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Analysis of Influencing Factors of Water and Sediment Condition Change in Fenhe River

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Abstract: Fenhe River is the second largest tributary of the Yellow River, and its water and sediment conditions have undergone tremendous changes in the age scale. The change of water and sediment conditions will inevitably lead to the change of river morphology, which poses a threat to the surrounding ecological environment and building safety. Firstly, this paper analyzes the changes of water and sediment conditions in Fenhe River through historical data. Secondly, according to the engineering measures and policies in the Fenhe River Basin, the influencing factors are put forward. Finally, the effects of rainfall, soil and water conservation, hydraulic construction, industrial water and coal mining on river flow and sediment conditions are considered. The results show that the increase of rainfall and inflow will weaken the sediment generation and carrying capacity, and further reduce the sediment yield. Soil and water conservation will effectively intercept runoff and sediment, reduce the content of the two in the river ; reservoir construction will regulate runoff and incoming sand to reduce the content of river sand. Industrial development and reservoir filling will reduce the amount of river water ; coal mining activities may aggravate the infiltration of the leakage area, resulting in a decrease in upstream runoff.

Keywords: Runoff; sand amount; influencing factors; fenhe River.

1. Introduction

The Fenhe River is the second largest tributary of the Yellow River, with a length of 710 kilometers. The Fenhe River has suitable boating conditions and well-developed traffic activities in history. In fact, until 1929, its downstream can still be used for rowing transportation. However, discontinuous flow was first discovered in the middle reaches of the Fenhe River in 1958, and it has often occurred in various sections of the middle reaches of the Fenhe River in recent decades. By the end of the 1990 s, the upper reaches of the Fenhe River had a serious water shortage problem. At the same time, the region has experienced a trend of warming and drying during the period, and large reservoirs and multiple coal mine bases have been established in the Fenhe River Basin. In order to alleviate serious soil erosion and improve the environment, the national ‘soil and water conservation’, ‘natural forest protection’ and ‘green food’ programs have been implemented in the basin[1-4].

In the early 21st century, a large-scale inter-basin water transfer project was implemented to meet the growing demand for water[6-8]. In view of the increasingly complex and interactive factors and processes in the basin, there are still two basic problems : how have the water (Q) and sediment (S) values changed in the upper reaches of the Fenhe River in the past 60 years? At present, what are the main influencing factors of water and sediment changes in the Fenhe River Basin and how are they affected? This paper will solve the above problems by means of field investigation and data analysis, so as to provide theoretical support for the ecological protection of Fenhe River Basin.

2. Research Area, Data Collection and Methods

2.1. Region of study [6-9]

The Fenhe River Basin is located in the central and southwestern parts of Shanxi Province. The east and west sides are the Taihang Mountains and the Lyuliang Mountains respectively. The terrain is high in the north and low in the south. The topography of the basin includes four basic types : plains, platforms, loess hills and mountains. The main stream of the Fenhe River is about 716 km long, passing through the two basins of Taiyuan and Linfen, and the basin area is about 39741 km2. The basin is located in the mid-latitude continental semi-arid monsoon climate zone. The average annual precipitation is about 500 mm, and the interannual variation of precipitation is large. The precipitation from July to September accounts for about 70 % of the whole year. The urbanization rate of the basin is 64 %, the population accounts for about 40 % of the province, the GDP accounts for about 46 % of the province, and the grain output accounts for about 41 % of the province. Cultivated land, forest land and grassland are the main land use types in the basin (Fig.1). The area with vegetation coverage of 70 % is located in the mountainous area of the basin boundary, among which forest parks and nature reserves are located. The vegetation coverage in most of the remaining areas is below 40%.

2.2. Data and method collection

The hydrological data of annual water volume (Qa) and annual sediment volume (Sa) of four hydrological stations in the upper reaches of the Fenhe River Basin represent the longest time series (1955-2015), and the time changes of Qa and Sa values in these 60 years are investigated. The four hydrological stations include three stations in the upper reaches of the Fenhe River (Jingle, Zhashang, Lancun ; they are called JL, ZS, LC) and a station at the end of the Lan River (Shangjingyou, SJY).

The annual precipitation (Pa) data of four hydrological stations from 1955 to 2015 and the data of six other rainfall measurement stations (Dongzhai, Ningbao, Po, Ting, Gong, Chakou) in 1955 were collected to explore the changes of the average Pa value and Pa value (Pma) of JL, SJY, ZS, LC. The annual average temperature data of Taiyuan Meteorological Station (TTY) from 1955 to 2015 were collected only, mainly

because other meteorological stations lacked these long-term time series data. TTY data were collected from the Shanxi Meteorological Information Center to explore the changes of Qa and Sa values with temperature at the nearby LC station. Table 1 provides the Pma changes of JL, SJY, ZS, LC watershed and TTY in different periods.

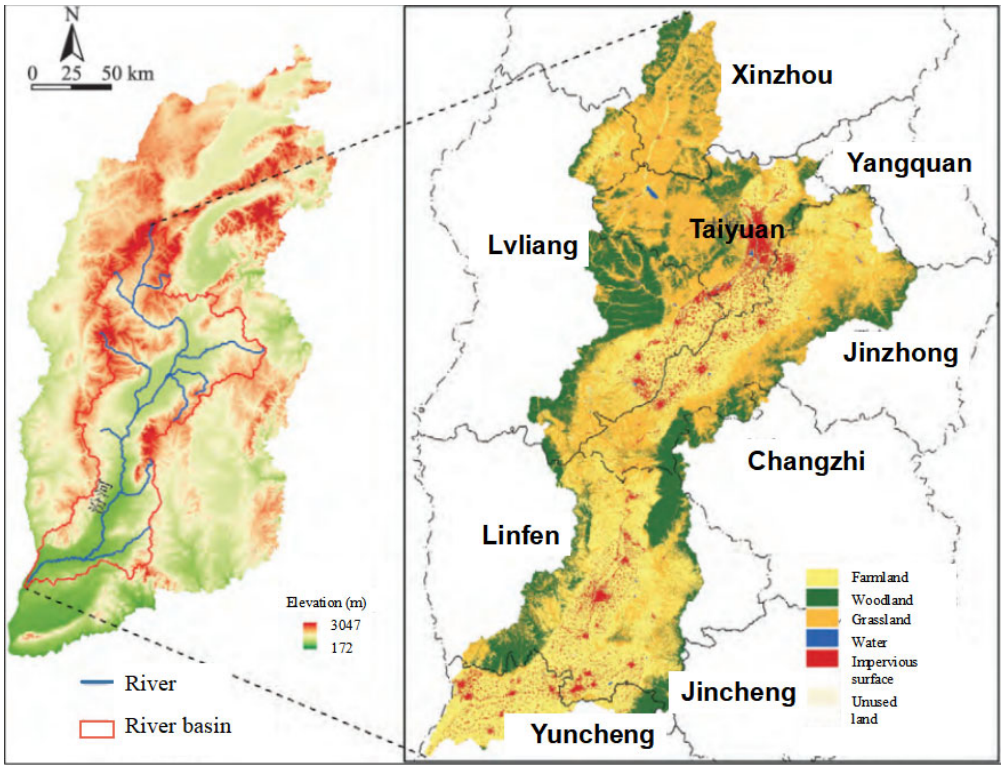


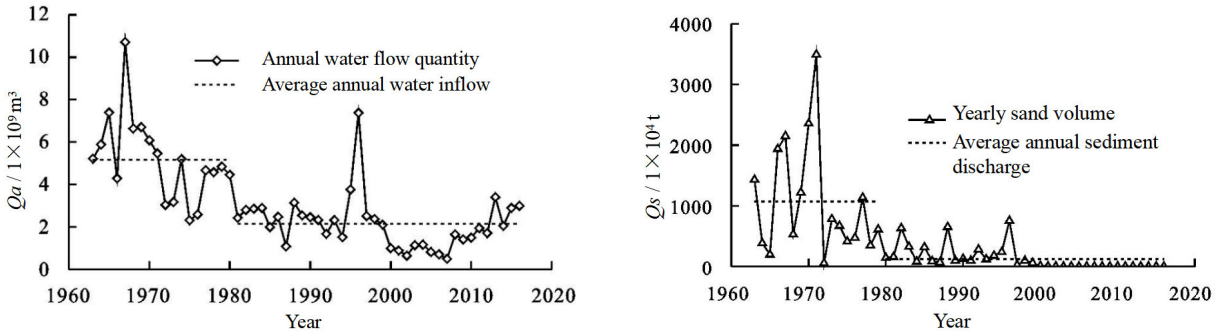
Figure 1. Study area

Table 1. Annual average precipitation in the basin and annual average temperature change of Taiyuan meteorological station

Time	JL (mm)	SJY (mm)	ZS (mm)	LC (mm)	TY (°C)
1955-1959	541	436	492	494	9.4
1960-1969	529	484	509	510	9.5
1970-1979	468	443	449	453	9.6
1980-1989	432	424	437	437	9.7
1990-1999	500	408	450	449	10.4
2000-2009	515	469	488	487	11
2010-2015	565	553	533	530	11

3. Changes of Water and Sediment in The Study Area

The flow and sediment in the study area are taken as the research object in Lancun section, and the change of water and sediment in Lancun section is shown in figure 2.



(a) River water inflow (b) The amount of river sediment

Figure 2. Annual water and sediment change

It can be seen from Fig.2 that the interannual variation curves of annual runoff and annual sediment transport in the middle and upper reaches of the Fenhe River from 1963 to 2016 showed that with the increase of years, the annual precipitation in the middle and upper reaches of the Fenhe River showed a decreasing trend, and the reduction rate was

about 0.7mm/a. From 1963 to 1999, the annual runoff of Lancun Station showed a decreasing trend with a decreasing rate of about 8.67 million m^3/a, while it showed an increasing trend from 2000 to 2016. From 1963 to 2016, with the increase of the year, the annual sediment load of Lancun station showed a significant decreasing trend, especially after 1997, the annual sediment load was less than 2 million tons, and the annual sediment load reduction rate before 1990 was about 450,000 t/a.

The average annual precipitation in the middle and upper reaches of the Fenhe River Basin from 1963 to 2016 was 479.7 mm, the extreme value ratio of annual precipitation was 2.7, and the coefficient of variation was 0.21. From 1963 to 2016, the average annual runoff of Lancun station was 315 million m^3. The average annual sediment discharge of Lancun station is 4.168 million tons, and the interannual variation coefficient of annual sediment discharge is about 1.65.Therefore, compared with annual precipitation and annual runoff, the interannual variation of annual sediment discharge is more intense, which is mainly related to the large-scale implementation of the project of returning farmland to forest and grassland and soil and water conservation engineering measures such as check dams and terraces in the middle and upper reaches of Fenhe River since the 1990 s. The main influencing factors affecting the water and sediment changes in the Fenhe River Basin will be analyzed below.

4. Analysis of Influencing Factors

4.1. Rainfall factors

Table 1 and Fig.2 show that since the early 1980s, the Qa values of SJY, ZS and LC stations have decreased significantly. Around 1980, the two-mass curves of Qa − Pma at the three sites shifted significantly to the right. Similar results were obtained for the 1957-2010 Fenhe Qa series. The decrease of rainfall and water volume will weaken the sediment generation and carrying capacity, and further reduce the sediment volume.

4.2. Soil and water conservation

After 1988, a large-scale soil and water conservation plan was carried out in the upper reaches of the Fenhe River Basin. From 1983 to 1994,39 new check dams were built in the SJY basin, of which 33 were built after 1988, and only two reservoirs (Lancheng and Hamashen reservoirs) and three check dams were built in the first phase. These check dams and reservoirs have cumulatively controlled 50 % of the loess hilly gully basin in the SJY basin, effectively intercepted runoff and sediment, and greatly reduced the second phase of QaSJY and SaSJY. The decrease of rainfall and the increase of soil and water conservation measures are also the reasons for the decrease of QaJL and SaJL values in the same period. The SJY watershed is dominated by the characteristics of loess hilly and gully, which is more prone to soil erosion and is more affected by soil and water conservation measures. In addition, the construction of two reservoirs in the SJY basin may also lead to these observed differences.

4.3. Reservoir construction

In the 1980 s, after the soil and water conservation plan was carried out in the two basins, the Pma values of the ZS and LC basins were also very small. These may be attributed to the regulation of runoff and sediment interception effects by Fenhe No.1 Reservoir in the upper reaches of ZS. Reservoirs have different effects on the regulation of gradual flow and complete deposition. The reservoir mainly supports farmland irrigation, but since the 1980s it has been supplying water for industrial activities in Gujiao City in the ZS basin and Taiyuan City downstream of the LC station.

4.4. Industrial water

In the second phase, five large underground coal mines and supporting coal preparation plants were built in Gujiao City. By the end of this year, the annual output of coal reached 16.5 million tons, and the total industrial output value of the city was 36.3 times higher than when China's reform and opening up policy was implemented in 1978. Taiyuan is an important industrial city in northern China. The port high water consumption industry (such as metallurgy, coal, coking, chemical industry) accounts for 68.81 % of the industrial output value in the early 1990 s. The sharp decline of QaZS and QaLC in the second phase is the result of industrial development and reservoir filling in the two cities, resulting in increased river diversion, reduced rainfall, reduced upstream inflow, and the implementation of soil and water conservation measures.

4.5. Coal mining

The large amount of mining activities in the Gujiao coal mine may aggravate the infiltration of the leakage area, resulting in a decrease in upstream runoff. These factors also lead to a decrease in SaZS and SaLC values.

5. Conclusion

In this paper, the change of water and sediment conditions of Fenhe River in the age time scale is analyzed by historical data, and the influencing factors are studied. The main conclusions are as follows :

The interannual variation curves of annual runoff and annual sediment discharge in the middle and upper reaches of the Fenhe River from 1963 to 2016 showed that with the increase of years, the annual precipitation in the middle and upper reaches of the Fenhe River showed a decreasing trend, and the reduction rate was about 0.7 mm/a. From 1963 to 1999, the annual runoff of Lancun Station showed a decreasing trend with a decreasing rate of about 8.67 million m^3/a, while it showed an increasing trend from 2000 to 2016.

The main factors affecting the water and sediment changes in the study area are : rainfall, soil and water conservation, hydraulic construction, industrial water and coal mining.

The increase of rainfall and inflow will weaken the sediment generation and carrying capacity, and further reduce the amount of sediment. Soil and water conservation will effectively intercept runoff and sediment, reduce the content of the two in the river ; reservoir construction will regulate runoff and incoming sand to reduce the content of river sand. Industrial development and reservoir filling will reduce the amount of river water ; coal mining activities may aggravate the infiltration of the leakage area, resulting in a decrease in upstream runoff.

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