EVALUATION OF VARIOUS CONSERVATION PRACTICES ON RUNOFF AND SEDIMENT YIELD USING SWAT FOR

T. NARASIPUR WATERSHED, SOUTHERN KARNATAKA, INDIA

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Abstract:
The soil and water management deals with the implementation of various suitable conservation practices especially on agricultural land with an emphasis on to retain soil moisture and reduce runoff and consequent sediment generated from the respective watershed area. The present study demonstrates how the practice of various conservation methods such as contour farming, terracing, strip cropping and grass water way help to reduce the sediment erosion and runoff from the watersheds. The study helps the planners and managers of various watersheds in choosing the appropriate conservation practices for implementation.

Index Terms: SWAT, Sediment yield, Runoff, Conservation Practices, Semi-arid.

I. INTRODUCTION

Agricultural best management practices, also known as conservation practices, are widely used as effective methods for reducing erosion from agricultural areas of any watershed (Arabi, M. et al., 2006). Degradation of soil and water quality due to erosion is a worldwide problem in agricultural areas, and severe erosion can lead to land become unfit for cultivation. A rise in the sediment concentration in a river can result in aquatic pollution and decreases storage capacity of reservoir (Dipesh, N. and Parajuli, P. B., 2022). Conservation practices are a widely accepted method for controlling agricultural erosion and pollution within a watershed. On the other hand, the conservation practices are expensive and time consuming to receive benefits from conservation practices implementation. It is recommended to undertake conservation practices on Critical Sub Basin Areas (CSAs), which contribute the most to water quality impairment. The conservation practices implementation on priority basis over the CSAs, help to reduce pollution greatly (Uniyal, B. et al., 2020). Michael, S. et al., (2013) have reported their analysis of various conservation practices that is terraces, small retention basin and multi-diversion crop rotation techniques to inspect the contribution of Conservation practices for sustainable management of water resources and Protection of top fertile soil in the Brazilian Federal District with the help of SWAT Model. In this study they were found that structural Conservation practices namely, parallel terrace and small sediment barraging did reduce the sedimentation up to 40% while crop rotation and irrigated by dry season crop have shown to be unfavorable to the water accessibility by considerably decreasing the stream flow during low flow period.The spatially distributed effect of bench terraces on stream flow and sediment load, with a focus on the addition soil conservation practice factor (PUSLE) interconnected with slope length and steepness have been studied by Khalifa, W. B, et. al., (2017). The model setup was capable of simulations. The catchment runoff regime achieved NSEs of 0.89 and 0.60 on a monthly basis for calibration and validation, respectively. Furthermore, the scenarios that resulted in sound sedimentation results over an eleven-year period (1996–2006) recommended the use of the SWAT model for estimation of the spatial sedimentation outline intended for both treated and untreated conditions. The calibration of the model with a hypothetical zero treatment simulation, for example, removing bench terraces, revealed that conservation structures reduced stream flow by 19% and erosion by up to 22%. The effect of best management practices on existing land use in Jatigede watershed with terrace, vertical mulching, silt pit, agro-forestry and filter strip can be decreased the erosion up to 30% or into 40.8 tons/ha/year and stream flow reduced up to 75.8mm from 99.7mm.

Ridwansyah, I. et al., (2018) have demonstrated the use of SWAT Model on several soil conservation scenarios to simulate and analyses sediment production. They found terracing and implementing soil conservation techniques will dramatically lower sediment production at the watershed's outflows. Furthermore, the SWAT model's simulation of optimal management techniques gives us an idea of the most effective strategies for minimizing sediment output in the watershed.

Swamy, R.K, and Shivapur, A. V., (2021) have found that increasing the agroforestry area in the catchment could reduce flooding. The increase in agroforestry by 20%, 40%, and 60% over the present agricultural area reduces runoff by 1.1%, 2.1%, and 3.2%, respectively

The present work attempted by the authors, demonstrates identifying critical sub watersheds of T. Narasipur watershed based on the stream flow generation and sediment yield from the respective sub watershed using SWAT model. It also shows how effective the various conservation practices in terms of decreasing sediment erosion from their land surfaces. Also how does the implementation of various combinations of conservation practices help to reduce surface runoff and sediment erosion/load from the identified critical sub-basins.

II. WATERSHED CONSIDERED

The T. Narasipur watershed, which is part of the Kabini River, is one of the major tributaries of the Cauvery in southern Karnataka, India. The Kabini River flows eastward through Wayanad district, entering Mysore district of Karnataka, to join the Cauvery in Mysore district. There are three reservoirs in the study area namely Kabini, Nugu and Taraka. The T. Narasipur watershed (Figure.1) is located in Karnataka State, India with latitude and longitude of 12˚ 21' 50.87 88'' N to 76˚ 54' 57.95 64'' E and 11˚ 39' 35.41 68'' S to 76˚ 2' 17.62 08'' W respectively. The catchment area of T. Narasipur watershed is 4701 sq. km. and its elevation ranges from 623m to 1454m. The total number of sub basins in the watershed is 85, with the smallest sub basins covering an area of 31.47 hectares and the largest covering an area of 14014.53 hectares. The average annual rainfall of watershed is 720mm and the average annual temperature lies between 18˚C to 44˚ C.

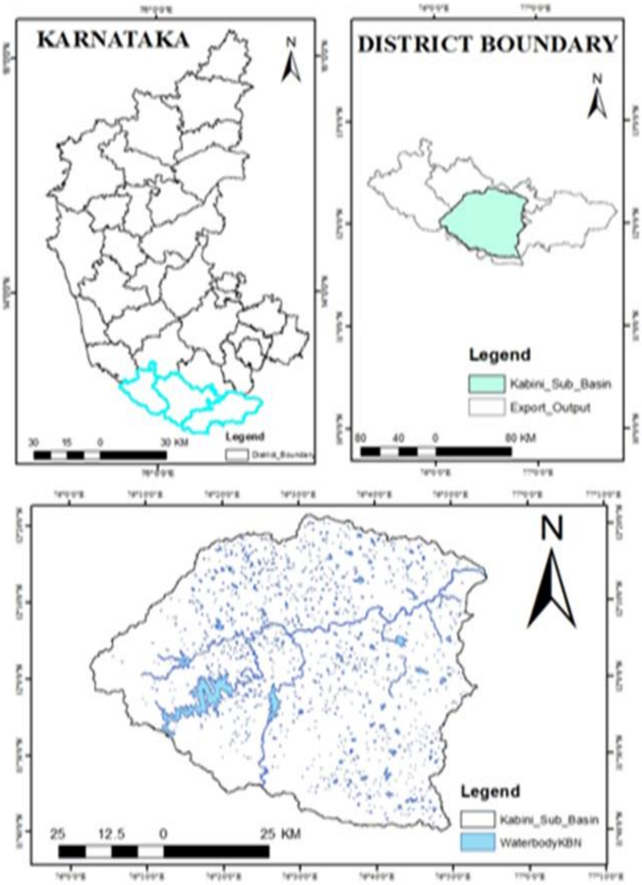

Figure 1: Study Area

III. METHODOLOGY

The following paragraph discusses the various processes involved in determining the impact of various conservation practices and their combination on different sub watersheds of T. Narasipura watershed. The Figure 2 give the steps followed in assessing the effect of conservation practices on reducing the runoff and sediment yield.

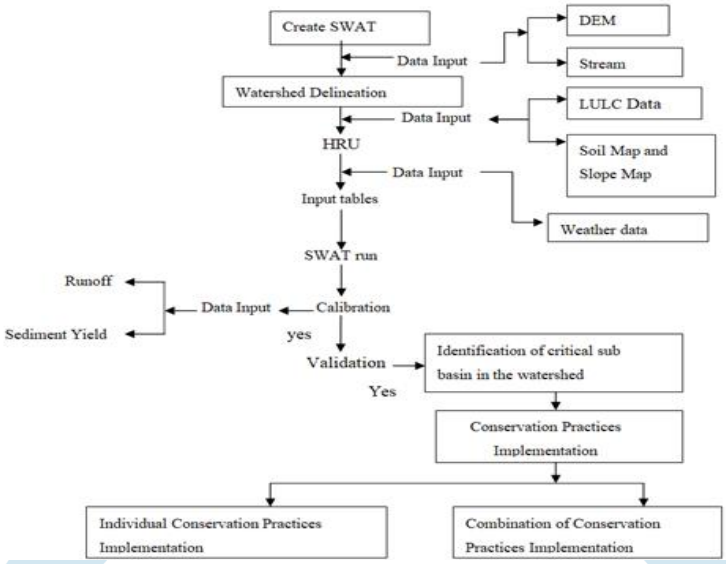

Figure 2: Impact of various conservation practices on watershed by SWAT model.

IV. SWAT MODEL SIMULATION

The present study uses the SWAT 2012 interfaced with Arc GIS 10.3 software. An interfaced Arc-SWAT is used for preparation of required input files to run the SWAT model. The study area was divided into 85 sub basins based on the input DEM and a drainage area of 3314.34 hectares. The land use/land cover map, soil map and slope map were then superimposed. HRUs were defined based on the overlaying of basic modelling units. In each sub-basin, an overlay of land use, soil, and slope with respective SWAT threshold percentages of 10% for land use and land cover, 10% for soil, and 10% for slope resulted in 426 Hydrologic Response Units (HRUs). By combining similar land, soil, and slope areas in each sub-basin, an HRU in SWAT captures watershed variety. To simulate the hydrological response of the study area, Arc-SWAT (SWAT Model: SWAT2012.Rel64) compatible with Arc-GIS 10.3 version is used. The Hargreaves method is used to estimate potential evapotranspiration, and the SCS curve number method is used to estimate runoff. To estimate erosion rates, a modified universal soil loss equation is utilized. To write management files, the default potential heat unit is used. The weather data for SWAT model is downloaded from SWAT web site, and then data input to the SWAT model is done. After preparing all data files and completing all model inputs, the model is run for monthly time series from 1985 to 2005, with the warm up period of two years.

V. APPLICATION OF VARIOUS CONSERVATION PRACTICES SCENARIOS

The critical sub basins should be identified (Refer Figure 12) because implementation of conservation practices at the watershed scale requires a lot of time and money. To do this, the average yearly sediment production from each sub basin was examined. In the present work various conservation works were considered to evaluate their impact individually and in combination on the watershed runoff yield and sediment erosion. The conservation works such as contour farming, Terracing, Vegetated filter strips (VFS), and grassed waterways (GWW) were used on the agricultural areas of watershed. The effectiveness of these combinations was also evaluated and compared with the individual implementation of conservation practices. The SWAT model's key parameters were altered to replicate a variety of scenarios, and the sediment declines resulting from each simulation were studied. Sediment reduction is calculated using the following equation:

$$\text{Sediment yield (\%)} = \frac{A-B}{A} * 100$$

Where, *A*= Sediment yield for base line scenario, *B*=Sediment yield on implementation of conservation practices.

A. Conservation practices scenario considered individually:

The implementation of different kinds of conservation practices independently on critical sub watersheds (Refer Figure 12), determined based on the sediment yield per unit area of individual sub watersheds, is discussed in the subsequent paragraphs.

i). Contour farming

In contour farming, slopes are tilled following regular height lines to save rain water and reduce soil loss from surface erosion. Create a surface flow inhibitor through contouring that improves water absorption and reduces silt transfer. The implementation of this practice by change the CN (mgt. file) and USLE_P (mgt. file) values in the model parameters. The Table 1 shows USLE_P factor used for implementation of contour farming and filter strip.

ii). Terracing

Terrace farming is a typical agricultural method used in mountainous areas. On the sides of hills and mountains, terraces are horizontal man-made areas built for the growing of crops. The CN, USLE P, and the slope length (SLSUBBSN in SWAT hru. file) factor will vary when this method is applied to the SWAT model (refer Table 2).

Table 2: CN, P factor and slope length (SLSUBBNS) values used for implementation of conservation practices after

calibration. (Reference: Mwangi, H. M., et al., 2013).

Slope	CN	P_ factor	Slope Length (m)
0-2.8%	59	0.5	70
2.8-7.0%	59	0.5	70
7.0-15.78%	64	0.6	55
15.78-44.53%	64	0.7	35
>44.53%	71	0.8	25

iii). Vertical strip crops

In order to filter sediments from runoff water, vegetated spaces have been built between croplands, pasture fields, forests, and water bodies. Delaying the rate at which runoff water leaves a field allows sediments to settle and lowers the amount of nutrients that are taken up by plants and absorbed into deposited sediments. By changing the width of the filter strip edge in the management option (FILTERW) file while running SWAT to simulate the impact of VFS width on the reduction of sediment production is done. In this study, the effects of filter strip widths (refer Table 1) of 5, 10, 20, 30, 40, 50, and 60 m on runoff yield is determined. The GIS derived length and width, with depth and slope is taken as defaults in the process.

Table 1: USLE_P factor used for implementation of contour farming and filter strip values after calibration. (Reference: Mwangi, H. M., et al., 2013).

Slope (%)	Contour farming/ USLE_P	Filter strip/ USLE_P
0-2.8%	0.60	0.30
2.8-7.0%	0.50	0.25
7.0-15.78%	0.60	0.30
15.78-44.53%	0.70	0.35
>44.53%	0.80	0.40

iv). Grass waterway "GWW"

By creating appropriately vegetated natural or manmade channels to convey concentrated flow at safe velocities, surface erosion is reduced. Vegetation also aids in nutrient reduction through soil sorption, plant uptake, and absorption into sediment entrapments. By altering the planned management operation (. ops) file refer Table 3), SWAT is utilized to mimic the GWW.

Table 3: Parameters modified in SWAT model (rte. file) for implementation of the GWW after calibration (Reference: Nepal, Dipesh, and Prem B. Parajuli, 2022).

Parameter	Parameter Adjusted value
CH_COV .rte	0.1
CH_ERODMO. rte	0.3
CH_N. rte	0.2
CH_K. rte	280

v). Conservation practices scenario considered together

While implementing various conservation practices together on different agricultural areas of T. Narasipura watershed critical sub basins the SWAT models parameters are adjusted (refer Table 4). The impact of implementation of all the various conservation practices considered in the present study is evaluated by comparing the results of runoff and sediment yield for the existing watershed (Without considering any of these conservation practices) in SWAT environment.

Table 4: Modified values of parameters in the SWAT model on implementation of various conservation practices together on critical sub basins of T. Narasipura watershed. (Reference: Mwangi, H. M., et al., 2013).

Sl. No.	Conservation practice type	Parameters	Parameter Adjustment
1	Contour farming	CN, mgt.file	40
		USLE_P, mgt.file	0.6
2	Terracing	CN, mgt.file	40
		USLE_P, mgt.file	0.6
		SLSUBBSN, hru. file	70m,60m, and 50m
3	Vertical Filter Strip	FILTERW, mgt.file	5m,10m, 20m, 30m, 40m, 50m, and 60m.
4	Grass Waterway	CH_COV_1, rte. File	0.19
		CH_ERODMO, rte.file	0.17
		CH_N_2, rte. File	0.15

V. RESULT AND DISCUSSION

The impact of implementing various conservation practices individually and together on the runoff yield and sediment yield is discussed in the following paragraph highlighting the importance of such practice in reducing the harm on the land and management of natural resources.

A: Impact of application of individual conservation practices on critical sub basins of T. Narasipur watershed

Of the many conservation practices practiced on agricultural area across various regions, contour farming, terracing, filter strips, and grass waterways have been tried in the present work towards reducing runoff and sediment on watersheds. Only the critical sub basins, that are identified based sediment yield per unit area, were subject to these activities.

i). Contour farming on critical sub basins

The sediment erosion into the stream and reservoir area reduces with the increases number of conservation practices on the watershed is the general trend (Mwangi, H. M., et al., 2013). In the present work contour farming is implemented in SWAT model over all the 26 critical sub basins of the watershed. It has been observed to reduce the sediment yield by 6.99%.The water balance evaluation on contour farming implementation (Table.5) shows reduction of surface runoff by 13.60%, while base flow is increased by 25%. The change in water yield is insignificant (2.74%). The sub basin 8, 13, 17, 19, 22, and 24 shows a larger greater reduction (Figure 2) in surface runoff compared to other sub basins. Whereas the sediment reduction in sub watershed 37, 37, 43 and 65 shows is maximum in these sub watershed when compared to other sub watersheds. The percentage reduction in these sub watersheds varies from 16 to 18 percentages, which is substantial.

Table 5: Water balance on implementation of contour farming.

Basin/s	Surface runoff (mm)	Base flow (mm)	Lateral flow (mm)	Water yield (mm)	Percolation into shallow aquifer (mm)	Recharge into shallow aquifer (mm)
On existing	500.74	0.27	5.51	5564.25	221.59	11.08
On implementation of contour farming on existing	432.69	0.36	10.32	5415.44	280.34	14.0
Percentage change	-13.60	+25	+46.60	-2.74	+20.95	+20.97

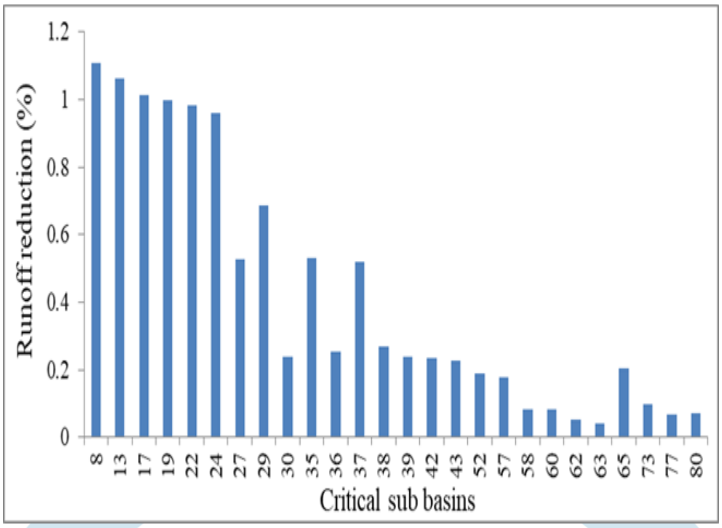

Figure 2: Percentage reduction in runoff

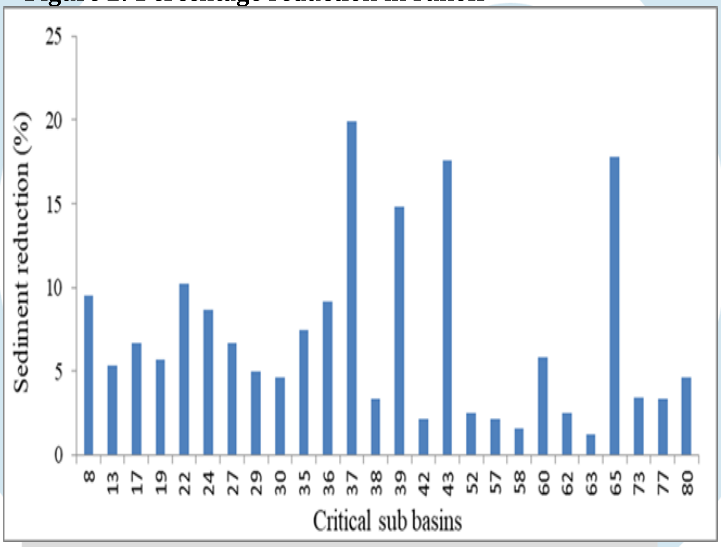

Figure 5: Sediment yield from critical sub basins

ii). Terracing on critical sub basins On introduction of terraces on critical sub watersheds in SAT environment, the water balance study reveals that there is a reduction in surface runoff by 12.27 percent, increase in base flow by 20.58 percent (refer Table 6). The change in lateral flow is found to be significant i.e. 6.87 percent, whereas water yield does not vary significantly. The terrace creation improves the percolation (38.84 %) and recharges rates (14.9). Terracing has reduced flow by 1.71 percent from sub basin 8 and the sediment yield by 19.64 percent from sub basin 37 when terracing in introduced over the critical sub basins in SWAT environment. The sub basins 8, 13, 17, 19 and 22 have shown the reduction of surface runoff more than 1% on implementation of terracing on these sub basins. Similar results were reported by Mwangi, Hosea M., et al. (2016) in which base flow improves by 10.2 percent while surface runoff decreases by 21.8 percent.

Table 6: Water balance on implementation of terracing practice

Basins	**Surface runoff (mm)**	**Base flow factor**	**Lateral flow (mm)**	**Water Yield (mm)**	**Percolation into shallow aquifer (mm)**	**Recharge into deep aquifer (mm)**
Existing Basin	500.74	0.27	5.51	104.54	221.59	11.08
implementation of terracing	5.99	0.34	12.38	107.59	260.43	13.02
Percentage change	2.27	+20.58	+6.87	-3.05	+38.84	+14.9

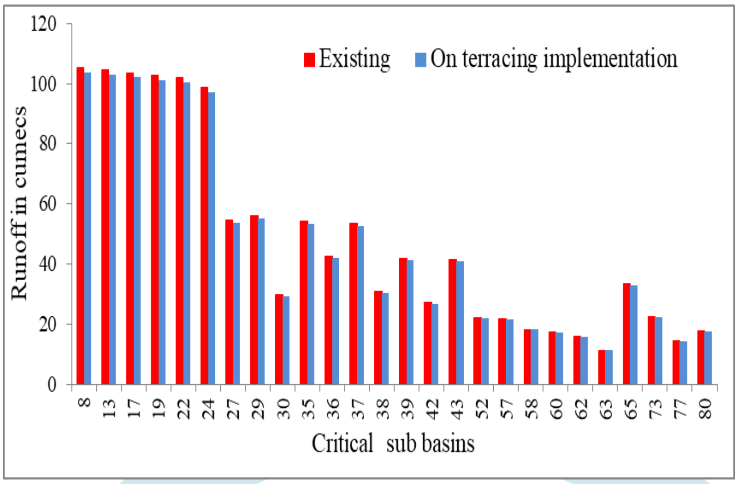

Figure 4: Runoff from critical sub basins

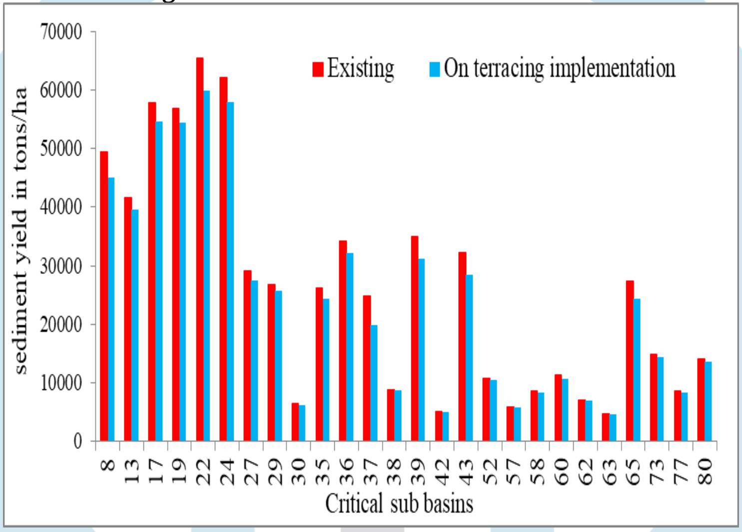

Figure 5: Sediment yield from critical sub basins

iii). Filter strip on critical sub basins

The influence of width of filter strip on the runoff and sediment yield from watershed is studied considering filter strip implementation by incremental increase of 10 m each time. The Figures 6 and 7 shows a decrease in runoff and sediment yield respectively as the width of the filter strip increases from 5, 10, 20, 30, 40, 50, and 60 meters. The reduction in runoff rate decreases consistently with the increase in filter width, however for 60 m width of filter strip there is a significant drop in runoff volume compared to 50m filter strip. On the other hand, the sediment yield decreases as the width of the filter strip increases (Figure.7) consistently up to 40 m filter strip. Though there is a sudden reduction in sediment yield when filter strip of 50 m is implemented compared to 40m width of filter strips. At the same time there is no much change in sediment yield from 50 m to 60 m filter strip. The study revealed that the implementation of 60 m width filter strips on watershed can reduce the sediment yield by 20.68% and runoff by 0.77% in sub basin 43.

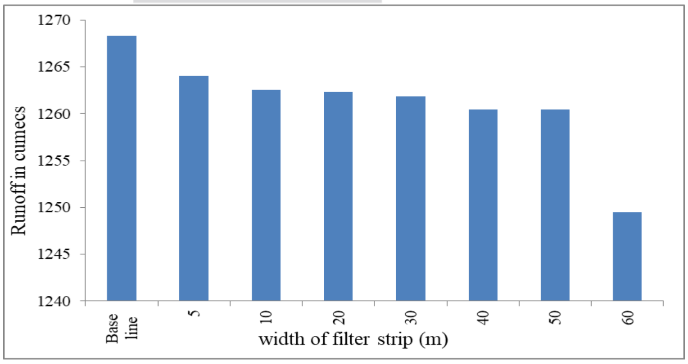

Figure 6: Runoff from critical sub basins.

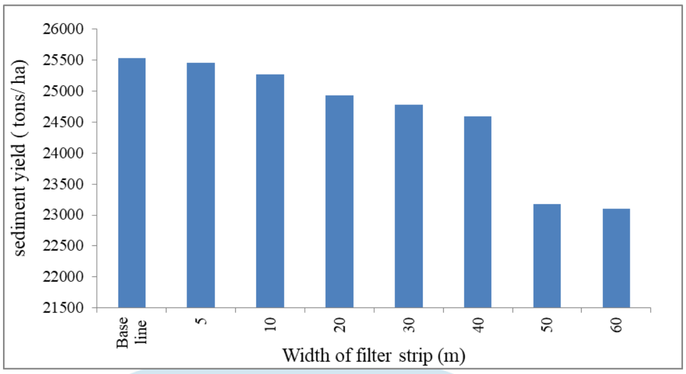

Figure 7: Sediment yield from critical sub basins.

iv). Grassed waterway on critical sub basins

The implementation of grassed waterway on all the identified critical watersheds in reducing the runoff and sediment yield is studied. The results show that runoff (Figure 8) from the sub basins 8, 13, 17, 19, 22 have reduced when grassed waterways are introduced on the existing watershed in GIS environment while running swat. The sub basin 24 has little influence due to grassed waterway intervention on runoff generation from watershed. The grassed waterways on existing critical sub watershed shows lesser sediment yield on sub basins 8, 13, 17, 19, 22. 24 and 80 significantly up to 35 percent. Whereas sub basins 35, 36, 37, 39,43,65 experience a moderate reduction in sediment yield. The result model simulation shows 42.39 percentage reduction in sediment yield (Figure 9) from sub basin 80, however no change in runoff is observed on the sub watershed 80. Similar results have been reported by Mwangi, H.M. et al 2013 for Sasumua sub watershed in reducing runoff and sediment yield by 23.45% and 40.72% respectively on implementation of grassed waterways.

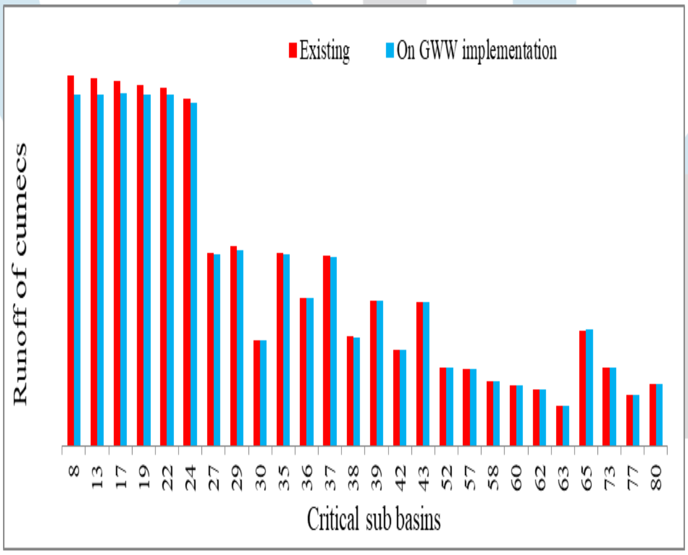

Figure 8: Runoff from critical sub basins.

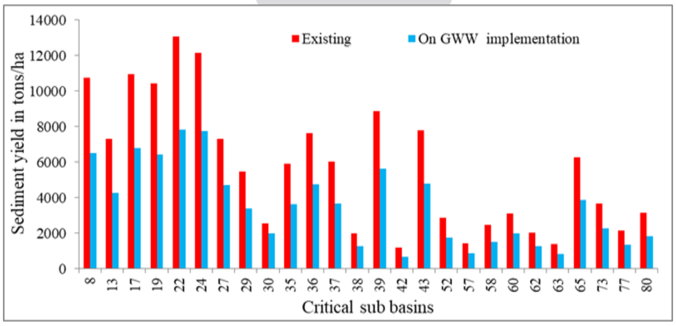

Figure 9: Sediment yield from critical sub basins.

v). Conservation practices implemented together on critical sub basins

In this section, impact of implementation of all the four conservation practices on all the 26 critical sub watersheds has been investigated. For identified critical sub basins, the four conservation strategies previously described have been taken into consideration.

The study on the water balance with SAT model reveal that there is a reduction in surface runoff by 13.87 percent, increase in base flow by 24.138 percent (refer Table 7). The change in lateral flow is found to be significant from 5.51 to 12.41 on implementation of conservation practices i.e. 55.6 percent, whereas water yield does not vary significantly. The combined effect of all the conservation practices improves the percolation (20.9 %) and recharges rates (26.44 %). The implementation of all the four conservation practices results in a reduction of flow on all the sub watersheds marginally (Figure 10). However, the reduction in sediment yield is predominant in most of the sub watershed. However, it is found that the sub watersheds 30, 38, 42, 58 and 77 shows significantly low sediment yield on implementation of all the four conservation practices (Figure 11 and 12). The result also shows that percentage reduction in sediment yield from sub watershed 80 as 34.42 and from sub watershed 77 as 86.88. All the other sub watershed shows a decrease in sediment yield more than 30 percent when all the four conservation practices are implemented on all the 26 critical sub watersheds determined.

Table 7: Water balance for simulation of conservation practices together

Basin/s	Surface runoff (mm)	Base flow factor	Lateral flow (mm)	Water yield (mm)	Percolation on into shallow aquifer (mm)	Recharge into deep aquifer (mm)
Existing Basin	500.74	0.27	5.51	5416.31	221.59	11.08
On implementation on of conservation practices	430.77	0.36	8.57	5411.48	280.16	14.01
Percentage change	-13.82	+24.13	+55.6	-0.089	+20.9	+26.44

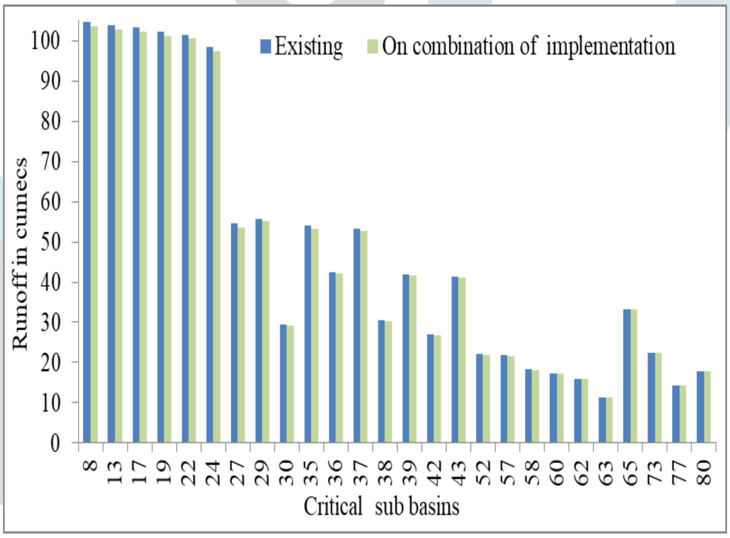

Figure 10: Percentage reduction of runoff in critical sub basins.

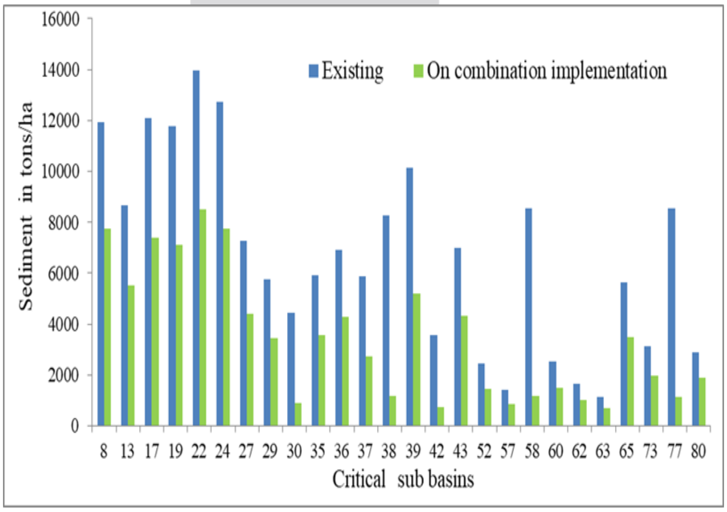

Figure 11: Percentage reduction of sediment yield in critical sub basins.

The present work demonstrates how effectively the sediment yield can be reducing by implementing various conservation practices on the watershed. It also helps to enhance the land productivity by improving the soil properties in terms of its capabilities.

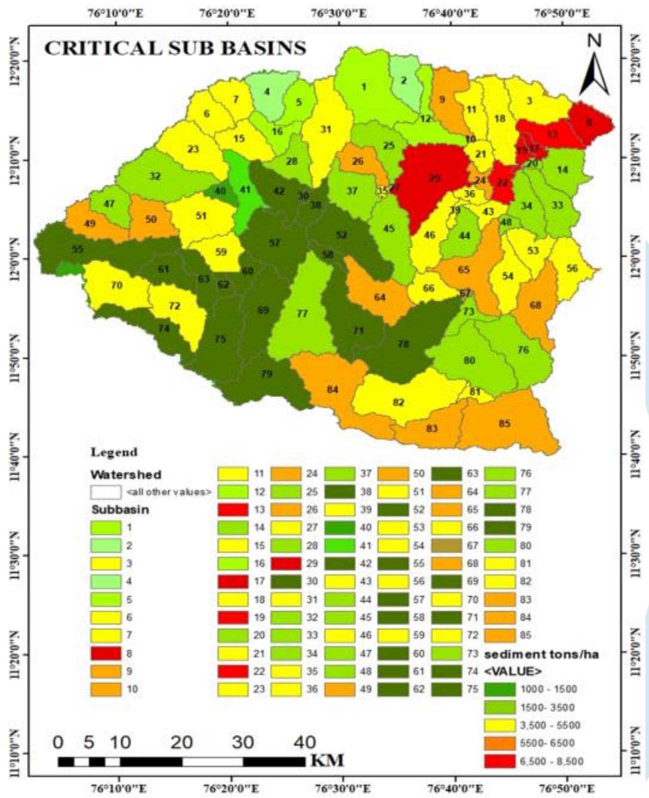

Figure 12: Sediment yield (tons/ha) from sub basins on implementation of various Conservation Practices.

CONCLUSIONS

The SWAT model is used to analyses how conservation measures affect sediment yield and runoff from T. Narasipur watershed. The SWAT model was used to replicate contour farming, terracing, vegetated filter strips, and grassy waterways separately and together.

The increase in vegetative strip on sub watershed is found to reduce runoff and the sediment yield from watershed. The sediment yield reduces significantly with the increase of width initially such as 5, 10, 20 and 30 meter. It is found that the implementation of filter strips reduces the sediment yield by 20.68% in sub watershed 43 and decreases runoff by 0.77%.

The sediment yield from the T. Narasipur watershed is found to be reduced by 39.48% from sub watershed 8 as a result of the Grass waterway implementation scenario, and the average reduction in sediment yield from the entire T. Narasipur watershed is 37.88%. The runoff does not affect much with the grassed waterway simulation significantly.

It is determined on simulation of contour farming reduced runoff by 1.71% and sediment yield by approximately by 19.8% from (sub watershed 37. In all the sub basins, base flow is increased by implementation of terracing and contour farming.

Terrace practices is found to be the most effective conservation practices in enhancing eco system services namely: reducing sediment yield in streams and increasing water infiltration. Many farmers may not be willing to practice terrace kind of conservation practice as they require lot of money and labour to implement. The sediment yield reduction potential of different Conservation practices scenarios is variable, with the highest reduction in the case when all four Conservation practices are considered i.e. 86.88% for sediment reduction and 1.11% for runoff.

The results of the study reveals that filter strips, contour farming, and grassed waterways are effective in improving the conditions of the watershed. Bench terraces are the alternative to filter strips. This work demonstrates how the implementation of various conservation practices can reduce the sediment yield.

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