Assessment of impact of watershed management structures on hydrology

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Abstract

Watershed management practices are the prime considered factors for a healthy environment, Construction of bunds, trenches, check dams, land leveling, and some of the gully control structures are some of the watershed management practices. The most important and widely used management practice is the check dam. The study aimed to investigate the impacts due to the assessment of check dams in the study area Chikkodi taluka area, Karnataka, India. In this study, the model SWAT was used to simulate the runoff in the study area. The calibration and validation of the model was done for the period 1997 to 2001 and 2001 to 2005 respectively. The statistical parameters used are the regression correlation coefficient (R^2) and the Nash-Sutcliffe model efficiency (NSE) and got the good values. The calibrated model was then used to simulate to evaluate the effect of watershed management practices (implementation of check dam) on the hydrology of the watershed. The runoff value for the case without the implementation of the check dam duration (1983-2005) was 16.3854 $m^3s^{-1}$and for the case with a check dam, the runoff was 11.1961 m^3s^{-1}.

The implementation of the watershed management practice has reduced the runoff in the watershed, and which has helped to a reduction of sediment transport and an increase in groundwater recharge.

Keywords:*check dam, modelling, runoff, SWAT, watershed.*

Introduction

Watershed is one of the prime considered factors in the health of biodiversity. Water from the surface water features and runoff from stormwater flows and finally drains out through an outlet of the watershed, and alsothe possibility of water enters the other water bodies. So as flow throughout the watershed, it carries the sediments from the area of various micro watersheds within the corresponding macro watershed, which results in soil erosion, sedimentation of reservoirs, loss of soil fertility and water quality reduction, etc. To overcome these problems watershed management practices are to be followed.

Hydrological modeling is done to analyse the impacts of watershed management practices in the study area and also compared results for both treated and untreated micro watershed by the help of the Soil and Water Assessment Tool (SWAT). Hydrological models help in planning of water resources, constructing the hydraulic structures, for suggesting the best management practices, for environmental impact analysis,and also to predict the downstream impacts by the proposed structures or by runoff. Check dams are the very widely used management practices that are constructed to control the sediment and it allows infiltrating the water; this improves the groundwater table. The sedimentary load control was taken by check dams as detailed for varying or different environment, there are indications that check-dams induce erosion processes locally, this affects the sediment budget at the

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catchment scale (Carolina Boix-Fayos et al., 2008). Check dams are also made alter in the water flow and sediment flow in the network of channel, this reduces the crest of the flow and discharge flood volume, such as controlling rate of the runoff by being an abstraction to flow this retards and impound the stormwater flow towards downstream, providing control over runoff volume by permitting therainwater to infiltrate moderately as it flows through the channel of drainage allowing as pretreatment through decreased rates of sedimentation (A. Mishra et al., 2006). The main reasons for changes in the watershed are land use and land cover changes, rapid urbanization, and changes in climate. An extension of vegetation cover results to decrease in runoff generation and results in the sediment detachment in the stabilization of sedimentary structures at the scale of the catchment and sometime there will be some variation or alteration in land use can have a significant effect on regional soil erosion rates (Carolina Boix-Fayos et al., 2008). The combined impact of land-use change and climate variability resulted in rapid variability in surface runoff, water yield, soil water content, evaporation, and also in groundwater flow and percolation (Mou Leong Tan et al., 2014).By considering all these literatures the land use, land cover changes make more variation in the watershed to overcome all negative impacts the watershed management practices are to be followed.

This paper revealed about scenarios of the study area, explanation about the SWAT tool and method which we followed, and the setup of the model. The validation and calibration of the SWAT model took major importance in this study. The study aimwas to discuss the impacts due to the assessment of check dams in the study area. Check dams made many changes in watershed like changes in volume of the runoff, change in discharge peak, andrate of the runoff and so on. The major important objective of the study is to compare the flow in both scenarios between with check dams and without check dams in the study area and to find the most sensitive parameters are made changes in hydrological processes in the watershed and also significant changes in the watershed health.

MATERIALS AND METHODS

2.1. Study area

To find the impacts of watershed management structure, check dams on the specified area. The study area is located in chikkodi taluka, Belagavi district, Karnataka, India (fig 1.). Study area composed of villages of Chikkodi taluka and the area was lies at latitude E 16^0 25’44.3”, longitude N74^0 35’9.28”E. These all villages are integrated as a micro watershed and it is connected to roadways and power supply. Treated and untreated micro watersheds are the main two types of composition of the study area. One of the treated micro watersheds lies 18km towards the west of the Chikkodi taluka and untreated micro watershed lies 14km towards the east of the Chikkodi taluka. The watershed with watershed management practices is called treated watershed and the watershed without watershed management practices is called untreated watershed. The whole study area comes under the Krishna river basin. The treated watershed comes under the middle Krishna sub-basin and untreated comes under the Ghataprabha sub-basin. The main streams are passing through the study area are highly silted without any water harvesting structures, these are connected to many secondary and tertiary streams .Stream flow can be observed in the rainy season. And the duration of the flow may vary from the month of July to October without any infiltration. Local The local livelihood of people depends on dry land agriculture which is subjected to vagarious of nature. The rainfall of the area is about 614.00mm annually. And nearly 80%-90% runoff escapes as muddy water into the river Krishna. Fertile soil loss, groundwater depletion, poor crop yield, deforestation, and biotic pressure on resources necessitate watershed management programs in the area.

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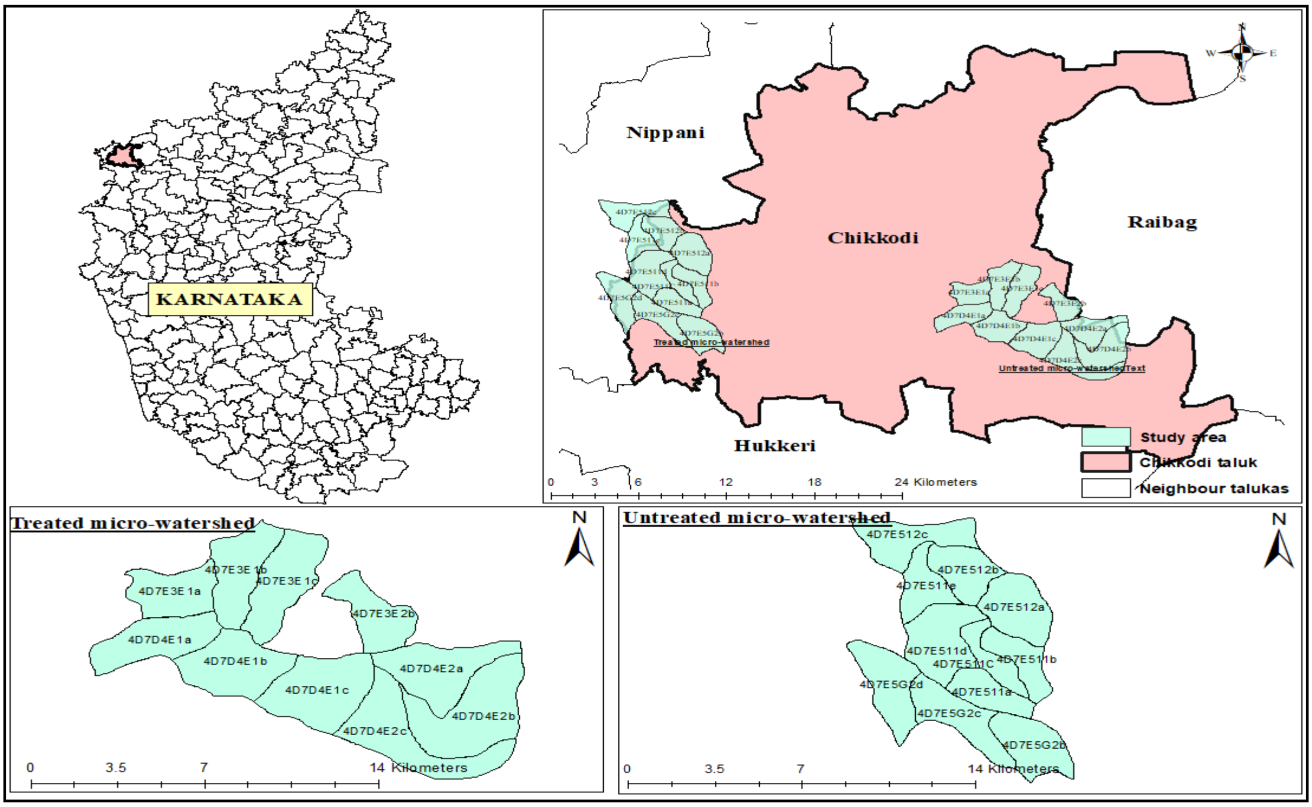

Figure 1: Chikkodi study area location

2.2. Soil and Water Assessment Tool (SWAT)

Based on the peer-reviewed literature, the SWAT model is one of well know hydrological model for the simulation of hydrological parameters.

The soil and water assessment tool (SWAT) is a physically-based, continuous-time, watershed modeling program, this is developed by USDA and Texas University. SWAT model can be used tosimulate water yield, sediment transport, nutrients, and agricultural chemicals in large scale watersheds (Laura M. Norman et al., 2015). Open-source software that can work on a daily and monthly

time basis in basin-scale and this model calculates surface runoff and also sediment transport. It requires various input data are Digital elevation model (DEM), land use map (LULC), soil map, weather data, rainfall data, temperature data, solar radiation data, wind speed data.

SWAT is one of thephysically-based model and it works on the water balance controlled by climate inputs such as daily precipitation, maximum and minimum air temperature. And the conceptualized water balance equation is written as follows (Kumar Raju B C et al., 2015).

$$SW_t = SW_0 + \sum_{i=1}^{t} R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw} \qquad (1)$$

Where,

SW = Soil water content

i = Time in days for the simulation period t.

R_{day}= Daily precipitation.

Q_{surf}= Surface runoff.

E_a= Evapo-transpiration.

W_{seep}= Percolation flow.

Q_{gw}= Return flow.

Surface runoff was calculated using the following equation.

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$$Q_{surf} = \frac{P_e^2}{p_e + S} \qquad (2)$$

Where,

P_e = Depth of effective precipitation (mm).

S = Retention parameter (mm).

And retention parameter is defined as

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \qquad (3)$$

Where,

CN = Curve number.

The Soil Conservation Service Curve Number (SCS-CN) method was used to calculate the surface runoff and the model calculates separately plant transpiration and water evaporation from the soil toestimate the real evapo-transpiration (ET) (DONIZETE DOS R. PEREIRA. et al., 2014).

2.3. Model calibration and validation

Application of the SWAT model in this study follows some important steps and those are project setup, delineation of the watershed, HRU analysis and definition, sensitivity analysis, and calibration. The data required for the study are digital elevation model (DEM), LULC map; soil properties data, daily wise minimum and maximum data, rainfall data, and these all are extracted from various sources. The data digital Elevation Model (DEM) of 32m resolution was collected from Bhuvan portal of Cartosat Version 3R1, Land use Land cover data obtained from SWAT website (downloaded from https://swat.tamu.edu/software/india-dataset/), soil data from FAO, precipitation data of 0.250 x 0.25^0 Gridded data from India Meteorological Department (IMD) (Pune) by selected gauge station (fig 2.) and temperature 1^0 x 1^0 Gridded data from IMD.

The SWAT model calibration was simulated for treated and untreated micro watersheds separately. The calibration and validation was performed for runoff, using observed data. Flow data were obtained from Sadalaga gauge station for calibration of the treated micro watershed and Hudli station flow data for untreated micro watershed. The gauge stations were selected based on the proper data availability and micro watershed flow accumulation. The gauge station locations are selected for the study is shown in fig. 2.

Along with the graphical representation, the regression correlation coefficient (R^2) and the Nash-Sutcliffe model efficiency (NSE) coefficient were used output of the model correctness. The statistics R^2 value varies from 0 to 1, typical values higher than 0.5 are acceptable and for statistics NSE varies from 0 to 1.0, these are the acceptable limits (D. N. Moriasi et al., 2006). The effort has made to similar the trend of the simulated runoff to the trend of the observed runoff, but the observed runoff was slightly higher than that of the total simulated runoff for the Sadalaga station and vice versa for Hudli station.

The Statistical analysis validated that the anticipated runoff generally slightly similar to the corresponding computed(measured) values, as evidenced by the R^2 and the values of NSE calculated for monthly comparisons(table 1& 2). The calibration has done separately for treated and untreated watershed, by taking the gauge stations Sadalaga and Hudli respectively.

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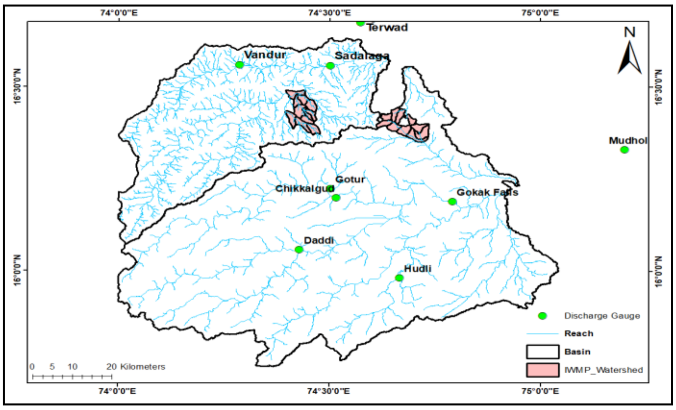

Figure 2: Map showing location of gauge station

Table 1. The modeling efficiencies for Sadalaga station

Sl. No.	period	variable	R^2	NSE
1	Calibration (1997-2001)	Runoff	0.719	0.5756
2	Validation (2001-2005)	Runoff	0.876	0.5659

Table 2. The modeling efficiencies for Hudli station

Sl. No.	period	variable	R^2	NSE
1	Calibration (1997-2001)	Runoff	0.827	0.5366
2	Validation (2001-2005)	Runoff	0.695	0.5533

In the calibration for the period of 1996 to 2001, parameter sensitivity was tested. The sensitive parameters were calibrated by using the SWAT calibration manually and those calibrated parameters were used in the validation. The sensitive parameters found during the calibration separately for both treated and untreated watershed (table 3. & table 4.).

Table 3.Sensitive parameters of treated microwatershed

Sl. No	parameters	default value	calibrated values
1	CN2	87	85
2	ALPHA_BF	0.048	0.048
3	GW_DELAY	31	50
4	SOL_K	1.72	0.5
5	SOL_AWC	0.13	0.7
6	ESCO	0.95	0.01

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7	EPCO	1	1
8	SURLAG	2	2

Table 4. Sensitive parametrs of untreated microwatershed

Sl. No	parameters	default value	calibrated values
1.	ESCO	0.95	1.0
2.	EPCO	1	0.08
3.	CN2	87	76
4.	ALPHA_BF	0.048	0.035
5.	GW_DELAY	31	100
6.	SOL_K	1.72	0.5

In the validation period from 2001 to 2005, the adjustment ranges of the parameters remained unchanged for both stations Sadalaga and Hudli. The results of runoff (Table 1 & 2) are in an acceptable range.

3. Results and discussions

Comparison of measured and simulated time series and scatter plot, for the monthly and cumulative runoff at the watershed outlet, are shown in fig 3 & 4 for the calibration period.

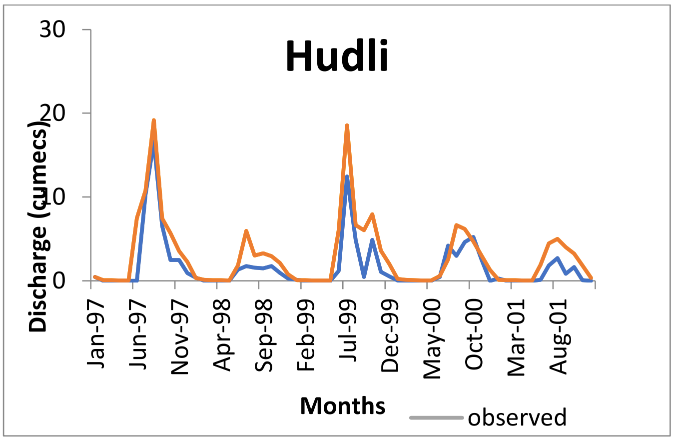

Figure 3 (a): Time series of simulated and observed runoff at Hudli station

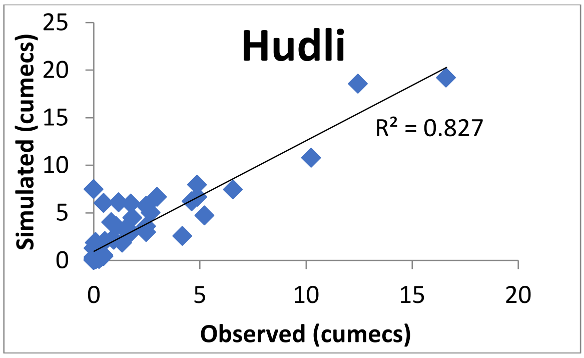

Figure 3 (b): Scatter plot between the simulated and observed streamflow at Hudli station

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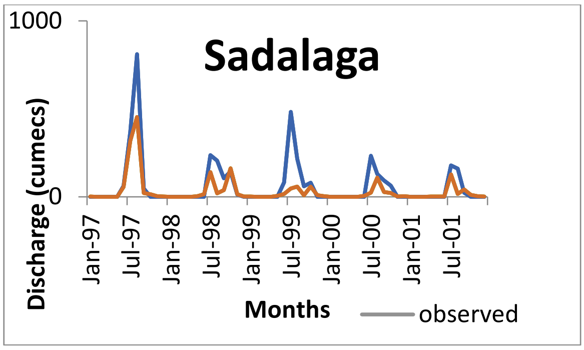

Figure 4 (a): Time series of simulated and observed runoff at Sadalaga station

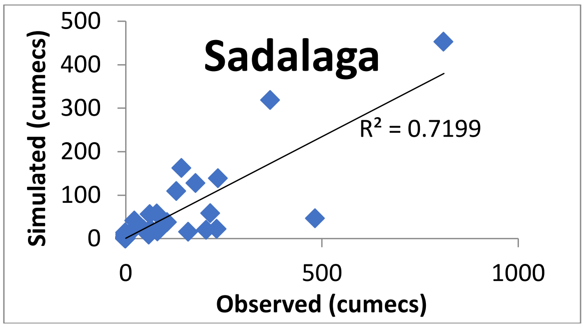

Figure 4 (b): Scatter plot between the simulated and observed streamflow at Sadalaga station

The calibrated model has considered as runoff for the case without a check dam and this average runoff value was compared with the average runoff value of the case with a check dam. There would be a difference in the runoff values between the case with check dam and without a check dam. The difference between those two isconsidered as the effect of the check dam and this can be expressed in the percentage.

$$E = \frac{R_1 - R_2}{R2} \times 100 \qquad (4)$$

Where R_1 is average runoff value for the case without check dam, R_2 is the average runoff value for the case with check dam, and the effect is expressed in percentage (%).
Once the model was satisfactorily validated, it could be regarded as suitable for the case watershed with check dams. There should be a difference between the two cases with check dams and without check dams. The runoff value for the case without check dam for the duration 1983 to 2005 was 16.3854 m^3s^{-1} and for the same duration but the case with check dam was 11.1961 m^3s^{-1}. As per equation (4), the percentage of runoff decreased after implementing the check dams, decreased runoff was 46.34% for the duration 1983 to 2005 and for the calibration period (1997-2001) the runoff value decreased about 8.95%. The flow would be more in the course of the wet season (June-September). In the wet season, the flow has decreased by about 61.86%. This reduction of flow also helps to reduce soil erosion.

4. Conclusion

The model SWAT was applied to Chikkodi watershed to assessment of the check dams in the study area. The predictions of the modelfor the surface runoff at the watershed outlet was replicated the measured trends on monthly basis, as proved by R^2 values that varied between 0.719 and 0.876 at Sadalaga station, 0.695 and 0.827 at Hudli station. The NSE statistics values ranges between 0.53 and 0.57 indicates that the somewhat less accurate in tracking the specific runoff.
The analysis of the study indicated that the check dams that have been installed in the study area watershed reduce the runoff about 61.86% in the wet season at the outlet of the particular watershed, and overall runoff from 1983 to 2005 was reduced about 46.34%. All over, the results confirm that the

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SWATcan be applied for small watershed with watershed management practices to analyze watershed management structures.

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