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STUDIES ON THE IMPACT OF WATER CONSERVATION MEASURES ON RUNOFF POTENTIAL OF MANASGAON WATERSHED USING SWAT

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Abstract: *The water conservation strategies are widely used as effective measures for water harvesting or runoff reduction from watershed. The lack of land use planning and the absence of conservation practices in a watershed can contribute to increased runoff which compromise the environmental quality in a watershed, especially the water resources. The objective of this study was to study the impact of soil and water conservation strategies on runoff potential of Manasgaon watershed located in Shegaon tehsil of Buldhana district. The hydrological simulation was carried out by using Soil and Water Assessment Tool (SWAT) model, which was integrated with Arc GIS software. The SWAT-CUP SUFI-2 model was used for calibration and validation of the model. The reasonably high Nash-Sutcliffe coefficient (NSE) values for the calibration and validation periods (0.81 and 0.76 respectively) indicated good performance of the model. The calibrated and validated model was used for simulation of runoff from the Manasgaon watershed for different soil and water conservation measures. The simulated average annual runoff after implementation of water conversion strategies viz., conversion of barren land to fair pastures, contour farming, strip cropping, terracing and farm pond reduced the average annual runoff by 2.71, 7.10, 9.78, 7.37 and 4.61 per cent respectively as compared to without treatment condition. The SWAT model can be effectively used for simulation of different water conservation strategies for Manasgaon watershed.*

Keywords: *SWAT, CUP, SUFI-2, optimization, water conservation, watershed, runoff.*

Introduction

Human activities have a profound impact on the environment. Alteration of the land surface for a variety of uses has changed water pathways and induced changes to natural processes (Starrett and Yunsheng, 2003). The models help in evaluating and selecting the alternative land use and management practices. Implementation of these practices can help to reduce the damaging effects of storm water runoff and the landscape. Developing reliable watershed simulation models and calibrating/validating them for watersheds with measured and simulated data is a challenging issue (Borah and Maitreyee, 2002). The increasing rate of water resources development activities have focused attention on development and application of physically based hydrological models to deal with constantly changing hydrological environment. When the hydrological system is subject to change or when a realistic physical representation of flow in space and time is required to study water quality and soil erosion, the conceptual representation of traditional rainfall and runoff models with lumped approach are not suitable. A number of simulation models have been developed to evaluate water quality parameters affected by agricultural land management at both field and watershed scale.

SWAT, the Soil and Water Assessment tool is a river watershed or watershed scale model developed at the United States Department of Agriculture (USDA) – Agricultural Research Service (ARS), Grassland, Soil and Water Research

Laboratory in Temple, Texas (Arnold *et al*., 1998). t is widely used to predict, over long periods of time, the impact of soil management practices in aquatic environments (surface and underground) in complex watersheds with variations in soil type, land use, application of fertilizers and pesticides, and the conditions of watershed management (Zhang *et al*., 2009).

Knowledge on how the local hydrologic cycle and water resources will be affected by soil-water conservation measures, land-use and climate changes is essential for designing reliable climate adaptation strategies and water policy. The regional impacts of land-use and climate change on hydrology vary from place to place, hence local scale studies should be conducted (Lai and Arniza, 2011; Mango *et al.,* 2011; Wang *et al.,* 2014). Predicting streamflow in a large arid and semi-arid basin is of great importance in understanding the availability of water for spatial planning and water resource management (Suliman *et al*., 2015). It is widely agreed that land use change and climate variability are two active environmental factors profoundly affecting watershed hydrology (Molina-Navarro *et al*., 2014; Wang *et al*., 2014). However, such detailed assessments of local hydrology are still limited in Vidarbha region.

In watershed planning, mathematical models are useful tools which quickly and inexpensively provide information to guide decision-making processes. They also enable the assessment of different scenarios based on land-use changes (Lenhart et al. 2002). Several simulators based on mathematical methods that describe physical processes (natural and anthropogenic) have been developed in order to predict runoff, erosion, and transport of sediments and nutrients in watersheds subject to different management practices (Debele *et al*., 2008).

Considering hydrological behavior of the study watershed and applicability of the existing models, the current study was undertaken with the application of SWAT in integration with GIS and remote sensing to estimate the surface runoff for Manasgaon watershed located in Shegaon tehsil of Buldhana District, Maharashtra. The specific objective of the present study is to calibrate and validate the Arc-SWAT model for runoff estimation in Manasgaon watershed, to study the impact of different water conservation strategies on runoff.

Materials and Methods

Location

The study area selected was Manasgaon watershed located in Shegaon tehsil of Buldhana district. The outlet of the watershed was at Manasgaon and located at latitude 20° 54' 45" N and longitude 76° 41' 27" E. The study area is located between 20°50' N to 20°58' N latitude and 76°42' E to 76°47' E longitude. The location map of Manasgaon watershed is depicted in Fig. 1. The total area of the watershed was 15197.23 ha.

Data Collection and Pre-processing

The daily gauge discharge data and meteorological data for the Manasgaon watershed *viz.,* rainfall, maximum and minimum temperature, wind speed, relative humidity, sunshine hours and evaporation for the period 1995-2014 was received from Water Resources Department, Hydrology Project Circle, Hydrology Project (SW), Nashik. The land use / land cover map, soil map was received from MRSAC, Nagpur (MS). The Digital Elevation Model (30m x 30m) of the study area was downloaded from http://www.gdem.aster.ersdac.or.jp/. The DEM of the study area is shown in fig. 2. The database was prepared as per the format required for SWAT model.

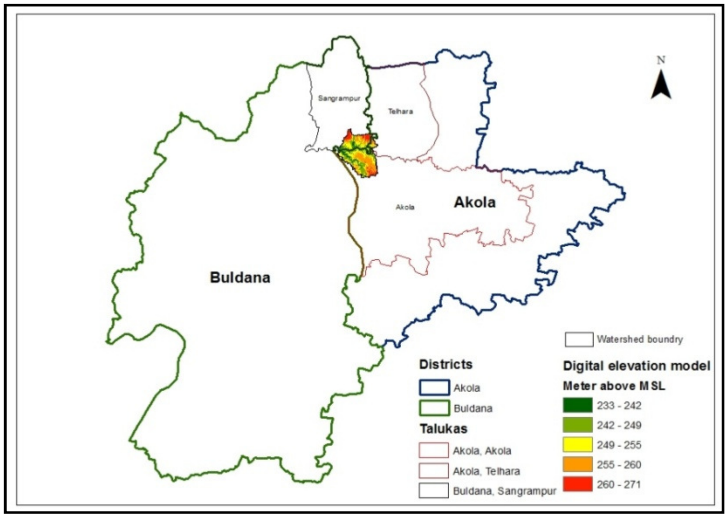

Fig. 1: Location map of the Manasgaon watershed

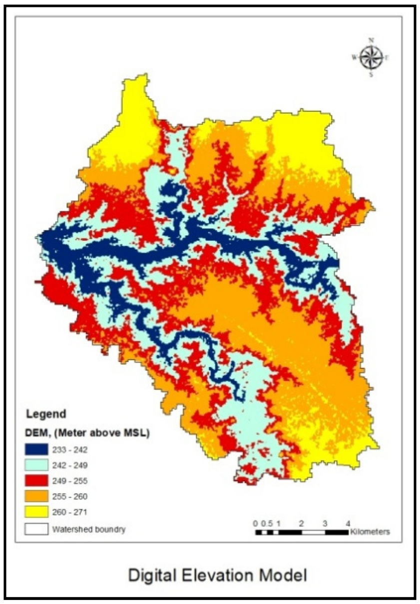

Fig. 2: DEM of the study area

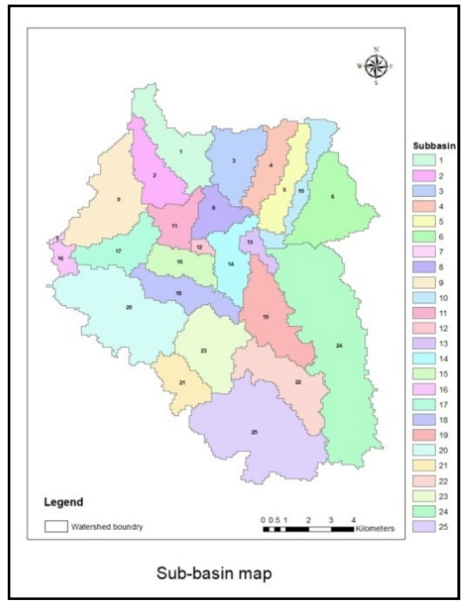

Fig. 3: Sub basins in the study area

The SWAT model for Manasgaon watershed was calibrated and validated using SWAT CUP-SUFI-2 method. Abbaspour *et al.* (2004) and Yang *et al.* (2008) applied the SUFI-2 technique for evaluation of SWAT model. The SUFI-2 technique needs a minimum number of model simulations to attain a high-quality calibration and uncertainty results (Yang *et al.,* 2008).

The calibrated and validated model used for simulation of water conservation strategies by modifying the corresponding parameters in the model. The different water conservation treatments considered based on land use land cover, soil type and slope of the watershed were Conversion of barren land to fair pasture (naturally growing grasses), Contour Farming on agricultural land, strip cropping of agricultural land, terracing and farm pond. The effect of individual treatment was studied by modifying the SCS CN II and USLE_P factor as suggested by Wischmeier and Smith, (1978) and A*rabi* et al. (2004 and 2008). The simulated runoff was compared with the baseline runoff i.e., without treatment and the effectiveness of the water conservation measure was calculated.

Results and Discussion

The model divided the watershed in 25 sub basins and 197 hydrological response units (HRUs). The model was calibrated using observed runoff data of watershed for ten years (1998-2007) and validated for another set of data for the period 2008-2014 (seven years) with three years data (1995 - 1997) for the warm up of the model. The calibration and validation results showed good agreement between simulated and observed data. Model performance was evaluated using Nash-Sutcliffe coefficient. The reasonably high Nash-Sutcliffe coefficient (NSE) values for the calibration and validation periods (0.81 and 0.76 respectively) indicated good performance of the model. The scatter plot diagram between observed and simulated runoff is shown in fig.4 and 5 respectively.

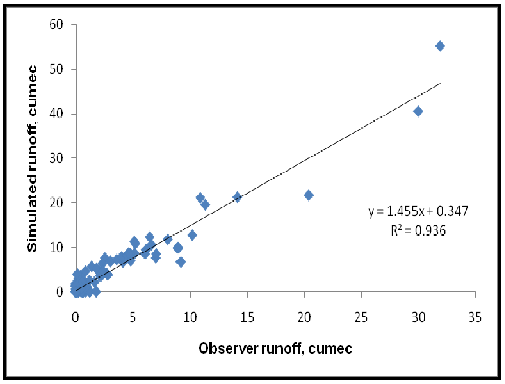

Fig. 4: Scatter plot for the observed and simulated monthly surface runoff during calibration period (1998-2007).

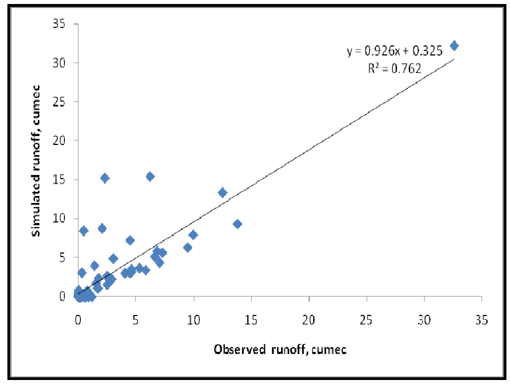

Fig. 5: Scatter plot for the observed and simulated monthly surface runoff during validation period (2008-2014).

The average reduction in runoff for the Manasgaon watershed was observed as 2.71 per cent with only converting barren land to fair pasture with naturally growing grasses (Scenario 1). The average annual reduction in runoff due to adoption of contour farming technique in the watershed was observed as 7.10 per cent (Scenario 2). The average reduction in runoff for the Manasgaon watershed was observed as 9.78 per cent with only strip cropping treatment to agricultural land (Scenario 3). The average annual reduction in runoff for the Manasgaon watershed was observed as 7.37 per cent with only terracing treatment to agricultural land with 2 - 4 per cent and 4 - 8 slope group (Scenario 4). The average reduction in runoff for the Manasgaon watershed was observed as 4.61 per cent with introduction of farm ponds in all the sub basins of Manasgaon watershed.

The average annual runoff from Manasgaon watershed before treatment (Baseline) and after implementation of different treatments is summarized in table 1. It is observed from table that, the baseline average annual runoff from the Manasgaon watershed was 276.10 mm (Scenario-0). The simulated average annual runoff after implementation of Scenario - 1, 2, 3, 4 and 5 reduced to 268.61 mm, 255.68 mm, 249.11 mm, 255.75 mm and 263.37 mm respectively which was 2.71, 7.10, 9.78, 7.37 and 4.61 per cent less as compared to baseline runoff respectively. The strip cropping treatment was found more effective in reducing runoff (9.78 per cent) followed by terracing (7.37 per cent), Contour farming (7.10 per cent), farm pond (4.61 per cent) and conversion of barren land to fair pasture (2.71 per cent).

Table 1: Average annual runoff from Manasgaon watershed due to different scenario and effectiveness of different treatments

Sr. No.	Scenario	Particulars	Average annual runoff, mm	Effectiveness (%)
1	Scenario - 0	Baseline	276.10	--
2	Scenario - 1	Conversion of barren land to fair pasture	268.61	2.71

3	Scenario - 2	Contour Farming	255.68	7.10
4	Scenario - 3	Strip Cropping	249.11	9.78
5	Scenario - 4	Terracing	255.75	7.37
6	Scenario - 5	Farm pond	263.37	4.61

Conclusion

The SWAT model can be effectively used for simulation of different water conservation strategies for Manasgaon watershed. The SUFI-2 technique of SWAT CUP is very useful tool in sensitivity analysis of the parameters, calibration and validation of the model. The different water conservation strategies can be optimized using SWAT model. From the simulated average annual runoff from Manasgaon watershed it can be concluded that, the strip cropping treatment was found more effective in reducing runoff followed by terracing, contour farming , farm pond and conversion of barren land to fair pasture.

Acknowledgement

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References:

Abbaspour K, Johnson C, and van Genuchten MT (2004) Estimating uncertain flow and transport parameters using a sequential uncertainty fitting procedure. Vadose Zone J 3:1340–1352.

Arnold JG, Srinivasan R, Muttiah RS, and Williams J (1998) Large area hydrologic modeling and assessment Part I : Model development. Journal of American Water Resources Association, 34 (1) :73 - 89

Borah DK, and Maitreyee B (2002) Modeling the Big Ditch Watershed in Illinois and Studying Scaling Effects on Water and Sediment Discharges, the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan.

Debele B, Srinivasan R, and Parlange JY (2008) Coupling upland watershed and downstream water body hydrodynamic and water quality models (SWAT and CE-QUAL-W2) for better water resources management in complex river basins. Environ Model Assess Springer Science + Business Media B.V. 2006 DOI 10.1007/s10666-006-9075-1 : 1-19

Lai SH, and Arniza F (2011) Application of SWAT hydrological model to Upper Bernam River Basin (UBRB), Malaysia. The IUP Journal of Enviromental Sciences, 5 : 7-18.

Lenhart T, Eckhardt K, Fohrer N, and Fred HG (2002) Comparison of two different approaches of sensitivity analysis. Phys Chem Earth 27(9–10) : 645 – 654

Mango LM et al. (2011) Land use and climate change impacts on the hydrology of the upper Mara River Basin, Kenya: results of a modeling study to support better resource management. Hydrology and Earth System Sciences, 15 : 2245- 2258.

Molina-Navarro E, Trolle D, Martínez-Pérez S, Sastre-Merlín A, and Jeppesen E (2014) Hydrological and water quality impact assessment of a Mediterranean limno-reservoir under climate change and land use management scenarios. J Hydrol., 509 : 354–66.

Starrett SK, and Yunsheng S (2003) Nutrient and Sediment Runoff from a Prairie Golf Course. Green Section Record. United States Golf Association 31(2) 16-18.

Suliman AHA, Jajarmizadeh M, Harun S, and Darus IZM (2015) Comparison of semi-distributed, GIS-based hydrological models for the prediction of streamflow in a large catchment. Water Resour Manage 29 : 3095 – 3110.

Wang R, Kalin L, Kuang W, and Tian H (2014) Individual and combined effects of land use/cover and climate change on Wolf Bay watershed streamflow in southern Alabama. Hydrol Process., 28(22):5530– 46. doi: 10.1002/hyp.10057

Yang J, Reichert P, Abbaspour KC, Xia J, and Yang H (2008) Comparing uncertainty analysis techniques for a SWAT application to the Chaohe basin in China. J. of Hydrol.358: 1–23

Zhang X, Srinivasan R, and Bosch D (2009) Calibration and uncertainty analysis of the SWAT model using Genetic Algorithms and Bayesian Model Averaging. J Hydrol 374(3–4):307–317. doi:10.1016/ j.jhydrol.2009.06.023