International Conference on Hydroinformatics

2014

Simulation Of Non-Point Source Pollution In Zhang River Basin

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SIMULATION OF NON-POINT SOURCE POLLUTION IN ZHUOZHANG RIVER BASIN

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ABSTRACT

Since 1987, the China Government started the “The Water Resource Protection and Management of Hai River Basin” program aimed at tackling the problem of water pollution and realizing the comprehensive control of the ecosystem and water resources in the whole basin. This study aims to model one of the program’s catchments – Zhuozhang River Basin (ZRB), which is a typical area with the striking water scarcity and water quality deterioration in Hai River Basin (HRB). The distributed hydrological model SWAT(Soil and Water Assessment Tool) was used to simulate all related processes affecting water quantity, sediment, and nutrient loads in the catchment using historical flow and meteorological data for 5 years(January 2005-December 2009). Data on management practices (crop rotation, planting date, fertilizer quantity and irrigation) were included in the model during the simulation period of 5 years .The main objectives of this study were to evaluate the long-term impact of point source (PS) and non-point source (NPS) pollution on water quality loadings and to determine the contribution of point and non-point sources in the entire catchment. Based on the simulated results, the spatio-temporal distributions of flow, sediment and nutrient loads are analyzed; hence the critical areas of soil erosion and nutrient loss were identified, so as to provide the scientific basis for the water resources allocation and pollutant control in the basin.
Keywords: non-point source pollution; SWAT; water quality modeling; Zhuozhang River Basin

INTRODUCTION

SWAT is the acronym for Soil and Water Assessment Tool, a river basin or watershed scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time [1]. It was used to simulate all related processes affecting water quantity, sediment, and nutrient loads in ZRB, which is a typical area with the striking water scarcity and water quality deterioration in Hai River Basin. SWAT is a semi-distributed hydrological model. It is a continuous model which simulates both the water balance and the nutrient cycle with a daily time step. Because of its availability and user-friendliness in handling input data, SWAT model has been widely used to model hydrology and water quality and simulate the agricultural non-point source pollution [2] not only in America

([3], and [4]) but also in Canada [5], Europe [6], Africa [7] and China ([8], [9], and [10]). No matter what type of problem studied with SWAT, water balance is the driving force behind everything that happens in the watershed. The model's hydrological components are comprised of surface runoff, percolation, lateral flow, ground water, and evapotranspiration and channel transmission loss [11].

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METHOD AND PROCEDURES

Study area

The ZRB with an area of 12088 km^2 is situated in Changzhi City of Shanxi province in the southeastern border of Loess Plateau, and is part of the HRB. Mean elevation of the watershed is about 1084 m above sea level and mean slope is around 17.5%. The lowest point is located at Pingshun County at about 380 m above sea level and the highest point is the chief peak of Taihang mountain at 2541 m above sea level. The study area has a Continental monsoon climate, which is characterized by moderate winters and rainy summer seasons. Mean annual temperature ranges from 7.5 ^{o}C to 12 ^{o}C with the lowest -6.9 ^{o}C in winter and the highest 22.5 oC in summer. The mean annual precipitation for the watershed is about 538 mm to 657 mm, most of which falls during the summer months.

SWAT model setup

The basic data sets both spatial and non-spatial data required to set up the model inputs are: DEM (Digital Elevation Model), soil type map, land use map and climate data. Besides, there are 3 large reservoirs in the upstream areas and the water consumption for irrigation, industrial and domestic water uses in this watershed are extremely complex, which made the hydrological simulation more challenging. Accurately reproducing water management practices is one of the most complicated portions of data input for the model. These collected data are described in Table 1.

The processing of watershed delineation is achieved in a two-step approach. First the digital elevation model (DEM) was used by SWAT to generate the stream network and the watershed boundary. Then the subbasin outlets for calibration should be added. Besides, the locations of point sources and reservoirs should also be added during the procedure. In this model, we divided ZZRB into 37 watersheds with the threshold area of 242 km2. Figure 1 shows the ZZRB with delineated subbasins, digital elevation model, river network, and meteorological stations. Interpolation of weather data is achieved through the nearest-neighbor method, i.e. every subbasin receives precipitation from one single rain gauge nearest to its centroid. We have 31 rain gauges and 3 weather stations in the watershed to make sure that each subbasin has at least one rain gauge as shown in Figure 1.

In the SWAT model, soil water content, surface runoff, nutrient cycles, crop growth and management practices are simulated for each HRU (Hydrologic Response Unite), and then aggregated for the subbasin by a weighted average. Hydrologic response unites are portions of a subbasin that possess unique land use and soil classes. As shown in Figure 2, agriculture is the dominant landuse within the study area. Approximately 52% of the land within the basin is used for agricultural activities. Close to 25% of the total area is covered by pasture, about 20% under forests. The rest of the area is occupied by surface waters and urban areas. The dominant soils of the catchment are Calcaric Cambisols (CMc) and Calcaric Fluvisols (FLc). Soil map used in this study can be seen in Figure 3. In this model, we divided ZZRB into 792 HRUs with the landuse and soil thresholds of 6% and 6%.

Table 1. Model Input Data Sources for ZZRB

Data Type	Source	Data Description/Properties
DEM	International Scientific Data Service Platform	Digital elevation model, a grid size of 30 m × 30 m
Soil Map	Harmonized World Soil Database	Soil physical properties such as texture, etc. scale (1:1000,000)
Land Use Map	West Data Centre	Land use classifications, scale of map (1:100,000)
Climate Data	China Meteorological Data Sharing Service System	Temperature, wind speed, humidity (3 weather stations, 1986-2011)
Precipitation	Hydrological Yearbook	31 precipitation gages, 2005-2009
Reservoir	Hydrological Yearbook	3 large reservoirs, storage capacity, out flow, water supply
Point sources	Haihe River Water Conservancy Commission	81 wastewater outlets, discharge flow, discharge loading of COD, NH3-N

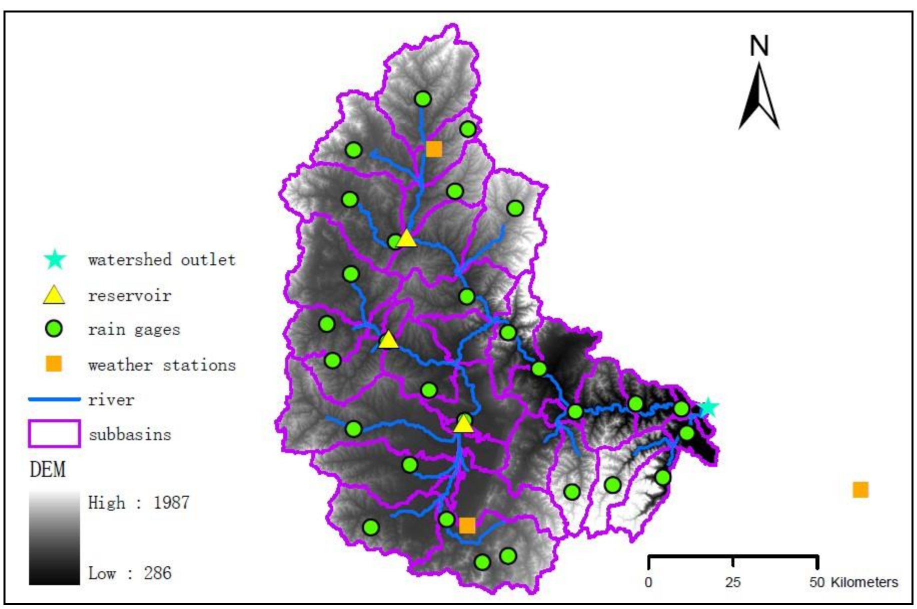

Figure 1. The ZZRB with Delineated Subbasins, Digital Elevation Model, River Network, and Meteorological Stations

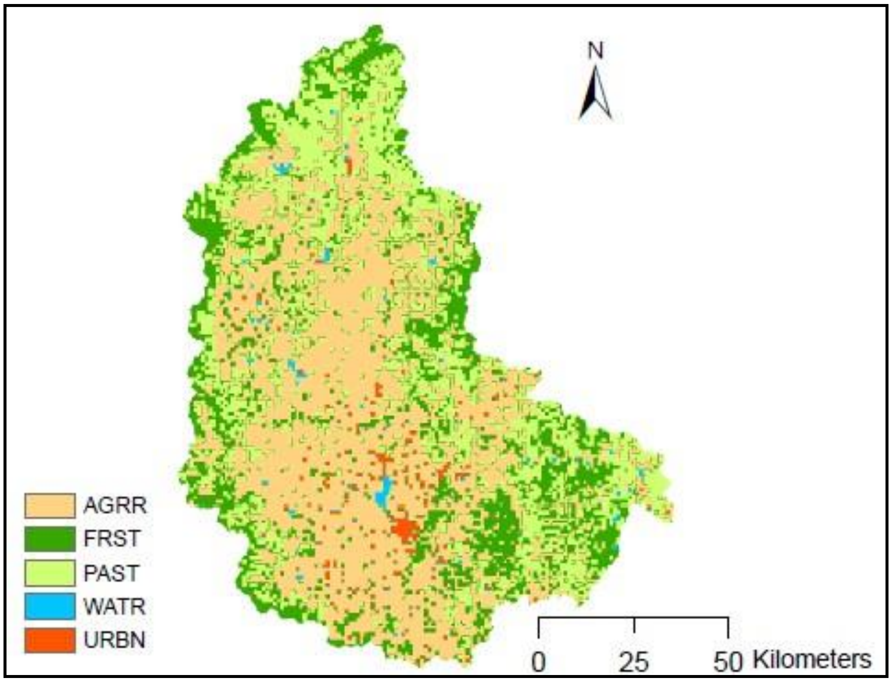

Figure 2. Land Use Classification

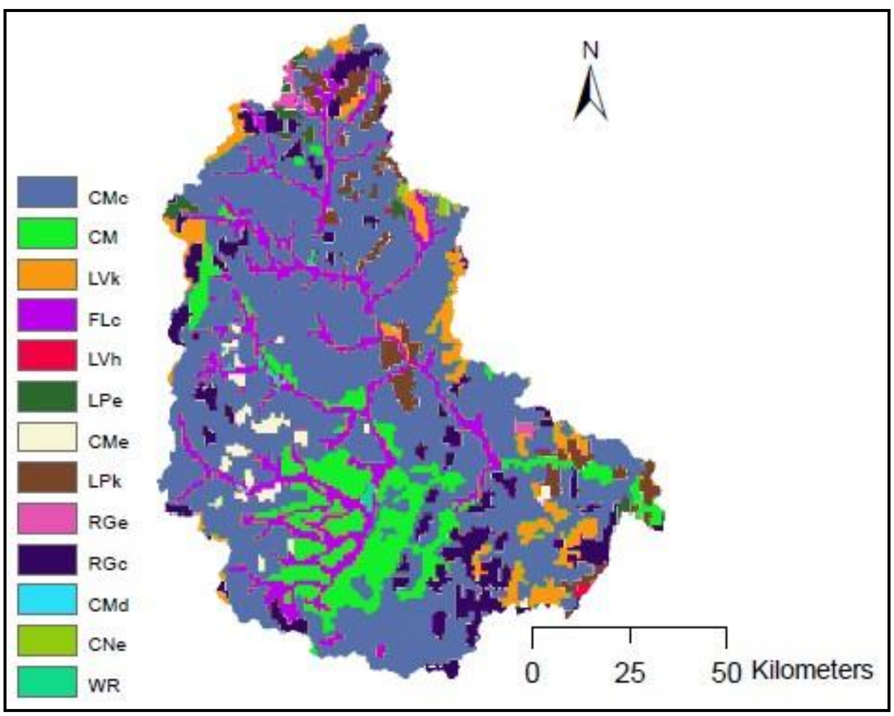

Figure 3. Soil Classification

RESULTS

SWAT model was applied successfully in ZRB. Based on the simulated results, the contributions of point and non-point source were evaluated for the entire catchment. Because precipitation is considered to be the driven force of non-point source pollution, nutrients load loss were analyzed for flood season which was calculated from June to September in this study. Results can be seen in Table 2. Get rid of point source data to calculate the non-point source pollution and thus the source contributions results were achieved, which can be seen in Table 3. The average contribution of non-point source pollution for total nitrogen (TN) was 48.6%, and 42.9% for total phosphorus (TP). In rainy 2007 year, average contributions of non-point source pollution reached 61.1% and 59.2% for TN and TP respectively, which means the non-point source pollution is positively correlated with the precipitation. Meanwhile, the critical areas of soil erosion and nutrient loss were normally located in mountainous agricultural area with relatively high amount of precipitation. Practices must be implemented for critical source areas to prevent severe non-point source pollution.

Table 2. Nutrient loss for flood season

year	Runoff (10^8 m^3)		TN (t)		TP (t)	
	6-9 months	Percent (%)	6-9 months	Percent (%)	6-9 months	Percent (%)
2006	1.7	55.2	2610.3	59.3	140.3	52.1
2007	1.5	54.0	1496.0	27.5	204.0	59.5
2008	0.8	54.2	1415.3	27.0	135.0	40.6
2009	0.2	32.6	1029.9	20.1	52.0	16.0
average	1.0	49.0	1637.9	33.5	132.8	42.0

Note: the percent means continent total yield for flooding season (6-9 months) versus that for total year

Table 3. Source contributions

year	TN		TP	
	Point source	Non-point source	Point source	Non-point source
2006	47.5	52.5	55.2	44.8
2007	38.9	61.1	40.8	59.2
2008	60.6	39.4	69.3	30.7
2009	58.6	41.4	63.1	36.9
average	51.4	48.6	57.1	42.9

Acknowledgment

This research was supported by Haihe River Water Conservancy Committee of Ministry of Water Resource for “The Water Resource Protection and Management of Haihe River Basin” program.

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