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# Simulation of Water Resources in Gundlakamma Sub-basin Using SWAT Model

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**ABSTRACT**

Water is a finite resource and the availability of which is declining with each passing day. A study has been conducted on the Gundlakamma sub-basin to simulate the water availability in the sub-basin. The Soil and Water Assessment Tool (SWAT) can be effectively applied to simulate the flow into a reservoir very accurately in the Gundlakamma sub-basin. The data base has been developed using the secondary data and field survey. SWAT model was applied to simulate the available water resource and reservoir volume in sub-basin. The water yield was simulated during 2010 to 2016 from Gundlakamma sub-basin. The most sensitive input parameters in SWAT was delay time for aquifer recharge (days), saturated hydraulic conductivity (mm/hr) for the Gundlakamma sub-basin. The calibration and validation NSE and $R^2$ of 0.79, 0.87 and 0.65, 0.72.

**Key words:** *Parameters, Reservoir flow, SWAT, Simulation, Water resources.*

Water is a finite resource and the availability of which is declining with each passing day. Agriculture sector, the largest consumer of water (82.8%), is facing competition from other sectors due to the ever increasing demands of the burgeoning population and accelerated pace of urbanization and industrialization in the country. It is expected that reduction in the average size of land holding, declining per capita water availability, deterioration of water quality, etc. will seriously affect the sustainable use of water resources and will make it difficult to accomplish the target of producing 345 Mt in 2030 and 494 Mt in 2050 AD. With growing scarcity and increasing inter-sectoral competition for water, the need for efficient and sustainable water allocation policies has also become more important. Finding ways to meet the competing demands, while also achieving positive economic and environmental outcomes, requires the aid of modeling tools to analyze the impact of alternative water allocation policy scenarios.

Therefore, hydrological modelling studies in basins with spatial and temporal variability are important because they help to understand processes that control water movement and the likely impacts on water quantity and quality. Impact assessments on water resources is one of the most relevant factors of hydrological models, which are fundamental tools for a basin planning and management (Viola *et al.*, 2009). Several hydrological models have been developed and applied in several basins for varied purposes. Among the hydrological models, the conceptual distributed one, which simulate various processes that make up hydrological cycle based on empirical functions and input parameters in spatial form, which is possible through model and Geographic Information System (GIS) integration. With the advent of GIS, it has become easier to handle a large amount of data that conceptual distributed hydrological models demand, thus, enabling process simulations with greater physical foundation.

SWAT is one such conceptual model, semi-distributed and continuous in time, and was developed to predict effects of different uses, land covers and soil managements on water and sediment production as well as water quality (Duraes *et al.,* 2011) and predominantly used for agricultural watersheds. For implementation and greater flexibility in simulation, the model has been highlighted in relation to others. SWAT has been calibrated and applied in hydrological simulation for several basins worldwide by several authors.

Gundlakamma is one such basin which is predominantly agricultural based. Gundlakamma is a seasonal river that flows through the east central part of the state of Andhra Pradesh, India. It covers an area of 45% in Prakasham District. The catchment area of the Gundlakamma River is 7910 Km$^2$. The capacity of the reservoir is 29.29 TMC and the Utilization is 12.845 TMC and it supplies drinking water for 2.56 lakh population and the command area of the project is 32,400 ha. At present the major portion in the command area is under cultivation of rain fed dry crops only as flows into the reservoir have been reduced due to no rains in the catchment and no regenerated water from Nagarjunasagar project right canal. Hence, presently the project is not able to meet the total demand of water for Agriculture, Domestic and Industrial needs.

## MATERIAL AND METHODS

### Study area

Gundlakamma sub-basin was predominantly agricultural based and Gundlakamma is seasonal river. The Gundlakamma rises in the Nallamalla Range of the Eastern Ghats. After crossing the mountains, it enters the plains. It flows in a north easterly direction past Markapur to the Coromandel Coast of the Bay of Bengal, after a course of 140 miles (225 km) that flows through the east central part of the state of Andhra Pradesh, India. It is located at (15° 50' 59.166" N, 79° 38' 7.794" E) and (15° 29' 27.166" N, 80° 11' 24.858" E). It covers an area of 45% in Prakasam district of Andhra Pradesh. The Gundlakamma sub-basin comprises thurupu vagu, pasapugalla vagu, nalla vagu, kalla vagu, dornapu vagu and chillakaleru which are tributaries to Gundlakamma.

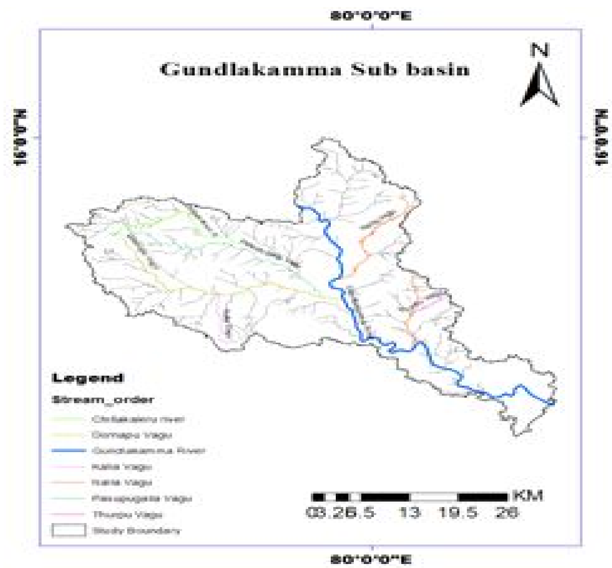


**Fig 1. Location of study area**

## SOIL AND WATER ASSESSMENT TOOL (SWAT)

SWAT is an evaluating tool of soil and water developed by the USDA-Agricultural Research Service (Neitsch *et al.,* 2002). This model was developed for the investigation of watersheds with surfaces going from a few hundreds of km$^2$ to several thousands of km$^2$.

## PREPARATION OF THEMATIC MAPS OF STUDY AREA

The basic maps required for the ArcSWAT include digital elevation model, soil, land use land cover and drainage network (stream lines). In addition, the SWAT interface requires the designation of land use, soil, weather as well as the simulation period to ensure a successful simulation. Universal Transverse Mercator (UTM) projections corresponding to zone 44N was used as the co-ordinate system for all the thematic maps. To create a SWAT dataset, the interface needs access to ArcGIS compatible raster and vector data sets (shape files and feature classes) and database files which provide certain types of information about the watershed.

### Weather

Custom weather database which includes all the climatic parameters of the study area was needed as input to obtain accurate estimate of the water yield of the catchment. The inputs like precipitation (mm), temperature ($^0$C), solar radiation ($MJm^{-2}d^{-1}$), relative humidity (%) and wind speed ($m^2sec^{-1}$) were prepared using DBase IV spread sheet since SWAT accepts the data in DBase IV format only. The location of the rain gauge stations and weather station in the study area

## RESULTS AND DISCUSSION

The model has strong predictive capability with $R^2$ as 0.87 in calibration and 0.72 in validation and NSE as 0.79 in calibration period and 0.65 in validation period (Table 1). This result confirmed that the SWAT model performed well in this sub-basin as statistical model efficiency criteria fulfill the requirement of $R^2 > 0.6$ and NSE >0.5 (Moriasi *et al.,* 2007).

**Table 1. Statistical performance indicators during calibration and validation period**

| Variable | NSE | $R^2$ |
|---|---|---|
| Calibration (2010-2012) | 0.79 | 0.87 |
| Validation (2013-2016) | 0.65 | 0.72 |

Further, the uniformly scattered points along the 1:1 line during calibration and validation indicated that the model is good in simulating discharges.

### Average Monthly Basin values for the changed LULC map (2014-15)

The monthly basin values were presented in the Table 2. The hydrological parameters such as percolation, surface flow, ground water contribution to flow indicated good relationship with precipitation. Generally, ET will be more during April to August in a year. However, ET was more even during the month of september and same was observed during the year 2010-11. This is mainly due to the *Kharif* crops namely paddy, chillies, cotton and redgram grown in the catchment.

**Table 2. Average Monthly Basin values of different components of water balance during the year 2014-15**

| Month | Rainfall (mm) | Surface Runoff (mm) | Lateral Flow (mm) | Water Yield (mm) | Soil Water (mm) | Actual ET (mm) |
|---|---|---|---|---|---|---|
| JAN | 8.29 | 1.09 | 0.73 | 25.41 | 92.14 | 26 |
| FEB | 15.34 | 3.84 | 0.52 | 26.7 | 110.6 | 17.69 |
| MAR | 0 | 0 | 0.51 | 24.45 | 178.49 | 11.86 |
| APRL | 13.41 | 0.96 | 0.34 | 24.69 | 218.59 | 12.41 |
| MAY | 67.08 | 23.84 | 0.34 | 47.6 | 280.6 | 24.49 |
| JUN | 54.13 | 6.1 | 0.45 | 28.45 | 236.51 | 37.42 |
| JULY | 99.64 | 14.44 | 0.54 | 36.79 | 202.42 | 49.51 |
| AUG | 130.51 | 26.2 | 0.76 | 48.13 | 185.73 | 64.18 |
| SEP | 123.58 | 22.53 | 1.14 | 44.52 | 150.85 | 65.29 |
| OCT | 170.58 | 50.63 | 1.18 | 73.48 | 125.81 | 45.82 |
| NOV | 95.13 | 31.64 | 1.23 | 54.71 | 90.22 | 26.97 |
| DEC | 66.22 | 29.51 | 1.02 | 53.78 | 80.75 | 23 |

Surface runoff contribution to flow was more in October (50.63 mm) which coincided the highest amount of rainfall (170.58 mm) recived during the month. Similarly, the water yield was highest in the month of October which is related to surface runoff contribution to flow and lateral flow. The surface runoff contribution to flow was 49.03 mm with highest rainfall of 175.63 mm for the year 2010-11 with different LULC. Soil moisture values varied from 80.80 mm to 280.41 mm under 2010-11 where as it was 80.75 mm to 280.60 mm under 2014-15 LULC.

**Average Annual Basin Values with 2014-15 LULC**

In order to present the order of magnitude of these allocations of precipitation in to different components of water balance, the annual average basin values were presented in the Table 3. The average annual precipitation was 843.5 mm. This precipitation was apportioned in to water balance components in which ET was accounted high followed by deep aquifer recharge. Surface runoff contribution to flow and lateral flow contributed less to the flow. The average annual ET of the basin is around 50 % of the precipitation.

**Table 3. Average Annual Basin Values of different components of Water balance**

| Process | Average Annual Value (mm) |
|---|---|
| Precipitation | 843.5 |
| Surface runoff contribution to | 210.67 |
| Lateral flow through Soil | 8.75 |
| Groundwater ( shallow aquifer) | 49.61 |
| Deep aquifer recharge | 217.4 |
| Actual Evapotranspiration | 404.2 |

The summary of the ratio of allocation of precipitation into different components of water balance under different LULC was presented in Table 4.

**Table 4. Water balance components under different LULC**

| Ratio | 2010-11 | 2014-15 |
|---|---|---|
| Stream flow /precipitation | 0.31 | 0.32 |
| Base flow | 0.21 | 0.22 |
| Surface runoff | 0.79 | 0.78 |
| Percolation /precipitation | 0.51 | 0.52 |
| ET/precipitation | 0.47 | 0.48 |

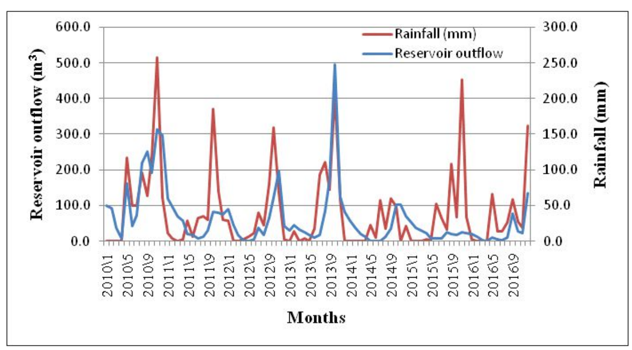


**Fig 2. Reservoir outflow and rainfall in sub basin during 2010 to 2016**

The above result clearly indicated the impact of change in land use on components of water balance. The surface runoff contribution to flow has been decreased during 2014-15 due to reduction in paddy area. The Evapotranspiration was increased due to increase in area during *kharif* and *rabi.*

**Table 5. Reservoir outflow ($m^3$/month) in Gundlakamma sub-basin during 2010 to 2016**

| S. No | Month | Reservoir outflow ($m^3$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| 1 | Jan | 49.08 | 49.95 | 47.67 | 9.87 | 34.34 | 31.55 | 8.97 |
| 2 | Feb | 47.98 | 43.82 | 25.08 | 20.11 | 27.73 | 22.22 | 8.17 |
| 3 | Mar | 22.42 | 29.27 | 14.47 | 12.10 | 20.97 | 14.75 | 7.66 |
| 4 | Apr | 8.64 | 26.83 | 8.85 | 15.86 | 18.20 | 11.19 | 7.03 |
| 5 | May | 94.94 | 14.76 | 8.70 | 17.59 | 12.26 | 9.46 | 13.33 |
| 6 | Jun | 19.01 | 16.49 | 10.42 | 14.91 | 11.12 | 12.13 | 6.28 |
| 7 | Jul | 27.03 | 7.98 | 16.93 | 12.29 | 6.90 | 3.95 | 0.00 |
| 8 | Aug | 101.90 | 17.59 | 8.08 | 47.43 | 13.97 | 17.22 | 9.72 |
| 9 | Sep | 106.50 | 24.80 | 20.27 | 81.64 | 19.83 | 12.34 | 36.14 |
| 10 | Oct | 80.44 | 50.62 | 41.36 | 249.40 | 47.76 | 11.34 | 8.66 |
| 11 | Nov | 132.10 | 45.35 | 75.79 | 62.51 | 50.64 | 15.07 | 6.06 |
| 12 | Dec | 138.90 | 48.86 | 15.94 | 48.09 | 43.99 | 17.16 | 59.03 |
| Total | | 828.94 | 376.32 | 293.56 | 591.80 | 307.71 | 178.38 | 171.03 |

**Simulation of reservoir flows**

There was a reservoir in the Gundlakamma sub basin and the inflow and outflow was simulated from 2010- 2016. The monthly reservoir outflow values were presented in the Table 5. The highest flow was simulated during October, 2013 (249.4 $m^3$) and minimum flow was simulated during July, 2016 zero (0.00 $m^3$). The similar trend was observed with the rainfall in the subbasin.

## CONCLUSION

1. The Soil and Water Assessment Tool (SWAT) can be applied to simulate the flow into a reservoir very accurately in the Gundlakamma sub-basin.
2. The most sensitive parameters in SWAT was delay time for aquifer recharge (days), saturated hydraulic conductivity (mm/hr) in the Gundlakamma sub-basin.
3. The average annual surface runoff and actual evapotranspiration was 210.67 mm, 404.20 mm in the Gundlakamma sub-basin.
4. The ground water contribution flow clay soil very high compared to clay loam soil in the Gundlakamma sub-basin.
5. SWAT model simulated the impact on change in land use land cover of water resources in the Gundlakamma sub-basin.
6. Increase in urbanization has let to more surface runoff and reducing infiltration in the Gundlakamma sub-basin.
7. Evapotranspiration in the Gundlakamma sub-basin was more by changing land use to plantation.
8. The highest out flow from reservoir was simulated during October, 2013 (249.4 $m^3$) in the Gundlakamma sub-basin.

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