Preliminary study on the influence of coal mining on river runoff

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Abstract. Coal mining is a major cause of decreases in river runoff, which can increase the disparity between the supply and demand of water resources. This paper presents runoff variation data from Tou-Tong to analyze the impacts of rainfall and human activity on runoff. This data showed that the annual runoff of Gushanchuan, Kuye and Tuwei river decreased significantly in the middle and latter half of the 1990s. Reservoirs, key dams, terraced fields and vegetation variation are all important factors that affect decreases in runoff. The effect of three types of coal mining on the water cycle is put forward and quantitatively calculated.

1. Introduction

Yellow River is an important energy base, and it is also China's major dryland[1] Scholars such as Wang Hao and Liu Changming have found that 52% of changes in annual runoff can be attributed to human activity[2–6].

The development and utilization of coal resources in the basin of Yellow River has a long history and has flourished, which makes it an important player in our economy. The coal industry and the associated processes are major consumers of water, which can cause a crisis of water resources. In addition, these activities cause serious ecological and environmental questions; the quality of the water environment is suffering serious and increasingly prominent damage, such as groundwater level recession, spring and river water decline, sometimes to the point of drying, and water pollution. Among these consequences, river runoff reduction is especially severe, and it intensifies the mismatch between supply and demand of regional water resources. Information on the influence of coal mining on river runoff and sustainable utilization of water resource management is extremely urgent in the face of river runoff reduction.
2. The runoff variation analysis of Toutong Region

The study region is Toutong in the middle reaches of Yellow River (figure 1). In recent 10 years, the runoff reduced greatly in Toutong region, the average annual rainfall is 501.1 mm between 1952 and 2000, natural runoff is about 17.07 billion m$^3$, average annual rainfall is 502 mm between 2003 and 2010, natural runoff is about 10.09 billion m$^3$, rainfall did not change, natural runoff reduced about 6.98 billion m$^3$.

![Figure 1](image1.png)

Figure 1. The study region is Toutong in the middle reaches of Yellow River.

2.1. The rainfall

Rainfall and human activity are the main factors that influence the changing of runoff. Changes to the Toutongjian region between June and September are shown in figure 2. From the figure, it can be seen that the change of rainfall is not obvious in the flood season after 2000. Therefore, changes to rainfall alone cannot explain the sharp decline of runoff during this period.

![Figure 2](image2.png)

Figure 2. Changes of Toutongjian region from June and September.

2.2. The change of the underlying surface

Table 1 shows big, small and medium-sized reservoirs in the study basins.

As a rough estimate, the evaporation of tributaries in the Toutong region is only about 130 million m$^3$, and the water reducing effect is limited.

During the 1980s, dams that were built were generally planned to be the backbones for dams that have been completed more recently. Through the survey, it was found that there is almost no sedimentation in areas where the vegetation and terraces are in good condition in recent years, and the impoundment was reduced. The new backbones of dams in the Shanbei branch are rare. As a rough estimate, the new evaporation was 150 million m$^3$ at its maximum.

The survey also indicated that the Longtou region does not have obvious increments. A large amount of observation proved that the water reducing effect of the terrace is up to
80–90%; a large number of other studies have shown that the water reducing effect of terrace can be reduced by 80–90%.

The observation in Yanan and Lishi shows that in the loess plateau, as the vegetation cover increased, surface runoff and the total amount of runoff reduced significantly. For example, when coverage increased from 20% to 70%, the runoff could reduce about 1/4.

### Table 1. Big small and medium-sized reservoirs in study basins.

| Scale | Huang Pu basin | Gu Shan Chuang basin | Ku Ye He basin | Tu Wei He basin | Jia Lu He basin | Wu Ding He basin | Qing Jian He basin | Yan He basin | Hun He basin | Qiu Shui He basin | San Chuan He basin | Bei Luo He basin |
|-------|----------------|----------------------|----------------|----------------|----------------|------------------|--------------------|--------------|--------------|------------------|-------------------|------------------|
| large number | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 3 | 6 | 1 | 3 | 2 | 1 | 1 |
| 10^6 m³ | 3 | 2.03 | 1 | 1.1 | 0.834 | 0.176 | 9.31 | 0.678 | 0.148 | 1.8 | 0.241 | 1.184 |
| middle number | 2 | 2 | 1 | 24 | 3 | 6 | 3 | 1 | 1 | 3 | 6 | 1 | 3 | 2 | 1 | 1 |
| 10³ m³ | 3 | 2.03 | 1 | 1.1 | 0.834 | 0.176 | 9.31 | 0.678 | 0.148 | 1.8 | 0.241 | 1.184 |
| small number | 11 | 1 | 10 | 12 | 1 | 63 | 2 | 2 | 2 | 6 | 2 | 2 | 2 | 1 | 1 |
| 10² m³ | 3 | 2.03 | 1 | 1.1 | 0.834 | 0.176 | 9.31 | 0.678 | 0.148 | 1.8 | 0.241 | 1.184 |

### 3. The influence of coal mining on river runoff

3.1. Annual runoff with the cumulative curves of raw coal production

Annual runoff with the cumulative curves of raw coal production is showed in figures 3-5, include Gushanchuan, Kuyehe and Tuweihe basins in the north Shanxi, which is a region with a large amount of coal production. It can be seen that the raw coal of the three river basins showed an increasing trend after 2000, the runoff accumulation curve in the 1990s showed a decreasing trend, and mine inflow and raw coal production had synchronous growth from 1991 to 2011 year by year. This indicates that coal mining is a major influencing factor on river runoff.

![Figure 3. Annual runoff with the cumulative curves of raw coal production and Water inflow with raw coal production in Gu Shan Chuan basin](image_url)
Figure 4. Annual runoff with the cumulative curves of raw coal production and Water inflow with raw coal production in Ku Ye He basin

Figure 5. Annual runoff with the cumulative curves of raw coal production and Water inflow with raw coal production in Tu Wei He basin
4. Research method

4.1. Diversion fissure zone and caving development height determination
At present, the research of multiple sets of coal mining under the conditions of water flowing fractured zone is still in its primary stage. In this paper, the building, water, railway, main shaft, coal pillar, and press coal mining regulations (hereafter referred to as “three under” rules) listed in the empirical formula were used to calculate and determine the coal seam mining height of water flowing fractured zones and the development of caving zones.

4.2. Ground subsidence calculation and analysis
The formation of the ground subsidence area and water area were calculated with the coal mining subsidence model. The corresponding simulation program was adjusted based on the future forecast of the ground subsidence deformation under different minable seam mining situations, while the calculation of evaporation changes analyzes the effect of coal mining under the scheme of surface water.

4.3. Calculation of deep and shallow water
In the distributed time-variant gain hydrological model, the hydrological cycle and the hydrologic method are combined with the theory of non-linear systems in order to simulate the hydrological process. The core of the model is the TVGM runoff module. The slope, flow, flow path, river grid, basin boundary and other information are determined by GIS. With consideration of the physical process of the hydrological system, a general pattern was adopted to construct a distributed hydrological model. DTVGM (raster units) in the spatial distribution of hydrological unit with the application of the theory of nonlinear systems with certain mechanisms of the hydrological cycle model were used to calculate the surface of the aquatic product flow, the application linear flow of free water reservoir was used to calculate soil water and the underground aquatic product flow. The actual evaporation gavelor model and the snowmelt model use the live factor model.

MODFLOW (Modular Three-dimensional Finite-difference Ground-water Flow Model) is a distributed physical model. This model can reflect the spatial characteristics of the groundwater and its movement. The limitations of performance in the model depend upon the specific conditions of input, including tributaries, water supplies, and evaporation data. The model lacks a specified in the form of surface and soil profile hydrological process method of these conditions.

When DTVGM is coupled with MODFLOW, the combined model can retain the advantages of the respective models to simulate surface water and groundwater while performing appropriate quantitative analysis of the hydrological processes in the watershed. The minimum grid and the grid size are the man differences between DTVGM and MODFLOW. First, conversion between the minimum grid and the grid space must be achieved; then, the DTVGM and MODFLOW models can be successfully coupled.

5. Conclusions
- After 2000, the rainfall in Toutongjian from June to September did not obviously change in flood season. Therefore, the rainfall change alone cannot explain the phenomenon of the drop off of runoff in the same period.
The water reducing effects of reservoirs and backbones of dams are limited, while terrace (article) fields and vegetation change were found to have a distinct effect in reducing water.

Through the mechanism combined with the model, three kinds of modes that impact the way coal mining interacts with the water cycle are proposed: water fracture zones without conduction bedrock, water fracture zones with conduction bedrock, the ordovician occurrence patterns of coal seams and water fracture zones. The development of caving zone height is also given, along with a method for the quantitative calculation of deep and shallow water.

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