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Hydrology modeling to assess soil water balance in Dal Lake basin using SWAT

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ABSTRACT

Estimation of soil water balance for a lake basin becomes significant in planning and executing sustainable management of water resources for any country. This valuation includes computation of different elements involved in hydrologic process and are mandatory to deal with water management problems. There are number of geospatial technology based models are available to understand the hydrology characteristics of any basin. In the current study hydrological model Soil and water assessment tool (SWAT) integrated with QGIS has been chosen to predict the water yield and soil water balance of Dal lake basin, Kashmir valley. SWAT is a physically based integrated watershed model and it is suitable to use worldwide for any complex watershed. Dal lake catchment is not only highly diverse but also covers a huge area of 309 Km2.QSWAT interface for QGIS has been used to carry out the analysis for the time period of 34 years from 1979 to 2013, Data such as slope, Landuse and Landcover (LULC), Soil and weather which includes daily precipitation, temperature, solar radiation, wind speed and Relative humidity has been used and processed on monthly time scale basis. Results of hydrological parameters includes Evapotranspiration, Actual Evapotranspiration (AET), Groundwater Contribution, Potential Evapotranspiration (PET) and Surface runoff are analyzed and represented as both in numbers and as wells as maps.

1. Introduction

Water is a valuable natural resource that has to be managed to have potential competence of sustainable growth and development of the society. Increase in population, expansion in agriculture, industrial development and economy growth has adverse effect on water resources across the globe. Therefore Integrated management and sufficient distribution of water resources between diverse water usage under altering conditions of land use and climate are chief challenges which numerous societies already face, or will need to face during the next eras (Simonovic, 2002).Balancing the water availability and demand in a spatial scale are the best way to understand the current trend. In this context, analysis of the impact of land-use and climate changes on river hydrology and surface water availability can be addressed by means of spatially distributed rainfall–runoff model applications (Harrison & Whittington, 2002; Eckhardt & Ulbrich, 2003; Haverkamp et al., 2005). To overcome these kind of impact it is mandatory to maintain and understand the soil water balance relations and also the quality and quantity of water with respect to space and time. Soil water balance referred to as the balance of water entering the system and the water that leaves the system within a specified time period. Calculation of water balance is a basic approach for determining stocks of water in different components (air, soil, and waterbodies) of the hydrological cycle and fluxes between the components.

The most significant hydrologic components from the water management system involves surface runoff, lateral flow, base flow and evapotranspiration. There are many number of integrated physically based distributed models are available, among them, researchers have identified soil water assessment tool (SWAT) as the most promising and computationally efficient hydrology model (S.L. Neitsch, et al., J. Arnold, J.R et al., 2005). SWAT is a continuous, long-term, physically based, semi-distributed hydrologic model, developed by the U.S. Department of Agriculture (Neitsch et al., 2005; Zhang et al., 2008). It is an effective planning tool, in that it can be used in order to gain an improved understanding of the water balance, while at the same time determining water savings from different management scenarios (Immerzeel et al., 2008; Santhi et al., 2005). Hence in this study, QGIS interface for SWAT named QSWAT has been used to determine all hydrology parameters that are required to study the soil water balance of Dal lake basin.

2. Study Area

Dal lake basin is located in Kashmir valley, north-west of Jammu and Kashmir with the spatial extent between the latitudes 34° 2' 4.48'' E to 34° 13' 48.36'' E and longitudes 74° 46' 33.96'' N to 75° 9' 32.976'' N (Fig 1). The lake catchment covers a huge area of around 309 km2 with a major outlet located to the western side of the lake. Altitude of the lake basin ranges from 1583 to 4390m which indicates that the basin suffers a steep cliff. Landuse and land cover are mostly ranging from cropland, horticulture and built-up where human activities have intensified during the last few decades. But the mountainous regions are mostly shielded by forest, grassland, shrub lands, and the hilly regions consist of natural vegetation and barren land. As the terrain has got steep cliff, most of the surface runoff carrying the eroded soil and sediments that originate from these mountainous and hilly areas of the catchment. The geological formations of the catchment area are dominated by alluvium, Panjal traps and agglomerate slates

(Wadia 1971; Varadan 1977; Data 1983; Bhat 1989).The average rainfall in dal lake basin ranges around 680 mm.

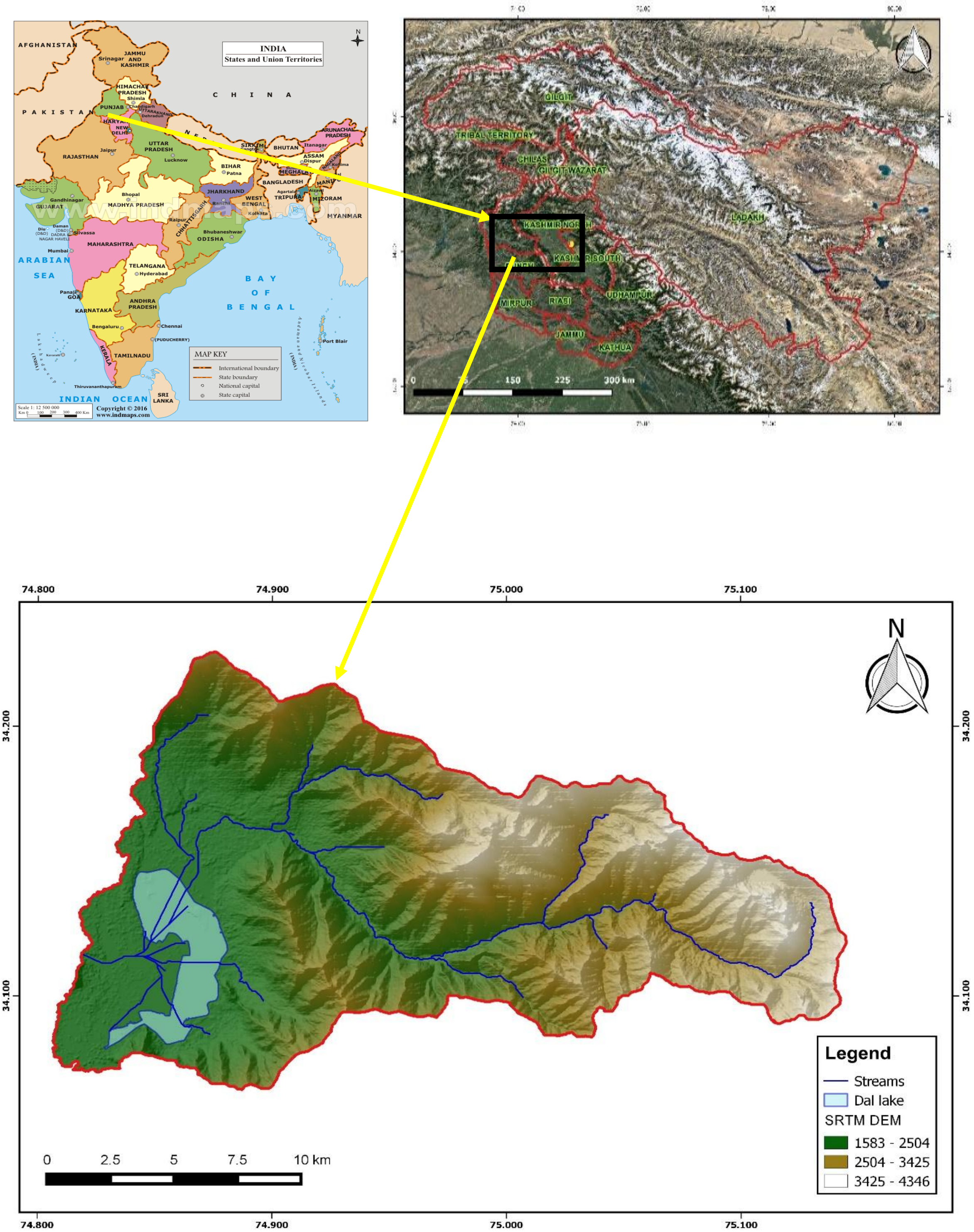

Figure 1: Location of Dal Lake Catchment

3. Data and Methodology

Spatial data required to process with the QSWAT interface includes Digital Elevation Model (DEM), Soil map, Landuse Landcover (LULC) map and weather data on daily basis. DEM was acquired from NASA's Shuttle Topography Radar Mission (SRTM) with a resolution of 30-meter (Fig 2). Hydrology process includes watershed delineation, drainage pattern analysis and surface terrain analysis are processed with the help of DEM.

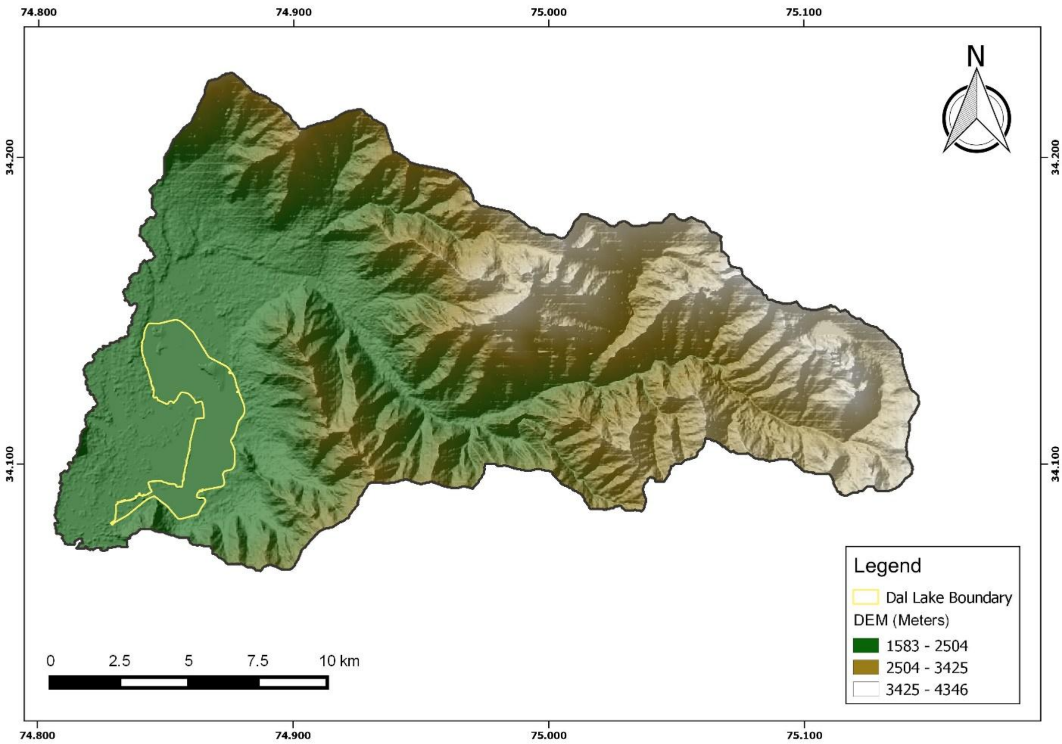

Figure 2: DEM of Dal Lake Basin

The flow direction was determined using DEM data through 'D8' eight direction. The stream network was delineated by applying threshold value of 50 to the flow accumulation. Then the DEM data was processed to develop slope map and flow direction. The landuse map of the Dal lake basin was determined through digital image processing of IRS1C LISS III data. SWAT code was assigned to each landuse and copied to excel file. Eight different landuse/land cover features has been extracted such as Builtup, agriculture, scrub land, barren, water, forest, ice and plantation are shown in figure 3.

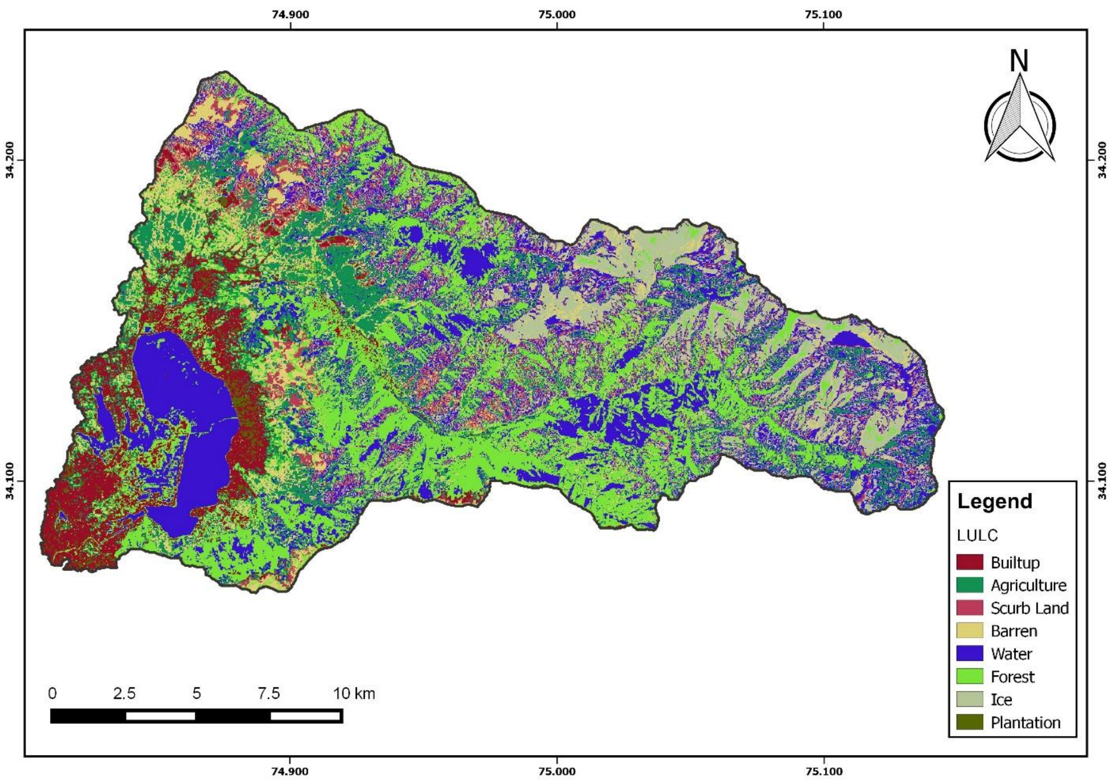

Figure 3: Landuse Landcover (LULC) of study area

The soil map of the Dal lake basin has been procured from National Bureau of soil survey and land use planning department (NBSSLUP). Nine soil types were identified and has been converted to raster format and connected to the swat database using lookup tables (Fig: 4). Similar to DEM data, the resolution of the soil map also plays a vital impact in modelling the stream flow for soil water balance and sediment load.Geza and McCray (2008), assessed the dependence of prediction accuracy of SWAT is based on resolution of the input spatial parameters. Weather data includes daily temperature, precipitation, relative humidity, solar radiation and wind speed are obtained from the global weather web page of Texas A&M University (TAMU). Precipitation related parameters and dewpoint were computed using customized software called pcpSTAT.exe and dewpoint.exe

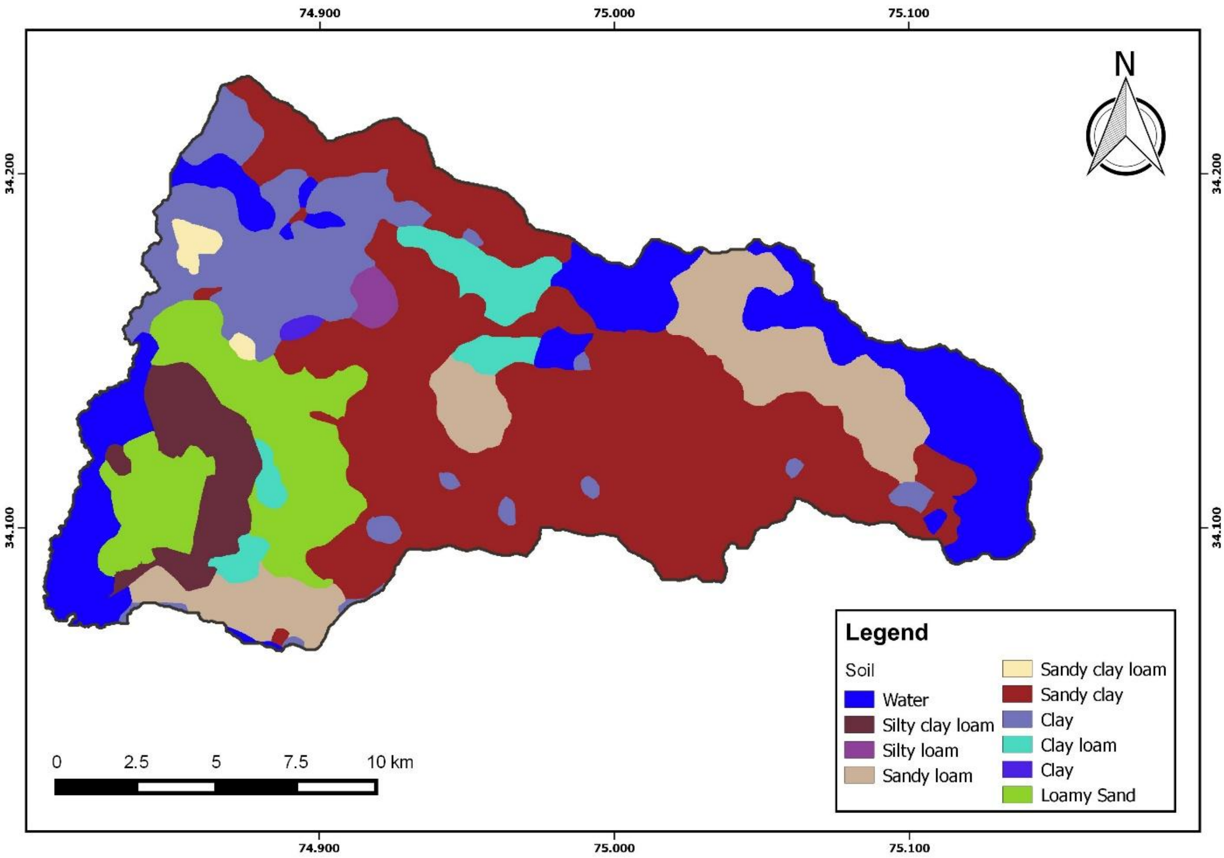

Figure 4: Soil Map of Dal lake basin

Hydrology modeling of the Dal lake catchment are processed using the QSWAT interface of QGIS software. Topography, soil properties, Landuse type and weather data of the Dal lake catchment are used to predict the surface runoff. Dal lake basin has been divided into 25 subbasins and based on the similar slope Landuse and soil distribution Hydrologic Response units (HRUs) are demarcated. Land phase and routing phase are the two hydrologic section delineated by the QSWAT interface, in which the land phase hold the details of the water movement from the land to the major channel in the basin and the routing phase frameworks the water movement through the channel network.

QSWAT computes various hydrology components like evapotranspiration, subsurface flow, potential evapotranspiration, return flow, ground water flow which are used to determine the soil water balance in the entire watershed. Surface runoff in SWAT model are computed using the SCS curve number method and Penman-Monteith method is used to determine the potential evapotranspiration.

Water yield is the total amount of water leaving the HRU and entering main channel during the time step. It is one of the important parameter that need to be estimated for sustainable management of water resources of the study area. Water yield of the catchment was estimated by the QSWAT model using the equation below;

$$\mathbf{WYLD = SURQ + LATQ + GWQ - TLOSS}$$

Where WYLD is the amount of water yield (mm H2O),
SURQ is the surface runoff (mm H2O)
LATQ is the lateral flow contribution to stream flow (mm H2O),
GWQ is the groundwater contribution to stream flow (mm H2O) and
TLOSS is the transmission losses (mm H2O) from tributary channels in the Hydrological Response Unit (HRU) via transmission through the bed.

4. Results and Discussions

SWAT runs successfully and produced various simulated results which can be visualized on different statistical basis like daily, monthly and annually. Hydrology components like evapotranspiration, potential evapotranspiration, groundwater contribution, surface runoff water yield and soil water content for the period of 34 years (1979 -2013) with a warmup period of 3 years were simulated. During SWAT simulation model it was observed that the basin has been sub-divided in to 25 subbasins and 234 HRU's. QSWAT interface provides both Numerical and graphical visualization of all the outputs.

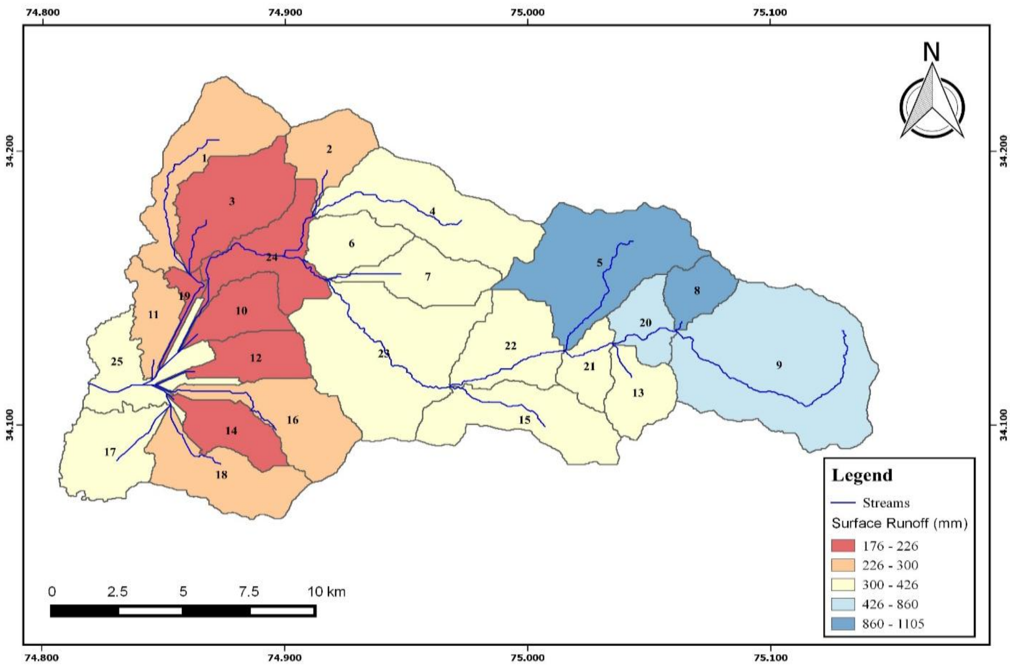

Figure 5: surface runoff in Dal lake basin

The highest runoff is noticed in the 5th and 8th subbasins, which represents highest elevation and occupies the N.E part of the subbasins (Fig 5). Also, it can be observed that the rate of runoff gradually decreases toward the western side and attained very low runoff in the 3, 10, 12, 14, 19 and 24th subbasins.

Higher amount of groundwater contribution were noticed in the subbasins 3, 10, 11,14,17,24 and 25, which occupies the spatial regions very closer to the Dal lake (Fig 6).The subbasins 2, 13, 15, 20, 21, 22 and 23 exhibit very low contribution of ground water within the Dal lake basin. The region with higher to moderate runoff nature shows low ground water contribution. The subbasins representing the western part 11, 17, 19, 24 and 25 exhibits very low lateral flow contribution (Fig 7). The subbasins 9 and 5 expresses higher amount of surface runoff and lateral flow. Also most of the regions falls as low lateral flow are at higher ground water contribution nature.

Most of the subbasins representing the central part of the Dal basin shows low soil water balance. The higher soil water balance is noticed in the subbasins 5, 8 and 9. This shows that there is a good relationship between the runoff, lateral flow, and soil water balance.

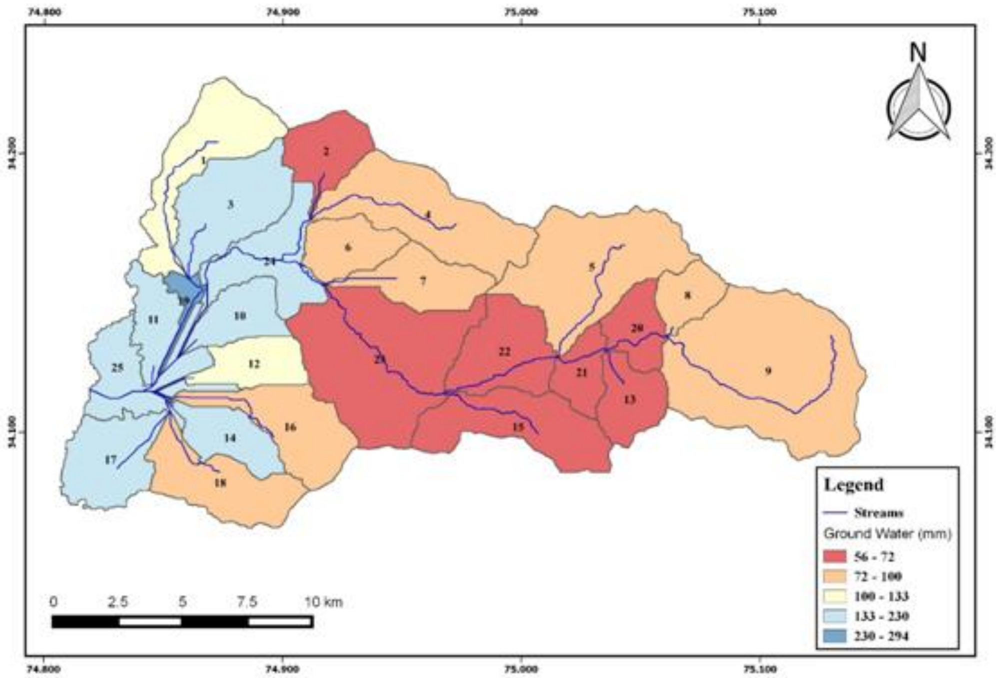

Figure 6: Ground water contribution in Dal lake basin

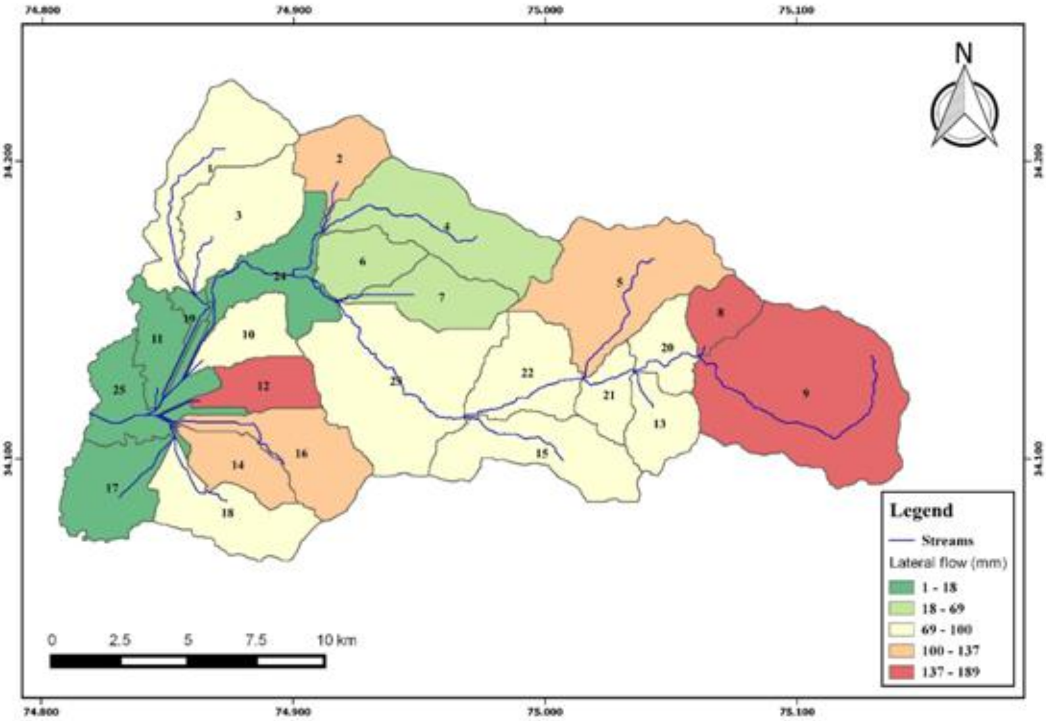

Figure 7: Lateral flow contribution in Dal lake basin

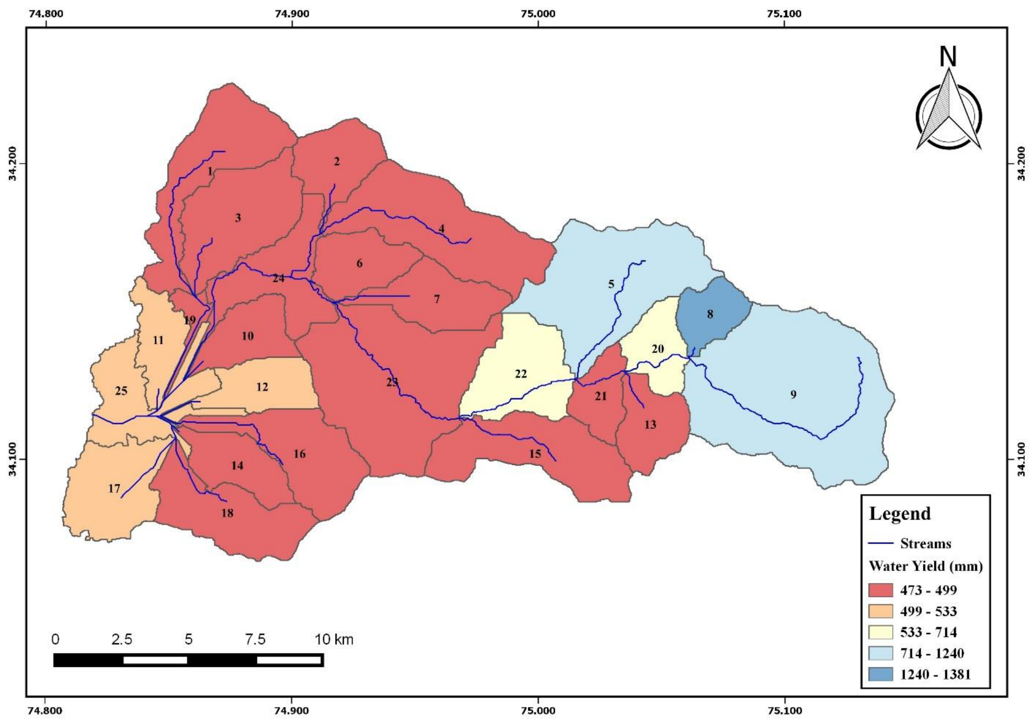

Figure 8: Soil water balance in Dal lake basin

Surface runoff and Precipitation

The SWAT based simulated values of the hydrological components are shown in Fig 9. The simulated daily runoff using the daily precipitation data and the annual average rainfall and runoff were estimated as 680.5 mm and 232.1 mm respectively Crop evapotranspiration (ET) and potential evapotranspiration (PET) during the time period was projected by the QSWAT model based on the daily maximum and minimum temperature and daily precipitation values. The average ET and PET during the time period was found as 1375 mm and 485.3 mm respectively. Average groundwater recharge and water yield i.e. soil water balance are found to be 49.95 mm and 595 mm respectively (Fig: 9).

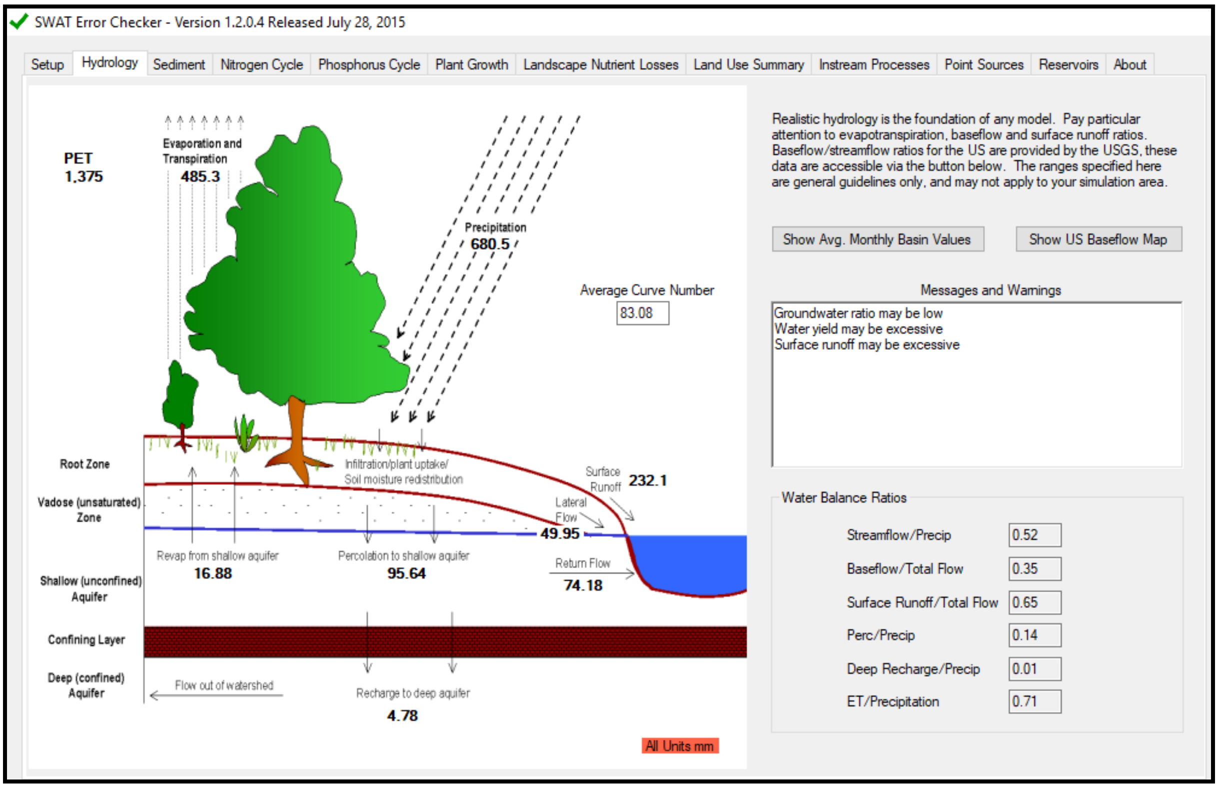

Figure 9: Average values of all Hydrology components - QSWAT

5. Conclusions

Based on the local conditions of the data availability, SWAT model for Dal lake basin confirms that it is a useful and mandatory tool .Model helps in making Primary assessment of the potential impact of soil, land use and weather of the Dal lake basin. Water in various components of the hydrology cycle and changes in these components are best studied by soil water balance of that particular basin. The study reveals that the deep aquifer receives 4.78 mm recharge and the percolation into shallow aquifer as 95.64 mm with the return flow of 74.18 mm. This study also proves that SWAT model is an effective tool in simulating large basins at watershed scale. Estimated parameters can be used for various other purposes that includes water management for agriculture, impact assessment of climate change and water quality etc. The study suggests that SWAT model could be a promising tool to predict water balance and water yield to support policies and decision maker for the sustainable water management at basin level.

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