CALIBRATION OF SWAT HYDROLOGICAL MODEL TO ESTIMATE EVAPOTRANSPIRATION OF HATHMATI RIVER

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Abstract : Evapotranspiration (ET) is a collective term that includes all processes by which water at the earth's surface is converted to water vapour. It is the primary mechanism by which water is removed from a watershed. Roughly 62% of the precipitation that falls on the continents is evapotranspired. Evapotranspiration exceeds runoff in most river basins and on all continents except Antarctica (Dingman, 1994). An accurate estimation of evapotranspiration is critical in the assessment of water resources and the impact of climate and land use change. With this objective the present paper is focused on Hathmati River which rises from Gujarat Malwa Hills having total catchment of 1574 sq.km and average annual rainfall 864mm. The co-efficient of variation of annual rainfall over the basin is rather high and ranges between 42-65%. The tool used is ArcSWAT (ArcGIS interfaced with Soil & Water Assessment Tool) which is a semi-distributed hydrological model and takes in Geo-Spatial data (and collateral data) to estimate various parameters such as ET, Runoff etc. The present work is an attempt to estimate the value of ET through hydrological modelling. The model run is attempted between the years 1990 to 2002 where modelled results are compared with the observed values (of ET). The calibration is attempted by identifying the sensitive parameters that affects the value of ET (considerably). By vigorous permutations & combinations in sensitive analysis the results of ET are obtained and validated with the observed values.

***Keywords* – ET, SWAT, Hathmati, Calibration, Sensitive Analysis.**

I. INTRODUCTION

The term Evapotranspiration includes evaporation from the plant canopy, transpiration, sublimation and evaporation from the soil. It is the primary mechanism by which water is removed from a watershed. Roughly 62% of the precipitation that falls on the continents is evapotranspired. Evapotranspiration exceeds runoff in most river basins and on all continents except Antarctica (Dingman, 1994). The difference between precipitation and evapotranspiration is the water available for human use and management. An accurate estimation of evapotranspiration is critical in the assessment of water resources and the impact of climate and land use change on those resources.

The hydrological parameter is estimated by using a semi-distributed hydrological model named SWAT. It is an acronym for Soil and Water Assessment Tool, a river basin, or watershed, scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS). SWAT is developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.

The model computes evaporation from soils and plants separately as described by Ritchie (1972). Potential soil water evaporation is estimated as a function of potential evapotranspiration and leaf area index (area of plant leaves relative to the area of the HRU). Actual soil water evaporation is estimated by using exponential functions of soil depth and water content. Plant transpiration is simulated as a linear function of potential evapotranspiration and leaf area index.

II. STUDY AREA & DATA COLLECTION

Hathmati is one of the major tributary (left) of Sabarmati River which lies in Bhiloda (Sabarkantha district). It rises from Gujarat Malwa Hills and travel a course of 98km to meet Sabarmati near village Ged. The Total catchment area is 1574 sq.km. (157400 ha). Two main tributaries of Hathmati are Bodoli & Guhai and average annual rainfall is 864mm. An earthen dam is situated near Himmatnagar. The co-efficient of variation of annual rainfall over the basin is rather high and ranges between 42-65%. On an average maximum and minimum temperature reaches about 38°C & 16°C. The spatial variation of rainfall is highest in Hathmati amongst all sub-basins of Sabarmati. There are five rain gauge stations at Bhiloda, Mankadi, Himmatnagar, Lalpur and Pal.

Table 1: Rain Gauge Stations & Locations

Sr. No.	Name of Rain-Gauge Station	Latitude	Longitude	Reference Toposheet Number
1	Bhiloda	23^0 46' 10''	73^0 24' 45''	46A-14
2	Mankadi	23^0 36' 00''	72^0 57' 50''	46A-14
3	Himmatnagar	23^0 37' 10''	72^0 55' 45''	46A-14
4	Lalpur	23^0 42' 00''	73^0 13' 10''	46E-02
5	Pal	23^0 58' 02''	73^0 17' 00''	46E-02

Table 2: data collection

Sr. No.	Data	Source
1	Topographical map on 1:50,000 scale (46/A)	SOI, Govt. of India 1972
2	Digital Elevation Model	SRTM, USGS
3	LULC & Soil Map	BISAG, Gandhinagar, Gujarat
4	Rainfall Data	SWDC, Gandhinagar, Gujarat
5	Temperature Data	IMD, Gandhinagar, Gujarat

III. HYDROLOGICAL MODELLING

SWAT is the acronym for Soil and Water Assessment Tool, a river basin, or watershed, scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS). SWAT is developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. To satisfy this objective, the model is physically based. Rather than incorporating regression equations to describe the relationship between input and output variables, SWAT requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. are directly modeled by SWAT using this input data. Benefits of this approach are watersheds with no monitoring data (e.g. stream gauge data) can be modeled the relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, etc.) on water quality or other variables of interest can be quantified uses readily available inputs. It is computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money. It enables users to study long-term impacts. Many of the problems currently addressed by users involve the gradual buildup of pollutants and the impact on downstream water bodies. To study these types of problems, results are needed from runs with output spanning several decades. SWAT is a continuous time model, i.e. a long-term yield model. The model is not designed to simulate detailed, single-event flood routing.

The present work shows the model run in two different ways, of which first run is model setup by incorporating default database (collateral) to compare the results with the observed data. Both the times the model is made to run for years 1979 to 2002. The tool used is Arc Map (version 10.2.2) interface with SWAT (version 2012).

IV. RESULTS & DISCUSSIONS

The model run is initiated by incorporating all the necessary spatial maps including DEM, LULC and Soil map. Run-1 does not undergo any considerable calibration to improvise the efficiency of the model. No user-defined tables for soil map and LULC are introduced. Moreover threshold value for LULC, Soil and Slopes are chosen anonymously without any permutation. The results are then compared with the observed values collected from rain gauge station located at Bhiloda. The results are as follows;

The present work shows the model run in two different ways, of which first run is model setup by incorporating default database (collateral) to compare the results with the observed data. Both the times the model is made to run for years 1979 to 1990.

Table 3: results before calibration

Sr. No.	Year	PCP (mm)	ET (mm) Observed	ET (mm) Modelled
1	1979	950	825	555.9858
2	1980	498	433	556.6636
3	1981	1059	919	556.0947
4	1982	1004	871	556.8925
5	1983	885	768	570.8242
6	1984	808	701	552.5545
7	1985	643	558	567.8668
8	1986	524	455	553.9974
9	1987	303	263	572.6468
10	1988	1634	1418	554.1637
11	1989	1175	1020	561.0813
12	1990	1486	1290	537.4832
		Average	793	558.0212

The model is calibrated by choosing parameters (Variables) affecting the value of ET (Considerably) for the period of 1991 to 1990 (12 years). The SWAT uses water-balance equation to find ET (P=Q+E+S). The following parameters are selected to undergo calibration;

1. Drainage boundaries.
2. User defined LULC distribution (existing condition).
3. User defined Soil cover distribution (existing condition).
4. Threshold values for LULC, Soil and Slopes.
5. Weather database (User defined).

By rigorous permutations & combinations the results are again compared with the observed values as;

Table 4: results after calibration

Sr. No.	Year	PCP (mm)	ET (mm) Observed	ET (mm) Modelled
1	1979	950	825	765.2858
2	1980	498	433	764.326
3	1981	1059	919	574.0947
4	1982	1004	871	801.8925
5	1983	885	768	710.8242
6	1984	808	701	693.5545
7	1985	643	558	683.68
8	1986	524	455	570.7674
9	1987	303	263	506.768
10	1988	1634	1418	789.1637
11	1989	1175	1020	829.0813
12	1990	1486	1290	870.9878
		Average	793	558.0212

V. Conclusion & Scope

A considerable change in the value of ET is observed after calibrating the model. From 558.02mm to 713.28mm, the results have improved considerably towards observed average of 793mm. The results can be improvised by using maps of better resolution and incorporating pre-defined stream lines.

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