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Using QSWAT for Simulating Streamflow in a Highland Catchment of Humid Tropics

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Abstract: The present study aims at applying Soil and Water Assessment Tool (SWAT) on QGIS platform – QSWAT- for predicting streamflow in Mundakkayam sub basin of Manimala river. The total catchment area of Mundakkayam sub basin is 111 km^2.The models was calibrated for the streamflow data at Mundakkayam station during the time period from 1981 to 1991. The flow parameters alpha_bf (base flow recession constant) and Gw_revap (groundwater "revap" coefficient) were changed as 0.8 and 0.19 respectively. The performance statistics obtained are Nash-Sutcliffe coefficient (N_{SE}) as 0.83, correlation coefficient (R^2) as 0.91 and percent bias (PBIAS) as -7.66%. The calibrated model was then validated for a period of 11 years (1999-2009). The model results in good performance with N_{SE} - 0.58, R^2 - 0.77 and PBIAS – (-9.8%), showing that it is good for predicting streamflow in Mundakkayam sub basin of Manimala river.

Keywords: *QSWAT, Streamflow, Manimala river*

1. Introduction

Kerala is facing severe water scarcity during six months in a year. The existing resources are adversely affected by population growth, land use change and climate change. Limitation of data and lack of decision supporting tools are main factors that obstruct proper research and development in the area. For the current and future water resources management hydrological models becomes essential. Many hydrological models has been developed and applied from long back itself. Among these the Soil and Water Assessment Tool (SWAT) is a well-established model for analysing the impact of land management practices on water, sediment and agricultural chemical yield in large complex watersheds. SWAT has been successfully applied for water quantity and quality issues for small watersheds to large river basins and also applied for land use change/climate change impact studies all over the world. Wenming *et al*., (2011) in his study found that SWAT could accurately predict the relative impacts of land use change in the upper San Pedro watershed in Southern Arizona. The impacts of hypothetical forest and other land use changes on total runoff using SWAT are presented by Lorz *et al.,* (2007) in the context of comparison with three other models. Gosain *et al*., (2006) simulated the impacts of a 2041-2060 climate change scenario on the streamflows of 12 major river basins in India and found that there is a decrease in surface runoff and an increase on the severity of both floods and droughts. The worldwide application of SWAT model has proved its capability of simulating long term environmental impacts under changing land use and climatic conditions. A comprehensive SWAT review paper summarizing the findings of more than 250 peer-reviewed articles is written by Gassman *et al*. (2007). Only a few applications of SWAT model are made to Kerala conditions (Sathyan *et al.,* 2009; Raneesh *et al.,* 2010; Celine *et al.,* 2013, 2015). Manimala river basin in Kerala is facing water scarcity during summer periods. Increasing population and the dynamic change in land use can make the situation worst. Hence there is a need to arrive at the total water availability before planning any developmental activity. In view of the above, feasibility study of SWAT model was made for Mundakayam watershed in Manimala river basin for simulating streamflow to arrive at the water availability in the area. In the present study SWAT which uses QGIS as its interface, ie., QSWAT has been applied. The output of the model application will help to have an insight to the problem existing and help in making better management decisions for implementing development activities.

2. Materials and Methods

2.1. Study Area

The Manimala river basin lies entirely in Kerala State between 09°18'45" and 09°40'01" N latitude and 76°33'45" and 77°00'00" E longitude. The basin is having an undulating topography with altitude varying between 20m to 1380m above msl (Celine, 2008). The Mundakkayam sub basin of the Manimala river is taken as the study area. This sub basin spreads in the Idukki and Kottayam districts of Kerala. The catchment area up to the Mundakkayam gauging point is 111 km^2. The average annual rainfall in the catchment is 3700mm. Figure 1 gives the drainage map Manimala river basin with the study area ie., the Mundakkayam sub basin highlighted.

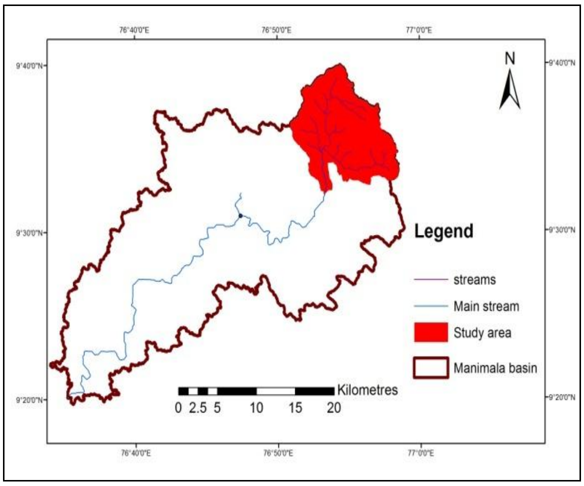

***Figure 1** Drainage map of Mundakkayam sub basin*

2.2. Data Availability

Rainfall data from two raingauge stations Mundakkyam R.H. and Boycee Estate were available for a period of 29 years (1981-2009). Streamflow data was available from 1981 to 2008 with 1992 to 2002 missing. The Digital Elevation Model (DEM) was downloaded from the USGS web site. The soil map and the morphometric details of the study area were collected from the Soil Survey Organisation under the Department of Agriculture, Government of Kerala. Land use map was digitized from the Survey of India toposheets 58C/14 and 58C/15 of 1:50000 scale using ArcGIS. The present land use was downloaded from the Water Resources Information System of India (Indis-WRIS) website and digitised.

2.3. QSWAT Model

The SWAT model is a watershed scale, continuous time model with a daily time step. SWAT is capable of simulating long-term yields for determining the effect of land management practices (Arnold and Allen, 1999). SWAT components include hydrology, weather, soil, temperature, sediment yield, agricultural management practices, nutrients, pesticides etc. SWAT simulation is based on the general water balance equation given by equation (1).

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

Where,

SW_t = soil water content at time t,
SW_o = initial soil water content,
t = time (in days),
R_{day} = amount of precipitation on day i,
Q_{surf} = amount of surface runoff on day i,
E_a = amount of evapotranspiration on day i,
w_{seep} = water percolation to the bottom of the soil profile on day i and,
Q_{gw} = amount of water returning to the ground water on day i.

Model setup

The input data required to execute QSWAT are the thematic maps of topography of the area, land use and soils and the daily climate data. The topography is represented by the DEM. The ASTER DEM for the study area was downloaded from the USGS web site and is given in Figure 2.

The DEM is used to partition the basin into sub units ie., sub basins. The land use maps and soil maps are then loaded to divide each sub basin into Hydrologic Response Units (HRUs). The number of HRUs in a sub basin is determined by the threshold value for land use and soil delineation in the sub basin.

In this study the Mundakkayam basin was divided into 35 sub basins, each of which were again divided into several HRUs. A total of 131 HRUs were created. A view of the model set up screen is shown in Figure 3.

Land use map (Figure 4) and soil map (Figure 5) were prepared in QGIS and converted to raster file to use with the model. The observed sreamflow data was prepared as .csv file to compare with the streamflow simulated through QSWAT.

The climate data required to execute the model are precipitation, maximum and minimum temperature, wind speed, relative humidity and solar radiation. A weather generator input file has to be created which contains the statistical data needed to generate representative daily climate data for the sub basins.

Since there was no climate gauging station data in the study area, data from the nearby station Puthupally (in Meenachil river basin) was taken and the weather generator file created to use with the model. Daily rainfall data from Mundakkayam R. H. and Boycee estate in the study area were collected and prepared as text files.

Model Calibration and Validation

For calibrating the model, data for a period of 11 years (1981-1991) were used. The land use map prepared from the toposheets (Figure 4) was input for this period. The model was executed with all the above prepared data; year 1981 was taken as the warm-up period.

The warm-up period allows the model to get the hydrologic cycle fully operational. The model was calibrated by changing the two flow parameters base flow recession constant (alpha_bf) and groundwater “revap” coefficient (Gw_revap). Alpha_bf was changed to 0.8 and Gw_revap was changed to 0.19 based on the previous study conducted by Celine *et al*., 2015 for Meenachil river basin in Kerala. The ‘visualise’ option, which will be active after model execution, was selected to compare the simulated streamflow values with the observed streamflow and is given in Figure 6.

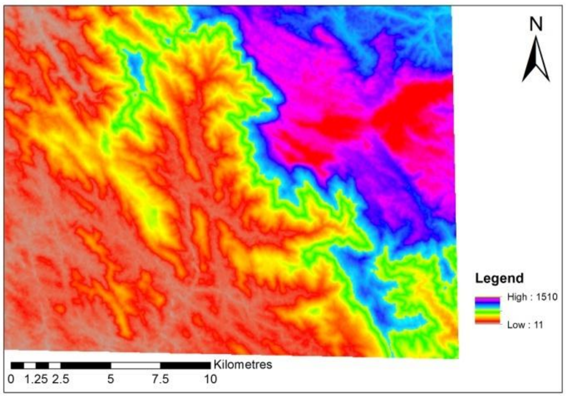

***Figure 2** DEM of Mundakkayam sub basin*

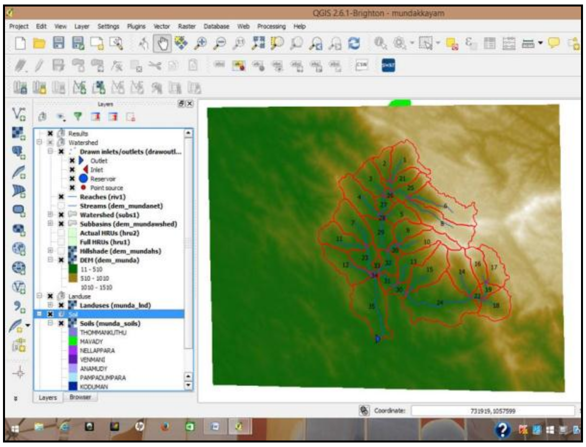

***Figure 3** A view of the Model set up*

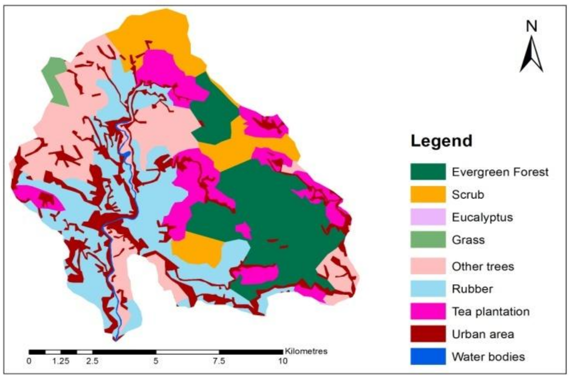

***Figure 4** Land use map of Mundakkayam sub basin*

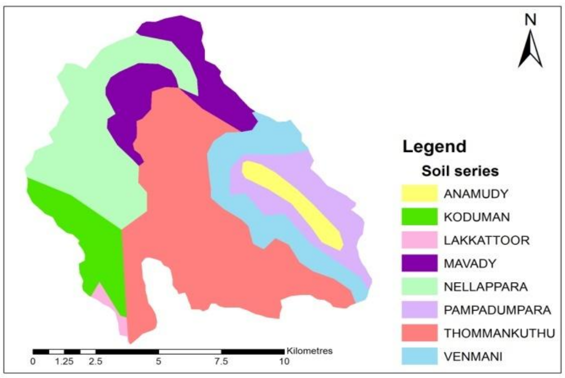

***Figure 5** Soil map of Mundakkayam sub basin*

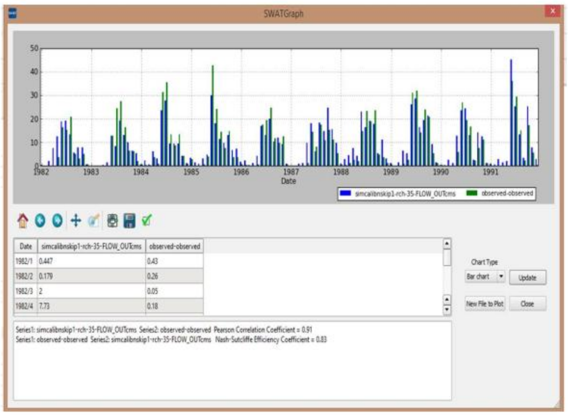

***Figure 6** Model result screen-calibration*

From Figure 6, the Nash-Sutcliffe Coefficient (N_{SE}) is 0.83 and the Correlation Coefficient (R^2) is 0.91. The PBIAS (percent bias) for the observed and simulated streamflow computed is -7.66%.

The model was then validated with data for a period of 11 years (1999-2009), with 1999 to 2002 taken as warm-up period, since streamflow data was available from 2003 only. For this validation period the new land use (Figure 7) taken from India-WRIS web site was used.

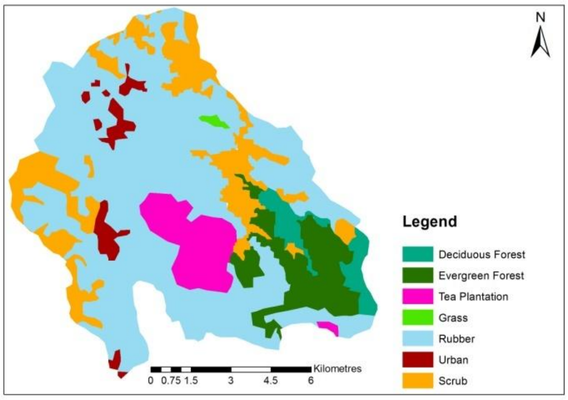

***Figure 7** Land use map used for model validation*

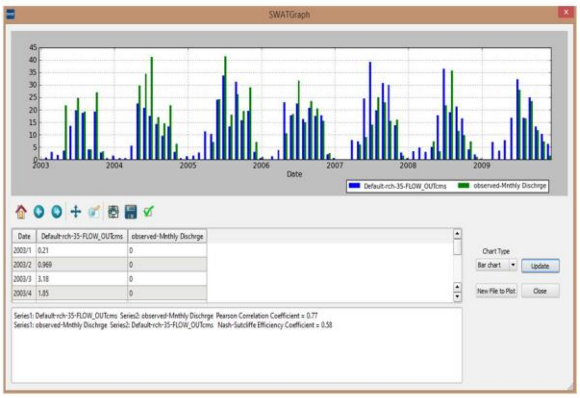

***Figure 8** Model result screen-validation*

The result obtained for the validation period is given in Figure 8. This shows that the N_{SE} is 0.58 and R^2 is 0.77 and the PBIAS computed is -9.8%. Hence as per the recommended statistics given by Moriasi et al., (2007) the performance of the QSWAT model is very good for Mundakkayam sub basin on a monthly scale.

3. Conclusion

The QSWAT model was used to simulate streamflow in Mundakkayam sub basin of Manimala river basin. Here the QSWAT package has been used, since QGIS is freely downloadable. QSWAT model was successfully calibrated and validated for Mundakkayam sub basin. The model was calibrated for the period from 1981 to 1991. The two flow parameters alpha_bf and Gw_revap were calibrated as 0.8 and 0.19 respectively. The N_{SE} value is 0.83 and R^2 is 0.91. The PBIAS computed is -7.66%. The model was then validated for the period from 1999 to 2009. The N_{SE}, R^2 and PBIAS obtained for this period were 0.58, 0.77 and -9.8% respectively. Studies carried out for other river basins in Kerala also have shown good results. The N_{SE}, R^2 and PBIAS for the Cheripad watershed in the highlands of Meenachil river basin, were 0.87, 0.89 and -1.4% for the calibration and 0.79, 0.84 and 1.9% for the validation period in predicting streamflow using SWAT (Celine *et al*., 2015). For Manali watershed of Karuvannur river, SWAT was used for predicting streamflow with a performance statistics of 0.90 for N_{SE} and 0.90 for R^2 during calibration and 0.92 for N_{SE} and 0.92 for R^2 during validation (Jayashree *et al.*, 2012). This good performance shows that QSWAT can be applied to high land catchments in humid tropics for predicting streamflows, which is a required factor for watershed development planning.

4. Acknowledgements

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References

[1] Arnold J. G. and Allen P. M., "Automated methods for estimating base flow and ground water recharge from streamflow records", *Journal of American Water Resources Association*, Volume No.35, Issue No.2, 411-424, 1999.

[2] Celine George and E. J. James, "Assessing the implications of extension of rubber plantation on the hydrology of humid tropical river basin", *International Journal of Environmental Research*, Volume No.9, Issue No.3, 841-852, Summer 2015.

[3] Celine George and E. J. James, "Simulation of streamflow using soil and water assessment tool (SWAT) in Meenachil river basin of Kerala, India", *Scholars Journal of Engineering and Technology*, Volume No.1, Issue No.2, 68-77, 2013.

[4] Celine George, "Rainfall runoff correlation for Manimala river basin in Kerala", *Indian Journal of Soil Conservation*, Volume No.36, Issue No.3, 129-130, 2008.

[5] D. N. Moriasi, J. G. Arnold, M. W. Van Liew, R. L. Bingner, R. D. Harnel and T. L. Veith., "Model evaluation guidelines for systematic quantification of accuracy in watershed simulations", *Transactions of the American Society of Agriculture and Biological Engineers,* Volume No.50, Issue No.3, 885-900, 2007.

[6] Gassman P. W., Reyes M. R., Green C. H. and Arnold J. J., "The soil and water assessment tool: Historical development, applications and future research directions", *Transactions of the American Society of Agriculture and Biological Engineers*, Volume No.50, Issue No.4, 1211-1250, 2007.

[7] Gosain A. K., Rao S. and Basuray D., "Climate change impact assessment of hydrology of Indian river basins", Current Science, Volume No.90, Issue No. 3, 2006.

[8] Lorz C., Volk M. and Schmidt G., "Considering spatial distribution and functionality of forests in a modeling framework for river basin management", *Forest Ecology and Management*, Volume No.248, Issue No.1-2, 2007.

[9] Raneesh K. Y. and Thampi Santhosh G., "Assessment of climate change impact on streamflow in Chaliyar basin", *Hydrology Journal*, Volume No.33, Issue No.1, 37-48, 2010.

[10] Santhosh G. Thampi, Kolladi Y. Raneesh and T. V. Surya, "Influence of scale on SWAT model calibration for streamflow in a river basin in the humid tropics", *Water Resources Management*, Volume No.24, Issue No.15, 4567-4578, 2010.

[11] Wenming Nie, Yongping Yuan, William Kepner, Maliha S. Nash, Michael Jackson and Caroline Erickson, "Assessing impacts of land use and land cover changes on hydrology for the upper San Pedro watershed", *Journal of Hydrology*, Volume No.407, 105-114, 2011.

[12] Jayashree S. and N. Sajikumar, "Runoff prediction in Manali River using SWAT", Proceedings of 24th Kerala Science Congress, 29-31 January 2012, pp. 376-378.

[13] Sathian K. K. and P. Shyamala, "Application of GIS integrated SWAT model for basin level water balance", *National Conference on Geospatial Technologies, GEOMATRIX '09, Resources Management*, IIT Bombay, 2009.