ISSN 2616-5872 Vol.6, Issue 2: 54-58, DOI: 10.25236/AJEE.2024.060207

Analysis of the Change Rule and Future Trend of Yellow River Water and Sand Flux Based on Linear Programming Model

Jinjin Dang*, **Zhenhao Cui, Jinyang Liu, Yitong Tian**

Luoyang Polytechnic, Luoyang, 471000, China
**Corresponding author: dangjinjin57@163.com*

Abstract: *Changes in the water and sand fluxes of the Yellow River are not only related to the environmental management along the Yellow River basin, but also have far-reaching impacts on climate change and people's lives. In order to deeply understand the dynamic change law of water and sand flux, this paper adopts a multiple linear regression model to analyse the influencing factors of water and sand flux in the Yellow River. Among them, multiple regression equations were established with water level and flow rate as independent variables, and the results of the model showed that water level is the main factor influencing the sand content. Meanwhile, the article also calculated the total flow and sand discharge in the last 6 years, which provided basic data for the follow-up study. The results show that there are obvious seasonal and interannual variations in the water and sand fluxes of the Yellow River, and there is a complex correlation relationship with meteorological factors. Possible trends of the Yellow River water and sand fluxes are derived through model prediction and simulation, which provide a scientific basis for the development of sustainable water resources management strategies and help to ensure the sustainable use of water resources in the Yellow River Basin.*

Keywords: *Water-sediment Monitoring; Time Series Analysis; Linear Regression; Seasonality*

1. Introduction

The Yellow River, as one of the important water systems in China, the changes of its water and sand fluxes are of great significance to the ecosystems, agricultural irrigation, flood control projects and socio-economic development in the basin[1]. With the changes of climate change, human activities and land use, the water and sand fluxes of the Yellow River show complex and dynamic characteristics, and an in-depth study of its changing law is crucial for effective water resources management and ecological environmental protection. Although the Yellow River has nurtured a bountiful land, its flooding problem has also been of great concern.Yellow River floods are usually caused by river overflow, flooding or riverbed diversion, etc. Yellow River water and sand fluxes show complex and dynamic characteristics, which have attracted extensive attention from academics and policy makers. In order to better understand and cope with this change, the use of linear programming model has become an effective way to explore the changing law of Yellow River water and sand flux. Known for its mathematical rigour and good adaptability to complex systems, linear programming models can be used to analyse complex water resource management problems. By introducing relevant variables and constraints into the model, we can quantitatively analyse the changes of water and sand fluxes in the Yellow River and explore the interrelationships among different factors. The application of such a model is expected to provide critical insights that will contribute to effective water resource management and ecological protection.

Historically, floods in the Yellow River have occurred repeatedly, bringing serious damages and losses to the areas along the river. Methods such as water-sand relationship curve and linear regression method are used to estimate the contribution of human activities and climate to water-sand changes, and the impacts of the construction of terrace reservoirs and land use changes on water-sand are highlighted[2]. Zhao Yang et al. took the Ningxia section of the Yellow River as the research object, and carried out a study on the influence of regional soil erosion control on the change of water and sand in the watershed by comprehensively adopting the test of water and sand trend and the sediment quantity balance, etc. The results showed that the area of the soil and water conservation measures increased dramatically and the effect of the sand reduction was significant after the year 2000[3]. Hu Chunhong et al. constructed a multi-model prediction result ensemble assessment technique based on the attribution of water and sand changes and the uncertainty analysis of prediction results, and predicted the water and sand volume of the Yellow River Basin in the next 50 a. The results showed that the established watershed water and sand trend test and sediment load balance methods were used. The results show that the reason for the big difference between the attribution of water and sand changes and the prediction results of the existing river basin is the uncertainty of different methods due to the differences in data input, variable composition and accuracy evaluation methods[4]. Zheng Jiayun et al. used the coefficient of variation, Mann-Kendall test and wavelet analysis to analyse the law of water and sand changes in the Ningxia section of the Yellow River in terms of inter-annual variability of water and sand volume, change trend, sudden change characteristics and cyclic fluctuations, which provided a basis for the management of the river section and the layout of the project[5]. Xia Lu et al. used Mann-Kendall test and Pettitt test to analyse the trend of runoff, sand transport and sand content in the river basin and to test the mutation, and used the double cumulative curve method, regression analysis and elasticity coefficient method to compare and evaluate the attribution of the change of water and sand [6].

On the basis of the above research, this paper discusses in depth the changing law of water and sand fluxes in the Yellow River and analyses the future trend by applying a linear programming model. In this paper, the time series analysis of various hydrological data is carried out, and suitable models are constructed to describe the dynamic change relationship between water level, flux and sand content. For example, it tries to construct a multiple linear regression model or adopt machine learning algorithms to predict the sand content based on water level and flow. The total annual water flow and total annual sand discharge for the last 6 years can be estimated by this model. By analysing the future trend, we will provide strong scientific support for water resource management, ecological protection and sustainable development of the Yellow River Basin. This study is not only of great practical significance for the Yellow River Basin, but also provides useful experience for management and decision-making in similar river basins around the world.

2. Analysis of the dynamic change pattern of water and sand fluxes in the Yellow River

The dynamics of the Yellow River water and sand fluxes is a complex natural process, influenced by a variety of natural and anthropogenic factors. Rainfall and snowmelt are the main climatic factors affecting the water-sand flux of the Yellow River. By analysing the meteorological data of the Yellow River basin, especially the changes of precipitation and temperature, the seasonal and inter-annual patterns of water-sand flux can be revealed. The topography and geomorphological features of the Yellow River Basin have an important influence on the water-sand flux. Factors such as slope, soil type and vegetation cover of the watershed affect the process of water-sand generation and transport. Differences in water-sand fluxes in different regions can be understood by analysing topographic and watershed features. Water-sand fluxes are also affected by human activities, including the construction of reservoirs, agricultural irrigation, and urbanisation. Human activities may alter the hydrological cycle, soil erosion, and river morphology, thereby affecting water-sand fluxes. By analysing the spatial and temporal distribution of human activities, their impact on water-sand fluxes can be assessed. Time-series analyses using measured data from hydrological stations, including water level, flow rate and sand content, reveal seasonal and inter-annual variations and long-term trends in water-sand fluxes.

In this paper, when examining the relationship between water level, water flow and sand content, it is necessary to consider the impact of different data collection methods and time scales on the analyses. A common approach is to use a multiple linear regression model in which water level and water flow are used as independent variables and sand content as the dependent variable. Such models can be used to estimate the extent to which water level and water flow affect sand content. Finally, to better understand the relationship between water level, water flow and sand content, visualisation charts such as scatter plots and regression lines can be drawn. These graphs can visualise the distribution and trend of the data and help to interpret the results of the analysis. A number of aspects such as data collection, model selection, time series analysis and visualisation of results need to be considered in order to fully understand the relationship between hydrological data. This can help to predict sand content more accurately and provide important insights into water resource management and ecosystem protection. However, to account for possible non-linear relationships, more advanced machine learning algorithms, such as random forests or deep learning models, can be used to construct more accurate predictive models. These algorithms are able to capture complex data patterns and interactions, which improves the predictive power of the model. In addition, the dynamics of these data can be studied through time series analysis methods. Time series analysis can help us identify seasonal and cyclical patterns, which are critical to understanding the changing patterns of hydrological data. These patterns can be revealed through the analysis of autocorrelation functions and partial autocorrelation functions.

ISSN 2616-5872 Vol.6, Issue 2: 54-58, DOI: 10.25236/AJEE.2024.060207

The information in this paper comes from the official website of China Undergraduate Mathematics Competition. Before the establishment of the model, it is assumed that the Yellow River water and sand monitoring data provided are accurate and reliable, which can represent the actual situation of water level, water flow and sand content in the hydrological station in the past 6 years, and the Yellow River cross-section measurement data in the hydrological station in the past 6 years are accurate and reliable, which can be used for the calculation of the total annual water flow and the total annual sand discharge in this hydrological station, and in addition to this, it is assumed that the basic policy of "water transfer and sand transfer" of Xiaolangdi Reservoir will remain unchanged during the study period. In addition, it is assumed that the basic policy of "water transfer" and "sand transfer" of Xiaolangdi Reservoir will remain unchanged during the study period.This paper will use these three types of data and analyse the relationship between them. As there may be non-linear relationships between the three types of data, they can be modelled using statistical methods such as multiple linear regression or support vector regression. If the relationship between the data is more complex, more advanced machine learning methods such as neural networks can be considered to build more accurate models. In addition, in order to better understand the relationship between these variables, corresponding scatter plots and regression lines can be drawn to present the results more visually. In summary, the analysis of Problem 1 requires a comprehensive consideration of various aspects such as data collection, model selection, time series analysis and visualisation of the results in order to fully understand the relationship between hydrological data. This can help to predict sand content more accurately and provide important insights into water resource management and ecosystem protection.

3. Modelling and solving

3.1 Data pre-processing

Processing through the data in Problem 1, the year, month and day columns are filled, this paper uses multiple linear regression to fill in the value of the sand content at different moments in a day to supplement, so this paper will be the three columns of the year, month and day are merged into the day, the analysis is carried out. Calculate the water-sand flux:

$$Q = C \cdot V \tag{1}$$

where:

Q represents the water-sand flux (the amount of sand in the water stream, usually expressed in kilograms per second).

C is the sand content (usually expressed in kilograms per cubic metre).

V is the velocity of flow (usually expressed in metres per second).

3.2 Modelling

A linear regression model is a powerful tool for exploring relationships between variables. In this paper, we constructed a linear regression model based on the following assumptions:

1) Linearity assumption: We assumed a linear relationship between sand content and time, water level and water flow. This means that we assume that changes in these factors have a linear effect on sand content, i.e., sand content increases or decreases linearly with changes in these factors.

2) Independence assumption: We assume that each sample point is independent of each other, i.e., the sand content of one sample is not affected by other samples. This is an important assumption of the linear regression model.

3) Normality assumption: We assume that the residuals (error terms) follow a normal distribution, which is another key assumption of the linear regression model.

4) Assumption of homoskedasticity: We assume that the residuals have equal variance, i.e., the variance of sand content is the same for different water levels, water flow rates and time points.

In this paper, the null value in the sand content is incomplete and thus the water and sand fluxes are derived through the constructed regression equation, and the drainage and sand discharge over 6 years are derived through the cumulative method.

ISSN 2616-5872 Vol.6, Issue 2: 54-58, DOI: 10.25236/AJEE.2024.060207

3.3 Solving the model

1) Linear regression model:

The objective of a linear regression model is to find the best-fitting linear equation that minimises the sum of squares of the residuals between the predicted and actual observations of the model. Specifically, the linear regression equation is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \dot{\varepsilon} \quad (2)$$

To solve for the parameters of the model, the least squares method is often used to minimise the sum of squares of the residuals. Least squares minimises the error between the predicted and actual observed values by adjusting the regression coefficients. The solution process can be done using different mathematical methods such as gradient descent or regular equation methods.

Once the model parameters are determined, we can use this linear regression equation to predict the sand content. By substituting time, water level, and water flow into the equation, we can estimate the sand content at any point in time and further calculate the water-sand flux.

3.4 Analysis of results

As shown in Table 1, the total annual water flux and total annual sand discharge over the past 6 years can be obtained from the daily water and sand fluxes, which helps to understand the hydrological situation of the Yellow River hydrological stations and the trend of sand content more comprehensively.

Table 1: Table of regression equations

Year	Equation of regression
2016	Quantity of sediment (= 0.60 * water level(m) + 0.00 * rate of flow(m^3/s) + -25.08
2017	Quantity of sediment = 0.31 * water level(m) + 0.00 * rate of flow(m^3/s) + 12.96
2018	Quantity of sediment = -13.56 * water level(m) + 0.02 * rate of flow(m^3/s) + 569.83
2019	Quantity of sediment = -8.61 * water level(m) + 0.01 * rate of flow(m^3/s) + 362.19
2020	Quantity of sediment = 4.79 * water level(m) -0.00 * rate of flow(m^3/s) + 200.54
2021	Quantity of sediment = 6.73 * water level(m) + 0.00 * rate of flow(m^3/s) + 293.69

Water level has a significant effect on sand content, with coefficients indicating the extent to which a unit change in water level affects sand content.

Water flow has a relatively small influence in these models, with a coefficient close to zero, and may not be a major influence. Therefore, as shown in Table 2, the total annual water flow for the last six years is 16,129,674.00 m^3 and the total annual sand discharge for the last six years is 30790619185970848.00 kg.

Table 2: Estimates for 6 years

Total annual flows for the last six years	16129674.00 m^3
Total annual sand discharge for the last six years	30790619185970848.00 kg

4. Conclusions

Taking the change of Yellow River water and sand flux in a hydrological station as the research object, the annual total water flux and annual total sand discharge were calculated by establishing a linear programming mathematical model.

The linear regression model is verified to be a simple and easy-to-implement model for direct prediction of sand content, which is very practical for hydrological station applications, and the model is usually computationally efficient enough to obtain results in a short time, which is especially advantageous when dealing with large-scale data sets. However, the linear regression model is sensitive to outliers and may be affected by anomalous data. In addition, it is usually not applicable to the case of dealing with exogenous variables and requires additional extensions to deal with these variables.

Through the study in this paper, the relationship between the sand content of the Yellow River water and time, water level and water flow at a hydrological station is investigated, and the total annual water flow and total annual sand discharge at this hydrological station in the last six years are estimated by the model. The results of the study are very practical and have a good guiding effect on the water and sand flow of the Yellow River, which is an important theoretical guidance for optimising the allocation of water resources in the Yellow River Basin, coordinating human-land relations, water and sand transfer, flood control and disaster mitigation, etc.

References

[1] Sui Y, Shi H, You Z,et al. Long-term Trend and Change Point Analysis on Runoff and Sediment Flux into the Sea from the Yellow River during the Period of 1950-2018[J].Journal of Coastal Research, 2020, 99(sp1):203. DOI:10.2112/SI99-029.1.

[2] Shi Y, Fan M, Zhang Y, et al. Characteristics Identification of Runoff and Sediment Flux Based on Wavelet Analysis Approach in lower Yellow River[J].Applied Mechanics and Materials, 2015, 700:506-510. DOI:10.4028/www.scientific.net/AMM.700.506.

[3] Zhou Q .Assessment of the Carrying Capacity and Suitability of Spatial Resources and the Environment and Diagnosis of Obstacle Factors in the Yellow River Basin[J].International Journal of Environmental Research and Public Health, 2023, 20. DOI:10.3390/ijerph20043496.

[4] Yuqi W, Xiaopei L. A Preliminary Study on the Trends and Mechanism of the Upper Ocean Salinity in the East China Seas During 1976—1996[J].Periodical of Ocean University of China, 2018.

[5] Qi L, Jun W, Xin W,et al. Analysis of the Diurnal Characteristics of Water and Heat & CO_2 Exchanges at the Alpine Wetland in the Source Region of the Yellow River[J].Plateau Meteorology, 2017.

[6] Jinlei C, Jun W, Xin W,et al. Characteristics of Water and Heat Exchanges and Their Crucial Influencing Factors on the Alpine Wetland during the Warm Season in the Source Region of the Yellow River[J].Chinese Journal of Atmospheric Sciences, 2017.