ANALYSIS OF REMOTE SENSING TECHNOLOGY APPLIED ON HYDROLOGY AND WATER RESOURCES –TAKING WEIHE’S ECOLOGY AS AN EXAMPLE

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Abstract. In order to study the water resources of Weihe and to maintain its ecological environment, remote sensing technology is used to study the local water resources (monitoring water quality and quantity). Weihe is not only the political and cultural center of Shaanxi Province, but also an economically active zone. It has become an important part of hydrology and water resources work in Shaanxi Province to keep abreast of the relevant situation of Weihe waters at any time, and also a prerequisite for maintaining the ecological environment of Weihe. Remote sensing technology is a high-resolution tool for obtaining target information, information transmission and comprehensive utilization of information. Especially for the dynamic subject of hydrology and water resources, the depth of Weihe waters is obtained by remote sensing technology, and the pollutant concentration data are obtained according to the characteristics of pollutants. Therefore, remote sensing technology is used to monitor the water quantity and water quality of Weihe waters and to obtain effective information on Weihe waters, which provides a basis for other studies of Weihe waters, and also has a certain supporting role in the management of relevant institutions, and ultimately realizes the sustainable ecological environment of Weihe.
Keywords: *economically active zone, information transmission, the pollutant concentration data, water quantity, the sustainable ecological environment*

Introduction

With the rapid development of social economy, environmental problems are becoming more and more serious. One of the most closely related problems is water resources (Cheng et al., 2018). People’s daily life cannot do without water resources. Therefore, water quality and water quantity have become the focus of national attention. By means of administration, law and advanced science and technology, the State coordinates the relationship between social and economic development and water resources, and effectively controls pollutants entering the water body in order to maintain the balanced development of the water body and meet various needs (Xu et al., 2018). As the largest tributary of the Yellow River flowing through Shaanxi Province, Weihe needs to bear the vast majority of living and production sewage in Shaanxi Province. With the rapid economic development in Shaanxi Province and the growing urban population, it seriously threatens the ecological environment of the Weihe waters, greatly affecting the agricultural production of the surrounding farmland and the daily life of the surrounding residents, as well as the lives of the downstream residents. It poses a certain threat. Shaanxi government has issued a series of planning and renovation schemes to control the water environment of Weihe (Triegel and Guo, 1994; Mohammady et al., 2018). It can dynamically monitor the water volume and pollutant concentration of Weihe in an all-round way, so that the water volume can be guaranteed

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to a certain extent and the pollutants in the water can be kept within a certain range, so as to realize the self-purification of the water area.

Remote sensing technology is a comprehensive detection technology, which has been widely used in agriculture, address, meteorology, ocean, hydrology, environmental protection and military investigation. Especially in hydrology and water resources work, the use of remote sensing technology provides an important technology for the study of hydrology and water resources (Vikesland, 2018). With the continuous development of science and technology, the application of remote sensing technology in hydrology and water resources is becoming more and more extensive. It not only can accurately provide people with relevant data, and to a large extent, save human and time costs, improve work efficiency, and provide technical support for the related work of hydrology and water resources (Cavalagli et al., 2018). At the same time, because it is not affected by geographical location, and the bad weather and environment have less interference on remote sensing technology, remote sensing technology can achieve all-weather and all-round information collection, saving the time and cost of manual monitoring.

In this form, how to use remote sensing technology to monitor water quality in an all-round and dynamic way has become an important part of local government's environmental protection and water resources protection (Mace et al., 2018). As an important water source for crop growth in Guanzhong Plain, it is necessary to monitor the water quantity and water quality of Weihe to ensure that farmers' production and life are not affected, to ensure the sustainable development of Weihe, and to achieve ecological green and sustainable development.

Therefore, remote sensing technology is used to monitor the water quantity and quality of Weihe waters (Wang et al., 2018). It can acquire and process the water quantity and quality data at a relatively fast speed and in a relatively short period, which is conducive to the acquisition of water resources-related data, thus ensuring the water quantity and improving the water quality, providing a basis for other aspects of Weihe waters research (Liu et al., 2018). It also has certain reference significance in monitoring and improving the situation of water quantity and quality of related rivers, as well as the management of relevant departments and water conservancy construction in Shaanxi Province.

Literature review

With the rapid development of the world economy, environmental pollution has become a key issue of global ecological development. Water resources are the source of human survival, and production and life are inseparable from water. The total amount of water resources per capita in China accounts for only one quarter of the world's per capita water volume, and is considered to be one of the countries lacking water resources. How to control water volume and control rivers has also become the key contents that scholars discuss. Jiang pointed out in his paper that with the increasing water demand, serious shortages of surface water and groundwater appeared in Northwest China and North China (Maggiori et al., 2017). Cai et al. found that over-exploitation of water resources led to land subsidence and ecosystem degradation in many places through the study of water resources in recent years (Nogueira et al., 2017). Jin Shuquan pointed out in the study that the water quality of the Yellow River, Huaihe and Liaohe has been affected to varying degrees in recent years. Among the 47

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key cities studied, the water quality standard rate of less than 80% is up to 30% (Kussul et al., 2017).

Shi Xiaoliang, Zhou Zhenghui and Wang Xinshuang retrieved soil water content by using multi-dimensional geospatial data and long time series remote sensing images. Combined with relevant data, a groundwater monitoring model was constructed. The increasing trend of groundwater burial data in more than ten years was verified by an example, and its distribution characteristics were obtained (Zhu et al., 2017). Wang Jie and Wang Liang elaborated the basic principles and advantages of remote sensing technology, and monitored water resources. In the case of combining professional manual survey with remote sensing technology monitoring, they selected better data to ensure the effectiveness of technology and the correctness of results (Jucker et al., 2017).

Ma Qie and Hu Kun, through the comprehensive discussion on the application of remote sensing technology in hydrology and water resources, found a tool for the efficient utilization of water resources for the study of hydrology and water resources in China, and laid a foundation for their development and research (Lu et al., 2017). Fu Guobin and Liu Changming elaborated in detail the monitoring model of water area, precipitation, evaporation, soil moisture and the application and progress of remote sensing technology in the actual dynamic monitoring process from two aspects, and put forward the method of combining remote sensing technology with geographic information system (Gu et al., 2017).

Methods

Remote sensing technology

Remote sensing technology is a comprehensive earth observation science and technology. It uses sensors to receive electromagnetic wave characteristics of target objects or non-target objects, and through information transmission, storage, correction and identification of target objects, ultimately realizes the timing, positioning, quantitative and qualitative research of target objects. Remote sensing was first applied in the field of aviation, and then with the development of aerial photography technology, it gradually developed into a more practical space exploration technology (Mohanty et al., 2017).

The realization of remote sensing technology requires the participation and cooperation of many disciplines as well as a set of precise technical equipment. Therefore, the implementation of remote sensing is a relatively complex system engineering, which mainly consists of four parts (*Fig. 1*).

The information source refers to the object that needs to be detected. Because any target has the characteristics of absorbing, reflecting, transmitting and radiating electromagnetic waves, when the target encounters electromagnetic waves, they will form specific electromagnetic waves of the target. Information acquisition refers to the process of receiving and recording specific electromagnetic waves of objects by using a series of technical equipment, mainly relying on remote sensing platform and sensor equipment. Information processing mainly uses optical instruments and computer equipment to correct, analyze and interpret the information charts, words and data acquired by remote sensing, so that users can get the error of original information, and get the effective information needed by extracting the impact characteristics of the target object through sorting out and summarizing. Finally, it comes to information

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application. People use remote sensing technology in different fields and purposes, and they get different information. The information data obtained are mainly for the convenience of users in the inquiry, statistics and analysis of relevant content in the research field.

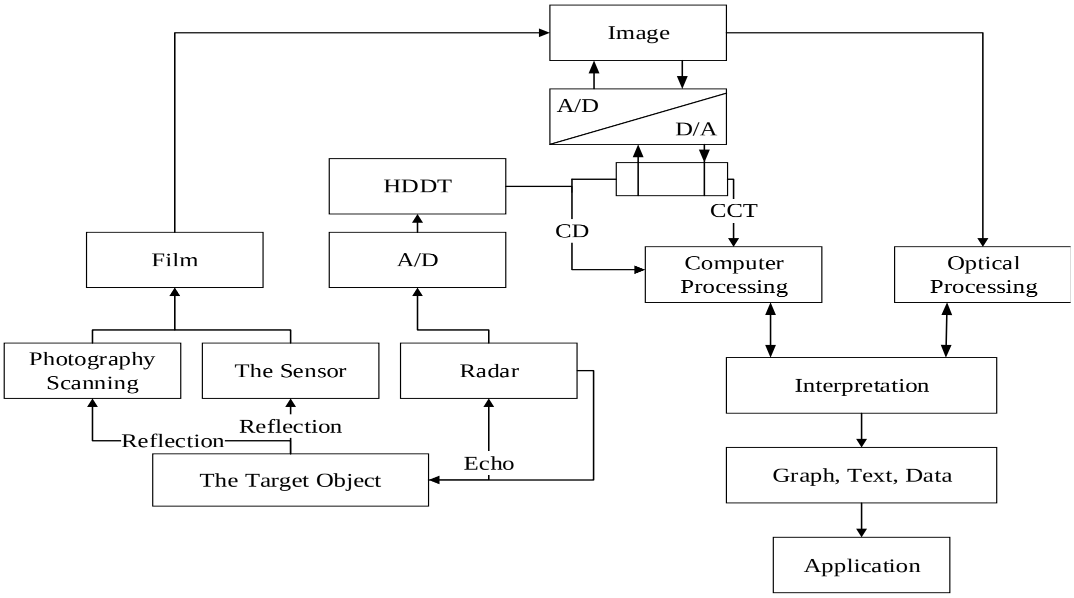

Figure 1. *Composition map of remote sensing system*

The reason why remote sensing technology can be widely used in different fields is that it is different from other technical means. There are three main aspects: firstly, the detection range is wide, the data acquisition speed is fast, and the cycle is short. It can observe the object in a relatively short period of time in a wide range, so as to obtain valuable data, which broadens people's horizons, enables people to study things from the whole, and provides valuable resources for later exploration of the rule of things (Audebert et al., 2018). Secondly, remote sensing technology can dynamically monitor the change of the object and obtain the periodic change of the object in order to predict the weather, disasters and environmental conditions. Thirdly, the data acquired by remote sensing technology is more comprehensive. It can centrally reflect the shape of objective things in each time period, truly reflect the characteristics of various things, and reflect the relevance of many things, as well as the situation for a period of time, which is conducive to the analysis of the causes of certain factors in each time period.

In hydrology and water resources work, remote sensing technology can be used to detect and remote sensing precipitation, evaporation, runoff, groundwater and sediment. When using remote sensing technology to measure precipitation, precipitation is usually indirectly judged by measuring cloud top brightness and cloud top temperature. When measuring evaporation, water evaporation and plant transpiration can be calculated by combining hydrological model. The remote sensing is used to monitor water quality mainly through the spectral analysis of water quality to classify the water quality indicators, and empirical model is used to combine the spectral characteristics of water quality and specific parameters of water body, to obtain relevant data and to provide effective data for the next step. Empirical model method requires effective combination of specific parameters of water quality and spectral characteristics of water body.

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$$Y = A + BX \quad \text{or} \quad Y = AB^{X} \qquad \text{(Eq.1)}$$

Represents the measured value of remote sensing, Y represents the water quality parameters of objects to be estimated (ElMekawy et al., 2018), and A and B are the undetermined coefficients (*Eq. 1*).

Overview of Weihe

Weihe is the largest tributary of the Yellow River basin, with the largest amount of water. It originated from Niaoshu mountain, Weiyuan County, Dingxi City, Gansu Province. It flows into Shaanxi after Tianshui, Gansu Province, and finally into Tongguan County. The main stream of the Weihe runs 502.4 km in Shaanxi Province, with an area of 671,000 km^2 and an average runoff of 5.38 billion m^3. With the acceleration of industrialization and the continuous development of economy and society, environmental problems are becoming more and more serious, especially water pollution. Weihe is regarded as the life river of Shaanxi in Guanzhong area of Shaanxi Province. Therefore, the water quality of Weihe is closely related to the social and economic development of the area. Moreover, on the one hand, the extreme shortage of water resources in Weihe is due to the decrease of water entering Shaanxi Province year by year (Cassidy et al., 2018); on the other hand, the rapid development of economy, the continuous expansion of cities and the rapid expansion of population make the water consumption for production and living increase sharply. Most of the areas along Weihe are the production areas of crops. Irrigation water demand is large and groundwater has to be collected. This also leads to the decrease of the flow of the river recharged by groundwater, and the decrease of groundwater level also needs to be supplemented by the water in the river. This repeated impact makes the lives of people around the groundwater as a source of living water threatened. The distribution of residential areas and factories along Weihe is relatively concentrated. The demand of sewage discharged from production and living and agricultural production for Weihe water is increasing year by year. The view of Weihe Basin (*Fig. 2)* and the main cities flowed by the Weihe Basin (*Fig. 3*) are shown.

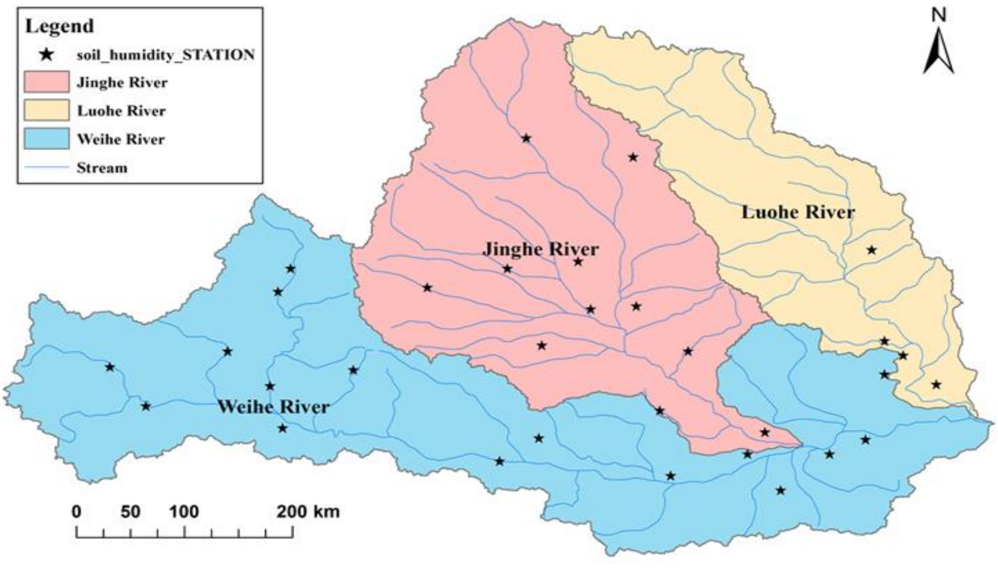

Figure 2. *View of Weihe Basin*

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Figure 3. *Major cities in the Weihe Basin*

The relevant government departments have also formulated a series of treatment programs, and relevant enterprises have formulated sewage treatment measures, but the concentration of pollutants in river water is still high, so that river water cannot rely on its own purification capacity to maintain ecological balance. Therefore, in view of the problem of water pollution in Weihe, it is very important to quickly establish an effective method to detect the water quality of Weihe.

When monitoring water quantity, a zero-dimensional water quality model is adopted, and a river section is assumed to be a fully mixed reactor. When the sewage with Q_0 and C_0 inflow enters the reactor, due to stirring, the pollutants can be completely uniformly distributed in the tank (Chen et al., 2018). Thus, the equilibrium equation between water quality (*Eq. 2*) and flow rate (*Eq. 3*) is established when the water quality and flow rate are not stable.

$$\frac{dV_c}{dt} = \left(Q_0 c - Q_1 c\right) + \sum S^{'}\left(c,t\right) \tag{Eq.2}$$

$$\frac{dV}{dt} = Q_0 - Q_1 + q \tag{Eq.3}$$

When V is constant (*Eq. 4*):

$$\frac{dc}{dv} = \frac{Q_0}{V} c_0 - \frac{Q_1}{V} c + \sum S\left(c,t\right) \tag{Eq.4}$$

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C is the concentration of pollutants in the tank (unit: ML-3); Q_1 is the flow rate at the time of outflow (unit: L3T-1); V is the volume of water in the tank (unit: L3); $\sum S(c,t)$ is the flow rate of source and leakage in the tank (unit: ML-3T-1); and q is the flow rate of element leakage (unit: L3T-1). As a result, there is:

$$c = \frac{1}{\left(1+\frac{Vk}{Q_1}\right)}\left(\frac{Q_0}{Q_1}\right)c_0 + \frac{1}{\left(1+\frac{Vk}{Q_1}\right)}\left(\frac{q}{Q_1}\right)c^* \quad \text{(Eq.5)}$$

c* denotes the inflow of source and drain terms, and k is the reaction rate coefficient of pollutant attenuation (*Eq. 5*).

The precipitation and evaporation of water flow are related to the balance of water flow. Therefore, it is required to control the water flow in a certain river section and keep the balance in a period of time.

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \quad \text{(Eq.6)}$$

A represents the river bed area, Q is the discharge, q is the input discharge, t represents the time, and X represents the length of the river section.

Water quality monitoring is mainly to detect the types of pollutants, concentrations and changes of various pollutants in different monitoring points, so as to judge the water quality. The testing items mainly include two kinds of indicators reflecting water quality and toxic and harmful substances. The items that must be determined in water quality indexes are water temperature, suspended matter, total hardness, pH value, conductivity, dissolved oxygen, chemical oxygen consumption, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, volatile phenol, cyanide, arsenic, mercury, hexavalent chromium, lead, cadmium, petroleum, etc. (Liu et al., 2018). They can be used for sulphide, fluoride, chloride, organochlorine pesticides, organophosphorus pesticides, total chromium, copper, zinc, intestinal flora, uranium, radium and so on. The concentration of COD and $NH\text{-}N_3$ is studied only.

Sampling points should be determined according to water depth (*Table 1*), sampling time and sampling frequency (*Table 2*).

Results and discussion

The water quality and quantity of Xi'an, Baoji, Xianyang and Weinan along Weihe are studied. The data of these four regions are collected. The number of sewage outlets in each city (*Fig. 4*) and the data of pollutant concentration in 2007 (*Table 3*) are shown.

Table 1. *Determining sampling points according to water depth*

Water depth	Number	Position
Smaller than 5 m	1	0.3-0.5 m under the water
5-10 m	2	0.3-0.5 m under the water, and 0.5 m above the bottom
10-50 m	3	Half water depth, 0.3-0.5 m under the water, about 0.5 m above the river bottom
Larger than 50 m	Increase sampling points as appropriate	

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***Table 2.** Sampling time and frequency*

Objects	Sampling time and frequency
Main stream of larger river system and small and medium rivers	Sampling is not less than 6 times in a year, in rich, dry and peaceful seasons, usually twice in each period
Running through urban industrial zones, polluted rivers, browsing waters, drinking water sources, etc.	Samples are taken at least 12 times a year and at least once a month
Understand changes in water quality in a day or a few days	Sample in 24 h or in 3 days at different equal parts of time. In case of special circumstances, the number of sampling times will be increased
Background section	Sampling once a year

***Table 3.** Concentration of pollutants in the sewage outlet of Weihe, Guanzhong City*

Town	Chemical oxygen demand (COD) (unit: 10,000 tons/year)	NH-N3 (unit: 10,000 tons/year)	Subtotal (unit: 10,000 tons/year)
Xi’an	9.3515	0.8319	4.4676
Baoji	1.993	0.2048	0.9396
Xianyang	2.896	0.217	1.0299
Yangling	0.018	0.009	0.0798
Weinan	2.5203	0.1735	1.0282

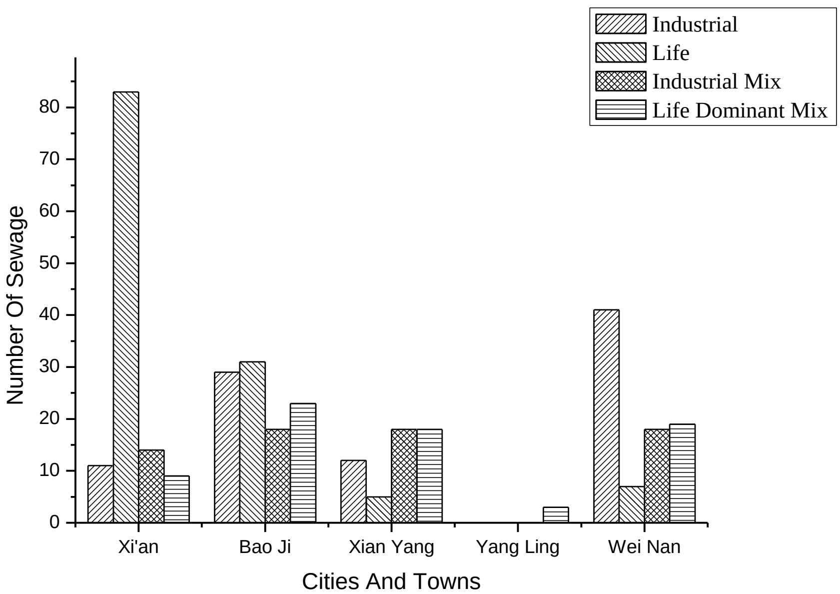

***Figure 4.** Number of urban sewage outlets in the middle section of Weihe*

According to the data obtained by remote sensing technology, the discharge of wastewater is 79344 million tons per year, of which COD is 153.351 thousand tons per year and $NH\text{-}N_3$ is 135.68 thousand tons per year. The discharge of urban wastewater is 75.422 thousand tons per year, of which COD is 167.766 thousand tons per year and $NH\text{-}N_3$ is 143.62 thousand tons per year. The monitoring data (*Fig. 5*) are shown below.

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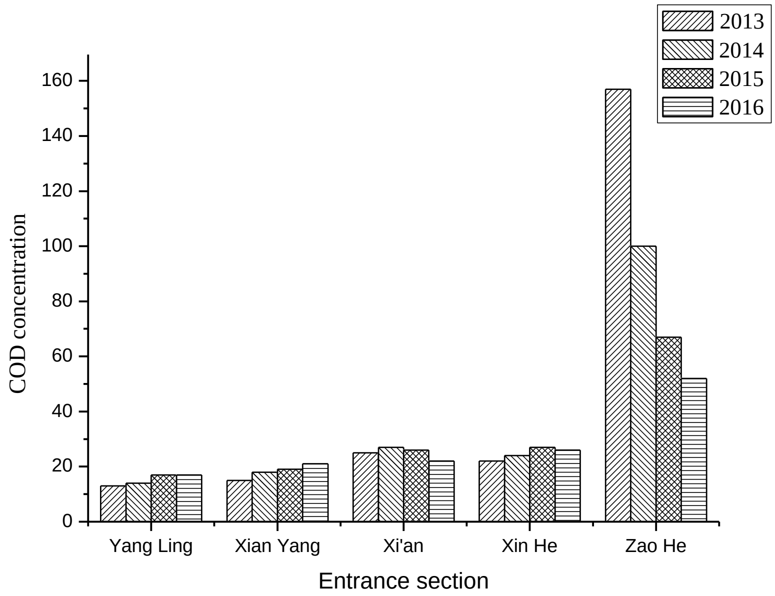

Figure 5. *Monitoring data of COD concentration (mg/L) in different sections from 2013 to 2016*

The annual total runoff variation map measured at Weinan Station is shown in (*Fig. 6*) and the relationship between precipitation and surface water resources in Weihe Basin (*Fig. 7*) are shown below.

The water balance relationship between snowfall and evaporation is calculated by water balance model, and water balance map of Weihe Basin (*Fig. 8*) is obtained.

The natural reasons for the change of water quantity in the Weihe are mainly caused by precipitation and man-made factors. There will be more precipitation in Yangling, Baoji and Weinan, less water in Xi'an and Xianyang, and higher vegetation coverage in Yangling. Therefore, the precipitation and annual runoff are less. This is because the increase of vegetation coverage increases evapotranspiration in the region. Additionally, the amount of water is affected to a certain extent, and the amount of water is reduced.

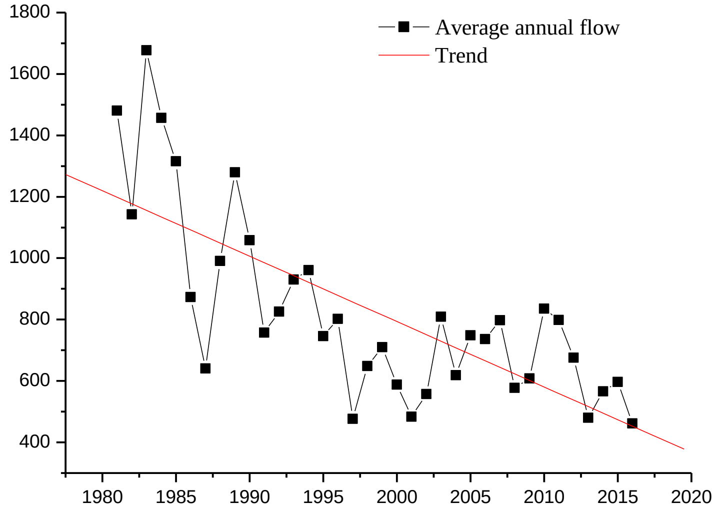

Figure 6. *Annual runoff variation map of Weinan Station from 1980 to 2017*

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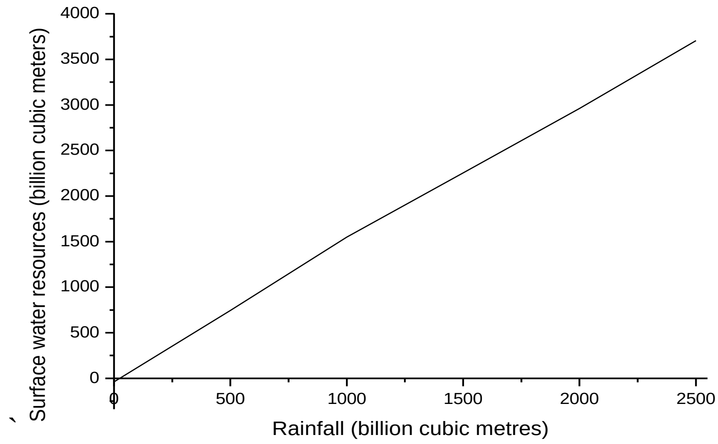

Figure 7. *The relation map between rainfall and surface water resources in Weihe Basin*

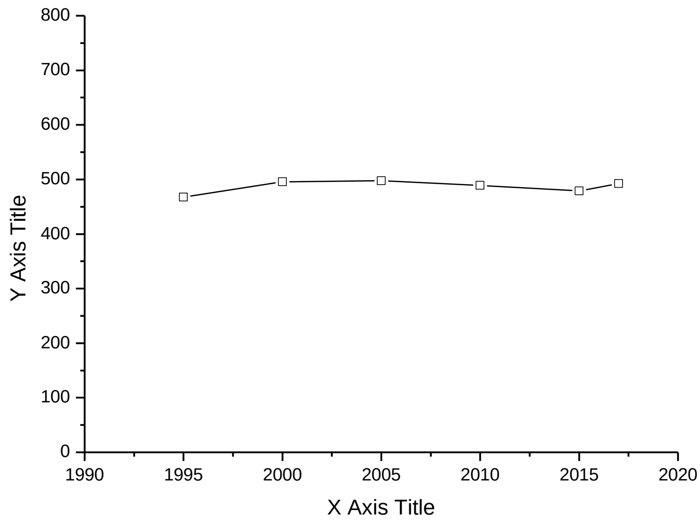

Figure 8. *Water balance map of Weihe Basin*

Moreover, because of the uneven distribution of precipitation in Weihe Basin, its tributaries are unevenly distributed and may even dry up. According to statistics, the actual runoff in the 1970s, 1980s and 1990s was 2.378 billion m^3, 2.333 billion m^3 and 2.231 billion m^3, respectively. Compared with the actual runoff, it increased by 17.0 mm, 16. 3 mm and 15.3 mm, respectively.

Using remote sensing technology to monitor precipitation can greatly improve the accuracy of monitoring, that is, to predict precipitation through cloud top brightness and cloud top temperature, which provides a reliable basis for hydrological departments to predict. The evaporation is monitored by physical methods, and the layered model is used to distinguish soil conditions, while the evaporation is measured. At present, there are also computer models for evapotranspiration, which realize the calculation of evapotranspiration and evapotranspiration on non-uniform ground. For the river runoff, it is monitored by remote sensing technology, which combines this part of data with hydrometeorological station data to survey the river runoff, and calculates the relevant data through hydrological model, which is transformed into effective information, and

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then estimates the precipitation, evaporation and groundwater, finally obtains the relevant results of the river runoff. Because of this, the water volume of Weihe has been kept within a certain range in recent years, the surrounding agriculture also has a sufficient amount of irrigation water, and people's living water has been guaranteed, maintaining the sustainable development of Weihe Basin.

It can be seen that with the expansion of cities, people's living and industrial water consumption increases, while sewage discharge increases accordingly, but it is found that the discharge of COD and $NH\text{-}N_3$ decreases. On the one hand, it is because natural water has a certain self-purification capacity. When pollutants enter the water body, their pollutant concentration does not exceed the maximum bearing capacity of the water body. Through a series of biological and physical factors to purify the water, the concentration of pollutants in the water is reduced. On the other hand, related units of hydrology and water resources pay more attention to the water pollution and effectively treat the sewage. Using remote sensing technology to obtain relevant data, the sewage treatment rate is constantly improving.

At present, the application of remote sensing technology in hydrology and water resources is mostly qualitative research. Taking Weihe as an example, this paper studies its water quantity and water quality, lays a foundation for the protection of ecological environment in Weihe Basin, and provides ideas and methods for the study of soil water content along Weihe. However, due to the current use of remote sensing technology to obtain information, the process of interpreting information is more complex and consumes. Because of its high cost and large demand for professionals, remote sensing technology has not yet brought its energy efficiency into full play, which also has a certain guiding significance for enterprises and universities to cultivate talents.

Conclusion

Traditional hydrology and water resources research work is inefficient and has poor quality. The discovery of remote sensing technology provides technical support for hydrology and water resources related work, and largely solves the problem of low efficiency and poor quality of research work. As the "mother river" and "life river" in Shaanxi, Weihe affects the production of crops and people's lives. Therefore, the water quantity and quality of Weihe are closely related to the lives of the people around it. It is also closely related to the environment and ecology of Weihe and its coastal areas. It requires the relevant government departments to devote more energy to the governance of Weihe. Therefore, when using remote sensing technology to study the hydrology and water resources of Weihe Basin, the monitoring and remote sensing of precipitation, evaporation, runoff, COD and ammonia nitrogen ($NH\text{-}N_3$) in water quality are mainly applied, so as to obtain the relevant data of Weihe waters, which is conducive to improving the work efficiency of managers and maintaining the ecological environment of Weihe waters. It provides a technical branch for controlling the water quality and quantity of Weihe waters later. It also provides ideas for the water quality and quantity of other basins in Shaanxi Province, and provides a theoretical basis for relevant units to control water source problems.

Limited by the conditions, this paper inevitably produces errors in data monitoring. It is hoped that the impact of other factors on the accuracy of monitoring data can be reduced and more accurate data can be obtained in the future research process.

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