Research on the response of the water sources to the climatic change in Shiyang River Basin

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Abstract. The influence of the future climate change to the water resource will directly pose some impact on the watershed management planning and administrative strategies of Shiyang River Basin. With the purpose of exploring the influence of climate change to the runoff, this paper set Shiyang River as the study area and then established a SWAT basin hydrological model based on the data such as DEM, land use, soil, climate hydrology and so on. Besides, algorithm of SUFI2 embedded in SWAT-CUP software is adopted. The conclusion shows that SWAT Model can simulate the runoff process of Nanying River well. During the period of model verification and simulation, the runoff Nash-Sutcliffe efficient coefficient of the verification and simulation is 0.76 and 0.72 separately. The relative error between the simulation and actual measurement and the model efficient coefficient are both within the scope of acceptance, which means that the SWAT hydrological model can be properly applied into the runoff simulation of Shiyang River Basin. Meantime, analysis on the response of the water resources to the climate change in Shiyang River Basin indicates that the impact of climate change on runoff is remarkable under different climate change situations and the annual runoff will be greatly decreased as the precipitation falls and the temperature rises. Influence of precipitation to annual runoff is greater than that of temperature. Annual runoff differs obviously under different climate change situations. All in all, this paper tries to provide some technical assistance for the water sources development and utilization、 assessment and optimal configuration.

1. Introduction

The influence and the adaptability of the climate change to the forming process of water circulation and spatial and temporal distribution of water resources is one of the hot issues in the field of hydrological research, whose research and technical methods mainly include statistic analysis, cause analysis, scenario hypothesis, downscaling, model simulation, coupled model and so on [1]. The ways that the climatic change influence water cycle processes are multiple, which have the characteristics of complex, dynamic and no-linear [2, 3]. The application of hydrological model in the study of climatic change influence to the water resources is a good solution and is also a trend of current research. Distributed watershed hydrological model SWAT (soil and water assessment tool) is developed by the

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Agricultural Research Center of USDA, and has become one of the widely used hydrological models [4-6]. As a kind of distributed watershed hydrological model which is based on the procedure, SWAT integrates various digital techniques such as RS (Remote Sensing), GIS (Geographic Information System) and DEM (Digital Elevation Model) and can simulate and predict different climate, runoff under the underlying surface, silt and hydrological process of non-point source pollution. In the source region of the Yellow River, Hanjiang River Basin, Taihu Lake Basin, watershed of Miyun Reservoir, Huai River Basin, and Haihe Basin, SWAT Model has gained great effect in some research fields such as water and sediment simulation, assessment and management of the water resources, impact of the climatic change and soil utilization to water resources, and non-point source pollution simulation. However, in arid and semi-arid region of China, little research has ever been done about the application of SWAT Model. Besides, exploration on the algorithm of model parameter calibration and uncertainty analysis is also seldom involved [7, 8].

As an inland river, Shiyang River is one of the basins that have the most dense population, the highest degree development and utilization of water resources, the greatest contradiction of water use, the most serious problem of ecological environment. The current development and utilization of water resources in this basin has far outweigh its bearing capacity, which further deteriorate the ecological environment of this region. Currently, research based on SWAT Model in Shiyang River Basin is mainly doing some investigation in simulating the variation characteristics of the runoff. By using SWAT Model, Wang Junde did some simulation study on the runoff of Zamu River within Shiyang River Basin, and then discussed the hydrological characters of a model of 7 different kinds of vegetation combination within basin and micro terrain scale. Based on SWAT Model and set upper and middle reach basin of Shiyang River as his study object, Zhang Y F did some investigation on the variation characteristics of the mountain-pass runoff under various climate change scenarios from the year 1988 to 2005, and then discussed the impact of climatic change on the hydrological regime and water resources. Zhang L Y did a quantitative analysis of Gulang River Basin about the influence of climatic changes and land-utilization or land-cover changes to water cycle elements such as water evaporation, surface runoff and so on. However, few researchers have ever used this high-precision and comprehensive model to simulate the surface runoff and to study the future changes and trend of hydrological factors by supposing different climate change scenarios.

With the development of economy and society, shortage and uncertainties of the water resources caused by future climatic changes will bring new challenges to sustainable utilization and management of water resources and the socioeconomic system. The model is used to simulate monthly runoff of Nanyang River Basin in order to study the applicability of SWAT Model in Shiyang River, which will provide fundamentals for a quantitative analysis of runoff simulation in future climate change scenarios. By doing a scenario-based design of the climatic changes in Shiyang River Basin, this paper aims to make a response analysis of water resources and provide some technical assistance for the water sources development and utilization, assessment and optimal configuration.

2. Introduction of the study area

Shiyang River Basin is located on the ancient Silk Road—east of Hexi Corridor of Gansu Province, west of Wushao Ling, north of Qilian Mountains, and the latitude is between 36°29′～39°27′ N and 101°41′～104°16′ E. Connecting with Baiyin and Lanzhou City in southeast, adjoining Zhangye City in northeast, neighboring Qinghai Province in southwest, and bordering on the Nei Monggol Autonomous Region, this basin totally involves 4 cities and 9 counties/districts, and covers an area of 41,600 square kilometers. Lying in hinterland of China, this region generally belongs to temperate continental arid climate, which can be further divided into three types from south to north: semi-arid and semi-humid alpine area in the south Qilian Mountains, arid and cool area in the middle Hexi Plain region, and warm and arid area in the north. With an annual precipitation of only 150-300 mm, the annual evaporation of the plain is as high as 1300-2600 mm, which has far outweigh its amount of precipitation, therefore the drought index has reached as high as over 52. Besides many brooks, Shiyang River Basin is mainly composed by 8 main rivers named Dajing River, Gulang River,

Huangyang River, Zamu River, Jinta River, Xiying River, Dongda River, and Xida River. These rivers and streams are mainly supplied by atmospheric precipitation and snowmelt water from the mountain area, whose runoff area and annual runoff are 1.11×104 km² and 1.56×109 km² separately. Types of soil include sierozem, grey desert soil, grey-brown desert soil, and so on. Types of vegetation include kobresia pygmaea, picea crassifolia in medium high mountains, sabina przewalskii, artemisia frigida, reaumuria soongorica, stipa breviflora and so on.

3. Data and methods

3.1.Basic data

The input data in SWAT Model include spatial data, attribute data, meteorological data, and hydrological data (table 1).

Table 1. Data and format needed in SWAT model of Shiyang River.

Data	Item	accuracy	format	source
spatial data	DEM LUCC soil type	1:100,000 1:100,000 1:1,000,000	GRID GRID/shape	National Natural Science Foundation "Environmental and Ecological Data Center of Western China"
attributes data	soil attributes data		DBF	Soil-type Records of Gansu Province, Soil Records of Gansu Province and soil records of every county around the basin.
meteorological data	Precipitation, maximum and minimum temperature, radiation, humidity, wind speed	date	DBF	China Meteorological Administration, Meteorological Bureau of Gansu Province
hydrological document	quantity of flow	date, month, year	DBF	Hydrological Bureau of Gansu Province

- Meteorological data

The measured data are collected from 5 meteorological stations (Yongchang, Minqin, Wuwei, Menyuan, Wushao Ling) and mountain-exit hydrological stations of 4 Rivers from 1956 to 2010. They include solar radiation, wind speed, humidity, maximum temperature and humidity, and daily precipitation from precipitation stations.

- DEM data

DEM data is obtained firstly by projection transform with the method of Albers projection and then undergo processes of ArcGIS splicing, depression detention and basin demarcation. After a series of digital processing, a DEM Model is established (figure 1).

- Soil data

Soil-type data derive from soil shp data of Chinese Mainland. A soil-type map for this study is achieved by projection transform and cut with the help of GIS software and then stored it into a format of grid or shape. The soils are divided into 8 orders, 11groups, and 12types. Types and area of soil can be seen in table 2. As to soil attributes data, depth value of vegetation root systems, depth of the whole soil layer, quantity of layers, depth of soil surface to every layer, contents of clay particles, efutriation, sand particles, gravel, organic matters of every layer, they all come from Soil-type Records of Gansu

Province, Soil Records of Gansu Province and such records of every county within the study area. The study adopted documents that have gained achievements in soil texture conversion with different particle diameters, and conducted transformation by applying the method of linear interpolation. Table 3 shows the soil texture transformation of the main types of soil in Shiyang River Basin. *SOL_BD* (wet density of soil (mg/m³or g/cm³)), *SOL_AWC* (soil available water content (mm)), and *SOL_K* (saturated hydraulic conductivity (mm/h)) can be calculated by SPAW software [9, 10].

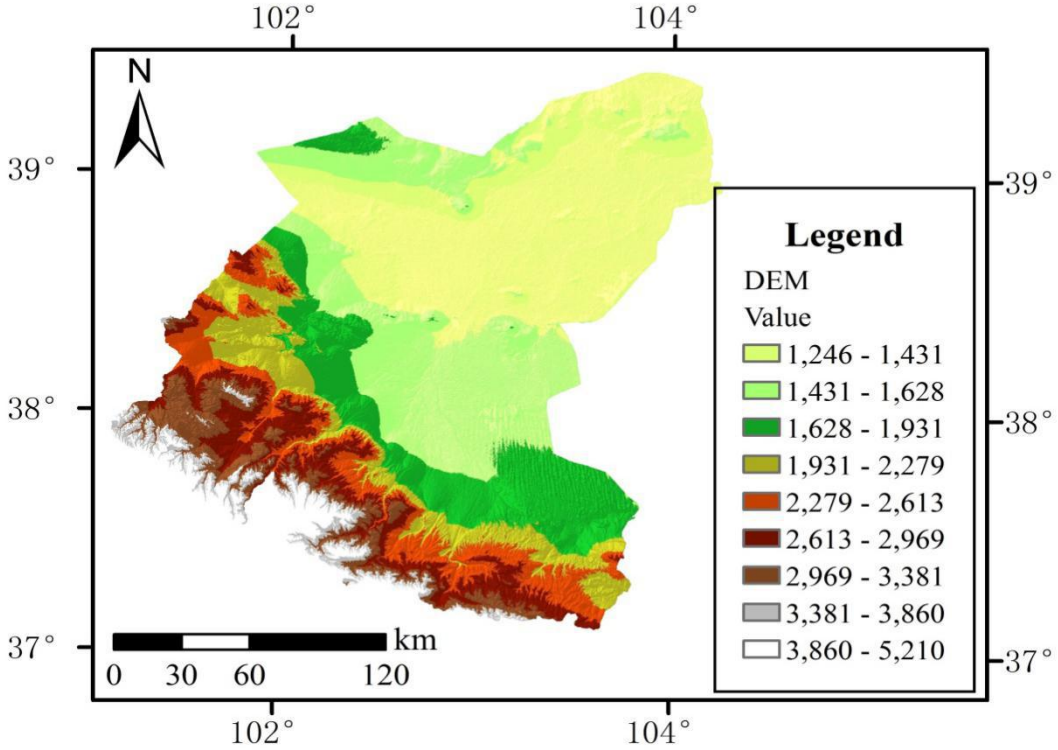


Figure 1. Digital elevation model of Shiyang River Basin.

Table 2. Types and area of soil in Shiyang River Basin**.**

Code	Sub Type	Soil Type	Soil Order	Area (km^2)
23118100	inland salty soil	salty soil	saline-alkali soil	4076.512
23115141	semifixed aeolian sandy soil	aeolian sandy soil	primitive soil	6610.549
23120151	frigid desert soil	frigid desert soil	alpine soil	566.518
23120102	frigid calcic soil	frigid calcic soil	alpine soil	683.547
23112111	castanozem	castanozem	pedocal	2467.572
23111121	grey cinnamon soil	grey cinnamon soil	semi-Luvisols	1838.687
23114104	salty gray-brown desert soil	gray desert soil	desert soil	10418.459
23112103	(shajiang black soil)	chernozem	pedocal	474.531
23114101	oasis spodosol	gray desert soil	desert soil	4443.778
23120102	felty soil	felty soil	alpine soil	2291.078
23113113	meadow sierozem	sierozem	aridisol	3023.46
23112101	chernozem	chernozem	pedocal	3662.313

Table 3. Soil texture conversion of the main types of soil in Shiyang River Basin.

Types	Depth (cm)	Particle Diameter (mm)					Texture
		>2	2-0.2	0.2-0.02	0.02-0.002	<0.002	
chernozem (062) 23112101	0-18			48.50	33.40	18.10	clay loam
	18-28			42.20	40.30	17.50	clay loam
	28-110			50.00	33.00	17.00	clay loam
	110-132			44.60	35.20	20.20	clay loam
meadow sierozem (109) 23113113	2-22	0	46.85		37.41	15.74	clay loam
	22-57	0	53.04		33.45	13.51	loam
	57-74	0	55.12		44.38	0.50	sandy loam
	74-107	0	48.76		50.24	1.00	silt loam
	107-163	0	46.04		50.69	3.27	silt loam
gray desert soil (123) 23114101	0-26		5.10	42.14	36.67	16.09	clay loam
	26-50		3.38	39.34	44.43	12.85	loam
	50-78		3.38	35.79	44.50	16.33	clay loam
	78-105		6.43	33.60	42.90	17.07	clay loam
	105-130		9.59	40.10	37.21	13.01	loam
calcic chernozem (064) 23112103	0-23		0.21	42.65	37.00	20.14	clay loam
	23-57		0.53	37.37	39.45	22.56	clay loam
	57-90		0.46	19.64	51.26	28.64	silty clay loam
	90-120		6.21	30.83	37.32	25.64	loamy clay loamy clay
salty gray-brown desert soil (129) 23114104	8-12	37.03	65.54	9.04	12.58	12.84	gravelly sandy loam loamloam gravelly sandy loam
	12-26	13.41	85.76	4.82	4.91	4.51	gravelly sandy loam loamloam gravelly sandy loam
	26-36	65.92	96.77	0.50	1.54	1.19	gravelly sandy loam loamloam gravelly sandy loam
	36-54	4.82	97.89	0	1.54	0.57	gravelly sandy loam loamloam gravelly sandy loam
	54-105	77.01	98.37	0	1.37	0.36	gravelly sandy loam loamloam gravelly sandy loam

grey cinnamon soil (042) 23111121	10-37	14.50		46.18	36.21	17.61	gravelly sandy loam loamloam gravelly sandy loam
	37-75	13.60		49.05	33.77	17.18	gravelly clay loam loamloam gravelly sandy loam
	75-135	39.60		56.24	28.20	15.50	gravelly sandy clay loam
Castanozem (072) 23112111	0-18		17.55	15.58	29.86	37.01	clay loam
	18-40		14.17	10.63	32.76	42.44	clay loam
	40-60		69.88	2.66	10.89	16.77	silty clay loam
semifixed aeolian sandy soil (164) 23115141	0-0.5		81.2	5.4	3.8	9.6	loamy sand
	0.5-23		89.3	0.5	1.9	8.3	loamy sand
	23-56						sandy soil
	56-86						sandy soil
inland salty soil (225) 23118100	0-14		0.1	34.9	54.0	11.0	silt loam
	14-34		0	37.0	50.0	13.0	silt loam
	34-85		1.5	66.0	23.5	9.0	sandy loam
	85-140		0	51.0	37.0	12.0	loam

- Land use data

Land use that can be recognized by SWAT Model is based on the classification of that of America, which is encoded by 4 English letters. Through a previous splicing processing by applying GIS software, this study worked out a map of types of land use (figure 2). Types of land use are classified into 6 genera and 31 subgenera, which is based on the classification method of land sources of China. However, land use data should be reclassified and converted into the English letters as the codes that are regulated by SWAT Model. Finally, by using these codes, a database of the types of land use in study area and vegetation attached to the model is generated, which will be connected with agricultural management database [11].

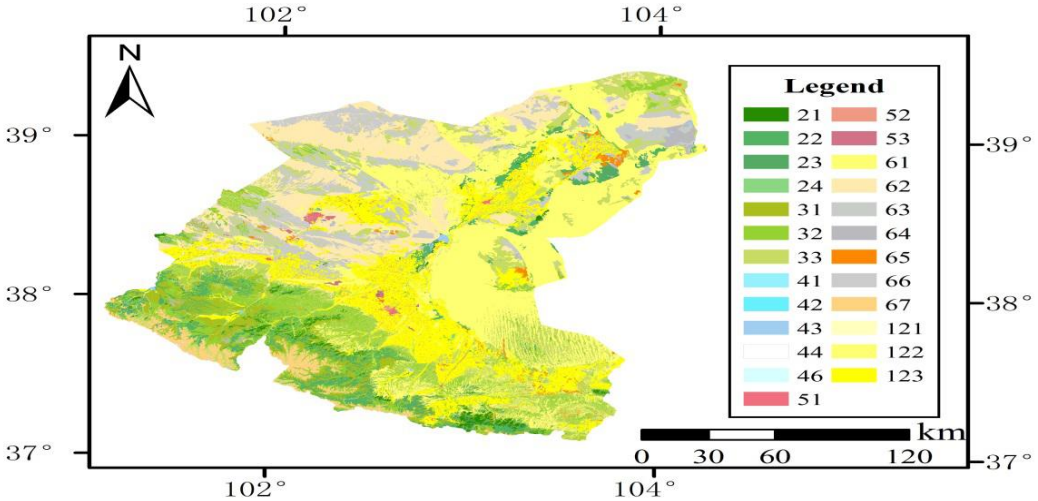


Figure 2. Land use of Shiyang River Basin.

- Hydrological Data

All the relative data are measured data that come from hydrological stations from the year 1956 to 2010. Besides setting surface area of the reservoir, storage capacity, upper limit of discharged flow, and evaporation coefficient, the reservoir parameters also include the setting of water outflow and supply according to the amounts of actual water demand.

3.2. Research methods

- SWAT Model

SWAT Model is adopted in this hydrological simulation. Based on DEM data, the whole basin is divided into several sub-basins according to the location of outlets. Considering the spatial and temporal variability of underlying surface, these sub-basins are further divided into several hydrological response units (HRU) according to soil types, land use types and slopes. Runoff is calculated on every sub-basin and HRU by applying traditional conceptual model, and flow quantity of the whole basin will be worked out by calculation of flow concentration. According to the data collected, the runoff simulation in this paper adopts the method of SCS, the river flow routing adopts method of Muskingum, and for potential evapotranspiration, it takes formula of Penman-Monteith [12].

- Methods of model calibration and verification

Model calibration and verification are critical during the process of modeling, which will directly determine the accuracy of the result. SWAT Model is complicated in structure and multivalued in parameters, in which there are more than 20 parameters only in the aspect of runoff. In order to improve the efficiency of model calibration and decrease the uncertainty of the model, sensitivity analysis (SA) is always carried out in the practical operation. According to the results of the analysis, values (sensitivity parameters) that have relatively greater impact on the model result should be adjusted in order to recognize and validate distributed hydrological model. Sensitivity analysis of the model often uses the method of LH-OAT (Latin-Hypercube-One-Factor-At-a-Time) which is fixed in SWAT software, because in the aspect of parameter choice, this method well integrates the advantages of the wholeness in LH (Latin Hypercube Sampling) and certainty in OAT (One-Variable-At-a-Time). However, the efficiency is a little bit low while doing analyzing. Therefore, SWAT-CUP, developed by Swiss Federal Institute of Water Biological Science and Technology, is a program specially designed for SWAT Model to do SA, calibration, verification and uncertainty analysis. It is embedded with algorithms of SUFI2 (Sequential Uncertainty Fitting Version 2), PSO (Partial Swarm Optimization), MCMC (Markov Chain Monte Carlo), ParaSOL (Parameter Solution), GLUE (Generalized Likelihood Uncertainty), which make it has the advantages of high-efficiency and visualization. This paper applies SUFI2 to make sensitivity analysis and do model calibration and verification [13].

4. Results and analysis

After being loaded and processed by GIS, a DEM map is used to calculate flow direction and accumulation of the basin, and the whole basin is divided into 127 sub-basins by integrating the actual situation of river network and taking the calculating efficiency into account. A simulation will be implemented after loading the reclassified data of land-use types, soil types and the slope is classified into 2 types.

4.1. Sensitivity analysis of model parameters

Calibration of parameters is to find a most consistent parameter between the simulation value and observed value. According to the result of sensitivity analysis, this paper finally chooses the following parameters to calibrate the model: *CN2, SOL_AWC, ECSO, EPCO, Canmx, SOL_K, SOL_Z, GW_DELAY, ALPHA_BF*.

Among these parameters, runoff curve number (*CN2*) is a very important parameter in SCS runoff model, which can describe the relationship between precipitation and runoff and comprehensively

reflect runoff capacity of underlying surface (land-use/land cover, soil types, hydrological conditions, moisture situation in earlier stage). Theoretically, value range of curve number should be within 0～100, which has a positive correlation with runoff volume; soil available water content (*SOL_AWC*) reflects the water storage capacity, which has an inverse relationship with runoff generation. The bigger the coefficient is, the greater the soil storage capacity will be, and the less the runoff volume will become. *ESCO* is a coefficient used to adjust water compensation among different soil layers. The evaporation in the deep soil will be reduced as this coefficient rises, and the runoff volume will thus increase; *SOL-K* relates soil water-flow rate with hydraulic gradient and can measure the difficulty level of water movement in the soil, which has a positive correlation with runoff generation; *GW_DELAY* and *ALPHA_BF* have great impact on hydrograph. *ALPHA_BF* is achieved by inputting data of daily runoff from the year 1993 to 2004 and applying digital filtering method to segment baseflow, which means to make a segment calculation to the ten-year daily runoff data by running bflow.exe module under DOS. Detailed description of these 9 parameters can be seen in table 4.

Table 4. Sensitivity analysis and data of SWAT model in Shiyang River Basin.

Parameters	Definition	Sensitivity Level	documents	Data Range
CN2	Curve Number	1	Management (mgt)	(59.85, 78.8)
SOL_AW	Soil Available Water Content	2	Soil (.sol)	0.010
ESCO	Soil evaporation correction coefficient	3	HRU (.hru)	0.957
EPCO	Plant transpiration correction factor	4	HRU (.hru)	0.766
CANMX	Maximum Canopy Interception	5	HRU (.hru)	0.568
SOL_K	Saturated Hydraulic Conductivity	6	Soil (.sol)	(52.09, 86.84)
SOL-Z	depth of soil layer	7	Soil (.sol)	(138.38, 222.69)
GW_DELAY	Groundwater delay time	8	Groundwater (.gw)	(23.25, 31)
ALPHA_BF	baseflow coefficient	9	Groundwater (.gw)	(0.048, 0.176)

4.2. Calibration and verification of parameters

Model calibration is to modify the parameters and compare the simulated value with the measured value until the predetermined objective function is achieved. This study chooses correlation coefficient (R^2), relative error (*RE*) and efficient coefficient of Nash-Sutcliffe Model as the index of assessing simulating result. Correlation coefficient R^2 can assess the coincide degree between the simulated value and the measured value. When R^2=1, it means the two values coincide with each other quit well; when $R^2 < 1$, the smaller the value is, the worse the coincide degree will be.

Calculation formulas of relative error RE and model efficient coefficient equations are (1) and (2) separately:

$$RE = \frac{Q_P - Q_0}{Q_0} \quad (1)$$

$$E_{ns} = 1 - \frac{\sum_{i=1}^{n} \left(Q_0 - Q_p\right)^2}{\sum_{i=1}^{n} \left(Q_0 - Q_{avg}\right)^2} \quad (2)$$

In these formulas, Q_O is the measured value, Qp is the simulated value, Q_{avg} is the measured average value, and n is the number of the value. $RE > 0$ means the simulated value is larger than needed; $RE < 0$ means the value is smaller than needed; $RE=0$ means the two values coincide with each other well. The more close to 1 the *Ens* value is, the better the simulated result will be; *Ens*=1 means the simulated result is coincide with the measured result; $Ens < 0$ means the application of simulated values is much less credible than the direct usage of measured average value.

According to the wholeness of data acquisition, this paper selected Nanying Hydrologic Station of 1993-2004 to do the runoff simulation. Years 1993 to 1999 are taken as the period of data calibration, and years 1999 to 2004 are taken as the period of data verification. Simulated results of yearly and monthly runoff are showed in table 5.

Table 5. Simulated result of monthly runoff in Nanying River.

Period	Efficient Coefficient (*Ens*)	Relative Error (*RE*)	Correlation (R^2)	Coefficient
Verification (1993-1999)	0.76	2.8	0.89	
Simulation (1999-2004)	0.72	5.6	0.86	

Calibration (1993～1999) and verification (1999～2004)of Nanying River, see figure 3.

If the expected value of simulated result can reach about 0.6, it indicates that SWTA Model can well generalize the parameters of the study area and accurately describe the hydrological process. Therefore, in geographical environment of Shiyang River, it is feasible to apply SWAT Model to operate runoff simulation. Besides, as is presented in parameter calibration, all of the 9 parameters are correlated with underlying surface of the basin. Although good results can be achieved after the model calibration, some of the parameters such as *CN2, SOL_AW, ESCO, EPCO, CANMX, SOL_K, SOL-Z, GW_DELAY, ALPHA_BF* are close to or have reached the critical values that are set in the model [13].

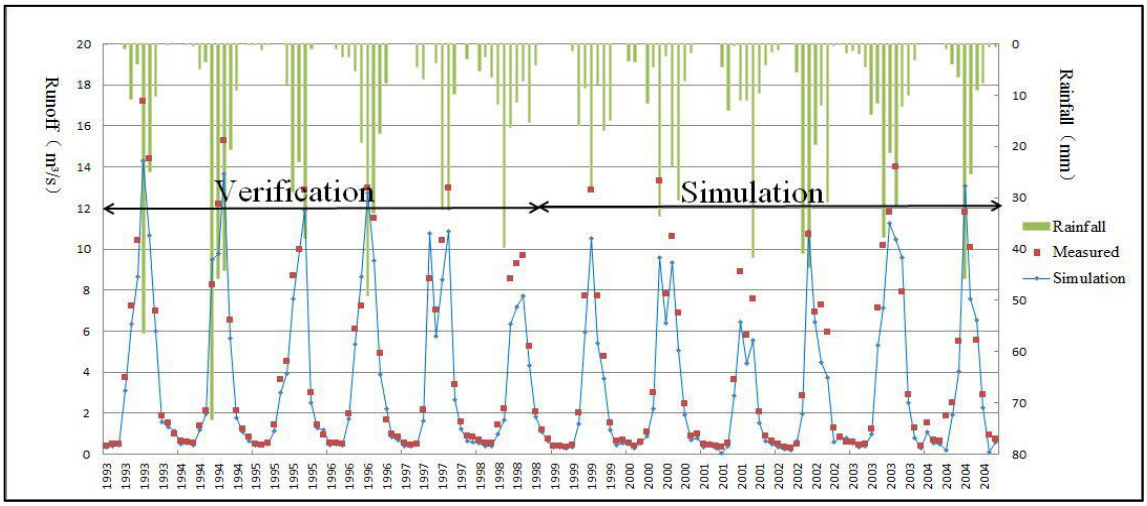


Figure 3. Simulation and verification of runoff process in Nanying hydrological station.

5. Response analysis on the water sources to the climatic change in Shiyang River Basin

5.1. Runoff effect under climatic change

Based on the measured data of Nanying Hydrological Station from the year 1956 to 2010, the study made a precipitation variation analysis in Shiyang River Basin an worked out the following two pictures:

Precipitation of Nanying Reservoir is continuously rising with an obvious increase in 1960s, and no point of abrupt change appeared. Precipitation and runoff of the reservoir are also in a completely opposite tendency, which can be seen in figure 4.

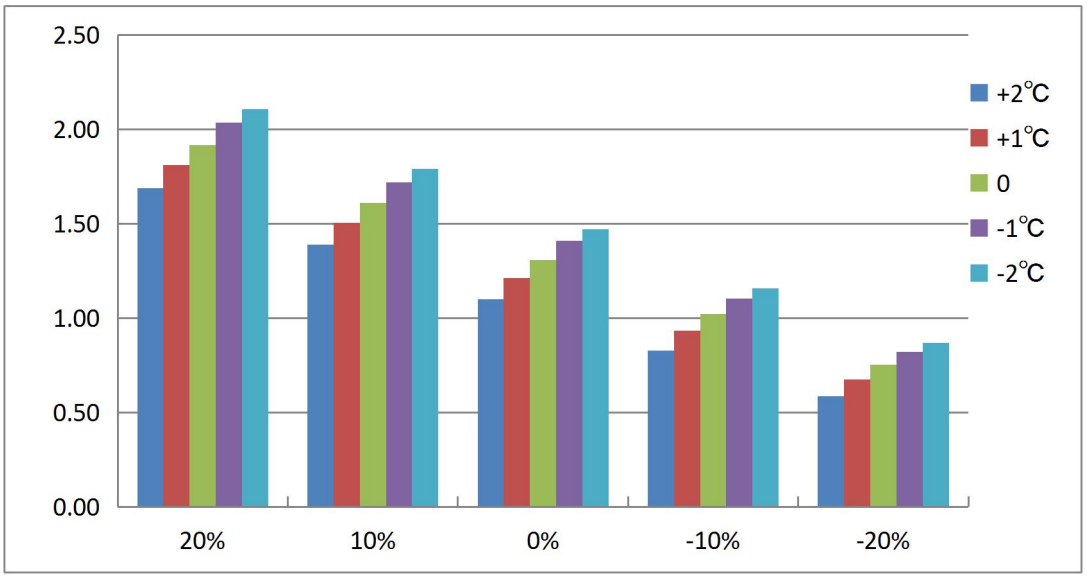


Figure 4. Results comparison of runoff simulation under different climate change situations in Nanying River.

5.2. Situation design of climate change

In order to analyze the great influence of climate change to hydrological water resources, a quantitative research is conducted by integrating the method of climate situation design with hydrological model simulation. Based on meteorological data of 1976-2010 in Nanying River, the future climate change situation are designed as follows: precipitation increases by +20%, +10%, -20%, -10% or remains unchanged; climate change increases by 1℃, 2℃, －1℃, －2℃ or remains unchanged [14]. Data of land use adopts the land cover data of 2012. There are 24 kinds of different situation combination according to the situation design of climate change, which can be seen in the following table 6.

Table 6. Design of climate change situations.

Precipitation Change						
Temperature Change		20%	10%	0	-10%	-20%
	+2℃	situation1	situation2	situation3	situation4	situation5
	+1℃	situation6	situation7	situation8	situatio9	situation10
	0	situation11	situation12	situation	situation13	situation14
	-1℃	situation15	situation16	situation17	situation18	situation19
	-2℃	situation20	situation21	situation22	situation23	situation24

5.3. Simulated results and analysis

Taking the result of future climate change prediction under a global model as a reference, this paper simulates the monthly runoff of Nanying River under the above-mentioned 24 kinds of climate change situations separately within the range of possible climate changes in the study area [15]. After a runoff simulation based on SWAT Model, the annual runoff, runoff variation and change rate will be achieved.

Table 7. Simulated results of annual runoff under different precipitation and temperature situations.

	Precipitation Change						
temperature change	annual runoff (m^3)		20%	10%	0	-10%	-20%
		+2℃	1.5419	1.3766	1.0273	0.8535	0.5312
		+1℃	1.6613	1.4180	1.0833	0.9548	0.6416
		0	1.7651	1.5564	1.2201	1.0407	0.7347
		-1℃	1.8972	1.6690	1.2905	1.0753	0.8735
		-2℃	2.0177	1.7549	1.4647	1.0923	0.8816
	runoff change (m^3)		20%	10%	0	-10%	-20%
		+2℃	0.2777	0.1124	-0.2368	-0.4107	-0.7329
		+1℃	0.3971	0.1539	-0.1808	-0.3094	-0.6226
		0	0.5009	0.2922	0.0000	-0.2235	-0.5295
		-1℃	0.6331	0.4048	0.0264	-0.1889	-0.3907
		-2℃	0.7535	0.4907	0.2005	-0.1718	-0.3826
	change rate (%)		20%	10%	0	-10%	-20%
		+2℃	21.9696	8.8925	-18.7334	-32.4871	-57.9788
		+1℃	31.4130	12.1705	-14.3046	-24.4734	-49.2468
		0	39.6220	23.1134	0.0000	-17.6803	-41.8817
		-1℃	50.0767	32.0198	2.0854	-14.9393	-30.9039
		-2℃	59.6038	38.8199	15.8600	-13.5932	-30.2622

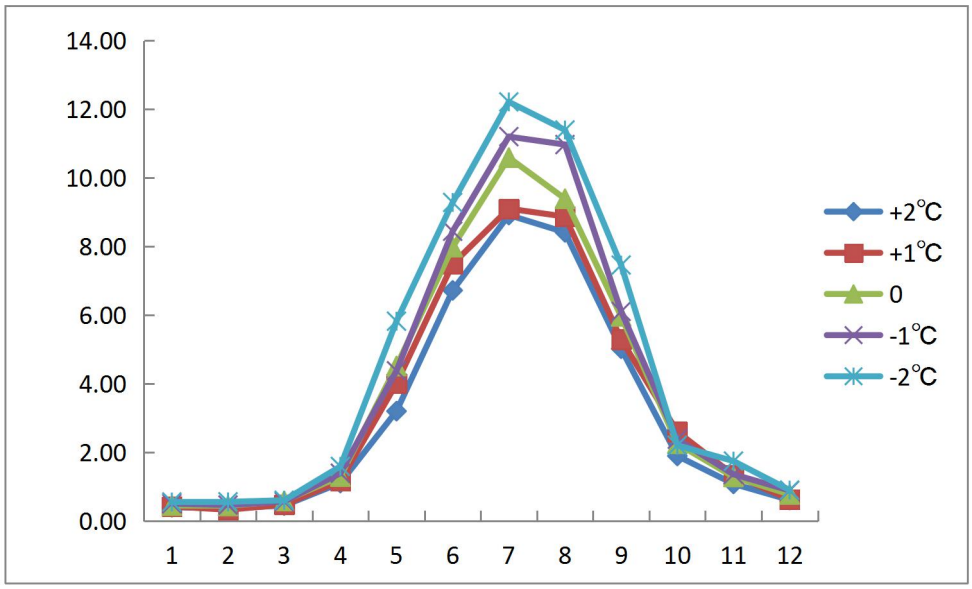


Figure 5. Simulated results of monthly runoff under the same precipitation and different temperatures situations.

From table 7 and figures 4 and 5, this study can draw conclusions as follows:

- Impact of climate change on runoff is remarkable.

Annual runoff will be greatly decreased as the precipitation falls and the temperature rises. That's because precipitation is the foundation of runoff formation, and is also the direct source of water resources. When the precipitation decreases, the water supply amount of the whole basin will thus be decreased, which will in turn reduce the runoff volume. Temperature rising will increase the evaporation of the basin, which will cause decline of the runoff under the premise of invariable water supply.

- Influence of precipitation to annual runoff is greater than that of temperature.

With the temperature being unchanged, 10% of increase or decrease of the precipitation will cause a change of 23.1% or - 17.7% to annual runoff; while with the precipitation being unchanged, 1℃ of rise or fall of the temperature will cause a change of - 14.3% or 2.09% to annual runoff. Consequently, change rate of the annual runoff that caused by 10% precipitation change is almost 2.49 times that of temperature change; With temperature being unchanged, 20% of increase or decrease of the precipitation will cause a change of 39.6% or - 41.9% to annual runoff; while with the precipitation being unchanged, 2℃ of rise or fall of the temperature will cause a change of - 14.3% or 15.9% to annual runoff. Therefore, change rate of the annual runoff that caused by 20% precipitation change is almost2.7 times that of temperature change.

- Annual runoff differs obviously under different climate change situations.

Different climate conditions will generate different annual runoff. When the precipitation increases by 20% and the temperature falls 2℃, the annual runoff will increase the most by 59.6%; on contrary, when the precipitation decreases by 20% and the temperature rises 2℃, the annual runoff will reduce the most by 57.9%. Therefore, to predict accurately the climate change is of great importance for analyzing hydrological water resources in the basin.

6. Conclusion

The introduction of SWAT Model provides a very useful tool for the scientific research and management of water resources in Shiyang River Basin. Its distinct distributed structure and operating mode also widen the horizon for developing distributed hydrological model in China. By applying SWAT Model and integrating GIS, RS, a distributed hydrological model of Shiyang River Basin is established based on spatial data, attribute data, meteorological data, and hydrological data. Besides, the model also goes through sensitivity experiment, calibration and verification. The results indicate that SWAT Model can properly simulate runoff process of Nanying River Basin, which is a sub-basin of Shiyang River Basin. Coefficient of linear regression and efficiency of the simulated runoff and the measured runoff can meet the requirements of regulation. During the period of model verification and simulation, the runoff Nash-Sutcliffe efficient coefficient of the verification and simulation is 0.76 and 0.72 separately. Comparing the simulation and actual measurement, the relative error is within the range of 10%. In Nanying River, both the relative error and model efficiency coefficient are within the range of acceptance, which means that SWAT Model can well be applied into runoff simulation of Shiyang River Basin. Analysis on the response of the water resources to the future climate change in Shiyang River Basin implies that the impact of climate change on runoff is remarkable under different climate change situations and the annual runoff will be greatly decreased as the precipitation falls and the temperature rises. Influence of precipitation to annual runoff is greater than that of temperature. Annual runoff differs obviously under different climate change situations.

7. Discussion

SWAT Model is constructed under databases abroad. Therefore, there is a necessity to modify the database when applying the model, especially need to establish the user's own soil attribute database and the code of land use also needs to be transformed. Data that are needed in constructing SWAT Model in China is hard to achieve, and the accuracy is also not high enough. Lack of some of the

parameters is also very common. Consequently, there is an urgent need to strengthen the data supervision and integration and establish a scientific, comprehensive, and unified basic database.

In the runoff simulation process of Shiyang River Basin, data are more reliable and accurate in this paper as it establishes the spatial database and attribute database such as soil attribute data, land use attribute data and so on. Results of SWAT Model simulation well reflect the runoff hydrological process of Shiyang River Basin, which can provide technical assistance for the water sources development and utilization, assessment and optimal configuration. It is suggested that attention should be paid to the soil concrete condition of the study area while establishing soil database and certainty of every parameter in the meteorological database while establishing meteorological database, such as dew-point calculation and so on. As to situation design of climate change, the overall changing trend of the global climate change should be fully simulated. In the future work, a more scientific, comprehensive, and unified basic database should be established in order to provide research support in the aspects of non-point source pollution, water and soil erosion, land use, agricultural management, and so on, which will lay a solid foundation for the comprehensive management of water resources by further application of SWAT Model.

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