

An Analysis of Driving Factors on Water and Sediment Evolution

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Abstract. The underlying surface has an influence on the characteristics of runoff and sediment characteristics in river basins. And the features of the different scales underlying surfaces have various effects on the runoff and sediment discharge in Kuye River. By analysing the concerned data from 1980 to 2013, this paper took 3 different scales watersheds in Kuye River Basin as the objects to study the influence of the underlying surface change on the runoff and sediment evolution in different scales and calculate the correlation degree of the driving factors by using grey relational analysis.

1 The background and the significance of research

Kuye River, as one of the main tributaries of the Yellow River, is the main sediment source of Yellow River, which spans Shaanxi province and Inner Mongolia. It is a national key rehabilitation area for soil erosion prevention, and the most serious soil erosion areas in Yellow River basins. The contradiction between resources and ecological environment is prominent in this area. ^[1] It has vital and practical significance to influence the degree of factors affecting soil erosion changes, the basin area of the sustainable utilization of soil and water erosion, ecological environment protection and recovery through analysing the water flow, sediment, runoff and other elements of Kuye River from 1980 to 2013.

The impacts of climate change and human activities on the underlying surface are the two main reasons for the water and sediment changes in the study area of the water cycle of the river basin. Human activities affect the change of landscape pattern of underlying surface, soil infiltration characteristics and erosion degree, and then affect the change of water and sand. ^[2] In recent years, the effects of climate change and human activities on runoff and erosion and sediment production have become increasingly obvious. The qualitative analysis of human activities has mainly focused on hydro-logical trends. We need the quantitative analysis to intuitively reflect the control effect of changes in land use and water conservancy measures. The study on sediment transport relationship is still a weak link in the study of soil erosion, because land cover is a time-consuming process and it is difficult to obtain quantitative expression data. In addition, the ecological engineering of soil and water conservation and the construction of silt dam in Kuye

River have been gradually carried out. The effect of soil and water conservation measures is lagging behind to some extent. ^[3] This paper selects Kuye river as the research object and divides Kuye River into three different scale regions to study the changes of water and sand in each block of Kuye River in a more detailed way. Based on the analysis of the trend of runoff and sediment transport in the three regions divided by Kuye River from 1980 to 2013, the paper divides typical periods and carries out quantitative research on the influence of precipitation factors and human factors in each period, and then obtains the main reasons influencing the water and sediment changes in different periods through comparative analysis, providing scientific basis for soil and water conservation and treatment.

2 Research contents and technical routes

2.1. Research contents

Taking Kuye River on the Loess plateau as the research area, this paper studies the change characteristics and correlation of the rainfall, runoff and sediment transport data and vegetation coverage data of Kuye River from 1980 to 2013 in order to reveal the influence rule of climate and human activities factors on the change of sand in Kuye River.

As an object of study, Kuye River basin was divided into three areas. The basin above Xinmiao hydrological station was taken as the first area, the catchment area was 1431km²; the basin above Wangdao Heng Tower hydrological station was taken as second area; the catchment area was 3838km², and the basin above Wenjiachuan hydrological station was taken as the third area and the catchment area was 8707km².

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In this study, the hydrological data of three stations from 1980 to 2013 were collected and the Mann-Kendall check method was used to determine the variation trend and typical characteristic years of the study area during the period from 1980 to 2013. The driving factors of water and sediment evolution were specifically analysed, and the disturbance of each factor was calculated with the grey relational analysis method combining with the documents of land use data on the production and construction.

The hydrological data of three selected hydrological stations were collected from 1980 to 2013. Among them, the basin rainfall data was calculated based on the Tyson polygon method for rainfall stations deployed in the basin. The runoff and sediment transport data were deduced from the hydrological monitoring data of three hydrological stations in the selected watershed. [4] The land use data of the river basin were obtained by processing the TM / ETM image maps of the vegetative period in the selected year and the hydrological data were provided by the Hydrographic Bureau of the Yellow River Water Conservancy Commission using ArcGis image processing software.

2.2. Identify typical years

The rainfall and runoff in Kuye River basin increased regularly, and two turning points occurred in 1988 and 1997 respectively, which can be preliminarily divided into three typical periods of water and sediment changes, namely, 1980~1988, 1989~1997, and 1998~2013.

In order to verify the accuracy of the selection of typical year periods, Mann-Kendall iterative correlation test was used to analyze the division of typical year periods of runoff and sediment transport from 1980 to 2013. This method was introduced into the inverse sequence, and another curve UB was calculated. Then the intersection point of the two curves within the

confidence interval was determined as the abrupt change point.

Given a significance level of $\alpha=0.05$, the critical value of UF and $>$ was 1.96uf, indicating an upward trend. Otherwise, it shows a downward trend, greater than or less than 1.96, indicating an obvious upward or downward trend or an insignificant upward or downward trend.

The Mk check method sets the original time series as $y_1, y_2, \dots, y_n, m_i$, which represents the cumulative number of the i -th sample y_i greater than y_j ($1 \leq j \leq i$) and defines statistics.

$$d_k = \sum_{i=1}^k m_i, (2 \leq k \leq n) \quad (2-1)$$

Under the assumption of random independence of the original sequence, the mean and variance of d_k are respectively shown below:

$$E(d_k) = k(k-1) / 4 \quad (2-2)$$

$$\text{var}(d_k) = k(k-1)(2k+5) / 72 \quad (2-3)$$

Normalizing the d_k of the above formula to indicate below

$$UF_K = \frac{d_k - E(d_k)}{\text{var}(d_k)} \quad (2-4)$$

UFK forms a UF curve, which can be obtained by reliability test to see if there is a clear change trend.

This method is introduced into the inverse sequence, and another curve UB is calculated. The intersection point of the two curves within the confidence interval is determined as the mutation point.

Given the significance level $\alpha = 0.05$, the critical value of the statistic UF sum is ± 1.96 . $UF > 0$ indicates that the sequence is on the rise; otherwise, it means that it is on the decline, greater or less than ± 1.96 , which shows that the upward or downward trend is obvious.

Table 2-1. The trend of runoff and sediment discharge at Wenjiachuan station in Kuye River from 1980 to 2013

	τ	Var(τ)	M	significance level α	Critical value	Criterion	Trend	
Runoff	1980—1988	0.04	6.69	0.05/0.01	1.96/2.58	$M > 2.58$	Extremely significantly increased	
	1989—1997	0.07	0.16	0.05/0.01	1.96/2.58	$1.96 > M$	Not significantly increased	
	1998—2013	-0.67	0.31	2.12	0.05/0.01	1.96/2.58	$2.58 > M > 1.96$	Significantly reduced
	τ	Var(τ)	M	significance level α	Critical value	Criterion	Trend	
Sediment	1980—1988	0.28	0.04	6.69	0.05/0.01	1.96/2.58	$M > 2.58$	Extremely significantly increased
	1989—1997	0.33	0.16	2.14	0.05/0.01	1.96/2.58	$2.58 > M > 1.96$	Significantly increased

1997—2013	-0.67	0.31	2.12	0.05/0.01	1.96/2.58	2.58 > M > 1.96	Significantly reduced
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As the results show that in the case of $\alpha = 0.05$, it can be seen from the UF icon of Mann Kendall method that the UF values in the first period from 1980 to 1988 are basically greater than zero and less than 1.96, which is insignificant increase periods. The trend of sediment transport quantity is consistent in the Xinmiao station. The sediment transport quantity of Wangdaoheng Tower does not increase significantly, while the runoff quantity is not significantly reduced. The reason is that the coal mine development in Yulin of Shaanxi Province leads to the destruction of the underlying surface, which affects the runoff. The runoff and sediment transport in the Wenjiachuan area show a consistent trend. The runoff and sediment transport in the Xinmiao area show an insignificant trend of decrease in the second period from 1989 to 1997.

With the implementations of the measures of returning farmland to forest, natural forest protection project, grassland and woodland have increased, and the function of water and soil conservation has begun to manifest. The bank protection of the caves and Kuye River Basin adopts Gabion mesh gabion slope protection and foot protection, and geotextiles are laid under the gabion protection slope. Using such advanced construction technology can not only ensure the safety of the main project, reduce the cost of treatment, but also plays an effective role in controlling and reducing soil erosion. Overall, such methods have a good comprehensive effect to restore and consolidate soil and water conservation facilities surrounding the project construction area, improve the ecological environment in the project area, and achieve coordinated development of the ecological environment and regional economy.

The effects of adopting soil and water conservation measures begin to emerge. The runoff in the Wangdao Heng Tower area did not decrease significantly. The calculated UF of the annual sediment transport was greater than 0 and less than 1.96, and the sediment transport did not increase significantly. The sediment transport volume and runoff in Wenjiachuan area did not increase significantly. In the third period from 1998 to 2013, the UFs of the three regions were less than -2.58, and the sediment transport volume and runoff volume showed a significant reduction trend. The trends of runoff and sediment transport volume changed significantly during each period, indicating that the division of time periods conforms to the change characteristics of runoff and sediment. Therefore, the period from 1980 to 1988, 1989 to 1997, 1998 to 2013 is defined as the typical years. The corresponding double cumulative curve and regression equation are obtained.

2.3. The Analysis on the evolution trend of water and sand

The first period from 1980 to 1988. It is the beginning stage of soil and water conservation in Kuye River Basin in 1970s and 1980s. The degree of soil and water

treatment was relatively low and the underlying surface was less affected by human activities. Therefore, compared with the latter two stages, it can be considered that the underlying surface during this period is a natural condition, and the runoff and sediment transport volume are only affected by rainfall. The runoff and sediment transport volume changed abruptly from 1985 to 1987, because in the mid-1980s, the large-scale coal mining in the middle stream of the Yellow River has changed the original structure of the underlying surface, affected the normal recharge of groundwater, and caused serious water and soil erosion, including river channel shrinkage and discontinuation, which affected the runoff and sediment transport.

The second period from 1989 to 1997. Water and soil erosion caused by massive coal mining has drawn the attention of Ministry of Water resources and other relevant organizations and special treatment projects have been carried out. It can be seen that the soil and water loss has slowed down from 1989 to 1997. On the other hand, the large-scale development of water conservation measures is conducive to water storage and soil conservation at this stage which was influence stage of human activities, and also the stage of slow decline of runoff and sediment transport.

The third period from 1998 to 2013. Soil and water erosion has decreased significantly, which shows that under the comprehensive management of rivers in Kuye River Basin, the runoff and sediment transport volume in this period has a significant downward trend, and the effect of water and sediment conservation is obvious. The total number of backbone dams and large-scale mud dams completed in Kuye River Basin reached 789, and the area of the controlled watershed reached 388.9km², accounting for 4.2% of the total area of the watershed. 3270 silt dams were built, and the area could be 4,873hm² [5]. On the other hand, the area of forest and grass in the third period increased by 90.1% over the second period, and the runoff decreased by 54% compared with the previous period. According to the results of soil and water conservation statistics, the current situation of Kuye River Basin has 291 backbone dams. There are 1071 small and medium-sized silt dams, and 1587 small-scale water storage and soil conservation projects (blocks, eyes). What really has a direct impact on river runoff is the construction of backbone dams. Compared with 1998, the backbone dams increased by 192 in 2010. After the construction of backbone dams, a certain water surface area will be formed due to the water storage capacity, which will increase the evaporation loss and reduce the runoff. The groundwater has been over-exploited in the past 10 years. From 1978, 1989, and 2010, remote sensing interpretation results show that the average vegetation coverage of the Kuye River Basin in 1978 was about 15%, and the average vegetation coverage of the Kuye River Basin in 1998 was 30% in 2010, the average coverage of cave wild river vegetation reached 47%. It can be seen that the vegetation in the Kuye River Basin has increased significantly in the past

ten years, which indicates that the combination of soil and water conservation engineering measures and forestry measures has made significant effect on Kuye River Basin water storage and soil conservation. The third period is the period when the runoff and sediment transport volume decreased significantly.

sediment discharge and runoff reduction in value calculated by formula 3-1 and 3-2 at different times during evaluation period, the average annual reduce annual runoff and sediment discharge, and each time the effect of water and sediment reduction .^[6]

$$B_Q = \frac{Q_c - Q_a}{Q_c} \times 100\% \quad (3-1)$$

$$B_S = \frac{S_c - S_a}{S_c} \times 100\% \quad (3-2)$$

3 The effect of water and sediment reduction

3.1. The Calculation on the effect of reducing water and sand

According to the cumulative rainfall accumulated runoff double mass curve and cumulative rainfall - accumulated sediment discharge double mass curve on the tropic of cancer each year accumulation plan calculation value and the measured values, can calculate the average annual

In the formula: BQ and BS represent the water reduction effect and the sand reduction effect (%) respectively; Qc is the annual average runoff during the study period (104m3) and the annual average runoff measured during the research year (104m3), and Sc is the annual average of sediment discharge quantity calculated in study period (104t).Sa is the average annual sediment discharge quantity measured in the study period (104t).

Tab.3-1. The results of water and sediment reduction in Xinmiao

Evaluation period Xinmiao	Actual measurements of annual Runoff/104m3	The predictions on Annual Runoff /104m3	Water Reduction Effect /%	Actual measurements of sediment discharge /104t	The predictions on annual sediment discharge /104t	Sand reduction effect /%
1980—1988	8116	7567	7	1087	972	12
1989—1997	8306	5860	42	991	869	14
1998—2013	3099	1880	64	176	127	38

Tab.3-2. The results of water and sediment reduction in Wangdao Heng Tower

Evaluation period Wangdao Heng Tower	Actual measurements of annual Runoff /10 ⁴ m ³	The predictions on Annual Runoff /10 ⁴ m ³	Water Reduction Effect/%	Actual measurements of sediment discharge /10 ⁴ t	The predictions on annual sediment discharge /10 ⁴ t	Sand reduction effect /%
1980—1988	16719	16616	0.6	1790	1986	9
1989—1997	14900	14113	5	1789	2075	14
1998—2013	7292	6843	6.6	45	34.5	30

Tab.3-3. The results of water and sediment reduction in Wengjiachuan

Evaluation period Wengjiachuan	Actual measurements of annual Runoff /10 ⁴ m ³	The predictions on Annual Runoff /10 ⁴ m ³	Water Reduction Effect /%	Actual measurements of sediment discharge /10 ⁴ t	The predictions on annual sediment discharge /10 ⁴ t	Sand reduction effect /%
1980—1988	46677	47091	0.8	6285	6278	0.2
1989—1997	49386	51970	6.9	7731	8028	2
1998—2013	17278	20147	14.2	1100	693	58

From Table 3-1 to Table 3-3, it shows that the effects of water and sediment reduction in the three periods increase with the evaluation period, indicating that soil and water conservation measures in the Kuye River Basin, including forestry and agricultural measures and water conservation engineering measures, have exerted the effect of continuous water storage and soil conservation. With the increase of the degree of governance, the water and soil conservation effect become more obvious. Observed from the entire evaluation period, the new temple 's water reduction effect was 64% during the effect evaluation period. The sand reduction effect was 38%, and the water reduction

effect was greater than the sand reduction effect. Wang Daoheng Tower 's tax reduction effect during the effect evaluation period was 6.6. The% sand reduction effect is 30%. During the effect evaluation period, Wen Jiachuan's water reduction effect was 14.2%, and the sand reduction effect was 58%; the sand reduction effect was greater than the water reduction effect.

4 The Impact of land use types on changes in water and sediment

Vegetation coverage is a sensitive driving factor for changes in the ecological environment, water and

sediment. Vegetation plays role in retaining water and retaining soil to intercept rainfall and regulate runoff. It is closely related to soil and water loss in the study area. The vegetation coverage has a significant effect on reducing soil erosion. Under the same climate conditions, the lower the plant coverage is, the more severe the soil erosion, the higher the plant coverage, and the less the soil erosion.

It can be seen from Table 4-1 that the average vegetation coverage of the Kuye River watershed in 1989, 1998, and 2011 was 22.1%, 21.8%, and 25.1%, respectively, showing a rising trend of fluctuations. The vegetation coverage in most areas of the river watershed is between 0-40%, of which the vegetation coverage area below 40% in 1989 and 1998 accounted for more than 80% of the total area of the river basin. Vegetation throughout the watershed is at a low-medium vegetation coverage level. From 1989 to 1998, the area of low, medium and low vegetation coverage increased, and the area of medium, medium and high vegetation coverage decreased. The vegetation coverage area of each grade has a small change range, and the changes mainly occur between low, medium-low, and medium vegetation coverage levels. [7] Among them, the area covered by low value increased by 223.67 km², with an average annual increase of 0.57%; the area covered by low and medium vegetation increased by 240.36 km², with an average annual increase of 0.93%; the area covered by medium vegetation decreased by 287.04 km², with an average annual change of -3.31%. In 1989, the area with better vegetation coverage was located in the loess hilly and gully area in the southeast of the basin and the northwest of the sandy grassland area. In 1998, the vegetation in the loess hilly and gully area in the southeast of the basin was degraded with decreased vegetation coverage. From 1998 to 2011, the area of low vegetation coverage

decreased, and the area of vegetation coverage of the other four levels increased. This shows that the vegetation in the Kuye River watershed has entered a period of rapid recovery. The area of low vegetation coverage decreased drastically, and the percentage of the watershed area decreased from 52.49% in 1998 to 23.32%, a decrease of 2539.47 km², with an average annual change of -4.27%. The vegetation coverage area of other grades has increased to varying degrees compared with the corresponding vegetation coverage in 1998. Among them, the medium vegetation coverage area accounted for the largest increase in watershed area, with an average annual increase of 17.63%. The changes in the area of low-medium and high-vegetation coverage were the second, increasing by 525.93 km² and 458.96 km², respectively. The area of high-vegetation coverage was relatively small, increasing by 2.76 km². It can be seen that the surface vegetation coverage and the ecological environment have improved. Some achievements have been made in ecological restoration. Analysing Table 4-1 and comparing the three-stage vegetation coverage map. In terms of quantity, the area of vegetation coverage at two levels of low vegetation coverage and high plant coverage decreased, and the area occupied by vegetation coverage at three levels of low, medium, and high increased. From the perspective of the change range, the coverage area of the middle and middle high values changed significantly, followed by the large change of the low vegetation coverage area, and the small change of the low and high vegetation coverage area. From a spatial perspective, it is obvious that the change of the vegetation coverage in Dongsheng District has decreased, while the vegetation coverage in Shenmu County has increased. Throughout the study period, the vegetation coverage showed an increasing trend, and the ecological environment developed in an upward trend.

Tab.4-1: Statistics of M_{NDVI} change trend in Kuye River Basin from 1982 to 1989

Year	Vegetation Coverage / m ²	Xinmiao/m ²	Wangdao Heng Tower/ m ²	Wenjiachuan/m ²
1980~1989	125491.0	20580.5	55303.9	125491.0
1990~1996	146655.1	24051.4	64630.9	146655.1
1997	154787.1	25385.1	68214.7	154787.1
1998	161414.7	26472.0	71135.4	161414.7
1999	169368.6	27776.5	74640.8	169368.6
2000	179414.4	29424.0	79067.9	179414.4
2001	191027.2	31328.5	84185.7	191027.2
2002	206470.4	33861.1	90991.5	206470.4
2003	220518.7	36165.1	97182.6	220518.7
2004	229707.1	37672.0	101231.9	229707.1
2005	238868.1	39174.4	105269.2	238868.1
2006	244317.5	40068.1	107670.7	244317.5
2007	251094.0	41179.4	110657.1	251094.0
2008	261399.3	42869.5	115198.7	261399.3
2009	271705.6	44559.7	119740.7	271705.6
2010	282007.2	46249.2	124280.6	282007.2

2011	293199.0	48084.6	129212.8	293199.0
2012	301569.9	49457.5	132901.8	301569.9
2013	301597.8	49462.0	132914.2	301597.8
Percent	—	16.40%	44.07%	100.00%

5 The analysis of driving factors on grey relational method

The specific calculation steps of grey relational analysis are as follows:

The reference sequence that determines the reference sequence reflecting system behaviour characteristics and the comparison sequence that affects system behaviour reflects system behaviour characteristics. A data sequence consisting of factors that affect system behaviour is called a comparison sequence. The reference series are runoff and sediment discharge, and the comparison series are human impacts and rainfall. The impact of human activities is reflected in vegetation coverage. The reference sequence and comparison sequence are dealt with in a dimensionless process due to the different physical meanings of various factors in the system. The dimension of data is not necessarily the same, which is not easy for comparison. Therefore, dimensionless data processing is generally required in the grey relational analysis.

Find the so-called degree of correlation between the gray correlation coefficient $\xi(k)$ of the reference sequence and the comparison sequence. For a reference sequence X_0 , there are several comparison sequences $X_1, X_2 \dots X_n$. Each comparison sequence and reference sequence at each time (ie, points in the curve). The correlation coefficient $\xi(k)$ can be calculated by the

following formula: where P is the resolution coefficient and $P > 0$, usually 0.5. The second-stage minimum difference is recorded as Δ_{min} . The maximum difference between two levels is marked as Δ_{max} . The absolute difference between each point on the X_i curve of each comparison series and each point on the X_0 curve of the reference series, so the correlation coefficient is also written as formula (5-1):

$$\xi(k) = \frac{\min_i \min_k |X_0(k) - X_i(k)| + P \max_k \max_i |X_0(k) - X_i(k)|}{|X_0(k) - X_i(k)| + P \max_k \max_i |X_0(k) - X_i(k)|} \quad (5-1)$$

Find the degree of correlation r_i . The correlation coefficient is the value of the degree of correlation between the comparison sequence and the reference sequence at each time (ie, each point in the curve). It is necessary to gather the correlation coefficients at each time (ie, each point in the curve) into one value, that is, to find the average. As the quantitative expression of the degree of correlation between the comparison sequence and the reference sequence, the correlation degree r_i formula is shown below (8):

The degree of correlation among the ranking factors of correlation degree is mainly described by the order of correlation degree, not only by the order of correlation degree. The correlation degree of M subsequences to the same parent sequence is arranged in order of magnitude.

The grey relational degree of the three studied areas of Xinmiao, Wangdaoheng Tower, and Wenjiachuan is less than that of the area covered by vegetation.

Table 5-1: The comparison of grey relational degree of runoff in different periods in the study area

Relational Degree r_i	Xinmiao Rainfall	Xinmiao Vegetation	Wangdao Heng Tower Rainfall	Wangdao Heng Tower Vegetation	Wenjiachuan Rainfall	Wenjiachuan Vegetation
1980~1988	0.56	0.80	0.65	0.85	0.52	0.755
1989~1997	0.49	0.68	0.25	0.47	0.39	0.57
1998~2013	0.56	0.84	0.44	0.72	0.52	0.76

Table 5-2 : The comparison of grey relational degree of sediment transport in different periods in the study area

Relational Degree r_i	Xinmiao Rainfall	Xinmiao Vegetation	Wangdao Heng Tower Rainfall	Wangdao Heng Tower Vegetation	Wenjiachuan Rainfall	Wenjiachuan Vegetation
1980~1988	0.92	1.19	1.46	1.53	0.86	1.03
1989~1997	0.75	0.94	1.49	1.68	1.09	1.29
1998~2013	0.77	1.05	0.98	1.24	0.92	1.15

According to the grey analysis method, the two driving factors that affect runoff, rainfall and vegetation coverage, the correlation of vegetation coverage is significantly higher than that of precipitation, and the correlation is not significantly affected by the size of the scale. During the three typical years, the corresponding rules are followed. For rainfall and vegetation coverage,

the two driving factors that affect sediment transport, the correlation of vegetation coverage is greater than the correlation of rainfall, and the correlation is not significantly affected by the size of the scale. This rule was followed in three typical years of division periods.

Firstly, this paper divides Kuye River into three regions. According to the regional rainfall-runoff and rainfall-sediment flow and the Mann-Kendall trend

analysis method, three typical periods are determined. The changes of water and sediment in three typical periods in three regions were discussed respectively to determine the effect of water and sediment reduction and its driving factors. The period did not increase significantly from 1980 to 1988, in the second period from 1989 to 1997, it did not decrease significantly and the amount of sediment transport did not increase significantly. In the third period from 1998 to 1997, the UFs of the three regions were all less than -2.58, and the sediment transport volume and runoff showed a significant reduction trend. The water reduction effect of Xinmiao during the effect evaluation period is 64%, the sand reduction effect accounting for 38%, and the water reduction effect is greater than the sand reduction effect. During the effect evaluation period, the water reduction and sediment reduction effects of Wangdaoheng Tower were 6.6% and 30% respectively. The water reduction effect of Wen Jiachuan was 14.2% with 58% of the sand reduction effect. The sand reduction effect was greater than the water reduction effect. According to the grey analysis method, the correlation degree of the change of water and sediment caused by the impact of human activities on the underlying surface is greater than the correlation degree of the change of water and sediment caused by the amount of rainfall.

The runoff of Kuye River decreased due to the effect of rainfall variation accounting for 32.3%, and the effect of the underlying surface change caused by human activities accounted for 67.7%. Among the impacts of human activities, the impact of groundwater mining accounted for 18.2%, the impact of vegetation change accounted for 34.5%^[3], the construction of silt dams accounted for 3.0%, and the impact of coal mining accounted for 17.2%. Other factors, such as reservoir construction, the increase of construction projects, urbanization, acceleration of highway construction, and other unpredictable factors, account for 27.1%^[8-9].

According to the process of change over the years, the sediment runoff at each station tends to decrease. The average annual sediment inflow in Kuye River basin decreased from 1.25×10^8 t in the 1950s and 1960s to 0.0462×10^8 t from 2001 to 2010, reducing 96.3% of the total sediment. The sediment in Kuye River reduced due to the rainfall variation accounting for 42.4%, and water conservancy and water conservation measures accounting for 57.6%.

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