Research on Response of Hydrological Process in Taozhuang River Basin, Danjiangkou City, China

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Abstract. The study of watershed ecohydrology and land use/cover change (LUCC) is a frontier field and research hotspot in ecology. This study found that there is a close relationship between the hydrological process and land use change in Taozhuang River basin of Danjiangkou City. The SWAT model is used to simulate runoff in the basin. Periodic R^2=0.69, NS=0.64, verification R^2=0.65, NS=0.66. Good results were presented in both the periodic and validation periods. Three simulated scenarios of land use were set up and compared with the actual scenarios of land use in 2020. The runoff of farmland with more than 15 degrees can be reduced by 9.33% and 7.27%, respectively, and the runoff of grassland with more than 25 degrees can be reduced by 19.62%. The annual average base flow of the three scenarios showed an increasing trend. The results have important academic value to improve the sustainable utilization of water resources and the integrated management level of the basin.

Keywords: Urban green ecology, Water resources supply, SWAT simulation.

1 Introduction

Under the combined influence of global climate change and human activities, land use/cover change (LUCC) has become an important factor affecting watershed hydrological processes [1]. With the deepening of the research on distributed hydrological models and the maturity of geographic information systems, the impact of land use change on hydrological processes has become the focus of many scholars at home and abroad [2].

Land use/cover change directly affects the underlying surface roughness, vegetation coverage and soil permeability characteristics of the basin, and then significantly affects the runoff production and confluence mechanism, water cycle process and distribution of the basin [3-4]. Domestic and foreign scholars' research methods on the impact of land use/cover change on hydrological processes can be summarized into three categories: experimental basin method, hydrological characteristic parameter time series method and watershed hydrological model simulation method. At watershed scale, the impact of land use change on runoff has always been the focus of attention. Existing research

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results based on observation experiments and mathematical model simulation show that the runoff and runoff coefficient increase significantly along the forest-range-farmland transition, and the rainfall intensity generated by runoff and the threshold of soil water content in the early stage change with the change of land use [5]. The water and energy balance of the basin is affected by land use to a certain extent, and land use change affects or changes the water cycle process of the original basin [6]. Some studies on the response of runoff and sediment under land use change have found that when forests are cut down or converted to farmland, surface runoff and sediment production will increase [6]. Some scholars also studied the hydrological response of land use and land cover change in Ethiopia's Ribb Basin, and found that when shrubbery forest land is transformed into forest land, surface runoff decreases, sediment transport decreases, and base discharge increases; when grassland is transformed into cultivated land, surface runoff decreases and sediment output increases in wet season.

This study takes Taozhuang River basin as the research object and is based on SWAT The model constructed four natural scenarios, quantitatively analyzed the distribution of runoff on the spatial and temporal scale under various development scenarios of the basin and the response to land use change, in order to quantify the importance of the impact degree of different land use types, in order to provide scientific basis for the management and protection of soil and water resources and ecological construction of the Taozhuang River basin.

2 Study Area and Methods

2.1 Study Area

Taozhuang River is located in the northwest of Hubei Province, the middle and upper reaches of the Han River, is a national key ecological function district county (Fig.1). It is a subtropical and semi-humid monsoon climate zone with mild climate, distinct four seasons, long light time, rain and heat in the same season and a long frost-free period. The average annual temperature is 15.9 ℃, the annual rainfall is about 800 mm. The cultivated land area of the basin is large, and frequent agricultural activities lead to the change of surface morphology and regional ecological environment. Therefore, setting scenarios based on land use type change and quantitatively evaluating the impact of land use type on watershed water production is an important basis and prerequisite for scientific development and adjustment of watershed management.

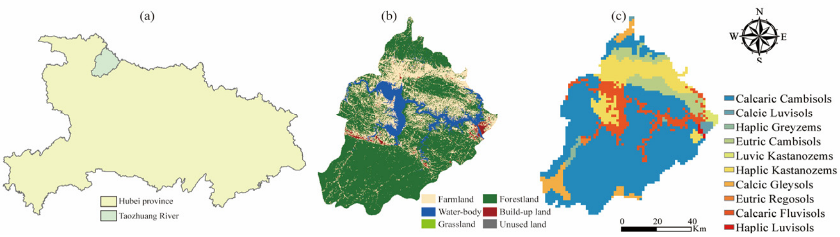

Fig. 1. Map of the study area (a) Location of the study area; (b) Soil type; (c) Land use patterns

2.2 Data Sources

The hydrologic data used in this research comes from Taozhuang River hydrologic Station, which is a national basic hydrologic station, a first-class precision flow station and a second-class precision sediment station. The daily precipitation data of meteorological stations around and inside the basin are derived from China Meteorological Data Network (https://data.cma.cn/). The data of the Digital Elevation Model (DEM) are derived from the geospatial data cloud (https://www.gscloud.cn/). Land use is derived from 1km data of resource and environmental data cloud platform of Resources and Environmental Sciences Data Center, Chinese Academy of Sciences.

2.3 SWAT Model

The SWAT model is considered to be one of the most appropriate models for assessing water, sand, and nutrient responses in catchments with different land use, soil, and management conditions [6]. The hydrological process simulated by SWAT can be divided into two parts: first, slope runoff and confluence. The second part is the river confluence, that is, the process of water, sediment, pollutants and so on in the river transport, this part is called the water surface process of the water cycle.

2.3.1 Parameter Calibration and Verification

Since there is a large error between the simulated value and the measured value of the SWAT model. Thus, the SUFI-2 algorithm in SWAT-CUP was used to analyze the parameter sensitivity of the SWAT model, and the sensitivity of runoff parameters in the study area was measured according to the statistic t-State value and significance index p-State value of each parameter.

Table 1. Simulated scenario of vegetation optimization

Number	Situational model	Optimization of ecosystem services
S1	Current vegetation pattern	The status quo of vegetation pattern in the study area was kept unchanged
S2	A certain range of vegetation restoration was carried out in the basin	Retain the original residence and cultivated land, and woodland is set up in the range of 50-100m along the whole river basin, and vegetation buffer zone is established
S3	Human activities have aggravated the damage to the basin ecosystem	Retain the original residence, the rest of the area set as grassland
S4	Watershed idealized vegetation restoration	Retain the original residence, the rest of the area set as woodland

2.3.2 Scenario Setting

The changes of hydrological processes are mainly influenced by three factors: climate, underlying surface and human activities. This paper adopts fixed climate factors, that is, changes only the land/vegetation cover factors in the SWAT model under the condition that the meteorological database remains unchanged, and establishes a variety of different vegetation restoration scenarios. To quantify the impact of vegetation restoration/cover change on the ecohydrological process of the basin (Table 1).

3 Results

3.1 Applicability Evaluation of SWAT Model

The results of parameter sensitivity analysis show that the top 5 parameters in the process of runoff simulation in Taozhuang River are CN2, CANMX, ALPHA_BF, GW_DELAY and SOL_BD, among which CN2 is the parameter with the highest sensitivity (Table 2). The runoff curve CN2 of SCS model can reflect the runoff production capacity of the underlying surface of the basin. The larger the CN2 is, the easier the surface runoff is to produce is affected by soil type, previous soil moisture and land use type. The simulation period of this study is 1990-2020, in which 1990-2010 is the model rate period, and 2010-2020 is the model validation period. The simulation results show that the simulation accuracy of R2 and NS are above 0.69 and above 0.64 respectively for the typical small watershed from 1990 to 2010, and the simulation accuracy meets the requirements. During the validation period from 2010 to 2020, the model simulation accuracy R2 was above 0.65, NSE was above 0.66, and the measured and simulated runoff values fit well. In general, the model is applicable in the study area.

Table 2. Model parameter calibration results

Parameter name	Predetermined range of parameters	Calibration range	Final value
CN2	-0.8~0.8	-0.38~0.51	-0.690
CANMX	-0.5~0.5	0~6.87	0.903
ALPHA_BF	0~1	0~1	0.889
GW_DELAY	0~500	262.90~278.74	270.903
SOL_BD	-0.8~0.8	-0.5~-0.39	-0.402
SOL_K	-1~1	-0.25~ -0.13	-0.209
ESCO	0~1	0.41~ 0.47	0.448
CH_K2	-0.01~500	-0.01~12.200	7.903
SFTMP	-5~5	-3.44~ -2.52	-3.093
GW_REVAP	-0.5~0.5	0.02~0.2	0.109

3.2 Runoff Response Under Different Land Use Scenarios

The four designed land use scenarios were substituted into the SWAT model (Table 3). The simulation results showed that compared with S1, the runoff of other land use scenarios showed a decreasing trend. As shown in Table 3, comparing the average daily runoff under S2 and S1 conditions, it can be found that when arable land is converted to forest land above 15°, the annual average daily runoff showed a decrease of 9.33%. It can be seen that forest land has a significant inhibitory effect on runoff. Comparing S2 and S3, it can be found that compared with grassland, forest land has a more obvious effect on inhibiting runoff, especially when the slope is higher than 15°. In order to better explain the advantages of forest land in reducing runoff and water conservation, S4 was set up. The results showed that the increase of forest land could effectively inhibit the generation of surface runoff, effectively reduce runoff, and effectively prevent flood and soil erosion.

Table 3. Reduction rate of runoff in different scenarios

Land use scenario	Average annual daily runoff (m^3/s)	Reduction rate (%)	Average daily runoff from July to October (m^3/s)	Reduction rate (%)
S1	0.2997	-	0.5502	-
S2	0.2854	8.92%	0.4901	10.9%
S3	0.2901	7.90%	0.5014	8.21%
S4	0.2871	8.99%	0.5113	12.43%

In this paper, the monthly runoff process under four land use scenarios was simulated [Fig.2(a)]. The simulation of runoff shows that the average daily runoff is 2-4 times the annual average daily runoff, and the monthly runoff accounts for more than 50% of the total runoff. Comparing the simulation results of S3 and S1, it can be found that when the cultivated land above 15° is converted to grassland, the monthly average daily runoff with a reduction rate of 8.14%, which indicates that the grassland has a significantly higher reduction effect on runoff than the cultivated land in flood season.

On the whole, the change rate of runoff depth was S4 > S2 > S3, and the change was greatest in summer and autumn [Fig.2(b)]. In terms of different land use scenarios, in S2, the runoff depth in all seasons showed a downward trend. In S3, the runoff depth showed a decreasing trend in all seasons, with the greatest change in summer and autumn, but its inhibition effect on runoff was much smaller than that of forest land. The results of S4 simulation showed that the runoff depth decreased in all seasons when the high-slope grassland was transformed into forest land, and the runoff depth decreased the most in summer and autumn.

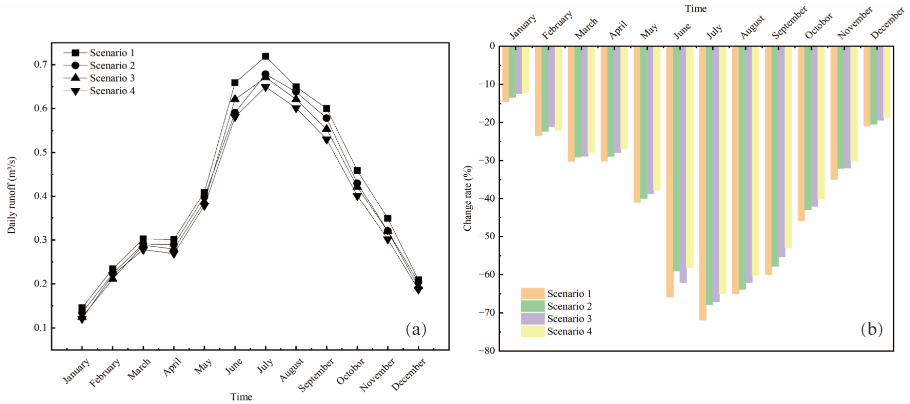

Fig. 2. (a)Simulated runoff under different land use scenarios. (b) Change rate of annual average monthly runoff depth under different land use scenario

4 Conclusions and Discussions

This study takes Taozhuang River Basin as the research object, based on the SWAT model after parameter adjustment, the runoff pro-duction in the study area was simulated, and the response of watershed runoff to land use change was simulated by setting different land use scenarios. In this study, the SWAT model showed good results, the rate period and the verification period. Based on the national policy measures for the project of returning farmland to forest and grassland in mountainous areas, four land use scenarios were set up, and the hydrological cycle process of Taozhuang River basin was simulated based on the SWAT model, revealing the response relationship of land use to the hydrological cycle in the study area. The simulation results show that compared with S1, S2, S3 and S4, the total output of runoff can be reduced, and 19.62% of runoff can be reduced by converting grassland above 25 degrees to forest. In addition, the multi-year average base flow showed an increasing trend in all three scenarios. On the whole, the contribution degree of different land use types to base discharge is obviously different. The responses of runoff to catchment spatial heterogeneity, land-use spatial pattern change and other human activities were not considered in this paper. In the future, the land use suitability allocation of the basin will be further studied by combining the spatial heterogeneity and other characteristics of the basin.

Acknowledgments

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