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Impact Assessment of BMP Scenarios on Sediment Yield in the Mohgaon Watershed

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***Abstract*: The objectives of this study were to evaluate the performance and applicability of Soil and Water Assessment Tool (SWAT) model in predicting monthly sediment yield and to suggest the Best Management Practices to control sediment yield. Eleven years monthly meteorological, flow and sediment data were used for model calibration and validation. The calibrated model is then applied in the Mohgaon Watershed to simulate BMPs including filter strip and stream bank stabilization. The results will help in deciding suitable conservation practices to be implemented over the watershed to reduce sedimentation.**

Key Words: SWAT; Sediment Yield; Filter strip; Stream bank stabilization

INTRODUCTION

Sediment yield refers to the amount of sediment exported by a basin over a period of time, which is also the amount that will enter a reservoir located at the downstream of the basin (Morris and Fan, 1998).

All reservoirs formed by dams on natural water courses are subject to some degree of sediment inflow and deposition. The deposition of sediment which takes place progressively in time reduces the active capacity of the reservoir which in turn affects the regulating capability of the reservoir to provide the outflows through the passage of time. Accumulation of sediment at or near the dam may interfere with the future functioning of water or wind. Sedimentation occurs when sediment falls out of suspension and is concurrently deposited onto a surface.

Slowing runoff velocities or impounding sediment-laden water for appropriate lengths of time can retain sediment. Modified Universal Soil Loss Equation (MUSLE) (William, 1975) is frequently used for estimation of sediment yield from catchment areas. The main objective of this study is control sediment volume in Mohgaon watershed by using Best Management Practices (BMPs) using Soil and Water Assessment Tool (SWAT).

STUDY AREA

Mohgaon watershed lies between 80° 47′ - 81° 30′E/22° 15′-22° 85′N is a part of Narmada River basin Madhya Pradesh in India. Narmada is the largest west flowing river of the peninsula India. It rises from a Kund near Amarkantak of Madhya Pradesh, at an elevation of about 1057 m in the Maikala range. The river flows through Madhya Pradesh, Maharashtra and Gujarat between Vindhya and Satpura hill ranges before falling into the Gulf of Cambay in the Arabian Sea. The total length of the river from the head to its outfall into the Arabian Sea is 1,333 km.

The study area has hydrological catchment area around 3975 km^2. Mean annual ainfall is 1547 mm. In the cold weather, the mean annual temperature varies from 6.0℃ to 26℃ and in the hot weather from 30℃ to 42.5℃. The evapotranspiration varies from 4 mm/day in winter to 10 mm/day in summer. The major soils of the watershed are Chromic Vertisols (62.5%). The second large group of soil in the watershed is Cambisols (32.05%), on the eastern reach with some at the middle and very small on the southern part. Luvisols (3.34%) soil formed in the south to north through south-west (large belt crossing from north-east west and west-north) of the watershed from the basaltic rock cap are deep, well structured, inherently well drained and relatively productive agricultural soil.

Table 1: Model input information for Mohgaon Watershed

DATA	SOURCE
Topography/DEM	http://www.ersdac.or.jp/GDEM/E/1.html
Land Use/ Land Cover	USGS
Soil	FAO GeoNetworkportal
Temperature, Wind, precipitation, speed, solar radiation, and relative humidity	http://globalweather.swat.tamu.edu
Runoff and Sediment Data	CWC Bhopal

Material and Method

Model Description

SWAT model is a watershed scale, continuous, long-term, distributed model designed to predict the impact of land management practices on the hydrology, sediment, and contaminant transport in agricultural watersheds (Arnold et al., 1998). SWAT subdivides a watershed into different sub basins connected by a stream network, and further into hydrological response units (HRUs).

The SWAT system is embedded within geographic information system (GIS) that can integrate various spatial environmental data including soil, land cover, climate, and topographic features. This study concerns the application of the latest version of the model, SWAT2009. Currently, SWAT is imbedded in an ArcGIS interface called ArcSWAT. There is a wide range of information on how conservation practices can improve environmental conditions. However, few studies have focused on the impact of these practices at the watershed level. These studies highlighted the need for quantifying the effect of such practices at the watershed level and the utility of the models. According to these studies, there is also a lack of information on the sensitivity of the parameters of environmental models for the representation of conservation practices, which limits simulations of land-use effects. Many studies revealed the effects of conservation practices or Best Management Practices (BMPs) in several watersheds and concluded that they are effective in improving the quality of water resources. The ideal situation is to implement several of these practices in order to guarantee a significant quality improvement in the watershed.

MODEL CALIBRATION AND VALIDATION

The monthly calibration and validation of the SWAT model for sediment yield were performed after conducting sensitivity analysis both for flow and sediment using Sequential Uncertainty Fitting (SUFI-2) algorithm (Abbaspour et al., 2004, 2007).

Eleven years of meteorological and measured sediment yield data were used for calibration and validation. The periods 2000-2006 and 2007-2010 were used for calibration and validation period, respectively including three years of warm-up period. Nash-Sutcliffe modelling efficiency (NSE) (Nash and Sutcliffe 1970) and coefficient of determination (R^2) were used to evaluate and quantify model performance during calibration and validation.

BMPS DESCRIPTION AND REPRESENTATION

Filter strips

Filter strips are vegetated areas that are situated between surface water bodies (i.e. streams and lakes) and cropland, grazing land, forestland, or disturbed land. They are generally in locations when runoff water leaves a field with the intention that sediment, organic material, nutrients, and chemicals can be filtered from the runoff water. Filter strips are also known as vegetative filter or buffer strips. Strips slow runoff water leaving a field so that larger particles, including soil and organic material can settle out. Due to entrapment of sediment and the establishment of vegetation, nutrients can be absorbed into the sediment that is deposited and remain on the field landscape, enabling plant uptake.

In this scenario, 5m to 30m filter strips was assumed to be applied to all agricultural lands. The previous versions of SWAT provided a specific method to incorporate filter strips through the *FILTERW* parameter defined in an HRU that reflects the width of the strip (Neitsch et al., 2005). The trapping efficiency for sediment, nutrients and pesticides is calculated:

$$trap_{ef} = 0.367(width_{filtstrip})^{0.2967}$$

Where, $trap_{ef}$ is the fraction of the constituent loading trapped by the filter strip, and $width_{filtstrip}$ is the width of the filter strip (m).

STREAM BANK STABILIZATION

Stream bank stabilization, vegetation or structural techniques are used to stabilize and protect banks of streams and channels against erosion. In this practice channel cover and hence roughness is increased which in turn decreases channel erodibility. To implement these functions, stream bank stabilization BMP was represented in SWAT using channel erodibility (CH_EROD), channel cover factor (CH_COV), and channel Manning's roughness coefficient (Manning's n) (CH_N2) for the main channels (Narasimhan et al. 2007). Some of the previous studies have used similar approach to model stream bank stabilization. The SWAT model default Manning's n was adjusted to 0.3 in the post-BMP, the channel erodibility factor (CH_EROD) was adjusted to 0.4 and the channel cover factor (CH_COV) was adjusted to 0.01.

Table 2: Table for the representation of BMPs and their functions

Scenario			Representing SWAT Parameters	
S.No.	Description	Function	Variable	Simulated value
1	Filter Strip	Reduce overland flow and sediment	FILTER_W	5,10,15,20,25, 30
2	Stream Bank Stabilization	Protect bank of stream	CH_EROD CH_COV	0.4 0.01

RESULTS AND DISCUSSIONS

Model Calibration and Validation

The monthly observed runoff and sediment yield was calibrated for the 5 year period (2002-2006) for Mohgaon outlet show value of R^2=0.72. Many researchers (e.g. Santhi et al., 2001; Benaman et al., 2005) suggested that the prediction efficiency of the calibrated model can be judged as satisfactory if R^2 and NSE values are >0.6.

Reductions by BMPs at watershed

Filter Strip

Filter strips were simulated over the whole agriculture area of the watershed. The width of the filer strips was increased during simulation from 5 m to 30 m. Increment in the width of the filter strips resulted in reduction in sediment yield having quite good impact for first few metres. The trend was found similar to other studies *(Arabi et al., 2008; Mwangi et al., 2011)*.

Stream Bank Stabilization

Stream bank stabilization was simulated at the outlets of all the second and third order streams contributing to the watershed outlet. The results from the simulation of stream bank stabilization show a reduction of 39.45% in sediment yield at the Mohgaon outlet.

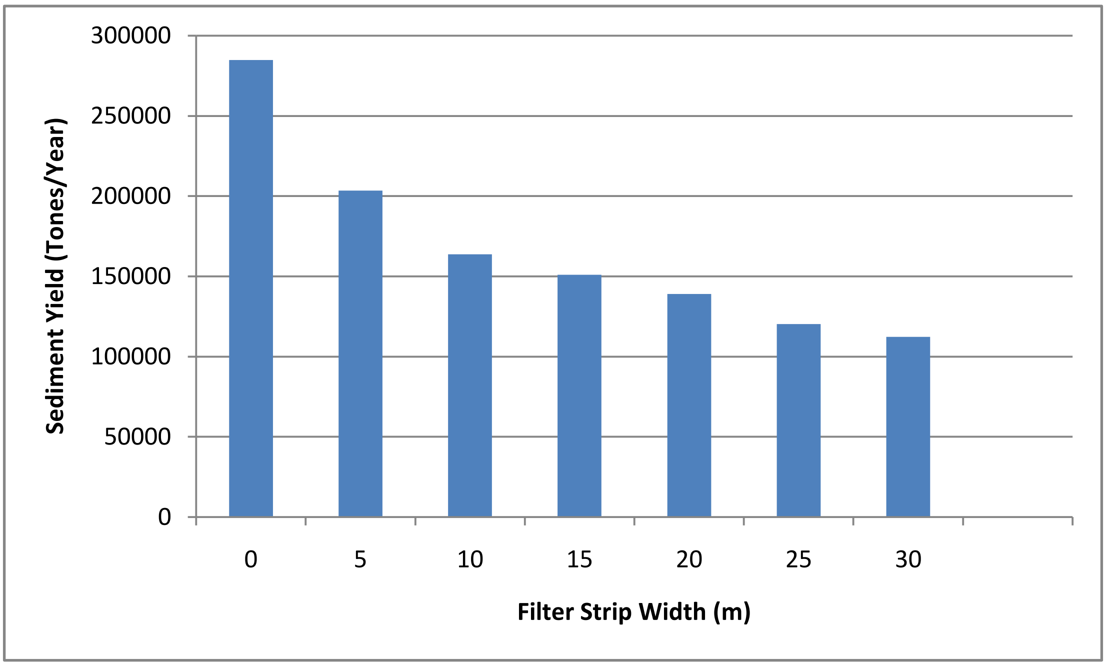

Figure 1: Total decrease and percent reduction in sediment yield as a function of the width of the filter strip

Combined Scenarios:

A combined scenario of the two BMPs was also simulated over the watershed.

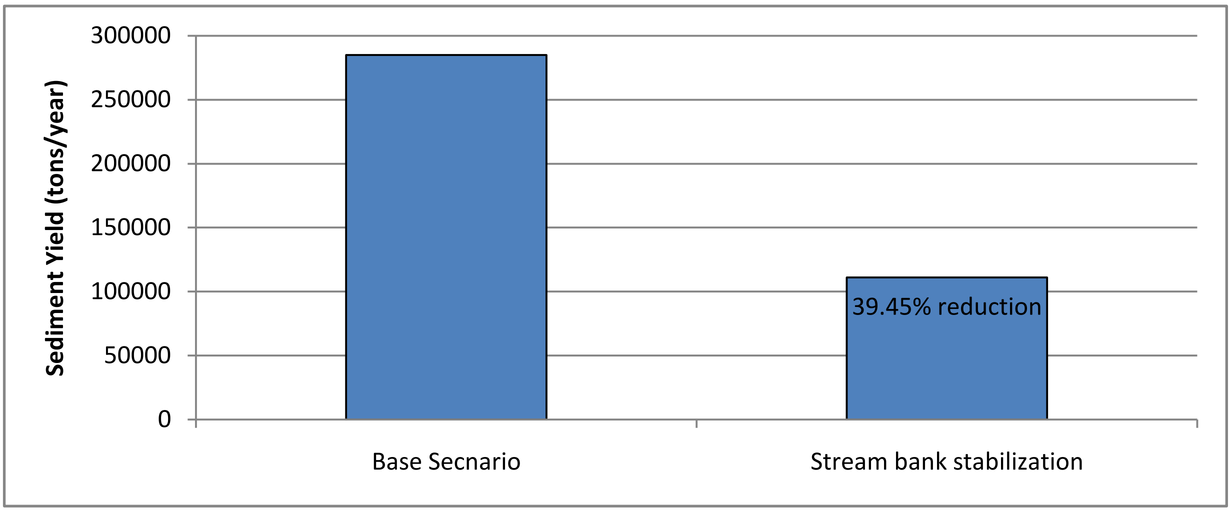

Figure 2: Simulated sediment yield for stream bank stabilisation

Filter strips were simulated over the agricultural area, and stream bank stabilization was simulated on channels. The combination resulted in a reduction of 65% of sediment yield at the outlet which showed that as a better management practices both the BMPs can be adopted simultaneously.

CONCLUSION

The performance of SWAT model is satisfactory and provides viable platform for simulation of BMPs on watershed scale. Model predictions on the impacts of the BMPs and their combination scenarios were found consistent with previously reported studies. Results of the simulation suggested that the combination of filter strip and stream bank stabilization is most effective in reducing the sediment load at the outlet.

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