Preliminary Assessment of the Human Activity Impact on Weihe River Runoff Using SWAT Model

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Abstract—**Aiming at the facts that water resource is insufficient and the environmental base flow is hard to guarantee in Weihe River, which is a typical river in northern China with characteristics like water scarcity, high sediment concentration and pollution, an assessment of human activity effect on Weihe River runoff was carried out by predicting the main river runoff of a typical wet year (2003) using the verified SWAT model of the basic standard period (1960~1969). The results showed that the human activity had caused significant reduction of the main river runoff in wet year. The average annual runoff at Linjiacun station decreased 1.78 billion m^3, and at Huaxian station the value reached 4.96 billion m^3. In the whole year, human activity had placed more reduction effect in non-flood season. The average runoff reduction, in non-flood season, caused by human being was 62.78%, while the effect in flood season was 42.47%. Therefore, making a reasonable united water resource management regulation as well as optimizing the arrangement of soil and water conservation measures would be significant for guaranteeing the environmental base flow and the sustainable development of Weihe River.**

Keywords- human activity; SWAT model; Weihe River

I. INTRODUCTION

River is a nature watercourse affected by both climate factors and human activities. Since recent years, the effect of human being toward hydrological circle of rivers has become harder and harder, and has made an even strengthened side circle. This side circle in China, with its annual water flux 560 billion m^3, takes 20% of the total river flux (2,800 billion m^3) all over the country[1-3]. On the other hand, with the effect of global warming, the runoff response toward climate changing has also become the hotspot of scientific researches, and the hydrological processes in arid and semi-arid area are even more sensitive to this change[4,5]. Thus, finding out the influences of human activities toward river runoff is meaningful and significant for making better use of water resource, ensuring the environmental base blow and sustainable development of river ecosystem.

Located in the south of the Loess Plateau, the Weihe River basin is a region with quite limited water resource, while at the same time, it is also the largest branch of Yellow River with its annual runoff and sediment yield taking 18.1% and 30.8% of that of Yellow River, respectively[6,7]. Various researches serves to illustrate that, in recent years, the runoff in the main Weihe River has decreased a lot because of the rainfall reduction and human activities like building water conservancy and water conservation measures[8-11]. But these researches mostly reach their results in qualitative perspective or through experiential methods, which cannot tell the exact influence of human effect. And this paper, making use of the widely applied distributed hydrological SWAT model and the dataset like DEM, land use, soil and meteorological data, predicted the runoff of a typical wet year in the last 10 years (2003), and evaluated the influence of human activity on Weihe River runoff.

II. MATERIAL AND METHODS

A. Study area

Weihe River, which originates from the north side of Niaoshu Mountain, is the largest branch of Yellow River. With its length 818km and the basin area 13.5×10^4km^2, Weihe River flows from east to west through the Loess Plateau in East Gansu, the Tianshui Basin, the Baoji Vally, the Guanzhong Basin, and make the confluence with Yellow River at Tongguan County in Shaanxi Province. And it takes 502.4km and basin area of 6.71×10^4km^2 in Shaanxi Province before the confluence. Being as the largest branch of Yellow River, the average annual flow of Weihe River reaches 8.09 billion m^3 at Huaxian Station[12,13].

The population of Weihe River basin in Shaanxi Province in 2000 is 22.04 million, with its population density 328 people per km^2, which includes 13.53 million of farmers and 8.52 million of urban population. The annual self-produced water resource of Weihe River basin in Shaanxi Province is 6.99 billion m^3 per year, of which surface and underground water take 6.22 billion m^3/a and 4.88 billion m^3/a and the mutual duplicated water 3.64 billion m^3/a. The water resource per capita in this region is 285.5m^3/a which is only 12.4% of the nation level (2,300m^3/a), and the water resource for farmland is 4,200m^3/hm^2 which is 17.71% of the nation level (23,715m^3/hm^2) [14,15].

B. Data source

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The dataset used in this research includes: DEM, soil and land use data, the serial data of hydrological and meteorological stations. The DEM data, with its resolution 30m, comes from the website of Computer Network Information Center; The Chinese Academy of Sciences (http://datamirror.csdb.cn). And the soil data comes from the 1:500,000 soil map of the Loess Plateau. The land use data comes from the Data Sharing Infrastructure of Earth System Science (www.geodata.cn) with its scale 1:250,000. In addition, the meteorological data comes from the Website of Chinese Meteorological Science Data, which consists of 25 stations. And the hydrological data comes from the database of Loess Plateau Eco-environment of ISWC. Based on the need of this research, the serial data of month runoff from 1960 to 1969 at three hydrological stations was picked up for model construction and verification, and that of 2003 was used for evaluating the human effect.

C. Study period

The Weihe River basin, especially for the Guanzhong region, is greatly affected by human activities. By now, there are more than 20 middle/large reservoirs including 3 of them with capability more than 100 million m^3, and most of which were constructed after 1970. On the other hand, the soil and water conservation measure in this region has expanded rapidly since 1970 which would affect water yield significantly.

Therefore, based on the result of the previous researches and the statue of the construction of water conservancy and water conservation measure, this study picked 1960~1969 as the basic standard period (BSP) when the river is slightly affected by human being. And on the other hand 2000~2008 were chosen as the testing period(TP), which is the human affected period.

The runoff data of different water-sediment condition year in TP was further extracted for assessment on account of the verification result, which had a diverse outcome in different water-sediment condition year.

D. Study methods

a. Research methodology

In this research, a verified SWAT model of the Weihe River basin in the basic standard period (BSP) was established. The verification result was used for estimating the accuracy of modeling the runoff in different typical water-condition year, with which the relative better-fitted simulating year in test period (TP) was picked up. And after that, this model was inputted with the weather data of the chosen year, by which the runoff of main Weihe River was predicted. By comparing with the observation data of runoff, the effect of human activity was assessed (Fig. 1).

b. Analyze methods

Human activities like building reservoir, soil and water conservation measures as well as the rain saving measures would cut down and affect water yield in watershed scale. In order to evaluate the influence, this paper picked the index of human effect using predicted and observed runoff data. This index was calculated as formula 1:

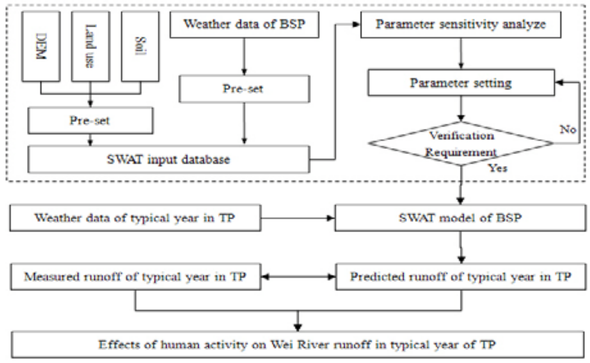


Figure 1. Research route

$$E_h = (Q_{pt} - Q_{mt}) / Q_{pt} \times 100\% \quad (1)$$

Where E_h is the index of human effect. Q_{mt} is the measured runoff of the chosen year in TP, and Q_{pt} is the predicted runoff of the chosen year in TP

III. RESULTS AND DISCUSSION

A. Model construction and verification

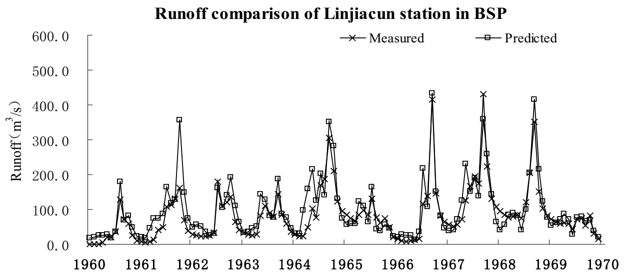
Firstly, the SWAT model database was built with DEM, land use, soil and weather data. After the sensitivity analysis, 14 parameters were picked up for setting the model. And the first 5 years' runoff data of BSP were used for parameter setting and the remaining 5 years' data were left for model verification.

Parameter setting is the most important part of building a model. So, the annual runoff of the main river was firstly verified, and after that the monthly runoff were verified by setting each parameter. The coefficients of Nash-Sutcliffe (NS) and correlation (R^2) were used for assessing the results of model setting. And the verifying criteria is NS≥0.5 and $R^2 \geq 0.6$, which means unless NS is more than 0.5 and R^2 is more than 0.6, the model would not be qualified for simulation(Fig. 2).

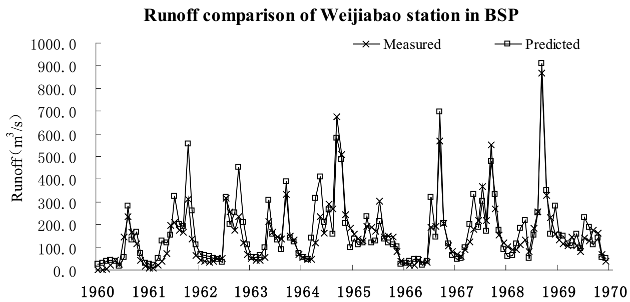
As shown in Tab. 1, the result of the verifying period met the criteria quite well, which meant that the model would be qualified for predicting runoff in a long run. However, the results in different water-condition year indicated that the model performed better in wet year. Thus, the year of 2003, which is a typical wet year in TP, was chosen for evaluating the human activity effect on Weihe River runoff in wet year.

TABLE I. RESULT OF VERIFICATION

Hydrological	Setting（1960~1964）		Verifying（1965~1969）		BSP（1960~1969）		Typical wet year of verification period(1968)		Typical average year of verification period(1965)	
stations	NS	R^2	NS	R^2	NS	R^2	NS	R^2	NS	R^2
Linjiacun	0.6485	0.7512	0.8763	0.8602	0.7808	0.8135	0.8891	0.9329	0.6609	0.7179
Weijiabao	0.7201	0.7533	0.8295	0.8420	0.7741	0.7923	0.9333	0.9374	0.3304	0.6987
Huaxian	0.7877	0.8222	0.7491	0.7337	0.7730	0.7790	0.8624	0.8713	0.2234	0.6241



(a)



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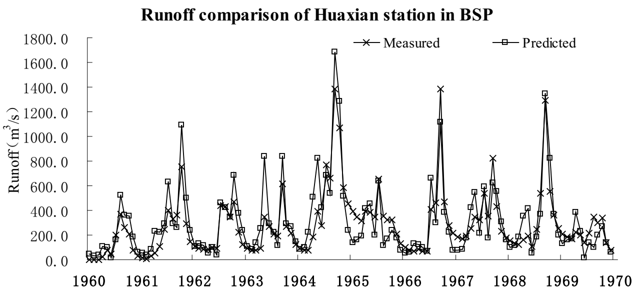

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Figure 2. Runoff comparison results of different stations in BSP: (a)Linjiacun station; (b)Weijiabao station; (c)Huaxian station

TABLE II. THE MEASURED AND PREDICTED ANNUAL RUNOFF IN 2003

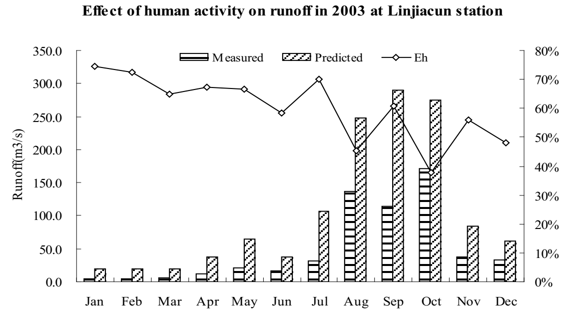
Hydrological stations	Predicted runoff[a]	Measured runoff	Runoff reduction
Linjiacun	33.44	15.60	17.84
Weijiabao	68.47	30.42	38.05
Huaxian	142.93	93.38	49.55

a. the unit of runoff is 10^8 m^3

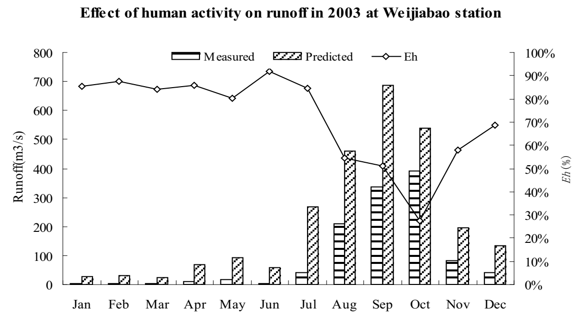
TABLE III. HUMAN EFFECT AT DIFFERENT STATIONS IN 2003

Hydrological stations	Total influence		Flood season (Jul-Oct)		Non-flood season (Nov-Jun)	
	Runoff reduction[a]	E_h (%)	Runoff reduction	E_h (%)	Runoff reduction	E_h (%)
Linjiacun	17.84	53.3	12.38	50.7	5.46	60.5
Weijiabao	38.06	55.6	25.85	49.9	12.20	73.3
Huaxian	49.55	34.7	27.48	26.8	22.06	54.5

a. The unit of runoff reduction is 10^8 m^3



(a)



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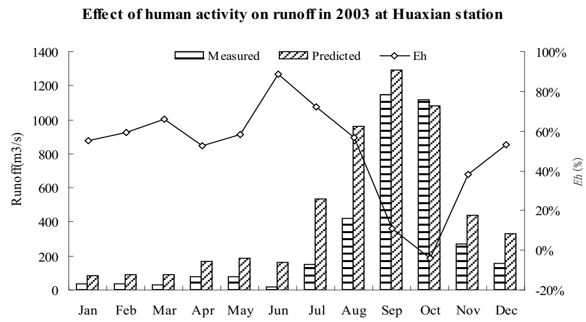

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Figure 3. Human activity influence on runoff in different months of 2003: (a)Linjiacun station; (b)Weijiabao station; (c)Huaxian station

B. *Runoff prediction*

After the verification of SWAT model in BSP, the weather data in 2003 was inputted into the model. In this way, the runoff in typical wet year (2003) with human effects eliminated was predicted(Fig 3).

C. *Human activity effect analyze*

Compared with the predicted result, the measured annual runoff in 2003 had decreased significantly. At Linjiacun station, the average annual runoff had decreased 1.78 billion m^3, which took 53.3% of the predicted runoff. And this reduction reached 4.96 billion m^3 at Huaxian station. The most intensive influence of human effect on annual runoff happened at Weijiabao station, which cut off 55.6% flow water of Weihe River (Tab. 2).

Figure 3 showed the variation tendency of the measured and predicted runoff data as well as the index of human effect at three stations distributed in the year, which indicated that the majority of flow water came at the period between Jul. and

Oct (flood season). And in the rest of the year (non-flood season), the flow water only took about 20% of the total runoff in the whole year. However, the index of human effect enjoyed a counter trend in the whole year. The most intensive influence of human activity mainly happened at those months with quite limited inlet water. At different stations, the average effect reached 62.78% of the predicted runoff. But in flood season, because of the huge sediment concentration and the defense of flood, a relatively small portion of water (the average effect is 42.47%) was utilized by human being (Tab. 3).

The runoff result of Linjiacun station showed that the human activity in the controlling area of this station, where water conservation measures were mainly placed, had caused 1.78 billion m^3 reduction of runoff, which indicated that soil and water conservation measure is also an important human factor that affects Weihe River runoff.

On the other hand, in the controlling area between Linjiacun and Weijiabao station, where large water conservancies like Baojixia Irrigation District, Fengjiashan dam and Wangjiaya dam, were placed, the influence of human factor was even larger due to the higher value of human effect index at Weijiabao station.

IV. CONCLUSIONS

The assessment was carried out through building a SWAT model in the basic standard period (BSP) which was slightly affected by human being. And by inputting the weather data of 2003 (typical wet year in TP), the runoff of main Weihe River without human influence was predicted. With this outcome, the preliminary influence of human activity on wet year runoff was investigated, which indicated:

(1) Comparing with the predicted result, the runoff of main Weihe River in 2003 had decreased significantly. The reduction of annual runoff at Huaxian station research 4.96 billion m^3, and in Linjiacun the value is 1.78 billion m^3.

(2) The human activity in non-flood season had placed more significant effect than in flood season. The human factor in non-flood season had caused 62.78% reduction at three stations, while the effect in flood season was only 42.47%.

(3)The water conservancy and soil and water conservation measures had played a crucial part in decreasing runoff among various factors of human activities. Thus, making a reasonable united water resource management regulation as well as optimizing the arrangement of soil and water conservation measures would be significant for guaranteeing the environmental base flow and the sustainable development of Weihe River.

(4) The SWAT model was a good choice for investigating the effect of human activity. And further in-depth research about the influence of different human activities in different water-sediment conditions would be needed.

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