Land use /land cover change in a hydrologic regime using swat model-A Review

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***Abstract*-The study has shown the integration of SWAT with GIS and remote sensing tool are helpful analyze and evaluate spatiotemporal land use/cover dynamics. It has also shown that Arc SWAT is an effective tool in analyzing the impacts of land use/cover changes on stream flow in areas with limited readily available data. The study also revealed that Hydrologic simulation models are very essential way used to assess hydrological characteristics of watershed. They are efficient tools for evaluating effects and impacts that occur in hydrologic regime. They can be used to find out, predict and understand what happened and will happen throughout a basin in time and space. This review determines the interactive role of SWAT and GIS technologies in improving integrated watershed management.**

***Index Terms*-SWAT, GIS, Land Use /land cover change**

I. INTRODUCTION

Land use/land cover (LU/LC) plays a vital role in water transport in the hydrologic cycle and primarily aids in reducing overland flows. Due to its effect on evaporation, transpiration and solar radiation interception, LU/LC is a driving factor in the energy balance within the hydrologic cycle [14]. The hydrology of local watersheds can vary drastically and water quality as well as water flow patterns is often dependent on a combination of soil, LU/LC and elevation characteristics unique to the area. For example, as forested area is lost and developed land expands it has shown to reduce base flow and/or an increase in soil erosion generally occurs [30].

To study sustainable water resources and land use planning and development understanding the consequences of changes in land use and land cover scenarios is required. Human activities can affect the integrity of natural resources and the output of goods and services in the ecosystem. The development of new patterns of land use and land cover conditions can be enhanced by careful planning for the wellbeing of people [1]. The scientific framework for the analysis of land use systems have changed by the modelling tools which can addresses both spatial and temporal dynamics. It is a universal concern the changes in land use and land cover in river basins resulted in flooding events that has increased sediment loads [16, 5]. There are some proportional alterations in the basin condition and hydrological response as a result of changes in land cover and land use scenarios. This is appropriately becoming one of the main existing land management issues [9].

The response of hydrological processes of river basins influenced by human activities and climate changes have been widely studied [10, 17] [11, 12]. In recent years, understanding the occurrences of natural processes at the watershed scale by the application of the model became an essential tool [18]. Geographic Information System (GIS) based spatial modeling has grown into an important tool to assess the effect of land use land cover changes on runoff and soil erosion studies and, consequently in advancement of suitable soil and water conservation strategies. Among several models SWAT linked with GIS has been extensively used in earlier studies.

Several research works have been carried out to study the impact of Land use /land cover change on the hydrology of river basins. Land use and land cover change very often due to the growing population and economy. In human history land, a fundamental factor of production, has been coupled to economic growth [26]. The rapidly increasing population pressure in many rural areas of developing countries has often led to changes in land use in terms of deforestation, reclamation of wetlands, etc. mainly aiming at agricultural production. Neither population nor poverty alone constitute the sole and major underlying causes of land cover change world-wide [13].

LU/LC monitoring is an important aspect to determine the LU/LC change and likely impacts on the ecosystem [3] that often lead to several environmental impacts, such as soil erosion, soil moisture, soil nutrients, change in micro-climate and so forth. These impacts not only affect within the watershed boundary but also bring in several harmful effects downstream [3]. Knowledge of LU/LC change is important for many planning and management activities [11]. Technological, institutional and natural resource policy forces also play an important role in changing land use pattern [25]. Therefore, knowledge of changes in LU/LC is becoming far more important from both ecological and economical point of view [12].

SWAT is a basin-scale continuous-time model that operates on a daily time step and is designed to predict the impact of management on water, sediment and agricultural chemical yields in ungauged watersheds [6]. SWAT could accurately predict the relative impacts of hypothetical land use change in the 8.2 km ^{2}experimental sub watershed within the San Pedro watershed [9]. Simulated streamflow impacts with SWAT in response to historical land use shifts in the 3,150km ^{2} San Pedro watershed in southern Arizona and the Cannonsville watershed in south central New York [19].

II. DESCRIPTION OF SWAT

SWAT is a physically-based and semi-distributed river basin or watershed-scale model developed to predict the impact of land management practices on sediment, water, and agricultural chemical yields on complex watersheds with varying land use, soils, and management conditions over long spans of time [1]. SWAT was developed in the early 1990s for the USDA Agricultural Research Services (ARS). SWAT has been updated to the most recent version, Arc SWAT 2012 [32] which is an ArcGIS 10.x extension. This interface streamlines data entry, the creation of required input files and parameter editing, all while allowing spatial parameters to be easily observed in the ArcGIS environment. In Arc SWAT, the watershed is delineated into a number of sub-basins, which are further divided into Hydrological Response Units (HRUs) that consist of homogeneous land use, management, and soil characteristics. The HRUs represent percentages of the sub-watershed area and are not identified spatially within a simulation [4]. Subdividing the watershed into HRUs enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers and soils. Runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed which increases the accuracy of load predictions [38]. By delineating the watershed, the user is able to reference different areas of the watershed to one another spatially. For each sub-basin input, information is grouped into the following categories: climate; groundwater; HRUs; ponds/wetlands; and the main channel draining the sub-basin [23].

Water balance is the driving force behind everything that happens in the watershed. As simulated by the model, the hydrologic cycle must conform to what is happening in the watershed to accurately predict movement of sediments [23]. The hydrology is simulated in two major ways: (1) the Land Phase, which controls sediment, nutrient and pesticides loading to each channel from sub-basins, and (2) the Water or Routing Phase that controls the movement through the channel network to the watershed outlet [22]. The SWAT soil-water routing feature is calculated from the interaction of four main pathways: soil evaporation, plant uptake and transpiration, lateral flow and percolation. Sediment yield in SWAT is estimated with the modified soil loss equation (MUSLE) developed by [31]. The hydrologic cycle is simulated by SWAT based on the following water balance equation.

$$SW_t = SW_0 + \sum \left(R_{\mathrm{day}} - Q_{\mathrm{surf}} - E_a - w_{\mathrm{sweep}} - Q_{gw} \right)$$

Where t is the time in days,$SW_t$is the soil water content at time t (mm), SW_0 is the initial soil water content (mm),Rday is amount of precipitation on day i (mm),Q_{surf}s the amountof surface runoff on day i (mm),E_a is the amount of evapotranspiration on day i (mm),$W_{sweep}$is the amount of water entering the vadose zone from the soil profile on day i (mm),Q_{gw} is the amount of return flow on day i (mm).

SWAT was chosen for the compatibility of available data and software and for its complex representation of fine spatial scales. Moreover, SWAT has become popular among environmental managers since it has been adopted as a component of the US Environmental Protection Agency's Better Assessment Science Integrating Point and Non Point Sources (BASINS) software packages [6]. SWAT has shown to be successful for land-use change assessments and has generated an expanding body of research projects. SWAT has also been extensively validated across the US for stream-flow and sediment loads [27]. Many researchers have utilized SWAT in their research questions in other countries including India [33, 8] and New Zealand [2]. Strong emphasis on vegetation and hydrological interactions within SWAT make it a preferable model for this land-use based hydrological analysis.

SWAT provides two infiltration methods for estimating the surface runoff volume component from HRUs, namely, the SCS-curve number (CN) method [SCS, 1972] or the Green &Ampt infiltration method [7]. Whereas the CN-method uses daily rainfall rates, the Green &Ampt technique requires smaller time-steps to properly simulate the infiltration process. This discards the use of the latter method in the present study.

Here the surface runoff is modeled in SWAT using the SCS curve number method, i.e.

$$Q_{surf} = \frac{\left(R_{day} - I_a\right)^2}{\left(R_{day} - I_a + S\right)}$$

Where:

Qsurf, accumulated runoff or rainfall excess (mm H20),

Rday, rainfall depth for the day (mm H20),

Ia, initial abstractions which includes surface storage, interception and infiltration, prior to runoff (mm H20), and which is usually taken as equal equal 0.2S, with

S, retention parameter (mm H20).

The retention parameter Sis defined by:

$$S = 25.4\left[\frac{1000}{CN} - 10\right]$$

Where CN is the SCS-curve number, which ranges from 0 to 100, depending on the soil permeability, land use and the antecedent soil water conditions. There are numerous other parameters in SWAT which control the various hydrological processes acting a across a basin, namely, the transitions and routing of the flow components across the different compartments of the SWAT-simulated section of the hydrological cycle [21].

III. IMPACT OF LU/LC BY USING SWAT

Hydrological effects of specific land use changes in a catchment of the river Pinios in Thessaly (Ali Efenti catchment, 2976 km^2), Greece, through the application of the SWAT model on a monthly time step. It should be noted that although the model was run for 23-years (1970 to 1993), the first 5 years of simulated output were is regarded in the calibration process, since they are required by the model as a warm-up period. This period was essential for the stabilization of parameters, as the results sometimes vary significantly from the observed values. The authors investigated the effect of land use change by using three land use scenarios which are: expansion of agricultural land, complete deforestation and expansion of urban area in the Trikala sub-basin. All the three scenarios resulted in an increased in streamflow during wet season and decreased during the dry season. Thus, the final calibration period was from April 1975 to December 1993. The result can be quite satisfactory [24].

Past land use changes between 1989 and 2009 and their impacts on the water balance in the Mula and Mutha Rivers catchment upstream of Pune. Land use changes were identified from three Rivers catchment multi-temporal land use classifications for the cropping years 1989/1990, 2000/2001, and 2009/2010. The hydrologic model SWAT (Soil and Water Assessment Tool) was used to assess impacts on runoff and evapotranspiration. Two model runs were performed and compared using the land use classifications of 1989/1990 and 2009/2010. The main land use changes were identified as an increase of urban area from 5.1% to 10.1% and cropland from 9.7% to 13.5% of the catchment area during the 20 year period. Urbanization was mainly observed in the eastern part and conversion to cropland in the mid-northern part of the catchment. At the catchment scale found that the impacts of these land use changes on the water balance cancel each other out. However, at the sub-basin scale urbanization led to an increase of the water yield by up to 7.6 %, and a similar decrease of evapotranspiration, whereas the increase of cropland resulted in an increase of evapotranspiration by up to 5.9 %[29].

Also integrated model has been applied for hydrologic impact on changing land use in Poisar watershed of Mumbai, India. The land use/land cover maps from the satellite imageries for 1972, 1992 and 2009 indicated that the impervious area increased by 116% between 1972 and 2009. The hydrologic impact studies for few rainfall events showed increase in peak discharge between 7 and 30%, decrease in time to peak discharge between 0 and 4% and increase in surface runoff between 14 and 48%, between 1972 and 2009. The hydrologic impact for rainfall with return periods of 25, 50 and 100 years indicated that the peak discharge increased between 6 and 9%, time to peak discharge reduced between 0 and 2% while the surface runoff increased between 11 and 16%. They found that the hydrologic impact of urbanization on this catchment is more visible for low and medium rainfall events than for high and extreme events for the catchment [10].

SWAT model used for the valuation of the total amount of available water, as well as prediction of the impact of changes in the land management practices on the availability of water in Cauvery basin, India. Nine reservoirs in the basin where data was available were also modeled as impoundments structures in this study. When monthly streamflow values were considered, the values of NSE and R^2 was 0.934 and 0.936, respectively, which reveals that the model had captured the system and there was no need to calibrate the model [28].

SWAT model for Calapooia River Basin in Western Oregon to model the effect of land use changes on water yield and quality from 2003 to 2007. By modifying the agricultural management practices and grain seed crops under different land uses from current eight crops to fifteen new crops scenario, there was not much change in total water yield (55.118 cm to 65.786 cm). However, the yield has been changed with the change in climate [20]. Hydrological consequences of Mesquite tree encroachment in the Upper San Pedro watershed (7400 km^2), Mexico by implementation of different changes in land use. The results indicated that complete replacement of grassland with mesquite increased the simulated annual average basin ET from 384.3 to386.1 mm and decreased the annual average basin runoff from 2.66 to 2.35 mm[23].

The effect of different land uses on the water yield of the Kothakunta sub-watershed in India (550 ha)with varying soils, land use and management conditions over long period of time was quantified by SWAT [32],. Zhang [34] generalized the characteristics of the human activities to predict future runoff using climate change scenarios, in the Biliu River basin, China. Results showed that future annual flow will increase by approximately 10% from 2011 to 2030 under normal human activities and future climate change scenarios, as indicated by climate scenarios with a particularly wet year in the next 20 years.

Yacob [33] applied the SWAT model to identify the effect of land use and land cover change on runoff and sediment in TikurWuha watershed (706 km^2) of Ethiopia. The model predicted a strong relation between water yield and land use change during the calibration. Higher value of the surface runoff correlated withorthicluvisols soil type and bare and open shrub land use was observed. Mango [15] explored the impact of LUCC on SWAT outputs, mainly on the discharge of the Nyangores River. They developed three land use scenarios, namely 1) partial deforestation, conversion to agriculture, 2) complete deforestation, conversion to grassland, and 3) complete deforestation, conversion to agriculture. The results of the analysis indicated that conversion of forests to agriculture and grassland in the basin headwaters reduced dry season flows and increased peak flows, leading to greater water scarcity at critical times of the yearand exacerbating erosion on hillslopes.

Moreover, the study presents a method to quantify land use and land cover change and their impact on hydrological regime. This has been achieved through a method that combines the hydrological model (SWAT) to simulate the hydrological processes, GIS and remote sensing techniques to analysis the land use and land cover change.

IV. CONCLUSIONS

This paper emphasizes that SWAT is a very flexible for Land-hydrologic models have proven to be efficient tools to meet the increasing demand for quantitative information on water availability and quality especially in response to changes in land-use, land management or climate.

SWAT model is a potential and powerful model once calibrated and validated effectively for wide range of applications. The development of GIS-based interfaces, which provide a simple means of translating digital land use, topographic, and soil data into model inputs, has greatly facilitated the process of configuring SWAT for a given catchment.

Furthermore, advancement of a new era in SWAT application for LUCC simulation with the highest possible accuracy as a result of the new facilities for SWAT auto-calibration and uncertainty analysis was presented. Simulation of hypothetical, real and future scenarios.

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