management in a watershed (Kaur et al., 2004; Tripathi et al., 2003).

This study has the following hypotheses: the hydrological modelling of a watershed enables the identification of soil erosion problem in terms of runoff and sediment load from the watershed at the outlet; the management practices simulation in the watershed then can provide an estimate of reduction in the soil erosion and soil and nutrient loss problems. The primary objective of the study was assessment of the contribution of management practices on the watershed in achieving remarkable reduction in soil erosion and thus sediment yield.

2. Materials and Methods

Watershed Description

The Mohgaon watershed, roughly 3500 km^2, in size is located in central region of south eastern Asian country, India. The watershed is a tributary to the Narmada River, which rises near Amarkantak, in the Anuppur district of Madhya Pradesh, flows towards the west to the Gulf of Khambhat in the state of Gujarat. The soil is characterised, in general by shallow black soil often interspersed with red sandy or laterite soils. The soil is generally fine textured, more than 50%, followed by medium textured soil. The hydrologic soil group C of the soil series is dominating in the watershed. The average annual rainfall for Mohgaon is more than 1100 mm (Narmada Basin Report, 2014, www.india-wris.nrsc.gov.in). Topography for the watershed has mostly gently sloping land and flat top plateaus with a 600-900 general elevation. Cultivation is by system of rotation of crops. Forest, agriculture and wasteland are the major land uses in the watershed. Paddy, soya bean are the main crops grown in the watershed, followed by wheat and other cereals.

Watershed characteristics, management information and BMP information

Figure 1: Mohgaon Watershed Map (study area)

Needed for BMP representation were collected for the period of around 10 years for the watersheds. Information about any management practices previously used was collected visiting the farmers and residents of Mohgaon. No management practice except cultivation by crop rotation was previously used or being used there in Mohgaon. Flow and sediment data were obtained from CWC, Bhopal. Data used for SWAT simulation are meteorological, slope, soil and landuse data.

Representation of BMPs

In the past, impacts of various structural and non-structural BMPs have been modelled using SWAT. Ogweno et al. simulated contour farming and filter strips by modifying the management practice factor USLE_P and filter width of the filter strips in SWAT to take filter cover and resistance to soil erosion into consideration.
In this study, based on the literature previously published, pertaining BMP implementation, grassed waterways and contour farming were simulated to reduce the soil erosion and sediment occurring from the catchment.

Contour farming was implemented to reduce soil erosion in the form of sheet and rills from the fields and other areas. The effect of contour farming was represented with model parameters curve number (CN2) and USLE practice factor (USLE_P). Implementation of grassed waterways helps in reduction of flow of water thus trapping the sediment and also prevents channel erosion in the channel. The parameters which were modified to represent grassed waterways are channel cover factor (CH_COV), channel erodibility factor (CH_EROD) and channel manning's coefficient (CH_N2). The parameters chosen to represent BMPs in good condition are listed below in table 1. Previously during calibration and validation a sensitivity analyses was performed to ascertain the sensitivity of SWAT to the chosen parameters.

The parameters were modified to represent BMPs after their selection and sensitivity analysis to validate their impacts on sediment predictions. The parameter values were interpolated between BMPs in good condition and no BMP scenario. The BMPs were simulated individually and in combination over the whole agriculture area which is nearly 50% of the watershed. Since there is no conservation practice been adopted there over the field and channels the current condition was simulated using the same parameters representing no conservation practices as the base scenario.

Table 1: Table representing BMPs and their functions

		Representative SWAT Parameter	
BMP	*Function*	*Variable*	*Value With BMP*
Contour Farming	Reduce overland flow Reduce rill-sheet erosion	CN2 USLE_P	86 0.16
Grassed Waterways	Increase channel cover Reduce channel erodibility Increasing channel roughness	CH_COV CH_EROD CH_N2	0 0 0.34

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Model Calibration and Validation

Calibration and validation of the SWAT model was performed using SUFI2 on monthly basis for stream flow and sediment using precipitation, flow and sediment load input data collected for the simulation. Calibration process involved comparison of average monthly observed and simulated values. Coefficient of determination (R^2) and Nash-Sut-cliffe efficiency (E_{NS}) were computed between the observed and simulated values to check the model performance. Model calibration resulting in R^2 value greater than 0.6 and E_{NS} value greater than 0.5 is considered satisfactory Bracmort et al. (2006). Validation is performed to check for the accuracy of the model prediction from an observational data set different from which is used for calibration (Wilson, 2002). Optimal parameters selected during sensitivity analysis and model calibration were used for validation for a period of four years.

3. Results and Discussions

SWAT outputs calculated at the outlet of the catchment were sensitive to the parameters used for the representation of BMPs, as shown by the results. The impact of various conservation practices on curve number, are illustrated in Neitsch et al. (2005), which recommends curve number values under various conditions. For contour farming, curve number was reduced from the default/calibrated value. The USLE support practice factor (USLE_P) for fields under contouring condition was taken as 0.16 to simulate the erosion reduction due to implementation of the corresponding practices. An increase in value of CH_N2 decreases the runoff velocity. Fiener and Auerswald (2006) assumed CH_N2 ranges between 0.3 and 0.4 over the year. This value was adjusted to 0.34 for the channel segment for grassed waterways. The channel segment is considered fully covered by vegetation i.e. channel cover factor (CH_COV) was adjusted to zero and thus a non-erosive channel therefore channel erodibility factor (CH_EROD) was also adjusted to zero.

Satisfactory results were obtained from the model calibration and validation for the watershed. Results as evaluated by coefficient of determination (R^2), and Nash-Sut-cliffe (E_{NS}) were satisfactory and are shown in table below. The model predicted well both low and high stream flow and sediment yield at the outlet of the watershed. The model was then used for the evaluation of the BMPs on sediment yield reduction after calibration.

Table 2: Calibration result of SWAT for average stream-flow and sediment (2002-2006)

Variable	R^2	E_{NS}
Stream-flow	0.90	0.87
Sediment	0.90	0.87

Table 3: Validation result of SWAT for average stream-flow and sediment (2007-2010)

Variable	R^2	E_{NS}
Stream-flow	0.89	0.82
Sediment	0.83	0.79

Reduction in Sediment

Contour Farming

The simulation result for contour farming showed that on average the sediment loading to the streams outlet would reduce by 35% from the base simulation (figure 2). Most of the sediment loads in the streams would result from the soil erosion on the watershed. It is thus necessary to show the spatial variation of soil erosion in the watershed.

The results indicate that implementation of contour farming would reduce the soil erosion in the farmlands. In general, contour farming can reduce soil erosion by 50% compared to up and down cultivation (Mati, 2007). Other studies (Quinton and Catt, 2004; Arabi *et al.*, 2008; Brunner *et al.*, 2008) have also found that contour farming have a positive effect in reducing sediment yield. Contour farming creates surface roughness blocking the surface runoff and encourages infiltration as water pond in the depressions. This reduces the erosive power of surface runoff and thus reduces soil erosion (Arabi, *et al.*, 2008).

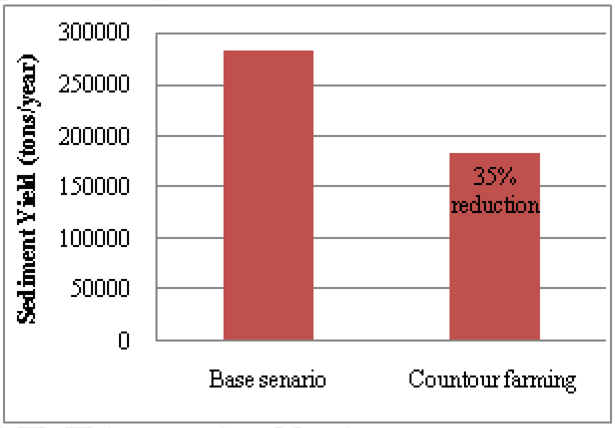

Figure 2: Simulated Sediment yield for Contour Farming

Grassed Waterways

Grassed waterways were simulated at the outlets of all the second and third order streams contributing to the watershed outlet. The results from the simulation of grassed waterways show a reduction of 39.45% of sediment yield at the Mohgaon outlet (figure 3). The results showed that grassed waterways can play great role in the reduction of sediment in Mohgaon watershed. Grassed waterways would be of much importance in Mohgaon, for reducing sediment that usually gets washed from the cultivated lands near the seasonal streams during the rainy season. The farmers cultivate close to the streams and channels which go dry during the dry seasons an when the rain comes the sediment and sometimes even the crops get washed by the increased stream water.

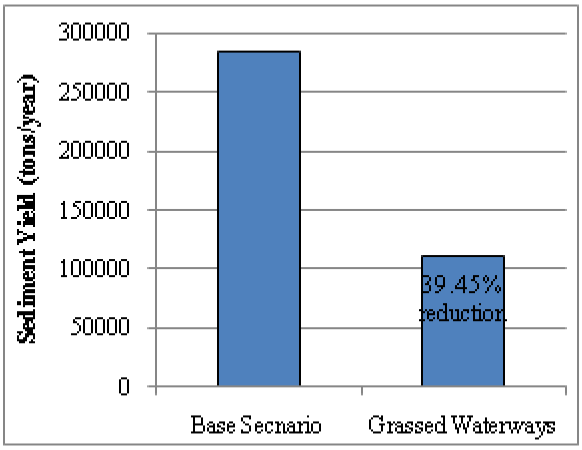

Figure 3: Simulated sediment yield for Grassed Waterways

The model outputs of the both the BMPs simulations when compared to the base line scenario revealed the efficacy of the BMPs. Under good conditions the BMPs resulted in the reduction of sediment at the outlet up to 40% when simulated individually. A scenario was prepared combining both the BMPs in a single simulation simultaneously. The combination scenarios thus resulted in a reduction of sediment at the outlet to a greater percent of 72%. Based on the function and sensitivity analysis at watershed scale the BMPs were modelled in the study by modifying chosen parameters. The outputs of the SWAT model are affected by the number and size of sub-watersheds, predicted performance of BMPs will be influenced by watershed size and discretization level. Therefore, the representation of BMPs if validated at multiple discretization levels and spatial scales would strengthen this study.

4. Conclusion

To protect soil erosion and sediment inflow directly into the streams contour farming was adopted and channels or waterways were grassed i.e. grassed waterways were adopted with the consideration of reduction of sediment load at the outlet. Each scenario was implemented individually and a single combination of both was also implemented and all the scenarios represented well in SWAT and in reducing soil erosion and sediment transport. Individually contour farming and grassed waterways were found quite effective in reducing soil erosion and sediment load in the streams but the combination of both the BMPs proved to be more effective in reducing the sediment load at the outlet. Effective decision can be taken in selecting the appropriate BMP

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