Water Quality Modeling Using Soil and Water Assessment Tool: A Case Study of Rawal Watershed

Tayyaba Qayyum and Abdul Shakoor*

Abstract—**The water quality of Rawal watershed has been highly deteriorated because of increased concentration of organic nitrogen and phosphorous coming from non-point sources causing eutrophication. The main objective of this study was to use a watershed scale model SWAT (Soil & Water Assessment Tool) as a modeling tool for predicting the impact of the Land Use change on water quality of Rawal Lake. Specific objectives were to (a)develop pollution source inventory mapping(b) quantify the pollutant load (organic nitrogen and phosphorus) with respect to Land Use change that causes eutrophication and (c) model the alternative Best Management Practices (BMP's) and evaluate their effectiveness. In the pre field phase the collection and preprocessing of data (DEM & Landsat images (30m resolution)) was done. Land Use (2001 & 2010) classification was done using Landsat imagery in ArcGIS. For the pollution source inventory, mapping the study area was surveyed. In the post field phase the model was calibrated (2002-2006) by using the observed and simulated surface runoff data and then validated (2007-2010) .The, model's accuracy was further verified by using R2 and Nash Sutcliffe Efficiency (NSE). SWAT simulations resulted in 392.40 % and 391.72 % increase in the quantity of organic nitrogen and phosphorus with respect to Land Use change (2001 & 2010). By the application of BMP's such as filter strips, the average reduction in the concentration of N could be 75.155% while that of P could be 96.93%, similarly by the application of terracing the average reduction in the concentration of N could be 52.73% while that of P could be 94.18% in the selected sub basins. By the application of contouring the average reduction of 35.64% for N and 92.09% for P could be achieved. This study would provide decision maker a source of information on most feasible and cost effective BMP's.**

Index Terms— **Energy, Wave Power, Mooring, Power take-off.**

I. INTRODUCTION

WATER is significant part of human life. The need for the pure water is growing day by day with increasing percentage of population. The waste generated from non-point sources adversely affects the natural environment of the water body. Tool to accurately analyze the impact of Land Use change on water along the accurate prediction of stream flow and hydrological processes occurring in the area. [1-2]. This study was conducted to model water quality of Rawal watershed using the SWAT. The water bodies of Rawal watershed are subject to pollution by the non-point pollution sources. The Lake is almost converted into the oxidation pond. The increase concentration of nutrients causes the eutrophication with the taste and odour problems.The contaminated inflow causes serious threats to the water quality of Rawal Lake and Kurrang River .So regular monitoring for maintaining the water quality of watershed is of prime importance to meet the water quality standards in order to supply clean drinking water to the inhabitants [3-10].

To make accurate in some cases due to the access to the areas of interest, computer aided technology developed in the field of Geographic Information System (GIS) has make easier this task by using the require data to monitor the present as well as future water quality condition. SWAT model was use for this study. SWAT model was use in this study for the simulations, several SWAT scenarios were simulated in order to have the desire results these were reducing the agriculture land from 77.25% to 46% with inorganic farming, afforestation from 10%to 15%, increase pasture from 4% to 15%, increase of protected wetlands from 0% to 9%, the study indicates that if these scenarios will be implemented practically than the goals of the WFD would be achieve. It buffer strips are the practices that can reduce the water contamination from the point and non-point source pollution. This study reveals that physical based model [11-22].

The SWAT model can be used to identify the Best Management Practices (BMP's) under what if scenarios, thus providing useful information to the water quality managers for making effective plans to control water pollution due to nonpoint source, a data frame for developing the Total Daily Maximum Load (TDML), the awareness regarding the water quality management through modeling approach [23-35].

II. LITERATURE STUDIES

GIS is an effective tool for modelling the water quality resources and nonpoint source pollution (Pelletier. 1985, Hession and Shanholtz. 1988, Srinivasan and Arnold.1994).There are limited number of models that are

The climate data (rainfall, temperature, wind and weather station etc) are than input to the model for the simulation

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purpose (for defined time period) in order to have the desire output linked with the GIS for the simulation of hydrology and determining the water quality on the river basin scale. SWAT model is on one of them that can be used for determining the impact of Land Use change on surface water qualities .Soil &Water Assessment Tool (SWAT) is a physical basin scale continuous time model, operable on a daily time step, Developed by the United States Department of Agriculture , Agriculture Research Services (USDA- ARS). It can be used for the watershed range in size from 0.15km^2 to 491,700km^2 [3]. It is the dynamic numerical model use for the evaluation of landscape potentials with respect to sediment transport, runoff rates, soil erosion and other geological characteristics.

There are total of eight components of model including hydrology, soil temperature, plant growth, pesticide, weather, erosion/sedimentation, nutrients and land management. It simulates watershed processes like hydrology, sedimentation, nutrient transfer, environment and climate change to depict the physical functioning and the interaction among these components through equations and by the use of input data thus helpful in decision making for the management of large basin. The input data includes digital data of topography, Land Use, soil properties, weather and land management data for the simulations by using the hydrological equations.

The Model uses the combination of daily or sub hourly rainfall, Natural Resources Conservation Service Curve Number (CN) (Mockus.1969) and Green and Ampt (Green and Ampt.1911) for estimating the surface runoff from each HRU's as given in (1):

$$Q = (R-0.2S)2 \div (R+0.8S) \quad R>0.2 \qquad (1)$$

$$Q = 0 \qquad R \leq 0.2S$$

where:
Q=Daily surface runoff (mm).
R= Daily rainfall (mm).
S= Retention parameter (varies among watershed).
The parameter S is related with CN by SCS (2)

$$S=25.4(1000 \div CN-10) \qquad (2)$$

The average annual rainfall is 990 mm during summer monsoon. The highest temperature is 52°C and lowest is -4 °C. The methodological framework defined for this research purpose is categorized in the three phases.

This includes problem identification, literature review, and formulation of objectives, data source identification and collection of data "table 1". The verification and analysis of data was done as well as water quality parameters were identified for this study purpose. Preparation of field instrument such as cameras and GPS was also done in this phase. The soil series classification was done using ArcGIS based on the information (porosity, bulk density & electrical conductivity etc) provided by the Soil Survey of Pakistan. The study area was categorized into three soil types' i-e clay loam, rock outcrop and urban soil. The soil vector layer was transformed into raster format for the input to the model (see Fig.1).

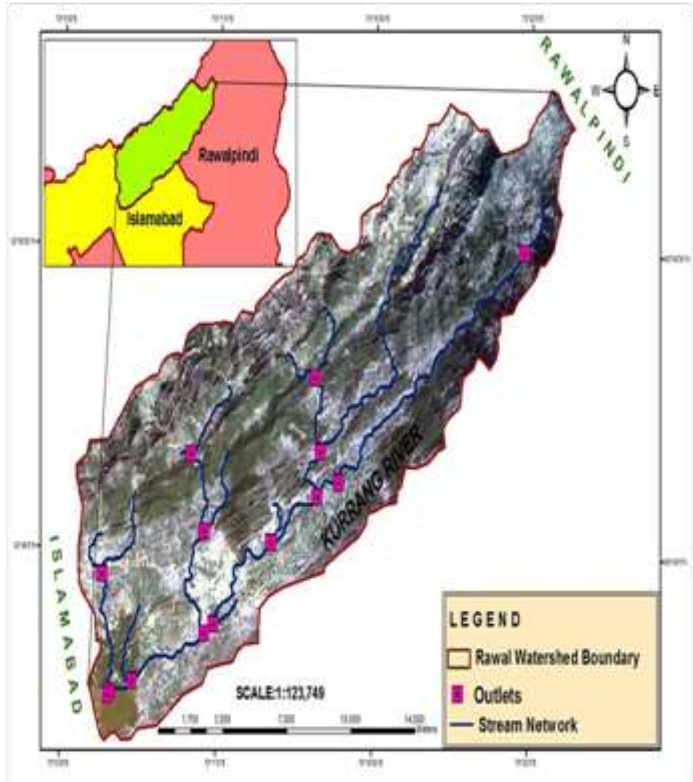

Fig. 1. Study Area Map.

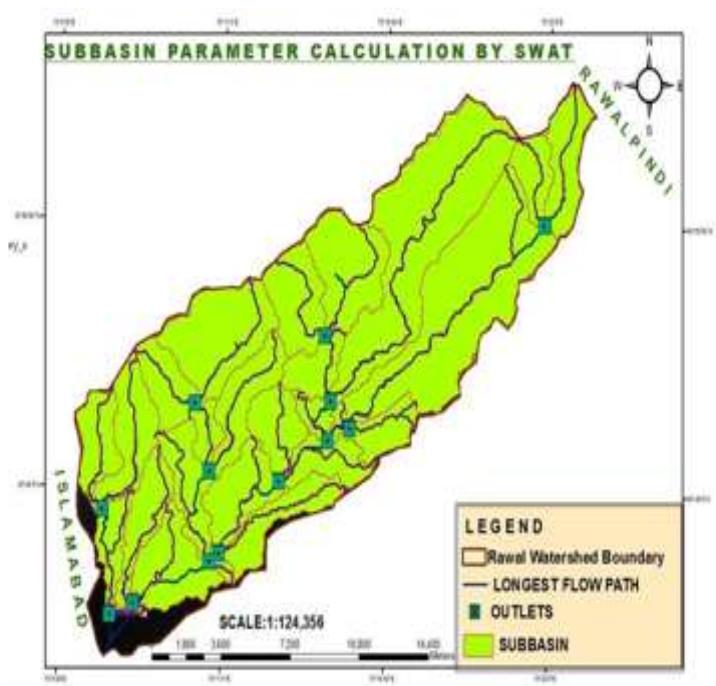

Fig. 2. Watershed delineation by SWAT.

The study area was surveyed to identify the pollution source sites as well as to observe the water quality condition on ground at different outlets that ultimately discharges into the Kurrang River. The eight outlet were visited which are Shahdaran

Picnic Point, Azmat Town, Quaid-e-Azam University, Diplomatic Enclave, Nurpur Shahan, Kurrang River, Chattar Park and Rawal Lake.GPS points were collected at these pollution source sites .

A pollution source inventory map shown in Fig. 2 was depicted based on the field observation using ArcGIS .The next step after watershed delineation is HRU's definition for which the soil data was added to the SWAT database.

III. Results and Analysis

For the successful water quality and any hydrological simulation, it is necessary to calibrate the model. For the estimation of pollutant load (organic nitrogen and phosphorus) with respect to Land Use change and identifying the Best Management Practices (BMP's) the model was simulated using the surface runoff data of the 10 years. Model was calibrated for the time of five years from 2002 to 2006. The first year (2001) data was used as a warm up period. The model was calibrated by comparing the simulated annual discharge with observed annual discharge data, by adjusting the different parameter values until a good fitness between observed and simulated flow was obtained. After several iteration of simulation process by adjusting a sensitive parameter, a good fit result Fig. 5 was obtained. The model was then validated as shown in Fig. 3 for the next four years from 2007 to 2010 without making any further adjustment in the parameter values.

Fig. 3. Pollutions source inventory map.

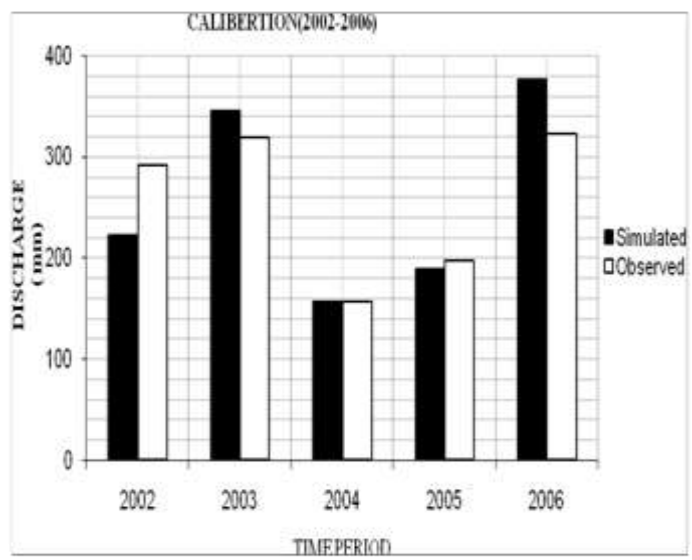

Fig. 5.Graphical representation of calibration.

To evaluate the model performance various statistical approaches were applied such as Coefficient of determination (R2), Nash-Sutcliffe Simulation Efficiency (NSE) Nash and Sutcliffe. 1970, and Root Mean Square Error (RMSE). The output values of these statistical approaches for the calibration and validation lie within the acceptable range, which ascertained the model accuracy. From the Fig. 5, it is clearly observe that a change in the Land Use of Rawal watershed had occur in the time period of ten years i-e 2001 to 2010.A decrease in the area of forest mixed and increase in the area of agriculture land, rang land, settlements and water bodies has been observed. In the year 2001 the area cover by the forest mixed was 63.92% which decrease up to 53.53% in the year 2010, this probably because of deforestation occurring in the watershed with increase in the demand for fuel. The percent area cover by the agriculture land in the year 2001 was 1.01% while in the year 2010 it was 3.88%, the expansion in the agriculture land is directly related with increase in the population with increasing demand for food. It is observed from Fig. 6 that the Land Use changes has the great impact on the quantity of nutrients such as organic nitrogen and phosphorus which enhances the eutrophication. An increase in the concentration of organic nitrogen of 18.544 kg/ha was observed in the year 2010. Similarly, the concentration of organic phosphorus increased up to 2.257 kg/ha in the year 2010.

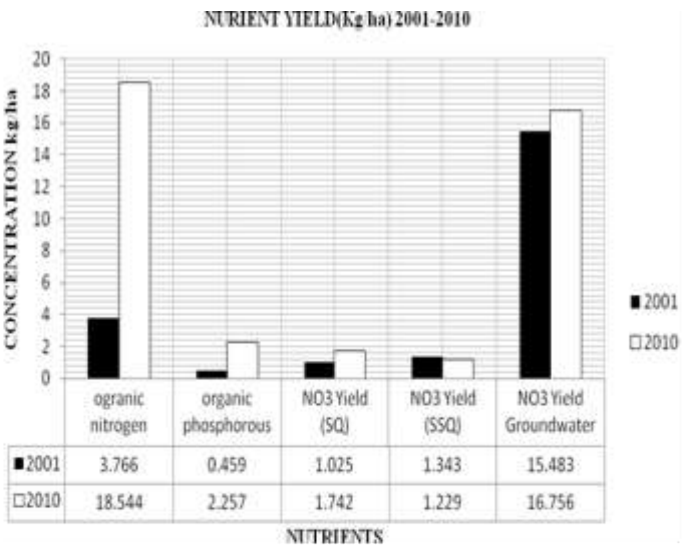

Fig. 6. Graphical representation of pollutant load computed by the model.

In the first scenario a filter strips with width of 2m with plantation of corn was applied by which the concentration of organic N reduces up to 3.734 kg/ha while that of organic P reduces up to 0.462 kg/ha. In the second scenario a filter strips with the plantation of Alfalfa of 2m width was applied by which the organic N load reduces up to 5.209 kg/ha and that of organic P reduces up to 0.641kg/ha. Among the 27 sub basins only 22 Sub basins were selected for the application of terracing, these sub basins were selected based on agriculture practices being present. In the first scenario, a simulation was made by keeping the curve number value (CN) 20 with the slope of 45 by this organic N load reduces up to 9.223 kg/ha and that of organic P reduces up to 1.134 kg/ha. In the second scenario SWAT model was simulated with the same CN value at slope of 35, by this organic N load reduces up to 8.558 kg/ha while organic P reduces up to 1.053kg/ha. Similarly, in the third scenario SWAT model was simulated with the same CN value at slope of 25, by this organic N load reduces up to 7.740 kg/ha while organic P reduces up to 0.953kg/ha.

First SWAT model was simulated by keeping CN value of 60 for the application of contouring by this organic N reduction of up to 16.556 kg/ha while that of organic P reduction of up to 2.029 kg/ha was observed. In the second scenario by keeping the CN value 40 a simulations were made as an output the organic N reduces up to 11.674 kg/ha while that of organic P reduces up to 1.433 kg/ha. In the third scenario a reduction in the organic N was 6.520 kg/ha while that of organic P reduces up to 0.804 kg/ha by running the simulation with the CN value of 20.

IV. Conclusion and Recommendations

The study was aimed at using the hydrological model SWAT for modeling the water quality of Rawal watershed, quantifying the pollutant load with respect to Land Use change and identifying the alternative Best Management Practices (BMP's).the results of this study obtained support the conclusion. Because of results obtained from the calibration and validation of SWAT model, it is concluded that it is necessary to calibrate the model well (for the specified time) for any of these basic parameters including surface runoff, sediment and nutrient before any simulations for obtaining the desire results.

The application of statistical approaches. Quantity of organic nitrogen and phosphorus has been increase up to 392.40 % and 391.72 % respectively in the year 2010, so it was concluded that if the Land Use change pattern continues in the same way in the following years it will pose a serious threat to the water bodies of the Rawal watershed, it was also concluded that SWAT model is efficient in determining the relationship between the Land Use change and pollutant load coming from point and non-point sources for the specified time period(present and future).

Based on simulations results in the selected sub basins for the application of filter strips it was concluded that average annual reduction in the organic nitrogen and phosphorus could be 75.155% and 96.93% respectively. By the application of this management, practice pollutant load coming from different point and nonpoint sources could be control thus protecting the water bodies from being contaminated. Filter strip installation at the banks of water bodies of different category could be apply including grass filter strip, timber strip and crop land depending upon the topography of the area.

Based on simulations results in the selected sub basins for the application of terracing it was concluded that average annual reduction in the organic nitrogen and phosphorus could be 52.73% and 94.18% respectively. By the application of this management practice in the selected sub basins pollutant load coming from the agriculture activities could be control.

Based on simulation results for the application of contouring it as concluded that average annual reduction in the organic nitrogen and phosphorus could be 35.64% and 92.09% respectively. By the application of this management practice, the pollutant load coming from different point and non-point sources could be control.

From the overall results of this study, it is concluded that SWAT model could be use efficiently for water quality modeling, thus providing the user with an effective outputs for the water quality management.

RECOMMENDATIONS

1. The management practice like terracing could be adopted for controlling the pollutant originating from the agriculture activities.

2. The filter strip and contouring are the management practice that could be adopted for preventing the water bodies from being contaminated from the pollution coming from the non-point sources.

3. The methodology could be replicated to address the other water quality problems in the other watershed of the Pothwar Region.

4. To address the problem of water quality, data on the rapid urbanization should be collected on regular basis.

5. Land Use should be monitor on regular basis using high-resolution data.

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