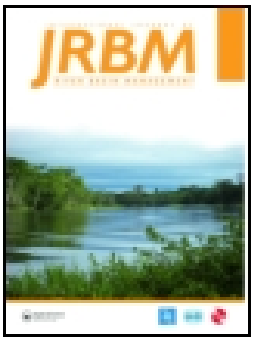

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Impact of BMPs on water quality: a case study in Big Sunflower River watershed, Mississippi

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ABSTRACT

Impact of Best Management Practices (BMPs) can be evaluated using hydrologic and water quality models. Although numerous models with diverse function, capability and degree of complexity are available, suitable model for each watershed should be determined. The Soil and Water Assessment Tool (SWAT) and Hydrologic Simulation Program-Fortran (HSPF) models were applied to the Big Sunflower River Watershed (BSRW) and their performances in simulating hydrology and water quality were evaluated. Both the models simulated streamflow, sediment, and nutrient concentrations with model efficiency greater than 50%. The SWAT model simulated streamflow and sediment concentration more accurately than HSPF whereas, for total nitrogen (TN) and total phosphorous (TP) concentrations, the HSPF model simulated equally good as SWAT. Models evaluated effect of two BMPs: vegetative filter strip (VFS) and tailwater recovery pond (TRP) in reduction of streamflow, sediment, TN, and TP concentrations. Average reduction of streamflow due to the implementation of both BMPs in SWAT and HSPF were less than 1% but average reduction of sediment concentration by VFS in SWAT was 26% and in HSPF was 38%. Average reduction of sediment concentration by TRP in SWAT and HSPF were 21% and 30% respectively. VFS reduced TN concentration by 51% in SWAT and by 25% in HSPF, while average reduction of TN concentration by TRP in SWAT and HSPF were 7% and 2% respectively. Similarly, average reduction of TP concentration by VFS in SWAT and HSPF were 56% and 31% respectively and that by TRP in SWAT and HSPF were 2% and 1% respectively. Differences in simulation results based on application of two models were mainly attributed by the modelling mechanism and equations used. The results from this study will provide a broader idea to other modellers and end-users in selecting appropriate model according to their need and type of watershed.

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SWAT; HSPF; nutrient; BMP; VFS; TRP

1. Introduction

Watershed management is very crucial for the protection and conservation of soil and water resources. Before adopting watershed management strategies, one needs to identify, quantify, and assess streamflow, sediment load and nutrient transport processes (Risal & Parajuli, 2019). Best Management Practices (BMPs), the structures or the activities that helps to maintain water quality to environmentally acceptable level, must be evaluated using different hydrologic and water quality models before implementation in a watershed. These models are the most widely used tools for the quantification and assessment of streamflow, soil erosion, sedimentation, nutrient transport, and impact of different BMPs in an watershed (Neitsch et al., 2005; Borah et al., 2019; Dakhlalla & Parajuli, 2019). Different hydrologic and water quality models, with numerous abilities and degree of complexity, are being used to assess currently implemented management practices and develop new management strategies (Parajuli et al., 2009; Risal et al., 2016, 2018). Before applying any model to a particular watershed, it is necessary to understand its capability to represent the real world scenario. The simulation results obtained from different hydrologic and water quality models, having varying mechanisms and structural complexities, may be similar or may vary significantly. In modelling studies, apart from the simulation outputs obtained from the model runs, model parameters and equations used by the models must also be analysed before completely relying in one model. Multiple models may be compared such that their applicability, reliability and limitation can be accessed. Thus, the performance of more than one model needs to be assessed and compared in order to determine a suitable model for the watershed studies (Abdelwahab et al., 2018; Clark & Tilman, 2017; Parajuli et al., 2009). The intention of this study is to to investigate and evaluate two widely used watershed scale models: SWAT and HSPF, in simulation of hydrology, water quality, and impact of management practices.

Among different models, SWAT is one of the extensively used model with numerous applications all around the world for the simulation of streamflow, sediment, water quality, and impact of BMPs (Behera & Panda, 2006; Dakhlalla et al., 2016; Maharjan et al., 2013; Ni & Parajuli, 2018; Risal & Parajuli, 2019; Saleh et al., 2000; Santhi et al., 2001). Similarly, HSPF is another widely applied model for assessment of water quantity and quality in variety of watersheds (Ackerman et al., 2005; Diaz-Ramirez et al., 2011; Im et al., 2003; Mishra, Kar, et al., 2007; Ouyang et al., 2013; Ribarova et al., 2008).

Comaprison of SWAT and HSPF, in simulating streamflow and sediment yield for the Polecat Creek watershed in Virginia, indicated that the performance of both the models were satisfactory, though HSPF performed moderately better than SWAT for higher time-step simulation (Im et al., 2007). Similarly, Application of SWAT and HSPF, in Delaware Creek and Salt Creek Watersheds in

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southwest Oklahoma, indicated that SWAT simulated monthly streamflow better than HSPF (Van Liew et al., 2003). Moreover, application of HSPF and the Soil Moisture Routing (SMR) models with different streamflow mechanisms for the simulation of streamflow at Irondequoit Creek basin in New York, showed that HSPF simulated winter streamflow slightly better than SMR, whereas SMR simulated summer flows better than HSPF (Johnson et al., 2003). Likewise, a study performing a comparison between SWAT and Annualized Agricultural Non-Point Source (AnnAGNPS), during calibration for hydrology, sediment, and total phosphorus at Red Rock Creek watershed and validation at Goose Creek watershed located in south-central Kansas, showed that SWAT was the most appropriate model for that watershed (Parajuli et al., 2009). Furthermore, SWAT and HSPF applied to the Illinois River Basin implied that HSPF performed better in terms of model fit, whereas SWAT had the advantage when calibration data are lacking or scarce (Xie & Lian, 2013). The SWAT and HSPF models, calibrated and verified for Upper North Bosque River watershed in Texas, indicated that SWAT was better predictor of nutrient loading than HSPF (Saleh & Du, 2004).

Although numerous studies has been conducted on the comparison of different models in the past, they were basically focused on calibration and validation of streamflow, sediment, and water quality (Im et al., 2007; Mishra et al., 2008). There are limited studies to date that evaluates models based on the nutrient reduction potential of different BMPs. Since different models may have different mechanism and may use different equations for same BMPs, we need to assess multiple models for the evaluation of BMPs impact of water quality in a watershed. Therefore, the objectives of this study are to: (a) compare calibration and validation statistics of SWAT and HSPF for streamflow, sediment, and nutrient concentrations; and (b) evaluate the impact of BMPs on water quality using SWAT and HSPF models.

2. Material and methods

2.1. Watershed Description

The Big Sunflower River Watershed (BSRW) is one of the major sub-watershed of the Yazoo River Basin (YRB). It lies between the latitude of 32° 30´N to 34° 25´N and longitude of 91°10´E to 90°13´E, and is located at the lower part of Mississippi River alluvial plain (Mississippi Delta) on the northwestern part of Mississippi (Figure 1). It has a drainage area of 10,500 km^2 and falls within ten different counties in Mississippi, namely Bolivar, Coahoma, Humphreys, Issaquena, Leflore, Sharkey, Sunflower, Tallahatchie, Washington, and Yazoo.

BSRW is an agricultural area having very high productivity in the Mississippi Delta because of very fertile soil and longer growing seasons (Gao et al., 2019). The major types of soil in the watershed are Alligator, Dowling, Dundee, Forestdale, and Sharkey. This watershed has a subtropical climate with an average annual temperature of 18 °C and annual precipitation of 1,371 mm (Gao et al., 2019; Ouyang, 2012). The majority (70%) of land within the watershed is covered by farmland and the dominant crops are soybean (43%), corn (14%), rice (8%), and cotton (5%).

2.2 . SWAT model description

Soil and Water Assessment Tool (SWAT), physically based continuous time simulation model, is capable of simulating surface streamflow, sediment, nutrients, and impact of different BMPs for each Hydrologic Response Unit (HRU), subbasin, and reach segment within a watershed (Neitsch et al., 2002). It is one of the extensively used model having numerous applications in various watersheds (Dakhlalla et al., 2016; Gassman et al., 2007; Gitau et al., 2008; Merriman et al., 2018; Ni & Parajuli, 2018; Risal et al., 2020). The SWAT model can be applied in prediction of long-term impacts of agricultural and management practice in the basin and thus can be helpful for assessment of the performance of different BMPs and alternative management policies. The schematic diagram showing input and output of SWAT model is given in Figure 2.

2.3. HSPF model description

The HSPF is one of the core watershed models of the United States Environmental Protection Agency (USEPA), Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), and Army Corps Watershed Modelling System (WMS). It is a continuous simulation, distributed parameter watershed scale model capable of simulating surface and subsurface streamflow, sediment loading, nutrient transport, and benthic process from various land surfaces, soil and within streams under different climatic conditions (Kim et al., 2007; Mishra, Kar, et al., 2007).

The HSPF model is fully integrated into BASINS through the WinHSPF interface, a windows interface to HSPF (Duda et al., 2012). The data preparation and modelling steps of the HSPF model using BASIN and external sources are explained in Figure 3.

2.4. Data

Topographic, land-use and land-cover, and soil data required by SWAT and HSPF were obtained through various national agencies and generated using the BASINS 4.5. For SWAT, DEM was downloaded from the United States Geological Survey (USGS, 2020), landuse and land cover data layer from United States Department of Agriculture (USDA), National Agricultural Statistics Service (*NASS*, 2020), and soil data from from USDA NRCS (NRCS, 2020). Similarly, for HSPF, DEM and Geographic Information Retrieval and Analysis System (GIRAS) Land use data layer were downloaded using BASINS 4.5.

Daily precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation as required by SWAT was derived from the National Oceanic and Atmospheric Administration (NOAA) (NOAA, 2020). Likewise, hourly time-series of precipitation, temperature, potential evapotranspiration, solar radiation, wind speed, cloud cover and dewpoint temperature as required by HSPF were obtained from the Delta Agricultural Weather Center, Mississippi State University Extension Service and formatted as a watershed data management (WDM) file using WDM utility program in BASINS. Necessary data on agricultural management practices such as plantation, harvest, irrigation, tillage, manure application, pesticide application on different crops like corn, soybean, cotton, and

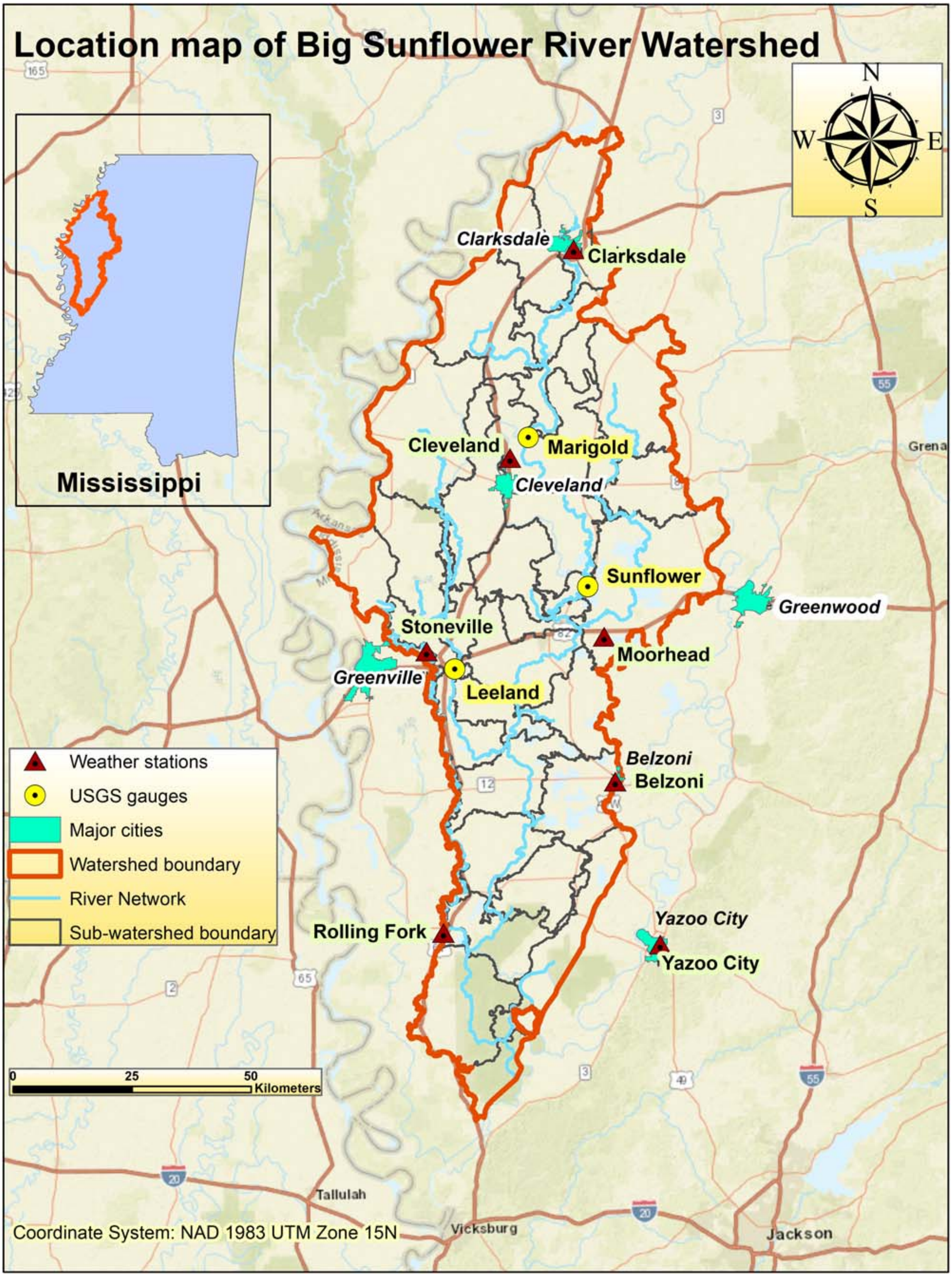

Figure 1. Location map of the watershed along with the sub-basins, rivers, cities, and USGS gaging stations.

rice were supplied by the Yazoo Mississippi Delta (YMD) Joint Water Management District (YMD, 2011).

Observed daily stream-flow data from 2005 to 2016 was obtained from the USGS (USGS, 2020) for three gauging stations: Marigold, Sunflower, and Leland. The data were used for the Calibration (2005 to 2010) and validation (2011 to 2016) of both SWAT and HSPF models. Similarly, the observed data for sediment, TN, and TP concentration from the USGS gaging stations was obtained every 15 days from 2013 to 2016. Calibration of SWAT and HSPF for sediment, TN, and TP concentrations was conducted from 2013 to 2014 and validation was conducted from 2015 to 2016.

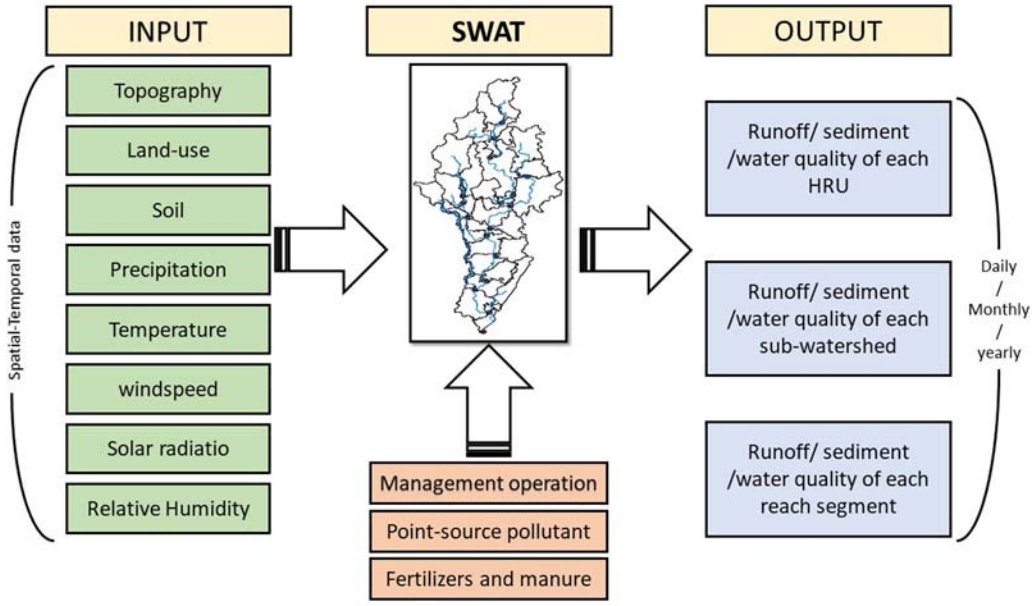

Figure 2 Schematic diagram showing the required input, management operation and output of the SWAT model.

2.5. BMPs scenarios

2.5.1. Vegetative filter strip (VFS)

Vegetative filter strip (VFS), a vegetated area between the water body and the edge of the cultivated land, is capable of reducing sediment, TN, and TP at the outlet of the watershed by slowing streamflow, settling sediments and absorbing nutrients. The VFS was simulated using both SWAT and HSPF to compare the reduction potential of the nutrients. The SWAT model simulates VFS effects using a very simplified equation based on width of the strip given by (Neitsch et al., 2005).

$$trap_{eff} = 0.367 \cdot (FILTERW)^{0.2967} \quad (1)$$

where $trap_{eff}$ is the sediment trapping efficiency and *FILTERW* is the width of the vegetative filter strip in metres.

The HSPF model uses a unique module called BMPRAC (Best Management Practice Evaluation) and uses recommended removal fractions for different pollutants based on documented studies conducted in diverse conditions (Xie et al., 2015).

The VFS BMP was applied to the edge of agricultural fields using both SWAT and HSPF in order to compare their reduction potential for TN, and TP concentrations. For SWAT simulation of VFS, The width of the filter strip was taken as 10 metres as the sediment trapping efficiency of 91.3% was achieved for this length based on 181 events from 16 studies all around the world (Luo, 2019). Similarly, the VFS management operation parameters such as fraction of total streamflow from the entire field entering most concentrated 10% of VFS (VFSCON), field area to VFS area ratio (VFSRATIO), and fraction of flow through the most concentrated 10% of channelized VFS (VFSCH) were set to the recommended value of 0.5, 50 and 0 (Waidler et al., 2011). For HSPF simulation of VFS, the default recommended removal fraction for different constituents were used (USEPA, 2003).

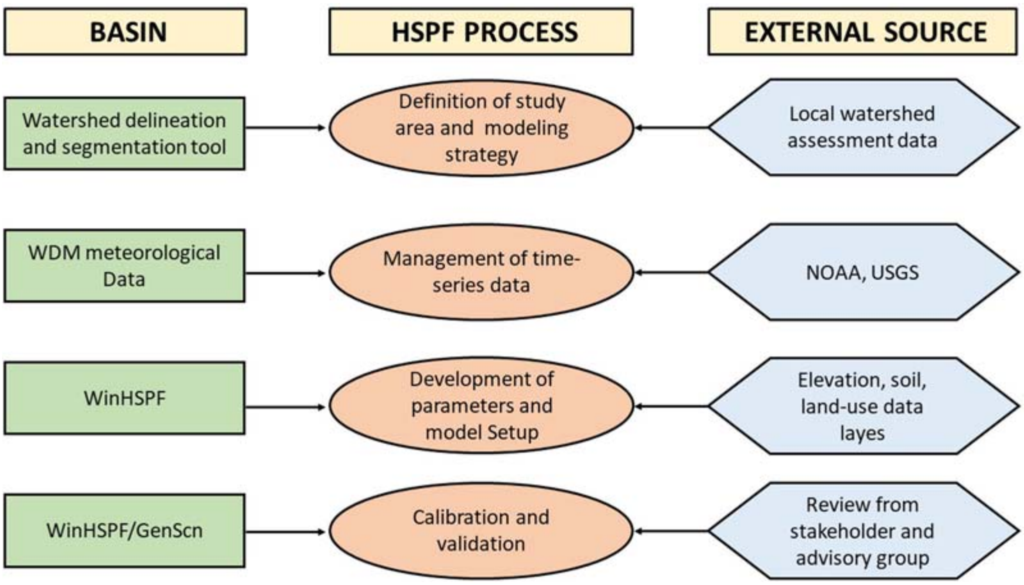

Figure 3 A schematic diagram showing application of BASIN and external sources in HSPF.

2.5.2 . Tailwater recovery pond (TRP)

Tailwater recovery pond (TRP), an artificial impoundment constructed within the watershed, is capable of reducing sediment, TN, and TP through the settlement of sediment and associated nutrient runoff. Effect of the TRP in the reduction of TN, and TP from the watershed was simulated using both SWAT and HSPF models.

The SWAT model has different modules for simulation of landscape depressions like a pothole, pond, and wetland (Mekonnen et al., 2016; Neitsch et al., 2002). The equations and processes used in SWAT for modelling pond and wetlands are similar (Arnold et al., 2012). The conceptual pond module of SWAT was used to simulate TRP in our watershed. For the pond and wetland modeule, the SWAT mass balance equation (Neitsch et al., 2005) was re-written as (Rahman et al., 2016):

$$S_i = S_{i-1} + (P + Q_{sur} + Q_{lat})_{pon,in} - (E + Q_{ch\&pon} + Q_{pon\&aq})_{pon,out} \quad (2)$$

where S is the pond water storage, P is the precipitation, E is the evapotranspiration, Q_{sur} is the surface runoff, and Q_{lat} is a lateral subsurface runoff, $Q_{ch\&pon}$ is the discharge of water from the pond and to the river, $Q_{pon\&aq}$ is the discharge of water from the pond to the aquifer.

A pond of varying dimension was placed in each sub-watershed according to the actual percentage of open water in each sub-watershed. Sub-watershed 16 had the highest percentage (10%) and sub-watershed 9 had the lowest percentage (1.2%) of open water. The pond parameters such as fraction of sub-basin draining into pond (PND-FR), surface area of pond when filled to principle spillway (PND_PSA), volume of water needed to fill pond to the principle spillway (PND_PVOL), initial volume of water in pond (PND_VOL), and number of days to reach target storage (NDTARG) were adjusted for each sub-watershed according to percentage of open water in each subbasin.

The HSPF model considers user-defined removal fractions for different pollutants based on previous studies for the simulation BMPs' effect in the watershed (Xie et al., 2015). The recommended removal fraction for different constituents within the HSPF model with application of constructed wetland was used to simulate effect of TRP in the reduction of nutrients from the watershed. (USEPA, 2003).

2.6. Model evaluation

Performance of SWAT and HSPF models during the calibration and validation of streamflow, sediment, TN, and TP was evaluated using NSE and R^2. The NSE, also known as efficiency index is one of the reliable and widely used statistics for assessing the goodness of fit of hydrologic models, which is given by (Nash & Sutcliffe, 1970).

$$NSE = 1 - \frac{\sum_{i=1}^{N}(O_i - S_i)^2}{\sum_{i=1}^{N}(O_i - \bar{O})^2} \quad (3)$$

where O_i is the observed value, S_i is the simulated value, $\bar{O}$ is the average of observed values, and N is the total number of observations. The value of NSE ranges from $-\infty$ to 1. NSE value near 1 refers to a good fit of the model. Generally, NSE greater than 0.75 is considered perfect, between 0.36 and 0.75 is considered satisfactory, and below 0.36 is considered unsatisfactory in hydrological modelling (Krause et al., 2005; Nash & Sutcliffe, 1970).

Coefficient of determination denoted as R^2 is another widely used statistics that estimate dispersal of the observed and predicted data. In other words, it is a measure to show a linear relationship between observed and simulated data. R^2 is given by (Draper & Smith, 1966)

$$R^2 = \left(\frac{\sum_{i=1}^{N}(O_i - \bar{O}) \cdot (S_i - \bar{S})}{\sqrt{\sum_{i=1}^{N}(O_i - \bar{O})^2} \cdot \sqrt{\sum_{i=1}^{N}(S_i - \bar{S})^2}} \right)^2 \quad (4)$$

where O_i is the observed value, $\bar{O}$ is the average of observed values, S_i is the simulated value and $\bar{S}$ is the average of simulated values and N is the total number of observations. The value of R^2 ranges from 0 to 1 and R^2 value of 0 means no correlation at all between observed and simulated data whereas R^2 value of 1 refers that the dispersion of the simulated data is equal to that of the observed data (Krause et al., 2005).

2.7. Model calibration and validation

2.7.1 . Streamflow

Both SWAT and HSPF models were calibrated for streamflow at the outlet of sub-watersheds 5, 10 and 17 of BSRW, using monthly streamflow data from USGS gages: Marigold (gage: 07288280), Sunflower, (gage: 07288500), and Leland (gage: 07288500) respectively, from January 2005 to December 2010. For the calibration of SWAT for streamflow, Sequential Uncertainty Fitting (SUFI-2) algorithm inside SWAT Calibration and Uncertainty Procedures (SWAT-CUP) package was applied (Abbaspour, 2007). 14 parameters were used during SWAT calibration of streamflow, among which the parameters streamflow curve number (CN2), saturated hydraulic conductivity of soil (SOL_K), snowfall temperature (SFTMP), soil evaporation compensation factor (ESCO) were the sensitive (Risal & Parajuli, 2019). The calibration of HSPF was performed manually varying parameters as shown in Table 1. Validation of SWAT and HSPF were performed using monthly streamflow from January 2011 to December 2016.

Table 1. HSPF Parameters used for the calibration of streamflow in Big Sunflower River Watershed.

Parameter	Description	Lower Range	Upper Range	Fitted value
LZSN	Lower zone nominal soil moisture storage (inch)	2	15	3.5
INFILT	Index to infiltration capacity (inch/hour)	0.01	1	0.1
NSUR	Manning's n (roughness) for overland flow	0.05	0.5	0.02
AGWRC	Base groundwater recession	0.92	0.99	0.6
DEEPFR	Fraction of groundwater inflow to deep recharge	0	5	0
BASETP	Fraction of remaining evapotranspiration from base flow	0	0.2	0.2
UZSN	Upper zone nominal soil moisture storage	0.05	2	2

Table 2. HSPF Parameters used for the calibration of sediment yield in Big Sunflower River Watershed.

Parameter	Description	Minimum value	Maximum value	Fitted value
SMPF	Supporting management practice factor	0	1	1
KGER	Coefficient in the soil matrix scour equation, simulates gulley erosion	0	10	0.1
JGER	Exponent in the soil matrix scour equation	1	5	0.8
AFFIX	Fraction by which detached sediment storage decreases each day as a result of soil properties	0.01	0.5	0.008-0.01
COVER	Fraction of land surface which is shielded from erosion by rainfall	0.0	0.98	0.03
KSER	Coefficient in the detached sediment wash off equation	1	10	0.1-0.6
JSER	Exponent in the detached sediment wash off equation	1	3	2

2.7.2. Sediment

The SWAT and HSPF models were calibrated for sediment concentration at the outlet of sub-watersheds 5, 10 and 17 of the BSRW, using sediment concentration data collected every 15 days from Marigold, Sunflower, and Leland USGS gauges. SWAT was calibrated for sediment concentration using 9 parameters, in which the parameter: USLE soil erodibility factor (USLE_K) was sensitive and was adjusted according to silt percentage in soil (Risal & Parajuli, 2019). HSPF was calibrated for the sediment concentration manually varying 7 parameters as shown in Table 2. Calibration of both the SWAT and HSPF models were conducted from 2013 to 2014 and validation was conducted from 2015 to 2016.

2.7.3. Total nitrogen (TN)

Calibration of SWAT and HSPF for TN were also performed at the outlets of sub-watersheds 5, 10 and 17 of the BSRW using TN concentration data from 2013 to 2014 collected every 15 days. SWAT was calibrated for TN using 6 parameters, in which the parameters: concentration of nitrogen in rainfall (RCN), and the nitrogen percolation coefficient (NPERCO) were more sensitive than others (Risal et al., 2020). HSPF was calibrated for TN manually varying 6 parameters as shown in Table 3. Both SWAT and HSPF models were validated for TN from 2015 to 2016.

2.7.4. Total phosphorous (TP)

Calibration of SWAT and HSPF for TP were performed at the outlets of sub-watersheds 5, 10 and 17 of BSRW using TP concentration data collected every 15 days from 2013 to 2014. SWAT was calibrated for TP using 6 parameters, among which, the parameters: phosphorus percolation coefficient (PPERCO), phosphorus soil partitioning coefficient (PHOSKD) and rate constant for decay of organic phosphorus to dissolved phosphorus (BC4) were the most sensitive (Risal et al., 2020). HSPF was calibrated for TP manually varying 5 parameters as shown in Table 4. Both SWAT and HSPF models were validated for TP from 2015 to 2016.

3. Results and Discussion

3.1. Comparison of calibration and validation statistics

3.1.1. Streamflow

Both SWAT and HSPF showed reasonable performance during their calibration and validation for streamflow. NSE and R^2 for SWAT during calibration of streamflow ranged from 0.71 to 0.76 and 0.74 to 0.81 respectively and that for HSPF ranged from 0.38 to 0.59 and 0.44 to 0.66 respectively. Similarly, during validation of SWAT for streamflow, NSE ranged from 0.48 to 0.70 and R^2 ranged from 0.74 to 0.84 and during validation of HSPF for streamflow, NSE ranged from 0.39 to 0.55 and R^2 ranged from 0.47 to 0.65. The summary of statistics for calibration and validation of SWAT and HSPF for streamflow at three USGS gauge stations are presented in Figure 4. From the comparison of observed and simulated monthly streamflow by SWAT and HSPF, it was observed that that there were minimal differences between simulated streamflow by these two models. The simulated value from both the models showed good agreement with observed value for both calibration and validation period for monthly streamflow. However, based on the calibration and validation statistics, the simulation of monthly streamflow by SWAT was slightly accurate than that by HSPF.

The modelling results for the simulation of streamflow from various SWAT and HSPF studies conducted by previous literature were not found uniform. The application of SWAT and HSPF to the Delaware Creek and Salt Creek Watersheds within Little Washita River Experimental Watershed in southwest Oklahoma suggested that that SWAT with NSE of 0.89 did a better job in estimating monthly streamflow that HSPF with NSE of 0.68 (Van Liew et al., 2003). Comparison of SWAT and HSPF during calibration and validation of monthly streamflow at several sites within Upper North Bosque River watershed, Texas indicated that the trends of measured and predicted monthly flow for HSPF were closer with NSE of 0.91 and 0.86 than that for SWAT with NSE of 0.50 and 0.78 respectively (Saleh & Du, 2004). Similarly, HSPF was found to have better statistics during calibration and validation of monthly streamflow with the mean error (*ME*) ranging from −4.05 mm to 1.88 mm, root mean square error (*RMSE)* ranging from 11.05 mm to 14.88 mm, and r-value ranging from 0.87 to 0.89 whereas for SWAT, ME ranged from −0.66 to 0.11, RMSE ranged from 14.89 to 19.96, and r-value ranged from 0.81 to 0.84 (Im et al., 2007).

3.1.2. Sediment

NSE and R^2 values for SWAT during sediment calibration ranged from 0.41 to 0.81 and 0.33 to 0.50, respectively and that for HSPF ranged from 0.32 to 0.43 and 0.39 to 0.53,

Table 3. HSPF Parameters used for the calibration of Total Nitrogen load in Big Sunflower River Watershed.

Parameter	Description	Minimum value	Maximum value	Fitted value
KTAM20	Nitrification rates of ammonia	0.006	0.9	0.75
KTN02220	Nitrification rates of ammonia and nitrite	0.001	0.1	0.1
TCNIT	Temperature correction coefficient for nitrification	1.03	10.7	1.04
KNO320	Nitrate Denitrification rate and 20° C	0.001	0.6	0.08
TCDEN	Temperature correction coefficient for denitrification	1.02	1.04	1.07
DENOXT	Dissolved oxygen concentration threshold for denitrification	1.5	10	25

Table 4. HSPF Parameters used for the calibration of Total Phosphorous load in Big Sunflower River Watershed.

Parameter	Description	Minimum value	Maximum value	Fitted value
KIMP	Phosphate immobilization factor	0	-	5
KDSP	Phosphate desorption factor	0	-	0.9
KADP	Phosphate adsorption factor	0	-	1.5
POTFW	The wash off potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (wash off or scour) outflow	0.005	1	0.001
WSQOP	The rate of surface runoff that will remove 90 percent of stored QUALOF per hour	0.01	-	0.03

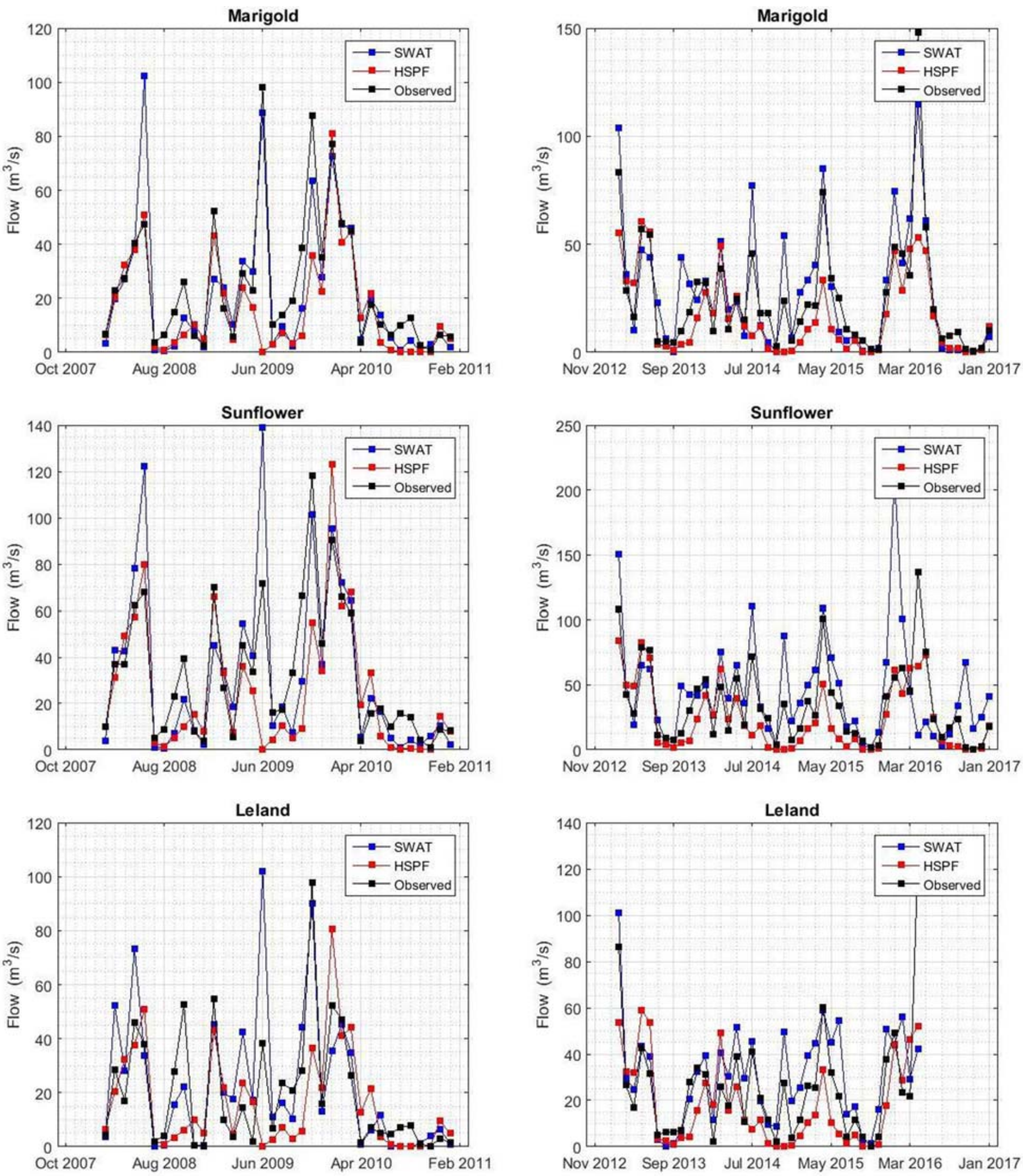

Figure 4. Observed and simulated monthly streamflow during the calibration and validation of SWAT at Sunflower, Marigold and Leland stations.

respectively. Similarly, during validation of SWAT for sediment concentration, NSE values ranged from 0.54 to 0.78 and R^2 ranged from 0.34 to 0.63 and during validation of HSPF for sediment concentration, NSE ranged from 0.34 to 0.48 and R^2 ranged from 0.35 to 0.50. The summary of statistics for calibration and validation of SWAT and HSPF for sediment concentration at three USGS gauge stations are given in Figure 5. From the comparison of observed and simulated data by SWAT and HSPF, it was observed that there were minimal differences between simulated

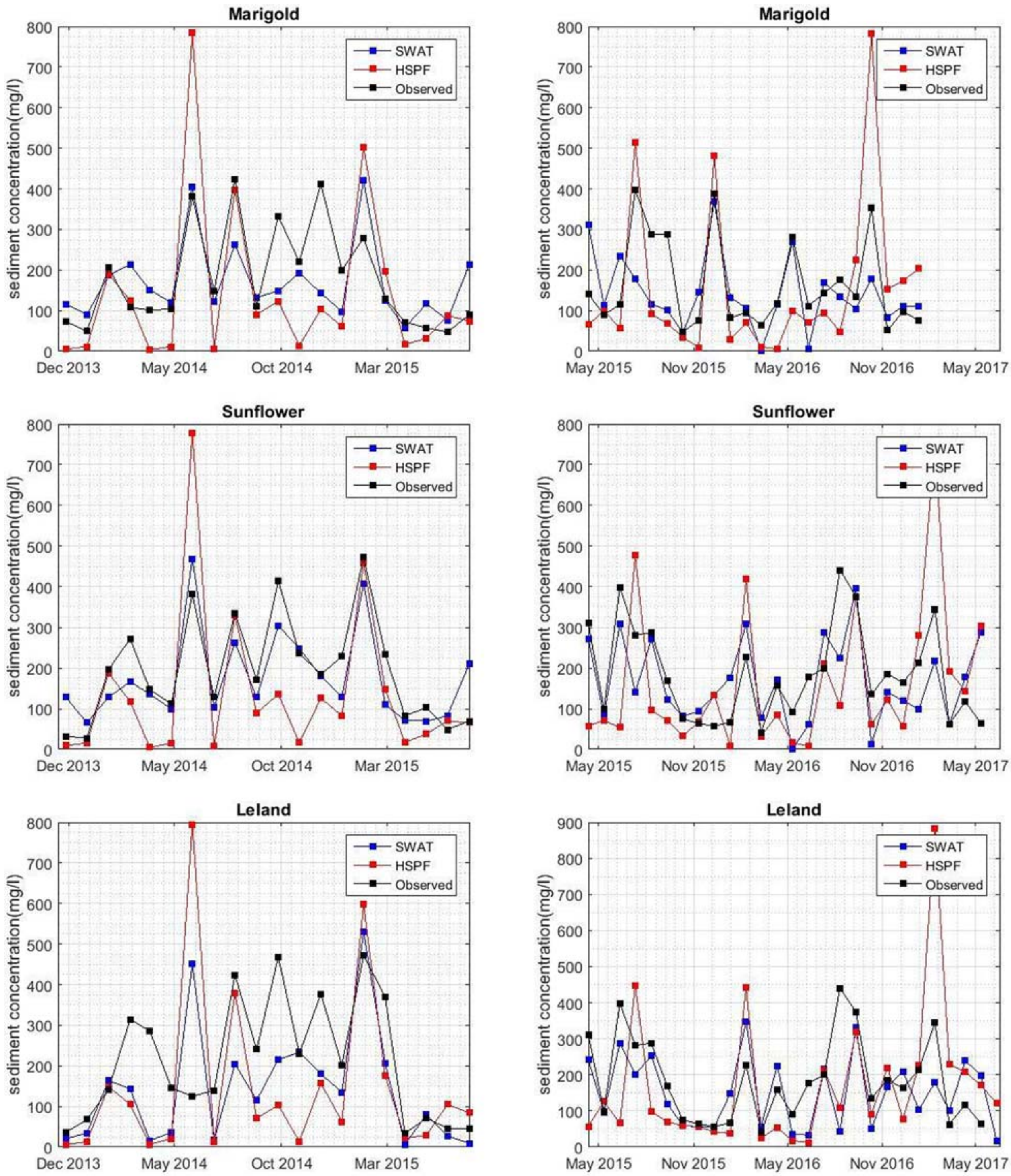

Figure 5. Observed and simulated sediment concentration during the calibration and validation of SWAT at Sunflower, Marigold and Leland stations.

sediment concentration by these two models. The simulated value from both the models showed good agreement with observed value during calibration and validation period. However, for the sediment concentration above 300 mg/L, HSPF overpredicted some higher values for all three gage stations. According to the calibration and validation statistics, SWAT simulated sediment concentration was more efficient than HSPF simulated sediment concentration.

Calibration and validation of sediment yield for different modelling studies conducted at different watersheds has varied greatly. SWAT model was found to be effective model than HSPF for simulation of sediment yield for a study conducted at small watershed located in a subtropical region of India, where NSE for SWAT ranged from 0.82 to 0.98 during calibration and 0.58 to 0.89 during validation (Mishra, Froebrich, et al., 2007); while for similar HSPF study, NSE during calibration was 0.71 and during validation, NSE ranged from 0.68 to 0.90 (Mishra, Kar, et al., 2007). While other study conducted at watershed located in central Texas indicated that HSPF is a better model to simulate sediment yield than SWAT based on their modelling results, where NSE ranged from 0.72 to 0.88 for HSPF, and 0.83 to 0.59 for SWAT during the calibration and validation period respectively (Saleh & Du, 2004).

3.1.3. Total nitrogen (TN)

NSE and R^2 for SWAT during calibration of TN ranged from 0.30 to 0.54 and 0.32 to 0.85 respectively; and that

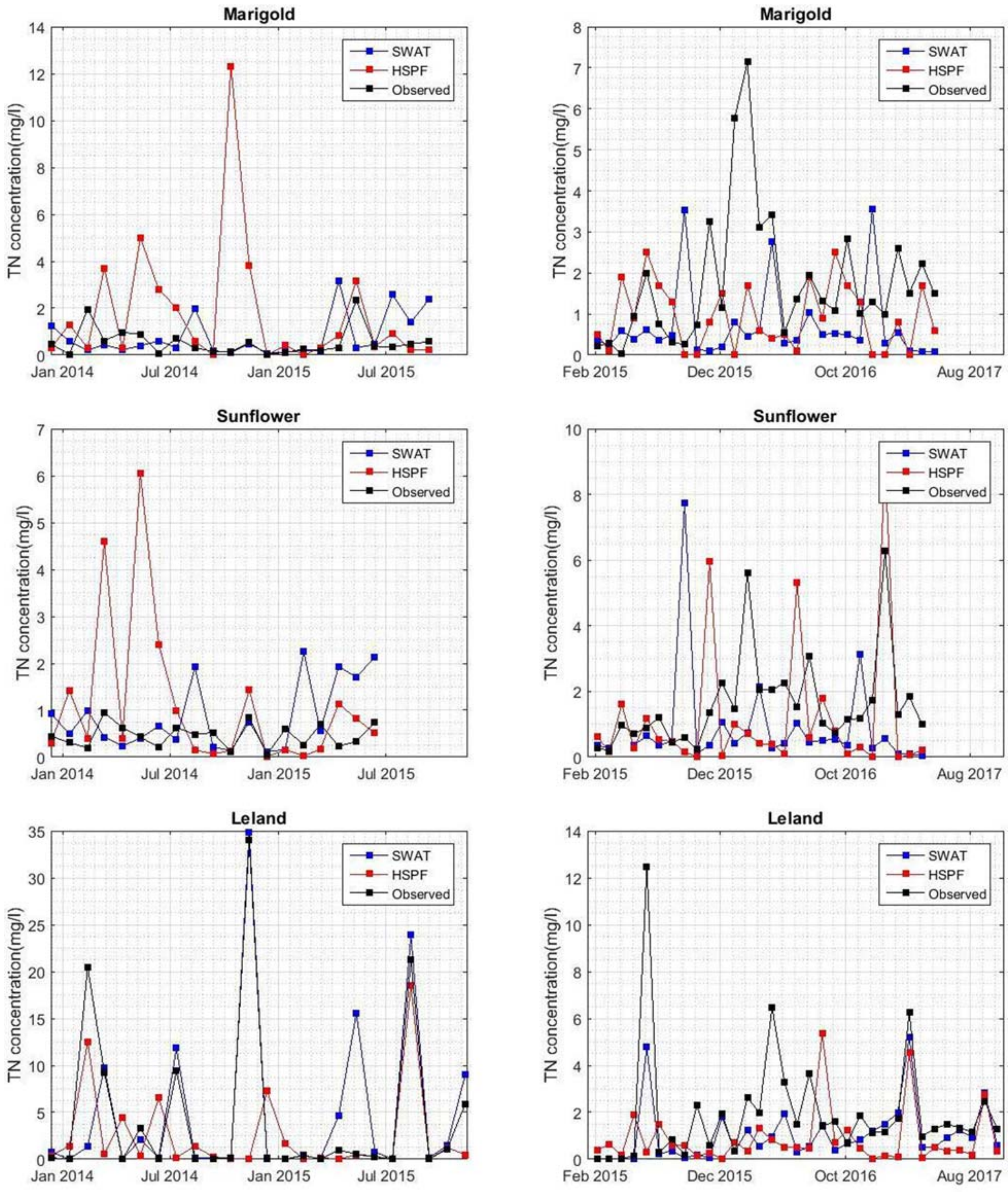

Figure 6. Observed and simulated TN concentration during the calibration and validation of SWAT at Sunflower, Marigold and Leland stations.

for HSPF ranged from 0.32 to 0.85 and 0.66 to 0.85 respectively. Similarly, during validation of SWAT for TN, NSE ranged from 0.45 to 0.53 and R^2 ranged from 0.67 to 0.84; and during validation of HSPF for TN, NSE ranged from 0.26 to 0.55, and R^2 ranged from 0.28 to 0.85. The summary of statistics for calibration and validation of SWAT and HSPF for TN at three USGS gauge stations are presented in Figure 6. From the comparison of observed and simulated TN by SWAT and HSPF, both the models were in agreement with the observed TN data with satisfactory statistics. However, calibration and validation statistics suggest that HSPF simulated TN more efficiently than SWAT.

Comparison of SWAT and HSPF during calibration and validation for a watershed having high dairy production in Texas indicated that SWAT better predicted total nitrogen loading with higher accuracy (ME ranging from −1.1 to 40.4) than HSPF (ME ranging from −2 to −86.9) (Saleh & Du, 2004).

3.1.4. Total phosphorous (TP)

NSE and R^2 for SWAT during calibration of TP ranged from 0.27 to 0.45 and 0.67 to 0.93 respectively, and that for HSPF ranged from 0.37 to 0.67 and 0.38 to 0.78 respectively. Similarly, during validation of SWAT for TN, NSE ranged from 0.38 to 0.42 and R^2 ranged from 0.43 to 0.69; and during

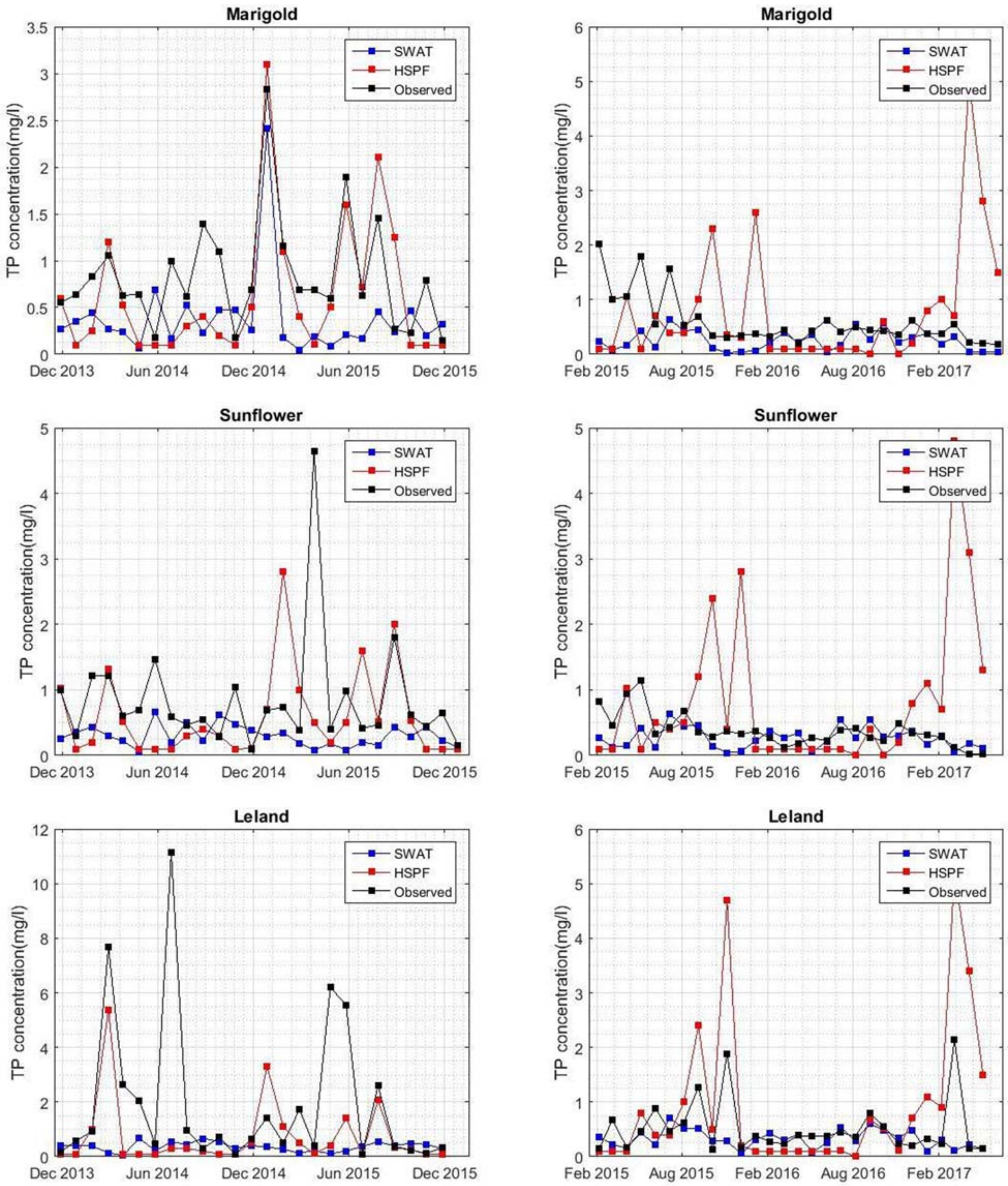

Figure 7. Observed and Simulated TP during its calibration and validation at Sunflower, Marigold and Leland stations.

validation of HSPF for TN, NSE ranged from 0.19 to 0.52 and R^2 ranged from 0.31 to 0.60. The summary of statistics for calibration and validation of SWAT and HSPF for TP at three USGS gauge stations are given in Figure 7. From the comparison of observed and simulated TP concentration by SWAT and HSPF, it was observed that both the models were in agreement with observed TP concentration values with satisfactory statistics. However, HSPF simulated TP more accurately than SWAT based on calibration and validation statistics.

Calibration and validation statistics for SWAT and HSPF for Upper North Bosque River watershed in Texas showed that SWAT is a better predictor of total phosphorous with mean eror ranging from −1.6 to 17.3 than HSPF with mean error ranging from −2 to −86.9 (Saleh & Du, 2004).

3.2. Effectiveness of BMP

3.2.1. Vegetative filter strip (VFS)

The percentage reduction in the concentration of sediment, TN, and TP after application of VFS to the agricultural lands within BSRW was not similar for two models as HSPF showed lower reduction rate than SWAT for VFS in BSRW. Reduction of surface streamflow due to VFS for both SWAT and HSPF were less than 1%. Reduction in sediment due to VFS using SWAT ranged from 22% to 30%, and

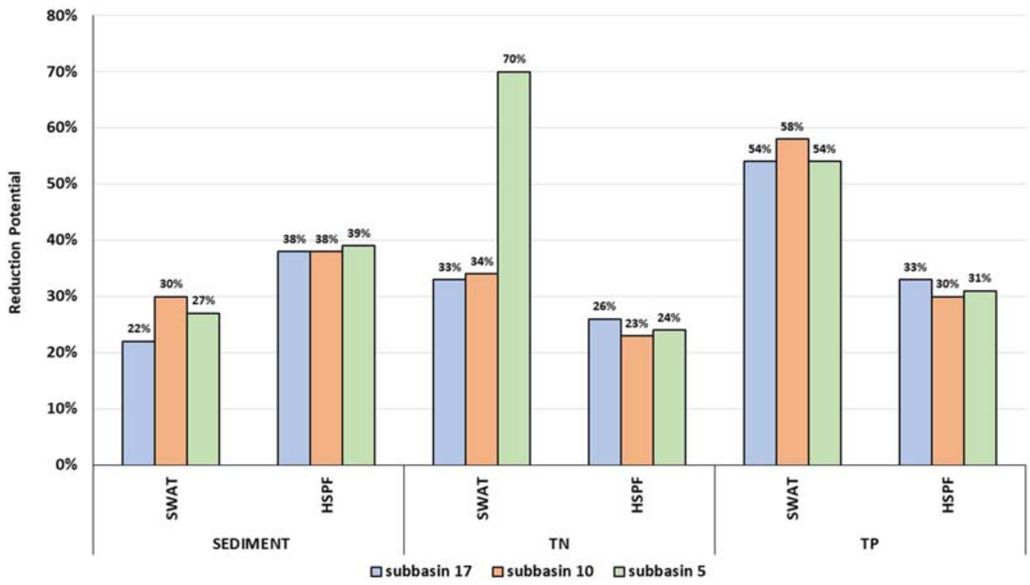

Figure 8. Reduction in sediment, TN, and TP concentration at subbasin 5, subbasin 10 and subbasin 17 after the implication of vegetative filter strip (VFS) in the watershed.

using HSPF ranged from 38% to 39%. Similarly the concentration of TN reduced after application of VFS to the agricultural fields using SWAT and HSPF ranged from 33% to 70%, and 23 to 26% respectively. Likewise, the reduction in concentration of TP after the application of VFS using SWAT and HSPF ranged from 54% to 58%, and 30% to 33% respectively. The percentage reduction of Sediment, TN and TP at three sub-watersheds after implication of VFS using SWAT and HSPF are presented in Figure 8.

SWAT uses simplistic equation based on only the width of VFS, assuming the flow and sediment are coming only from an agricultural field (Neitsch et al., 2005; Park et al., 2011) and HSPF uses user-defined removal fractions for different pollutants based on previous studies. The VFS simulation module of both the models has some limitations – such as the spatial location of VFS is not considered and its efficiency is based only on the VFS width in SWAT (Park et al., 2011) and the user-defined fraction used in HSPF may not represent effective application of BMPs leading to very basic results (Xie et al., 2015).

The implication of VFS of varying widths in HSPF for the Upper Little Miami River basin in Ohio, USA had indicated that these VFS were able to reduce the TN by 2.9% to 6.1%, and TP by 3.2 to 7.8% (Liu & Tong, 2011). Modification in SWAT model was performed to enhance the physical representation of VFS by improvement in the representation of ecohydrological processes and land management practices and its verification conducted at central Iowa showed 54% reduction in TN, and 83% reduction in TP after application of VFS (Cibin et al., 2018). Nutrient reduction potential due to the application of VFS in HSPF was always seen lower than in SWAT. SWAT is found to be a better alternative to other models like HSPF, AnnAGNPS, and VFSMOD for the simulation of VFS impact (Xie et al., 2015).

3.2.2 . Tailwater recovery pond (TRP)

The sediment, TN, and TP concentrations reduction by applying TRP using SWAT and HSPF models were not found similar as SWAT showed a lower reduction rate for sediment and nutrients than HSPF. Reduction of surface streamflow by application of TRP in both the models were less than 1%. Reduction in sediment by TRP using SWAT and HSPF ranged from 17% to 25%, and 18% to 43% respectively. Implication of TRP using SWAT reduced the concentrations of TN and TP by 6% to 7%, and 1% to 2% respectively. Likewise Application of TRP using HSPF reduced concentrations of TN and TP by 0.3% to 0.9%, and 0.9% to 1% respectively. The percentage reduction in Sediment, TN, and TP at three sub-watersheds after implementation of TRP using SWAT and HSPF are presented in Figure 9.

The difference in reduction potential for two models is probably because of their limitation in simulating the effect of TRP. Pond module used in SWAT considers a single equivalent pond for each sub-basin as an aggregation of all the TRPs within that sub-basin such that all the water is stored in the single virtual pond (Mekonnen et al., 2016). Similarly, HSPF considers user-defined removal fractions for different pollutants based on previous studies but does not considers other physical characteristics of the pond (Xie et al., 2015).

The effect of TRP was examined in BSRW using SWAT model which showed that it helped to reduce sediment concentration up to 20% (Ni & Parajuli, 2018). Effect of sediment pond was examined for Orestimba Creek Watershed in California using SWAT and found that sediment load was reduced by about 58% and dissolved phosphorous coming out of pesticides such as chlorpyrifos and diazinon was reduced by less than 10% (Zhang & Zhang, 2011). Effect of storage pond was examined for the site located in Middle Tombigbee-Lubbub watershed, Mississippi, which showed they can be effective in storm streamflow control and nutrient load reduction (Karki et al., 2018). SWAT was modified through the incorporation of nutrient in TRPs and the nutrient removal by TRPs before entering the main channel was evaluated (Luo & Zhang, 2009). Though the HSPF studies using TRP as a BMP to reduce nutrients from the watershed are not documented.

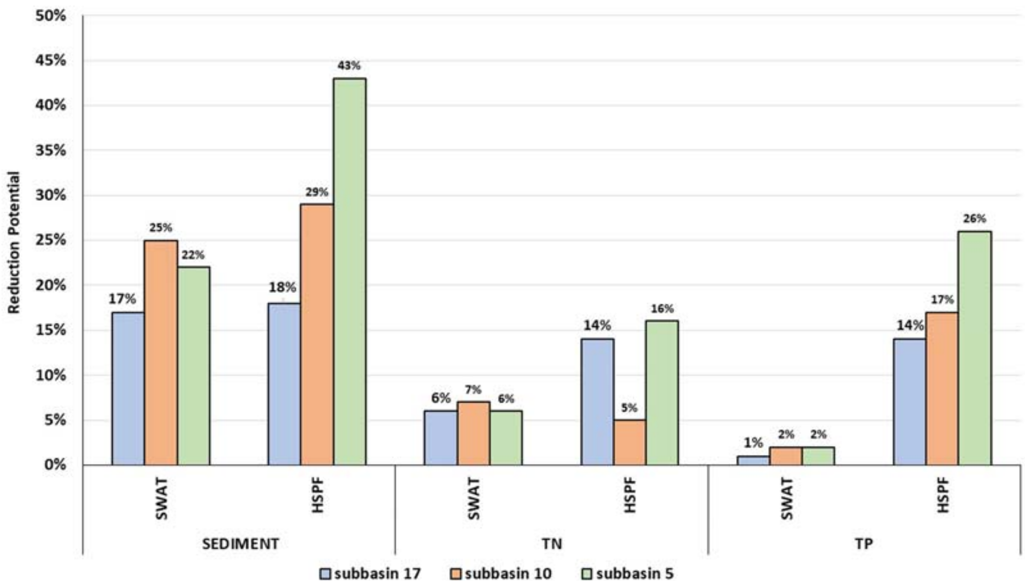

Figure 9. Reduction in sediment, TN, and TP concentrations at subbasin 5, subbasin 10 and subbasin 17 after the implication of Tailwater Recovery Pond (TRP) in the watershed.

4. Implication of the study results and future research direction

This study compared two hydrological models, simulated model outputs after model calibration and validation, applied BMPs, and quantified BMPs impact on sediment and nutrient concentrations within the BSRW. The results obtained from this study has implication within the BSRW especially for the selection of appropriate hydrological and water quality models to simulate hydrologic and water quality conditions. Modelling process, methods, BMPs selection, and results of the current study may be helpful to other similar agricultural watersheds and model users. Future study should consider modelling more BMP scenarios, which help to identify suite of BMPs appropriate for the BSRW to reduce pollutant concentrations.

5. Conclusion

The overall statistics for calibration and validation of SWAT and HSPF suggested that both the models were capable of simulating streamflow, sediment, TN, and TP concentrations with reasonable model efficiency. The statistics during the simulation for both the models suggested that SWAT was an appropriate model for the simulation of streamflow and sediment concentration with NSE and R^2 ranging from 0.41 to 0.81 and 0.33 to 0.84 respectively, than HSPF having NSE ranging from 0.32 to 0.59 and R^2 ranging from 0.35 to 0.66. On the other hand, model efficiency of HSPF was found equally good with NSE and R^2 ranging from 0.19 to 0.85 and 0.28 to 0.85 respectively, as that of SWAT during simulation of nutrient concentrations (TN and TP) having NSE and R^2 ranging from 0.27 to 0.64 and 0.36 to 0.93 respectively. In general, SWAT showed better performance during simulation of streamflow and sediment concentration, and HSPF performed better during simulation of nutrient concentration, according to the calibration and validation statistics. Apart from the statistics obtained during calibration and validation, additional factors such as equations used in the model, availability of input data, parameters used, and ease of model interface development should also be considered in selecting appropriate model for each watershed. SWAT is a very user-friendly model as compared to HSPF (Im et al., 2003), as it has an ArcGIS extension and interface called ArcSWAT (ArcSWAT, 2020), which is comparatively easier to use than HSPF. Apart from that, most of the parameters in SWAT can be generated from GIS data and can be easily adjusted within ArcSWAT. On the other hand, HSPF includes a lot of empirical parameters to represent the hydrologic cycle, sediment loss and nutrient transport and the calibration of these parameters in HSPF is very time-consuming.

During the evaluation of both VFS and TRP BMPs, SWAT had higher reduction rate for sediment, TN and TP ranging from 17% to 30%, 6% to 70%, and 1% to 58% respectively; than HSPF whose reduction rate for sediment, TN and TP ranged from 18 to 43%, 5 to 26% and 14 to 33% respectively. The difference in simulation results of same BMPs applying two different models was mainly due to the differences in equations, mechanisms and parameters used in the models. For example: SWAT uses SCS streamflow curve number method to estimate surface streamflow while HSPF used infiltration equation for the estimation of surface streamflow (Van Liew et al., 2003). Similarly, a simplified equation based on width of the filter strip is used in SWAT to estimate sediment trapping efficiency due to VFS (Neitsch et al., 2005); while HSPF uses the unique module called BMPRAC and pre determined removal fractions for different pollutants to estimate the effect of BMPs (Xie et al., 2015). In the same way, effect of TRP in SWAT is estimated using pond module based on mass balance equation, whereas in HSPF, it is evaluated using the BMPRAC module based on removal fractions for different pollutants.

The case study determined SWAT was more appropriate model than HSPF for the BSRW based on calibration and validation statistics and performance of BMPs in reduction of sediment, and nutrient concentrations. The results from this case study can be beneficial to other modellers and end-users in selecting appropriate model according to the need of modelling questions and type of watershed.

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References

Abbaspour, K. C. (2007). 'User manual for SWAT-CUP, SWAT calibration and uncertainty analysis programs', *Swiss Federal Institute of Aquatic Science and Technology, Eawag, Duebendorf, Switzerland*.

Abdelwahab, O. M. M., Ricci, G. F., Girolamo, A. M., & Gentile, F. (2018). Modelling soil erosion in a Mediterranean watershed: Comparison between SWAT and AnnAGNPS models. *Environmental Research*, *166*, 363–376. https://doi.org/10.1016/j.envres.2018.06.029

Ackerman, D., Schiff, K. C., & Weisberg, S. B. (2005). Evaluating HSPF in an arid, urbanized watershed. *Journal of the American Water Resources Association*, Wiley Online Library, *41*(2), 477–486. https://doi.org/10.1111/j.1752-1688.2005.tb03750.x

ArcSWAT. (2020). *Soil and Water Assessment tool software*. https://swat.tamu.edu/software/arcswat/.

Arnold, J. G., Kiniry, J. R., Srinivasan, R., Williams, J. R., Hanery, E. B., & Neitsch, S. L. (2012). Soil and water assessment tool input/output documentation version 2012. *Texas Water Resources Institute*, *7*.

Behera, S., & Panda, R. K. (2006). Evaluation of management alternatives for an agricultural watershed in a sub-humid subtropical region using a physical process based model. *Agriculture, Ecosystems & Environment*, Elsevier, *113*(1–4), 62–72. https://doi.org/10.1016/j.agee.2005.08.032

Borah, D. K., Ahmadisharaf, E., Padmanabhan, G., Imen, S., & Mohamoud, Y. M. (2019). Watershed models for development and implementation of total maximum daily loads. *Journal of Hydrologic Engineering*, *24*(1), 03118001. https://doi.org/10.1061/(ASCE)HE.1943-5584.0001724.

Cibin, R., Chaubey, I., Helmers, M., Sudheer, K. P., White, M. J. & Arnold J. G. (2018). 'An improved representation of vegetative filter strips in SWAT', *Transactions of the ASAE*. American Society of Agricultural and Biological Engineers.

Clark, M., & Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters*, IOP Publishing, *12*(6), 64016. https://iopscience.iop.org/article/10.1088/1748-9326/aa6cd5/meta

Dakhlalla, A. O., Parajuli, P. B., Ouyang, Y. & Schmitz, W. (2016). Evaluating the impacts of crop rotations on groundwater storage and recharge in an agricultural watershed. *Agricultural Water Management*, *163*, 332–343. https://doi.org/10.1016/j.agwat.2015.10.001

Dakhlalla, A. O., & Parajuli, P. B. (2019). Assessing model parameters sensitivity and uncertainty of streamflow, sediment, and nutrient transport using SWAT. *Information Processing in Agriculture*, *6*(1), 61–72. https://doi.org/10.1016/j.inpa.2018.08.007

Diaz-Ramirez, J. N., McAnally, W. H., & Martin, J. L. (2011). Analysis of hydrological processes applying the HSPF model in selected watersheds in Alabama, Mississippi, and Puerto Rico. *Applied Engineering in Agriculture*, American Society of Agricultural and Biological Engineers, *27*(6), 937–954. https://doi.org/10.13031/2013.40627

Draper, N. R., & Smith, H. (1966). Applied regression analysis, New York, 1966. In *EM Pugh and GH Winslow, The Analysis of physical Measurements* (p. 26). Addison-Wesley.

Duda, P. B., Hummel, P. R., Donigian Jr, A. S., & Imhoff, J. C. (2012). BASINS/HSPF: Model use, calibration, and validation. *Transactions of the ASABE*, American Society of Agricultural and Biological Engineers, *55*(4), 1523–1547. https://doi.org/10.13031/2013.42261

Gao, F., Feng, G., Han, M., Dash, P., Jenkins, J., & Liu, C. (2019). Assessment of surface water resources in the Big Sunflower River watershed using Coupled SWAT–MODFLOW model. *Water*, Multidisciplinary Digital Publishing Institute, *11*(3), 528. https://doi.org/10.3390/w11030528

Gassman, P. W., Reyes, M. R., Green, C. H., & Arnold, J. G. (2007). The soil and water assessment tool: Historical development, applications, and future research directions. *Transactions of the ASABE*, American Society of Agricultural and Biological Engineers, *50*(4), 1211–1250. https://doi.org/10.13031/2013.23637

Gitau, M. W., Gburek, W. J., & Bishop, P. L. (2008). Use of the SWAT model to quantify water quality effects of agricultural BMPs at the farm-scale level. *Transactions of the ASABE*, American Society of Agricultural and Biological Engineers, *51*(6), 1925–1936. https://doi.org/10.13031/2013.25398

Im, S., Brannan, K. M., Mostaghimi, S., & Kim, S. M. (2007). Comparison of HSPF and SWAT models performance for streamflow and sediment yield prediction. *Journal of Environmental Science and Health, Part A*, Taylor & Francis, *42*(11), 1561–1570. https://doi.org/10.1080/10934520701513456

Im, S., Brannan, K. M., & Mostaghimi, S. (2003). Simulating hydrologic and water quality impacts in an urbanizing watershed 1. *JAWRA Journal of the American Water Resources Association*, Wiley Online Library, *39*(6), 1465–1479. https://doi.org/10.1111/j.1752-1688.2003.tb04432.x

Johnson, M. S., Coon, W. F., Mehta, V. K., Steenhuis, T. S., Brooks, E. S., & Boll, J. (2003). Application of two hydrologic models with different streamflow mechanisms to a hillslope dominated watershed in the northeastern US: A comparison of HSPF and SMR. *Journal of Hydrology*, *284*(1), 57–76. https://doi.org/10.1016/j.jhydrol.2003.07.005

Karki, R., Tagert, M. L. M., & Paz, J. O. (2018). Evaluating the nutrient reduction and water supply benefits of an on-farm water storage (OFWS) system in East Mississippi. *Agriculture, Ecosystems & Environment*, *265*, 476–487. https://doi.org/10.1016/j.agee.2018.06.024

Kim, S. M., Benham, B. L., Brannan, K. M., Zeckoski, R. W., & Doherty, J. (2007). Comparison of hydrologic calibration of HSPF using automatic and manual methods. *Water Resources Research*, Wiley Online Library, *43*(1). https://doi.org/10.1029/2006WR004883

Krause, P., Boyle, D. P., & Bäse, F. (2005). Comparison of different efficiency criteria for hydrological model assessment. *Advances in Geosciences*, *5*, 89–97. https://doi.org/10.5194/adgeo-5-89-2005

Liu, Z., & Tong, S. T. Y. (2011). Using HSPF to model the hydrologic and water quality impacts of Riparian land-Use Change in a small watershed. *Journal of Environmental Informatics*, *17*(1). https:/doi.org/10.3808/jei.201100183

Luo, Y. (2019). Modeling the Mitigating effects of conservation practices for Pyrethroid uses in agricultural Areas of California. In Xiaotong Wang & Youji Wang (Eds.), *Pesticides in surface water: Monitoring, modeling, Risk assessment, and management* (pp. 275–289). ACS Publications.

Luo, Y., & Zhang, M. (2009). Management-oriented sensitivity analysis for pesticide transport in watershed-scale water quality modeling using SWAT. *Environmental Pollution*, *157*(12), 3370–3378. https://doi.org/10.1016/j.envpol.2009.06.024

Maharjan, G. R., Park, Y. S., Kim, N. W., Shin, D. S., Choi, J. W., Hyun, G. W., Jeon, J. H., Ok, Y. S., & Lim, K. J. (2013). Evaluation of SWAT

sub-daily streamflow estimation at small agricultural watershed in Korea. *Frontiers of Environmental Science & Engineering*, *7*(1), 109–119. https://doi.org/10.1007/s11783-012-0418-7
Mekonnen, B. A., Mazurek, K. A., & Putz, G. (2016). Incorporating landscape depression heterogeneity into the soil and water assessment Tool (SWAT) using a probability distribution. *Hydrological Processes*, Wiley Online Library, *30*(13), 2373–2389. https://doi.org/10.1002/hyp.10800
Merriman, K. R., et al. (2018). Calibration of a field-scale soil and water assessment Tool (SWAT) model with field placement of best management practices in Alger Creek, Michigan. In *Sustainability* (*10* (3), p. 851) Multidisciplinary Digital Publishing Institute.
Mishra, A., Froebrich, J., & Gassman, P. W. (2007a). Evaluation of the SWAT model for assessing sediment control structures in a small watershed in India. *Transactions of the ASABE*, American Society of Agricultural and Biological Engineers, *50*(2), 469–477. https://doi.org/10.13031/2013.22637
Mishra, A., Kar, S., & Pandey, A. C. (2008). Comparison of SWAT with HSPF model in Predicting hydrologic processes of a small Multivegetated watershed. *Journal of Agricultural Engineering*, Indian Society of Agricultural Engineers, *45*(4), 29–35.
Mishra, A., Kar, S., & Singh, V. P. (2007). Determination of streamflow and sediment yield from a small watershed in sub-humid subtropics using the HSPF model. *Hydrological Processes: An International Journal*, Wiley Online Library, *21*(22), 3035–3045. https://doi.org/10.1002/hyp.6514
NAAS. (2020). 'United States Department of Agriculture, National Agricultural Statistics Service', *USDA, NASS*. https://nassgeodata.gmu.edu/CropScape/.
Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models part I—A discussion of principles. *Journal of Hydrology*, Elsevier, *10*(3), 282–290.
Neitsch, S., Arnold, J., Kiniry, J.e.a., Srinivasan, R., & Williams, J. (2002). 'Soil and water assessment tool user's manual version 2000', *GSWRL report*, 202(02–06).
Neitsch, S. L., Arnold, J. G., Kiniry, J. R., Williams, J. R., & King, K. W. (2005). Soil and water assessment tool theoretical documentation, version 2005. Temple, Tex.: USDA-ARS Grassland. *Soil and Water Research Laboratory*, *8*.
Ni, X., & Parajuli, P. B. (2018). Evaluation of the impacts of BMPs and tailwater recovery system on surface and groundwater using satellite imagery and SWAT reservoir function. *Agricultural Water Management*, Elsevier, *210*, 78–87. https://doi.org/10.1016/j.agwat.2018.07.027
NOAA. (2020). *National Oceanic and Atmospheric Administration, National Centers for Environmental Information*. https://www.ncdc.noaa.gov/.
NRCS. (2020). *United States Department of Agriculture, Natural Resource Conservation Service*. https://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/.
Ouyang, Y. (2012). A potential approach for low flow selection in water resource supply and management. *Journal of Hydrology*, *454–455*, 56–63. https://doi.org/10.1016/j.jhydrol.2012.05.062
Ouyang, Y., Leininger, T. D., & Moran, M. (2013). Impacts of reforestation upon sediment load and water outflow in the lower Yazoo River watershed, Mississippi. *Ecological Engineering*, Elsevier, *61*, 394–406. https://doi.org/10.1016/j.ecoleng.2013.09.057
Parajuli, P. B., Nelson, N. O., Frees, L. D., & Mankin, K. R. (2009). Comparison of AnnAGNPS and SWAT model simulation results in USDA-CEAP agricultural watersheds in south-central Kansas. *Hydrological Processes: An International Journal*, Wiley Online Library, *23*(5), 748–763. https://doi.org/10.1002/hyp.7174
Park, Y. S., Park, J. H., Jang, W. S., Ryu, J. C., Kang, H., Choi, J., & Lim, K. J. (2011). Hydrologic response unit routing in SWAT to simulate effects of vegetated filter strip for south-Korean conditions based on VFSMOD. *Water. Molecular Diversity Preservation International*, *3* (3), 819–842. https://doi.org/10.3390/w3030819
Rahman, M. M., Thompson, J. R., & Flower, R. J. (2016). An enhanced SWAT wetland module to quantify hydraulic interactions between riparian depressional wetlands, rivers and aquifers. *Environmental Modelling & Software*, Elsevier, *84*, 263–289. https://doi.org/10.1016/j.envsoft.2016.07.003
Ribarova, I., Ninov, P., & Cooper, D. (2008). Modeling nutrient pollution during a first flood event using HSPF software: Iskar River case study, Bulgaria. *Ecological Modelling*, Elsevier, *211*(1–2), 241–246. https://doi.org/10.1016/j.ecolmodel.2007.09.022
Risal, A., Bhattarai, R., Kum, D., Park, Y. S., Yang, J. E., & Lim, K. J. (2016). Application of Web ERosivity Module (WERM) for estimation of annual and monthly R factor in Korea. *Catena*, *147*, 225–237. https://doi.org/10.1016/j.catena.2016.07.017
Risal, A., Lim, K. J., Bhattarai, R., Yang, J. E., Noh, H., Pathak, R., & Kim, J. (2018). Development of web-based WERM-S module for estimating spatially distributed rainfall erosivity index (EI30) using RADAR rainfall data. *Catena*, *161*, 37–49. https://doi.org/10.1016/j.catena.2017.10.015
Risal, A., Parajuli, P. B., Dash, P., Ouyang, Y., & Linhoss, A. (2020). Sensitivity of hydrology and water quality to variation in land use and land cover data. *Agricultural Water Management*, *241*, 106366. https://doi.org/10.1016/j.agwat.2020.106366
Risal, A., & Parajuli, P. B. (2019). Quantification and simulation of nutrient sources at watershed scale in Mississippi. *Science of the Total Environment*, Elsevier, *670*, 633–643. https://doi.org/10.1016/j.scitotenv.2019.03.233
Saleh, A., Arnold, J. G., Gassman, P. W. A., Hauck, L. M., Rosenthal, W. D., Williams, J. R., & McFarland, A. M. S. (2000). Application of SWAT for the upper North Bosque River watershed. *Transactions of the ASAE*, American Society of Agricultural and Biological Engineers, *43*(5), 1077. https://doi.org/10.13031/2013.3000
Saleh, A., & Du, B. (2004). Evaluation of SWAT and HSPF within BASINS program for the upper North Bosque River watershed in central Texas. *Transactions of the ASAE*, American Society of Agricultural and Biological Engineers, *47*(4), 1039. https://doi.org/10.13031/2013.16577
Santhi, C., Arnold, J. G., Williams, J. R., Dugas, W. A., Srinivasan, R., & Hauck, L. M. (2001). Validation of the swat model on a large RWER basin with point and nonpoint sources 1. *JAWRA Journal of the American Water Resources Association*, Wiley Online Library, *37* (5), 1169–1188. https://doi.org/10.1111/j.1752-1688.2001.tb03630.x
USEPA. (2003). Better Assessment Science Integrating Point and Nonpoint Sources, BASINS, Tutorial and Training. https://www.epa.gov/ceam/basins-tutorials-and-training.
USGS. (2020). *United States Geological Survey*. https://www.usgs.gov/.
Van Liew, M. W., Arnold, J. G., & Garbrecht, J. D. (2003). Hydrologic simulation on agricultural watersheds: Choosing between two models. *Transactions of the ASAE*, American Society of Agricultural and Biological Engineers, *46*(6), 1539. https://doi.org/10.13031/2013.15643
Waidler, D., et al. (2011). *Conservation practice modeling guide for SWAT and APEX*. Texas Water Resources Institute. http://hdl.handle.net/1969.1/94928
Xie, H., Chen, L., & Shen, Z. (2015). Assessment of agricultural best management practices using models: Current issues and future perspectives. *Water*, Multidisciplinary Digital Publishing Institute, *7*(3), 1088–1108. https://doi.org/10.3390/w7031088
Xie, H., & Lian, Y. (2013). Uncertainty-based evaluation and comparison of SWAT and HSPF applications to the Illinois River basin. *Journal of Hydrology*, Elsevier, *481*, 119–131. https://doi.org/10.1016/j.jhydrol.2012.12.027
YMD. (2011). *Yazoo Mississippi Delta Joint Water Management District. Annual work summary*. www.ymd.org.
Zhang, X., & Zhang, M. (2011). Modeling effectiveness of agricultural BMPs to reduce sediment load and organophosphate pesticides in surface streamflow. *Science of the Total Environment*, Elsevier, *409* (10), 1949–1958. https://doi.org/10.1016/j.scitotenv.2011.02.012