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Original Research

Simulation Analysis of Runoff and Sediment Yield under the Change of Land-Use Type: A Case Study of the Upper Jianjiang River Basin, China

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Abstract

In order to study the impact of changes in regional land-use types on regional runoff and sediment yield, this paper takes the upper reaches of the Jianjiang River as an example. It uses the SWAT hydrological model to simulate runoff and sediment yield in this area. Based on the land-use data of 2005 and 2018, the runoff and sediment yield effects of different land-use types in the study area and its sub-basins were analyzed. The results show that: (1) The constructed SWAT model has a good simulation effect on runoff and sediment yield for the study area. (2) The most sensitive parameter of runoff is Initial SCS CN II Value (CN2), and the most sensitive parameter of sediment is USLE equation support practice factor (USLE_P). Compared with runoff, sediment yield is more sensitive to the change of land-use type. (3) The simulation analysis results of runoff and sediment yield in each subbasin show that, under other conditions being the same, forest land has an obvious effect on water and sediment reduction compared with other land-use types, followed by grass land. The cultivated land has obvious effect of increasing water and sediment, and the urban and rural residential land also has obvious effect of increasing sediment. The corresponding solutions for different land-use types have a certain reference significance for the basin‘s water and soil conservation planning.

Keywords: the upper reaches of the Jianjiang river basin, SWAT model, land-use, runoff yield, sediment yield

Introduction

With the increasing intensity of human transformation of land-use types, the rate of land-use transformation in the basin has also accelerated. Different types of land-use have varying degrees of impact on the processes of runoff and sediment formation, such as water evapotranspiration, interception, infiltration, runoff and soil erosion. Changes in land-use types in the watershed will inevitably affect runoff and sediment yield in the watershed [1]. When sediment enters rivers and reservoirs, it will cause siltation of the river bed, and the nutrients carried by runoff will aggravate water pollution [2]. Therefore, to improve the basin's ecological environment and realize the harmonious

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coexistence between man and nature and sustainable development. It is important to analyze the impact of land-use changes on runoff and sediment yield, and formulate and implement effective soil and water conservation measures [3].

The rapid development of GIS technology and the distributed hydrological model SWAT (Soil and Water Assessment Tool) has provided convenient conditions for studying the characteristics of runoff and sediment yield in the watershed. The SWAT model was developed in 1994 by Dr. Jeff Arnold of the Agricultural Research Center of the United States Department of Agriculture (USDA). The model is a process-based continuous distributed watershed hydrological model. It has a strong hydrophysical mechanism and can be used to predict the long-term impact of climate, land-use and management measures on the processes of water yield, sediment yield and non-point source pollution [4]. Since the model was introduced into China, it has been widely applied, and the hydrological response analysis using this model has gradually increased [5-7]. Zhu Nan et al. [8] used the SWAT hydrological model to simulate and explore the impacts of different land-use structures on water and sediment in the Luoyugou Watershed. The analysis results showed that the concentration of forest land influenced the runoff and sediment yield. Compared with the low concentration of forest, runoff amount and sediment under high concentrated forest decreased at most of 4% and 27%, respectively. However, there was probably a threshold of concentration, and if the concentration degree was greater than the threshold value, the watershed runoff and sediment yield was almost invariable, but it remains to be further validated. Liu Xingyu [9] used the SWAT model to simulate the runoff and sediment yield in the Xihe River. He found that land-use will directly affect the runoff and sediment production process in this watershed. Under different land-use scenarios, factors such as physical structure, permeability, porosity, and porosity lead to a great difference in water holding capacity. Duan Xiangpei [10] chose the SWAT model and took the Longxi River Basin in Chongqing City as the research object to simulate the runoff and sediment yield in the basin. The analysis of the change of land-use types shows that the land-use planning of converting farmland to forest was beneficial to conserve water and soil conservation.

Most of the existing studies analyze the changes of runoff and sediment yield from the whole watershed by assuming land-use scenarios, while few of them consider the changes of actual land-use types and internal spatial distribution differences in the watershed. Therefore, this study simulated the runoff and sediment yield in the upper reaches of the Jianjiang River based on SWAT model. Starting from the study area and each subbasin, analyze and compare the average annual runoff and sediment yield change characteristics under the two phases of land-use types in 2005 and 2018 in this basin. The research aims to quantitatively assess the impact of different land-use types on runoff and sediment yield in the watershed and provide a reference and scientific basis for soil and water conservation measures in the region.

Material and Methods

Study Area

The Jianjiang River Basin is located in the southwest of Guangdong Province, covering an area of 9464 km^2, and is the third-largest river system in Guangdong Province. The geographical coordinates are 110°20'~111°20'E, 21°15'~22°30'N. In this paper, the upper reaches of Jianjiang River (above the area controlled by Gaozhou Station) are selected as the research object, and the control area of the study area is 2970 km^2. The study area is located in the transitional zone between tropical and subtropical, with mild climate, sunshine, and rainfall. The average annual temperature is 22.8ºC, the average annual rainfall is 1892.7 mm, and the rainfall varies greatly. The rainy season is from April to September, and the dry season is from October to March of the following year. The terrain of the study area is generally high in the northeast and low in the southwest. There are rolling mountains in the northeast and rolling hills in the central hinterland. There are platforms, small plains, mountains, valleys, and small basins interlaced in the west and south, and mountains and rivers intertwine. The soil types are mainly lateritic red soil, paddy soil, red soil and yellow soil. The land-use type is mainly forest land, accounting for about 71% of the total area, followed by cultivated land, accounting for about 19%.

Data Source

The data required by the research include the digital elevation model (DEM), land-use, soil, meteorological and hydrological data. Among them, the spatial resolution of DEM data is 30m, which comes from the Geospatial data cloud of the Chinese Academy of Sciences (http://www. Gscloud.cn). The DEM of the required watershed is obtained after the cutting and transformation by ArcGIS (Fig. 1a). The land-use data (2005 and 2018) are downloaded from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences (http://www. resdc.cn). It is reclassified according to the national land-use classification method to obtain the land-use type map of the study area (Fig. 1b), and established a land-use classification index table with the codes in SWAT. The soil data are obtained from the Nanjing Institute of Soil Science, Chinese Academy of Sciences (http://www.issas.ac.cn/), with a scale of 1:1000000. After reclassifying, the distribution map of soil types in the study area is obtained (Fig. 1c). The meteorological data uses the World Weather

Database (http://globalweather.tamu.edu). The rainfall data are derived from the daily precipitation observation data (1980~2018) of 4 rainfall stations set up by the local meteorological department in the study area. The runoff and sediment hydrological data (1975~2018) come from the hydrological yearbook of Gaozhou Hydrological Station. The locations of hydrological stations and rainfall stations are shown in Fig. 1d).

SWAT Model

Based on the DEM map of the study area, the basin area threshold is set at 4000ha, which can divide the study area into 43 sub-basins (Fig. 1d). With land-use in 2005 as the background land-use status, combined with soil type data and measured precipitation data, the construction of the SWAT model in the upper reaches of the Jianjiang River Basin was completed. Using the measured runoff and sediment data of Gaozhou Hydrological Station, the model warm-up period is 2005, the calibration period is from 2006 to 2010, and the validation period is from 2011 to 2015. Monthly runoff and sediment parameters are calibrated in the study area to simulate the process of runoff and sediment yield in the basin.

This study uses the SUFI-2 algorithm in SWAT-CUP to analyze the constructed SWAT model's parameters sensitivity, calibration, validation, and uncertainty analysis [11]. There are many parameters involved in the simulation process of SWAT model. According to the parameter definition and refer to related literature [12-13], we selected 16 parameters related to runoff: initial SCS CN II Value(CN2), effective hydraulic conductivity in main channel alluvium (CH_K2), threshold depth of water in the shallow aquifer for "revap" or percolation to the deep aquifer to occur (REVAPMN), deep aquifer percolation fraction (RCHRG_DP), groundwater "revap" coefficient (GW_REVAP), threshold depth of water in the shallow aquifer required for return flow to occur (GWQMN), maximum canopy storage (CANMX), channel regulation and storage coefficient (ALPHA_BNK), surface runoff lag time (SURLAG), available water capacity of the soil layer (SOL_AWC(..)), plant uptake compensation factor (EPCO), base flow alpha factor (ALPHA_BF), groundwater delay (GW_DELAY), manning's "n" value for the main channel (CH_N2), saturated hydraulic conductivity (SOL_K(..)), and soil evaporation compensation factor (ESCO). Moreover, 12 sediment-related parameters were selected for calibration: USLE equation support practice factor (USLE_P), USLE soil erodibility factor (USLE_K(..)), minimum value of plant cover factor in USLE (AGRL)(USLE_C{1}.plant), minimum value of plant cover factor in USLE (FRST) (USLE_C{8}.plant), channel erodibility factor (CH_ERODMO(..)), linear parameter for calculating the maximum amount of sediment reentrant when channel sediment routing (SPCON), channel erosion factor (CH_COV1), channel cover factor (CH_COV2), exponent parameter for calculating sediment re-entrained in channel sediment routing (SPEXP), peak rate adjustment factor for sediment routing in main channels (PRF_BSN),

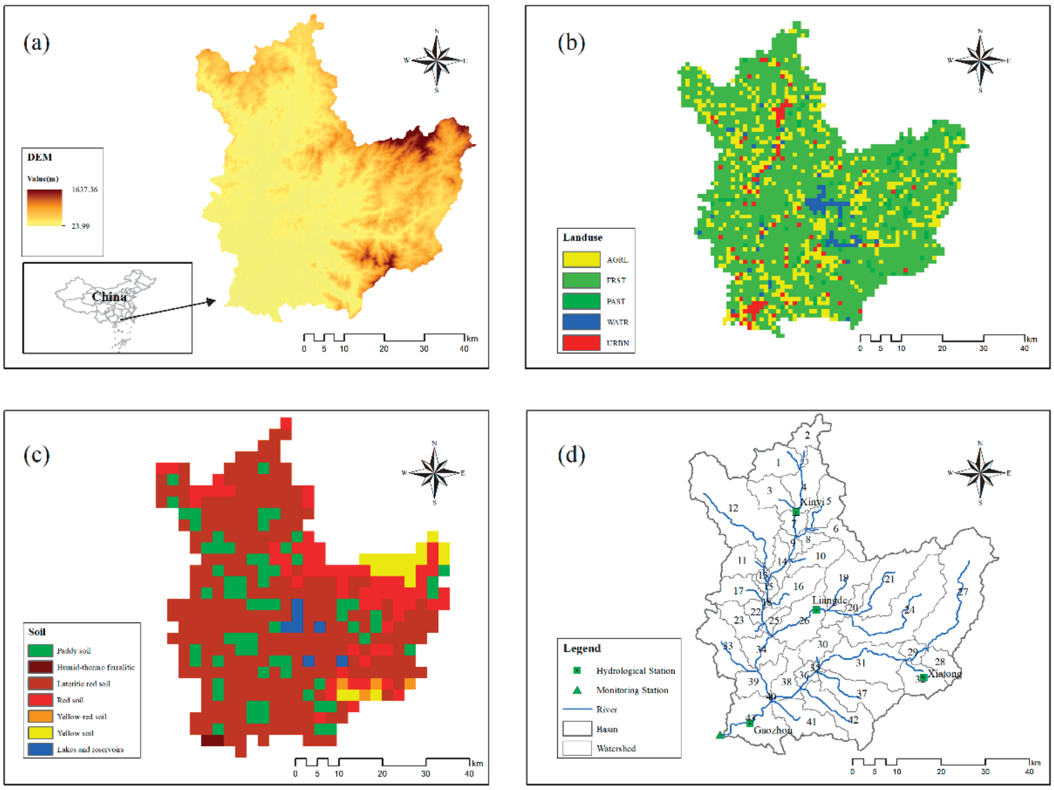


Fig. 1. Location of the study area.

the minimum value of plant cover factor in USLE (PAST) (USLE_C{12}.plant), and average slope length (SLSUBBSN). Determine the rationality of the simulation reference based on t-Stat, P-Value, coefficient of determination (R^2), Nash-Sutcliffe efficiency (NS), and percent bias (PBIAS), etc.

Results

Simulation Results of Runoff and Sediment

This study adopts a global sensitivity analysis method, and the sensitivity of the parameters can be expressed by the P and t values. The P-value reflects the confidence level of the parameter. The closer the P-value is to 0, the more important the parameter becomes. The t value reflects the relative significance of each parameter. The greater the absolute value of the t value, the more sensitive the parameter is [14].

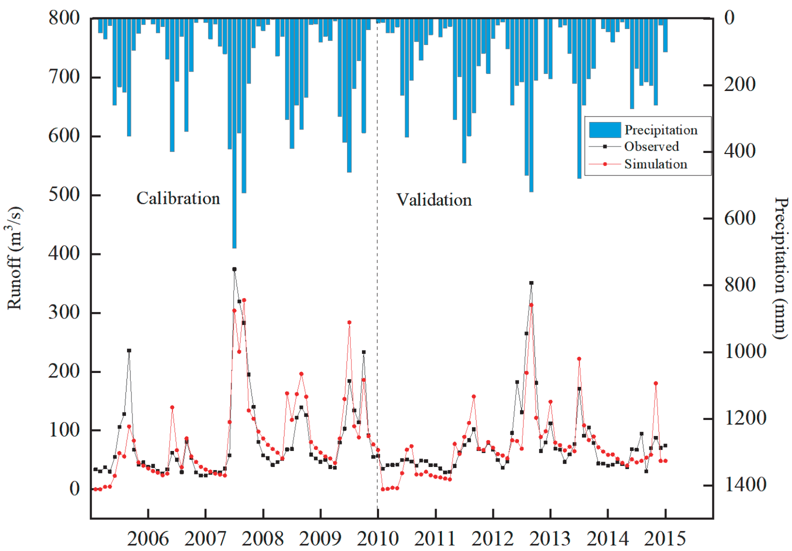
After selecting 16 parameters related to runoff, several iterative simulations are carried out, and after adjusting the range of the parameter, the results of the calibration period and the validation period are satisfactory. The runoff parameters are fixed, and 12 parameters related only to sediment are added for iteration. The research process is the same as that

Table 1. Parameters sensitivity analysis.

Parameter	File Ext.	Method*	t-Stat	P-Value	Object
CN2	.mgt	Relative	6.86	0.00	Runoff
CH_K2	.rte	Replace	-4.55	0.00	Runoff
REVAPMN	.gw	Replace	-1.92	0.06	Runoff
RCHRG_DP	.gw	Replace	-1.30	0.20	Runoff
GW_REVAP	.gw	Replace	-1.27	0.21	Runoff
GWQMN	.gw	Replace	-1.25	0.21	Runoff
CANMX	.hru	Replace	-0.80	0.42	Runoff
ALPHA_BNK	.rte	Replace	-0.76	0.45	Runoff
SURLAG	.bsn	Replace	-0.70	0.48	Runoff
SOL_AWC(..)	.sol	Relative	-0.63	0.53	Runoff
EPCO	.bsn	Replace	-0.57	0.57	Runoff
ALPHA_BF	.gw	Replace	-0.35	0.72	Runoff
GW_DELAY	.gw	Replace	-0.31	0.76	Runoff
CH_N2	.rte	Replace	-0.29	0.78	Runoff
SOL_K(..)	.sol	Relative	0.27	0.79	Runoff
ESCO	.bsn	Replace	1.22	0.22	Runoff
USLE_P	.mgt	Replace	25.75	0.00	Sediment
USLE_K(..)	.sol	Relative	-4.14	0.00	Sediment
USLE_C{1}.plant	.dat	Replace	-2.54	0.01	Sediment
USLE_C{8}.plant	.dat	Replace	-0.88	0.38	Sediment
CH_ERODMO(..)	.rte	Replace	-0.36	0.72	Sediment
SPCON	.bsn	Replace	-0.26	0.80	Sediment
CH_COV1	.rte	Replace	-0.19	0.85	Sediment
CH_COV2	.rte	Replace	0.35	0.73	Sediment
SPEXP	.bsn	Replace	0.47	0.64	Sediment
PRF_BSN	.bsn	Replace	0.87	0.39	Sediment
USLE_C{12}.plant	.dat	Replace	0.98	0.33	Sediment
SLSUBBSN	.hru	Relative	2.18	0.03	Sediment

*Replace: replaced by any values within the default range; Relative: the default value is multiplied by (1+given value) of runoff simulation. The final parameter sensitivity results are shown in Table 1.

Generally, the model performances on runoff and sediment simulation during calibration and validation periods at both stations were all satisfactory with NS>0.5 and R^2>0.5 [15-16]. The calibration and validation process lines of runoff and sediment at Gaozhou Station are shown in Fig. 2. When the rainfall is large, the observed value of runoff and sediment is larger than the simulated value. According to the evaluation indexes (Table 2), on the monthly time scale, the optimal R^2 and NS of runoff calibration period at Gaozhou station are 0.73 and 0.71, and the optimal R^2 and NS during the validation period are 0.69 and 0.67. The optimal R^2 and NS of sediment calibration period are 0.58 and 0.58, and the optimal R^2 and NS of sediment validation period are 0.69 and 0.67. They meet the simulation requirements. Generally, when the PBIAS of runoff is ±25% and sediment is ±55%, the model simulation results are satisfactory [15]. The PBIAS of runoff calibration period and validation period are -2.8% and +4.1%. The PBIAS of sediment calibration period and validation period are -3.2% and -12.4%. The results of the above three evaluation indicators illustrate that the simulation results of runoff and sediment in the studied area meet the applicability requirements of SWAT model. It is generally considered that NS and R^2>0.75, and the model's applicability is very good. NS and R^2 ≤0.50, the model fitting accuracy is not satisfactory. In between, the applicability and fitting accuracy of the model are considered satisfactory [17]. The results show that this model is applicable in the upper reaches of the Jianjiang River Basin.



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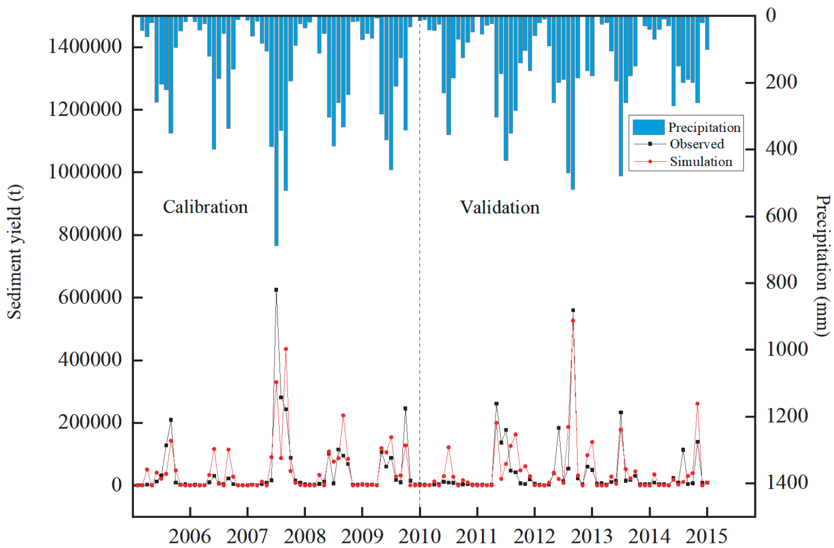

（b）

Fig. 2. Comparison between the observed value and simulated value of monthly runoff and sediment yield.

Table 2. Calibration and validation results of runoff and sediment yield.

Simulation	Period	R^2	NS	PBIAS (%)
Runoff	Calibration	0.73	0.71	-2.8
	Validation	0.69	0.67	+4.1
Sediment	Calibration	0.58	0.58	-3.2
	Validation	0.69	0.67	-12.4

Results of Runoff and Sediment Yield under the Change of Land-Use Types in the Basin

To explore the effects of runoff and sediment yield under different land-use conditions, under the same conditions as other data input, the land-use data of 2018 are used to replace the land-use data of 2005. The comparison of land-use types in different years is shown in Table 3. Based on this, the changes of runoff and sediment yield under the change of land-use type are analyzed. The analysis results are shown in Table 4.

The land-use data of 2018 is used to construct the SWAT model, and then the runoff and sediment are simulated. The simulation results are consistent with the measured values, indicating that the model is correct and can be used for the following analysis. It can be seen from Table 4 that the simulated average annual flow of land-use types in the two periods under the same climate conditions has little change. Compared with 2005, the multi-year average flow in 2018 has decreased by $0.07m^3/s$, and the rate of change is -0.04%. Compared with 2005, the multi-year average sediment yield in 2018 increased by 2.74×10^4 tons, and the rate of change is 2.77%. The results showed that the change of land-use types had little effect on the runoff yield but significantly affected the sediment yield. Since the change of total runoff yield in the basin is very small, and the land-use types in the basin are diverse, and the increase and decrease of the area are also different, it is difficult to determine from the perspective of the whole basin which land-use type change has an impact on the final runoff yield. Compared with the runoff, the sediment yield changed significantly, which could be preliminarily attributed to the increase of urban and rural residential land area and the decrease of forest land area.

Table 3. Comparison of land use areas in different years.

Land use	Area (km^2)		Difference (km^2)
	2005	2018	
AGRL	561	558	-3
FRST	2135	2105	-30
PAST	96	109	13
WATR	76	74	-2
URBN	102	124	22

Analysis of Simulation Results of Runoff and Sediment Yield Based on Sub-Basin Scale

Fig. 3 shows each subbasin's multi-year average runoff and sediment yield under the two phases of land-use types in 2005 and 2018. The subbasin with large runoff and sediment yield changes are selected to analyze the changes in land-use types. The results are shown in Table 3. Due to the large differences in the spatial distribution of land-use changes within the watershed, each subbasin‘s runoff and sediment yield also vary greatly. At the same time, it can be seen that runoff and sediment yield in different sub-basins have both increased and decreased, but the rate of change in sediment yield is significantly higher than that of runoff yield. This indicates that the sediment yield is more sensitive to the change of land-use types than the runoff yield.

It can be seen from Table 5 that the annual runoff depth of No. 34, 36, and 40 sub-basins increased significantly, increasing by 45.89, 42.43, and 40.36mm, respectively. The annual runoff depth of No. 15, 20, and 35 sub-basins decreased significantly, reducing by 30.09, 45.43, and 79.95mm, respectively. As can be seen from Table 6, the cultivated land area in sub-basins No. 34, 36, and 40, where the runoff yield increased

Table 4. Multi-year average runoff and sediment yield under different land use.

Simulation	2005	2018	Difference	Difference* /%
Runoff (m^3/s)	161.85	161.79	-0.07	-0.04
sediment yield (t)	988673.87	1016033.01	27359.13	2.77

*(Runoff under 2018 land use -Runoff under 2005 land use)/ Runoff under 2005 land use
(Sediment yield under 2018 land use - Sediment yield under 2005 land use)/ Sediment yield under 2005 land use

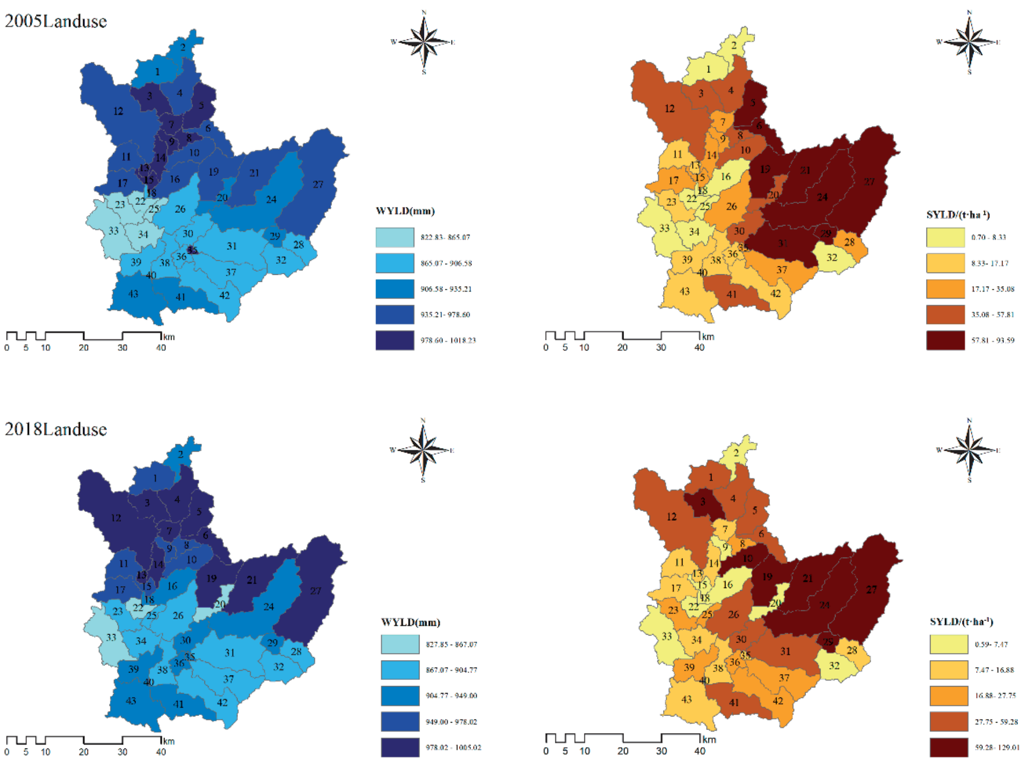

Fig. 3. Runoff and sediment yield of different land use types.

significantly, increased by 3, 4, and 1 m^2, respectively. In addition, the area of forest land in sub-basins No. 34 and 40 decreased by 2 km^2 and 1 km^2, respectively. The grassland area in sub-basin No. 36 was reduced by 4 km^2. The cultivated land area of No. 15, 20, and 35 sub-basins with larger reductions in runoff yield decreased by 3, 5, and 3 km^2, respectively. The area of forest land increased by 4, 11 and 2 km^2,

Table 5. Sub basins with large variation of runoff yield.

Sub. No.	15	20	34	35	36	40
WYLD2005[1]/mm	997.64	911.84	852.56	996.48	906.58	964.66
WYLD 2018[2]/mm	967.55	866.40	898.45	916.53	949.00	1005.02
Difference/mm	-30.09	-45.43	45.89	-79.95	42.43	40.36
Difference[3]/%	-3.02	-4.98	5.38	-8.02	4.68	4.18

1. Multi-year average runoff yield under 2005 land use 2. Multi-year average runoff yield under 2018 land use 3. (Multi-year average runoff yield under 2018 land use - Multi-year average runoff yield under 2005 land use)/ Multi-year average runoff yield under 2005 land use

Table 6. Changes in land use area of sub basins with large changes in runoff yield.

Land use	Difference (km^2)					
	15	20	34	35	36	40
AGRL	-3	-5	3	-3	4	1
FRST	4	11	-2	2	0	-1
PAST	0	0	0	0	-4	0
WATR	1	-6	-1	0	0	0
URBN	-2	0	0	1	0	0

Table 7. Sub basins with large variation of sediment yield.

Sub. No.	1	3	6	20	29	31
SYLD2005[1]/(t/ha)	1.34	56.31	87.78	57.81	78.53	93.59
SYLD2018[2] /(t/ha)	38.63	74.49	52.41	0.62	129.01	59.28
Difference /(t/ha)	37.29	18.18	-35.37	-57.19	50.48	-34.31
Difference[3]/%	2783.22	32.28	-40.30	-98.93	64.29	-36.66

1. Multi-year average sediment yield under 2005 land use 2. Multi-year average sediment yield under 2018 land use 3. (Multi-year average sediment yield under 2018 land use - Multi-year average sediment yield under 2005 land use)/ Multi-year average sediment yield under 2005 land use

Table 8. Changes in land use area of sub basins with large changes in sediment yield.

Land use	Difference (km^2)					
	1	3	6	20	29	31
AGRL	2	-1	-1	-5	0	0
FRST	0	-3	2	11	0	1
PAST	0	0	-1	0	0	1
WATR	0	0	0	-6	0	2
URBN	-2	1	0	0	0	-4

respectively. Compared with other sub-basins, the water area of the No. 20 sub-basin has the largest reduction, with a total reduction of 6 km^2.

In summary, it can be concluded that the increase of forest land will lead to a decrease in runoff yield, and the decrease of grassland will lead to an increase in runoff yield. This shows that forest land and grassland have the effect of reducing water. The increase of cultivated land will increase the runoff yield, indicating that cultivated land's water increase effect is significant compared with other land-use types.

It can be seen from Table 7 that the sediment yield increase in the No. 1, 3 and 29 sub-basins were the most obvious, with the increase in sediment yield being 37.29, 18.18 and 50.48 t/ha, respectively. The decrease in sediment yield in the No. 6, 20 and 31 sub-basins were the most obvious, and the sediment yield decreased by 35.37, 57.19 and 34.31 t/ha, respectively. As can be seen from Table 8, in sub-basin No. 1, where the sediment yield increased significantly, the cultivated area increased by 2 km^2. Although the area of cultivated land in sub-basin No. 3 decreased by 1km^2, the forestland area also decreased by 3 km^2. In the No. 6 and 20 sub-basins where the sediment yield decreased significantly, the area of cultivated land decreased by 1 and 5 km^2, respectively. The area of forestland increased by 2 and 11 km^2, respectively. In the No. 31 sub-basins where the amount of sediment yield decreased, the area of forestland and grassland increased by 1 km^2, respectively. Significantly different from other sub-basins is that the area of urban and rural residential land decreased by 4 km^2. Compared with other land-use types, the area of urban and rural residential land changed the most. The sediment yield in sub-basin No. 29 increased, but the area of land-use type did not change. From the perspective of spatial distribution, the land-use types of forest land in 2018 were more dispersed than those in 2005, and it can be judged that the distribution of forest land led to the increase of sediment yield in sub-basin No. 29.

In summary, it can be concluded that compared with other land-use types, forest land has a noticeable effect on reducing sediment, and cultivated land has an effect on increasing sediment. Compared with other land-use types, urban and rural residential land has an obvious effect on increasing sediment. The spatial distribution of land-use types also leads to the change of sediment yield in the watershed.

Discussion

Handling of Abnormal Rainfall Year

When SWATCUP is used for sediment calibration and verification, the R^2 and NS of the model during the calibration period are slightly lower. The main reason is that the calibration period includes an abnormally high rainfall year (2008), and this phenomenon will reduce the simulation accuracy of the SWAT model [18]. Taking 2006 to 2010 as the calibration period, the R^2 of the sediment simulation is 0.58, and the NS is 0.58. If abnormal rainfall is excluded and the calibration period from 2009 to 2010 is used, the simulation accuracy can be improved (R^2 of sediment simulation is 0.62, NS is 0.61). Although removing abnormal rainfall years can improve the accuracy of the simulation, it shortens the calibration period of the simulation and reduces the representativeness of the simulation. At the same time, considering that the simulation accuracy meets the requirements when 2008 is not excluded, this simulation selects 2006~2010 as the calibration period.

Sensitivity Analysis

Among the 16 selected parameters related to runoff, CN2 is more sensitive than other parameters. The CN2 value is a dimensionless parameter in the SCS runoff curve that reflects the characteristics of the basin in the early rainfall period. It is used to describe the rainfall and runoff relationship in the basin. It demonstrates the runoff yield capacity of the underlying surface in the basin under normal wet conditions. When the rainfall is constant, the value of CN2 increases, and the surface runoff increases [14]. Among the 12 selected sediment-related parameters, USLE_P is more sensitive than other parameters. USLE_P is one of the parameters of China‘s soil loss equation. The larger the value, the better the soil and water conservation measures. [19]. Sediment yield is more sensitive to the change of land-use type than runoff, which may be that runoff mainly comes from rainfall, while sediment directly comes from land. Therefore, the change of land-use type directly impacts the change of sediment yield.

Reference Significance for Soil and Water Conservation Program

From the perspective of the effects of different land-use types in the watershed on runoff and sediment yield, the interception of precipitation by forest land greatly weakens the gravity impact of rainwater on the soil surface and effectively prevents soil erosion. However, urban and rural residential land will change the permeability and water retention of the underlying surface. According to the secondary classification, urban and rural residential land can be classified into urban land, rural residential area, and other construction lands. In 2018, rural residential areas increased more, and the increase of this land-use type is prone to damage the soil layer structure. When it rains, the speed of the confluence will increase, leading to serious soil erosion.

Therefore, from the perspective of water and sediment control, the following measures can be considered: Try to protect the existing forest land from damage. Based on maintaining the current development and current land-use planning, slope land with a slope greater than 25 degrees that is not suitable for farming can be transformed into forest land [20]. Strengthen the management of the important waters and prohibit the blind expansion of construction land. Change the past farming methods and rationally allocate land-use resources in the watershed. This study uses the SWAT model to simulate the runoff and sediment yield in the watershed under different land-use types to obtain the impact of different land-use types on the runoff and sediment yield in the watershed. Therefore, the study provides a certain reference for the formulation of water and soil conservation plans in the basin.

Conclusions

This study took the upper reaches of Jianjiang River Basin as the study area, constructed SWAT model, verified the applicability of SWAT model in the upper reaches of Jianjiang River Basin, and analyzed the yield, runoff and sediment of the upper reaches of Jianjiang River Basin and its sub-basins under different land-use types. The main conclusions are as follows.

1) The optimal R^2 and NS of runoff calibration period at Gaozhou station are 0.73 and 0.71, and the optimal R^2 and NS during the validation period are 0.69 and 0.67. The optimal R^2 and NS of sediment calibration period are 0.58 and 0.58, and the optimal R^2 and NS of sediment validation period are 0.69 and 0.67. The PBIAS of runoff calibration period and validation period are -2.8% and +4.1%. The PBIAS of sediment calibration period and validation period are -3.2% and -12.4%. Although there was an abnormally high rainfall year in 2008, the simulation result of Gaozhou control station is better from the evaluation index.

2) Through the sensitivity analysis of the above regional parameters controlled by Gaozhou Station, it is obtained that the most sensitive parameter for runoff is CN2, and the most sensitive parameter for sediment is USLE_P. The sources of runoff and sediment are different, and the sensitivity of runoff and sediment yield to the change of land-use type is also different.

3) Compared with other land-use types, forestland has the most obvious effect of reducing water and sediment, followed by grassland. Cultivated land has the function of producing water and sand. According to the secondary classification, due to the large increase in rural residential areas in urban and rural residential land, it is easy to destroy the soil structure and cause serious soil erosion. Rational allocation of resources according to different land-use types can realize the organic unity of economic, social, and ecological benefits. Therefore, this study has a certain reference significance for the formulation of water and soil conservation plans in the basin.

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Conflict of Interest

The authors declare no conflict of interest.

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