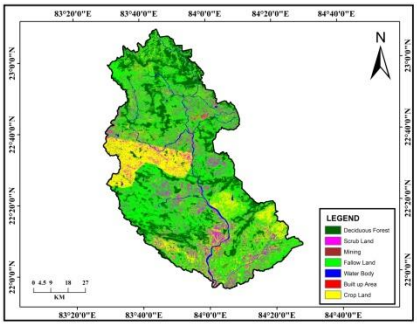

Figure 3.1: LU/LC of IB sub-basin

Table 1: Major LULC classes of IB sub-basin and its percentage to Total Catchment Area

LU/LC Class	**Area (sq. Km.)**	**Percentage of Area (%)**
Built up Area	184.99	2.54
Crop Land	652.60	8.9
Deciduous Forest	1,084.49	14.94
Fallow Land	4,910.86	67.68
Mining	172.26	2.37
Water Body	41.27	0.63
Scrub Land	208.37	2.94
TOTAL	**7,255.31**	**100%**

3.2. Soil Data

The soil data have been collected from NBSS&LUP Maharashtra Remote sensing application center, Nagpur. On the basis of hydrological soil group, the soil database was grouped and provided in the raster format. By using ArcGIS software, the data has been converted into vector data that is polygon data. For each polygon, a unique number is provided based on their color and shape and SWAT code has been generated for each number. Red and yellow soils are main type of soils present in the present study area of IB sub-basin. Soils may either be red gravelly, red sandy, red loamy, red and yellow or red earth according to the gravel, sand, or presence of fine particles and clay content. These are found in large tracts of basin. These are found in Raigarh, Jarsuguda, Simdega and parts of Sundargarh districts. The soils are medium to fine in texture and porous. These soils have low water holding capacity. The red loamy soils are moderately acidic in nature and deficient in Nitrogen, Calcium, Potassium and low in organic matter in content. The soils can be profitably managed for cultivation of fruits, vegetables and other cash crops. The main crop is paddy. The color of the soil is red due to presence of Iron oxide. The clay fraction of the red soil is much in Keolinite type of clay mineral with varying proportion of Iolite. These soils derive their name from the presence of laterite mass either at surface or at some depth beneath the ground level. The soil map with their number has shown in the below figure: 3.2

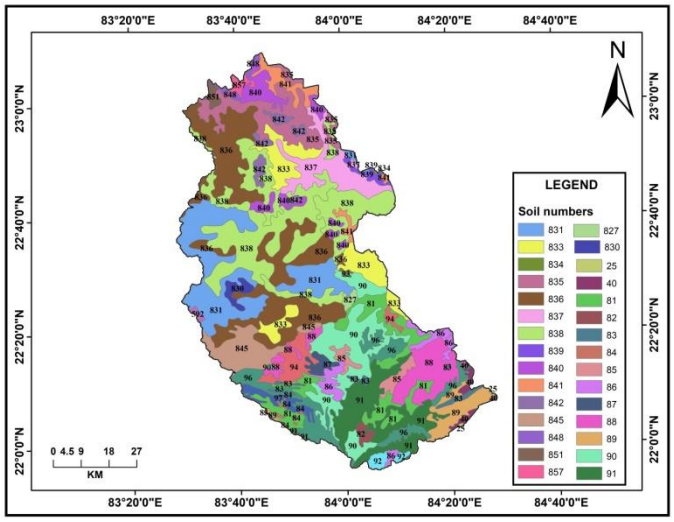

Figure 3.2: Soil map of IB sub-basin

3.3. DEM Data: Digital Elevation Model from SRTM (Shuttle Radar Topographic Mission) is an important input for SWAT model for watershed delineation and also used to play important role in estimating HRU analysis. Basically DEM is used to describe the elevation at any point of the specific area at a specific spatial resolution. This is also used to delineate watershed and analyze drainage patterns on the land surface terrain. DEM is also used for preparing slope map and it acts as input data for Hydrologic Response Unit (HRU) for analyzing the data in the SWAT model. Digital Terrain Model (DTM) is required for flood or drainage modelling, land-use studies, geological applications. The slope map is one of the input data for Hydrological Response Unit (HRU) as shown in the figure: 3.3

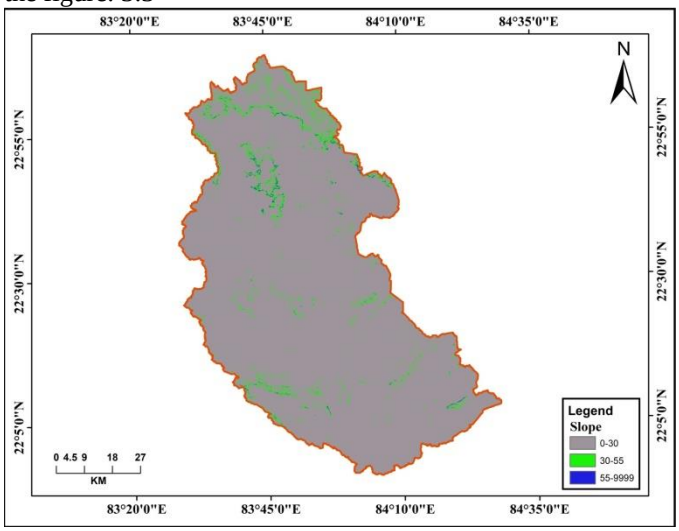

Figure 3.3: DEM for IB sub-basin

3.4. Hydro Meteorological parameters: The meteorological was collected from Indian Meteorological Department (IMD) India on daily basis. The collected have rainfall, runoff, maximum, minimum Temperature, solar radiation and wind speed.

4. RESULTS AND DISCUSSIONS

This study explains about rainfall runoff modelling process runs based on SWAT-based model. For SWAT simulation, it was done daily, monthly and yearly basis. The figure shows maximum runoff occurred in the year 2016 which can be seen for average runoff for average rainfall. For 2 years the rainfall runoff correlation has been done. R2 value of 0.6734 found with good correlation. 2016 and 2017 rainfall is used for validation and calibration of SWAT and it is also used to calibrate large number river discharge stations. Only readily available data used for model setup and to do validation and calibration. In this study, SWAT model has been applied to IB sub-basin for simulating the rainfall runoff process.

Digital Elevation Model (DEM) from SRTM, land use map from satellite data (Landsat8/OLI), soil map from NBSS&LUP, precipitation and weather data such temperature, relative humidity, solar radiation and wind speed on daily basis has been used in this study. The IB sub-basin was sub-divided in to 27 watersheds. Using the land use, soil, slope maps and their attribute information, 208 Hydrologic Response Units (HRU) have been generated for the full study area. The runoff was simulated for years 2016 and 2017 on daily basis. The simulated results reveals that during the year 2016, watershed number 27 generated maximum runoff of 44,477.34m³/sec whereas, watershed number 11 generated minimum runoff of 1,154.57m³/sec for the monsoon period June to September, Likewise for the year 2017, watershed number 24 generated maximum runoff of 77,406.17m³/sec and watershed number 5 generated minimum runoff of 2,207.98 m³/sec for the period June to September, because the rainfall and discharge is more in that particular watershed during the period of monsoon

4.1. Hydrological Response Unit (HRU): The HRU is the smallest spatial unit of the model. It is an analysis performed to re-classify Land use/Cover, Soil, Slope. These are the main three factors depends on HRU. The main aim is to predict long term impact on large basin of management. It is a representation all the surface characteristics like land use/cover, soil and slope into a single unit. The model increases the complexity and plays key role to combine. The sub-basin contains at least HRU. Each HRU consists of same type of soil and land type. More number of sub basins are delineated large drainage patterns (Di Luzio et al., 2002). There are 280 total numbers of HRU's and 27 sub basins present in the study area. SWAT erosion model is based on the sub-basin size. The execution of the model is mainly depends on the hydrological parameters in the data base. The input map for the simulation will be the output map of HRU analysis. Basically the HRU's are formed based on the combination land use, soil and slope range. The creation of HRU's first select the land use and soil map to create database tables like Lookup tables which related to the categories used in the maps to SWAT. GIS helps to run the SWAT model using windows as interface to get desired output. The full HRU is shown in the figure:4.1

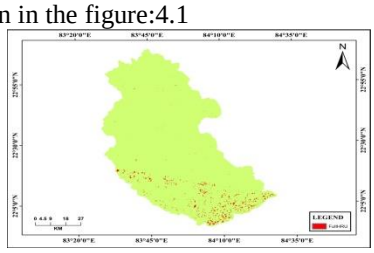

Figure 4.1: Full HRU

4.2 Soil Re-Classification in SWAT:

The below figure shows clearly gives information about soil numbers, soil type description and SWAT code. The source of the soil numbers from soil map 2003 which had taken from NBSS Nagpur. SWAT code has been given to each number based on hydrological soil group. They are divided into four categories. They are A,B,C,D and they are Low runoff potential, thoroughly wetted, high infiltration rate, deeply well drained, sands and gravely soils, Moderate runoff potential, thoroughly wetted, moderate infiltration rate, moderately well drained, fine to coarse textured soils and Moderately high runoff potential, slow infiltration rate, wetted, moderately fine to fine textured soils. The SWAT soil map is prepared by giving soil code to each individual to run in SWAT model as shown in the below figure: 4.2

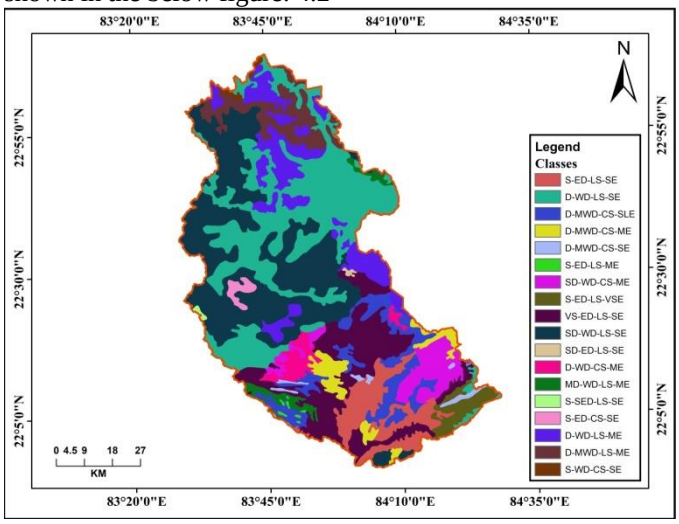

Figure 4.2: SWAT Soil map

4.3 Land Use/Soil/Slope Classification:

The SWAT land use and land cover code is directly indicating the land use classification. There are seven classes are identified in land use land cover map. They are built-up area, water body, mining, deciduous forest, fallow land, crop land and scrub land. The SWAT code is given individually for each class in the LU/LC map. In SWAT for each class a unique code has been given and called as HRUC (Hydrological Response Unit Code) and finally click on the reclassify. SWAT classified Land use/ Land Cover shown in figure 4.8 and Land use/ Land cover shown in figure: 4.3

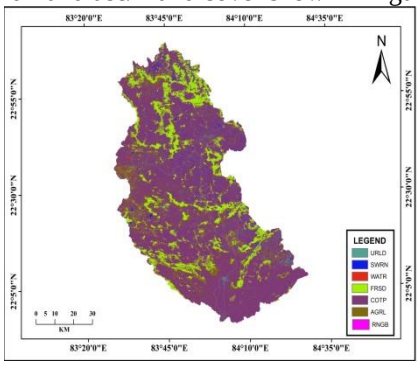

Figure 4.3: SWAT Classified Land use/Land cover map

4.4 Watershed Delineation:

DEM data uses Arc SWAT to delineate into number of sub-watersheds. The operation for watershed delineation uses and expands Arc GIS; spatial analyst tool bar function extends to perform watershed delineation. The very first step in the watershed delineation was used to load the projected DEM properly and the height should be mentioned in meters.

After that stream network was set burnt-into force SWAT sub-basin reaches. Burning in a stream network improves hydrological segmentation, and sub-delineation. After the DEM grid was loaded and the stream networks superimposes. As a result, streams and outlets are created to generate the Arc SWAT sub basin, streams and outlet feature classes. Then the watershed delineation activity was finalized by calculating the geomorphic sub-basin parameters as shown in the figure: 4.4.

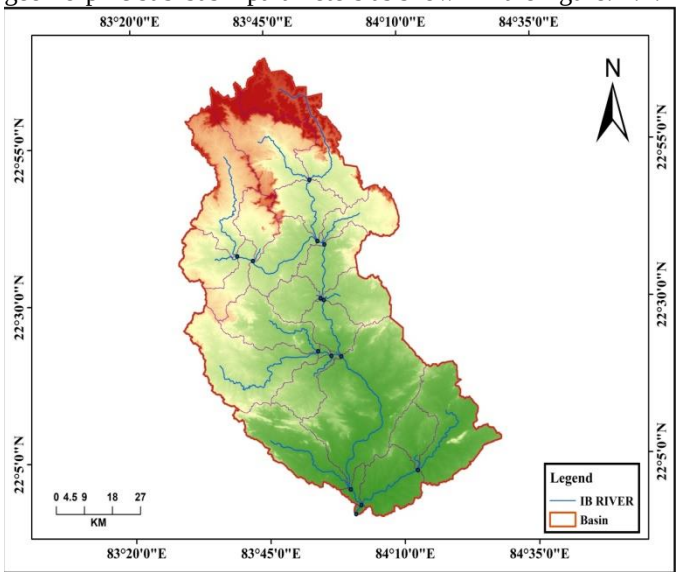

Figure 4.4: Watershed of the study area map

4.5 Simulated run off IB sub-basin for the year 2016 and 2017: For the years 2016 and 2017, the daily simulated runoff was graphically represented for monthly simulated runoff. The below two graphs represents with validation period. It was evaluated based on monthly stream flow simulation by SWAT. Finally we can observe the variation between two years.

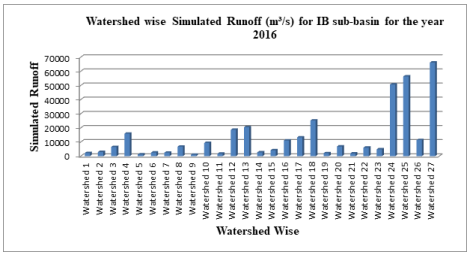

Figure 4.5: Bar Chart for Watershed wise for the year 2016

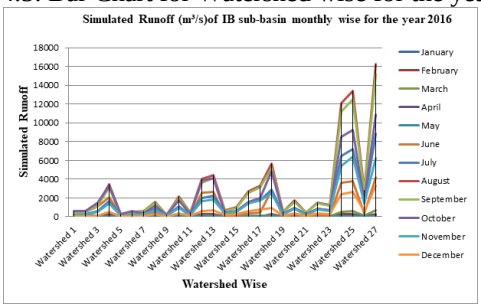

Figure 4.6: Simulated runoff for the year 2016

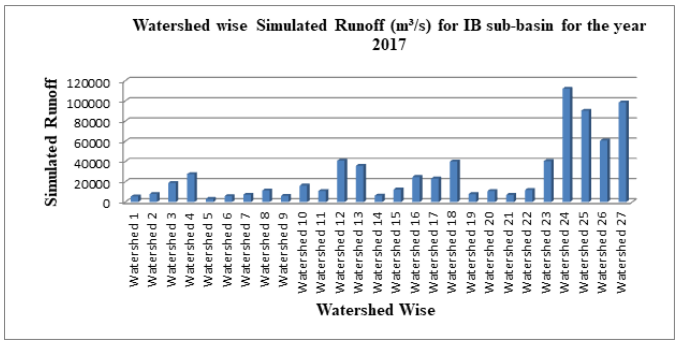

Figure 4.7: Bar Chart for Watershed wise for the year 2017

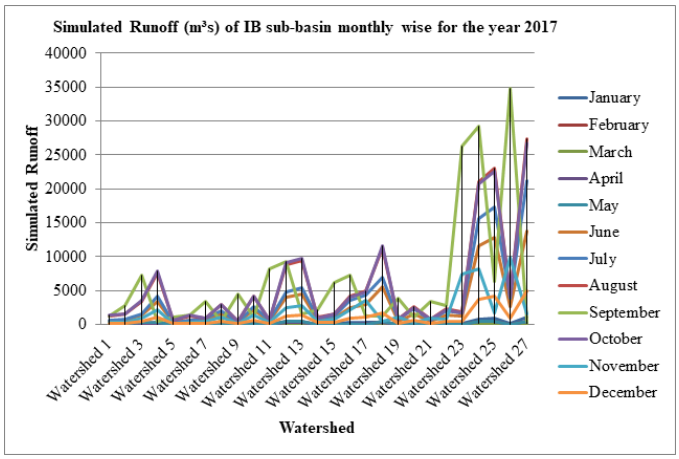

Figure 4.8: Simulated runoff for the year 2017

5. CONCLUSIONS

Soil and Water Assessment Tool (SWAT) had gained popularity in the recent past, because it is a watershed parameter model to predict the impact of land management practices on water. It requires various parameters and catchment characteristics to perform hydrological modeling. The model uses ARC GIS environment and calculates the surface runoff at various monitoring points in a catchment. In this study, SWAT model has been applied to IB sub-basin for simulating the rainfall runoff process.

Digital Elevation Model (DEM) from SRTM, land use map from satellite data (Landsat8/OLI), soil map from NBSS&LUP, precipitation and weather data such temperature, relative humidity, solar radiation and wind speed on daily basis has been used in this study. The IB sub-basin was sub-divided in to 27 watersheds. Using the land use, soil, slope maps and their attribute information, 208 Hydrologic Response Units (HRU) have been generated for the full study area. The runoff was simulated for years 2016 and 2017 on daily basis. The simulated results reveals that during the year 2016, watershed number 27 generated maximum runoff of 44,477.34m³/sec whereas, watershed number 11 generated minimum runoff of 1,154.57m³/sec for the monsoon period June to September, Likewise for the year 2017, watershed number 24 generated maximum runoff of 77,406.17m³/sec and watershed number 5 generated minimum runoff of 2,207.98 m³/sec for the period June to September, because the rainfall and discharge is more in that particular watershed during the period of monsoon.

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