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Analysis of Annual Available Water Resources of a Representative Basin in Upper Loess Plateau

ANALYSIS OF THE ANNUAL AVAILABLE WATER RESOURCE OF A REPRESENTATIVE BASIN IN UPPER LOESS PLATEAU

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ABSTRACT

Currently, land desertification has become a rigorous problem around Chinese Loess Plateau thereupon the effective countermeasures must be urgently adopted. Since increment of vegetation coverage is expected as an appropriate mean to resist desertification and will be extensively carried out on Loess Plateau thereby the available water is essential to implement this environmental project. However the annual mean precipitation is only about 400 mm with different seasonal distribution, thus estimation of the annual available water becomes very difficult. In the current study, a basin named Liudaogou which has representative hydrologic and topographic characteristics of upper Loess Plateau was chosen as the study location, based on the results of the field survey and numerical calculation of the surface runoff, we considered the simple process of the water income and expenditure, further roughly evaluated the annual available water of Liudaoghou basin in 2006.

Keywords: Loess Plateau, Liudaogou, water income and expenditure and available water

1. INTRODUCTION

Since the 17th century, serious desertification has occurred on Loess Plateau as a result of improper land use, including over-cultivation, over-grazing and over-deforestation (Bo, 2002). Currently, environment of Chinese Loess Plateau becomes much more severe and degree of the desertification gradually aggravates. It is estimated that desert area and the area affected by desertification covered one third of the territory of China. Every year, deserts eat up 2460 km^2 of land (Fan and Zhou, 2001). Nowadays the problem of land desertification around Loess Plateau is increasingly focused on more attention than before and the practical countermeasures must be urgently adopted to prevent this wide semiarid land region from being desertification. Since increasing green vegetation is expected as an effectual mean will be extensively implemented on Loess Plateau thereby the available water is essential for putting this environmental project into practice. However, the mean annul precipitation is only about 400 mm with different-seasonal distribution (Wei, Li and Liang, 2005), consequently estimation of the annual available water becomes very difficult. Specially, due to the continuous elevation increase coupled with gradual decrease in precipitation from south-east to north-west, the environment of north-west Loess Plateau is in serious condition.

In the current study, a basin named Liudaogou which is located at north Loess Plateau was chosen as a study location. We carried out the field survey and local observation on this basin. Based on the investigated results and numerical calculation of the surface runoff, simply analyzed the water income and expenditure and approximately evaluated the available water resources of Liudaogou basin in the year of 2006.

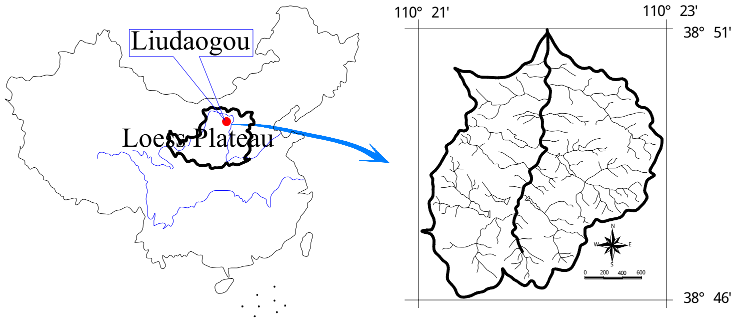


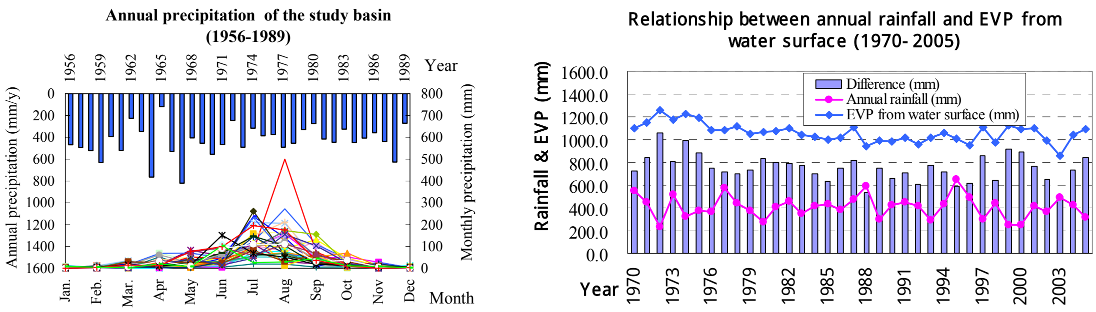
Figure 1 Position of Loess Plateau in China and Liudaogou basin

2. GENERAL SITUATION OF THE STUDY BASIN

Liudaogou basin is located at north Loess Plateau (110°21'-110°23' E longitude and 38°46'-38°51' N latitude, area, 6.89 km^2) (Figure 1) belongs to the water-wind erosion crisscross area. The study basin was chosen because it represents diversified landscape types in terms of geology, morphology, soil, hydrography and climate conditions, and is under a number of land-uses representatives of the upper Loess Plateau environment (Zheng, 2004).

2.1 Climate

Typical temperate continental monsoon climate is remarkable. The mean annual precipitation is 437 mm with non-uniform distribution, more than 70 % of the total occurs in the period from July to September generally with several heavy rains (Figure 2a). Except the rainy season, climate is awfully dry, especially in spring and winter the sandstorm occurs readily with thirteen times per year in recent years which is more frequent than before. Contrast to the deficient and different-seasonal rainfall, annual evaporation exceeds 1000 mm which is considerably more predominant than rainfall (Figure, 2b) (Huang, 2008).



(a) (b)

Figure 2 Annual precipitation and evaporation (EVP)

2.2 Topography and vegetation

Elevation is 1094.0 m-1273.9 m, due to the long-term water-erosion, terrain becomes considerably complicated many gullies in various scales crisscross in the study basin. And as a result of serious wind-erosion, the topsoil becomes very loose and surface soil is easily to be swept. Due to the excessive pasturage, the natural vegetation was severely destroyed and there is nearly no large-area distribution. The artificial vegetation was hardly developed in recent 20-30 years, however for the rigorous vegetal environment, the vegetation is in arduous condition and the coverage is less than 25%, thereby the ecology is very frail (Fan, 2005).

3. ANALYSIS OF THE WATER INCOME AND EXPENDITURE

Obviously, clarification of yearly process of water income and expenditure is indispensable for estimating the annual available water of the study basin. The real process of water income and expenditure will show apparent distinction with different-rainfall in different given year. In the current study, the year of 2006 was selected as considered time which could be regarded as a representative hydrological year of the upper Loess Plateau.

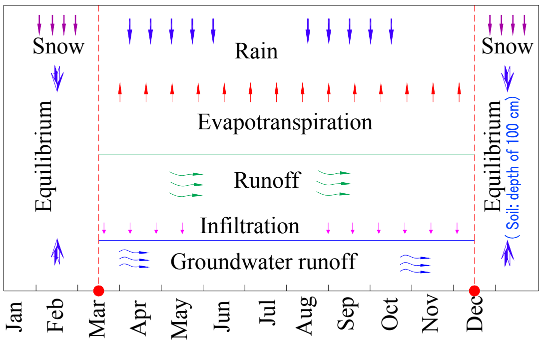


Figure 3 Diagram of water income and expenditure

3.1 Considered period

According to the result of field survey in the year of 2006, the considerable time of the water income and expenditure was about 270 days, because in winter (from the mid-December to the next mid-March) the topsoil was frozen and the moisture exchange between the soil from the ground to the depth of 100 cm and the atmosphere almost kept dynamic equilibrium (Fan, 2005), moreover, the shallow groundwater runoff was also stopped by the upper-frozen ground. Therefore, the simple process of the water income and expenditure can be described by a concise diagram as Figure 3.

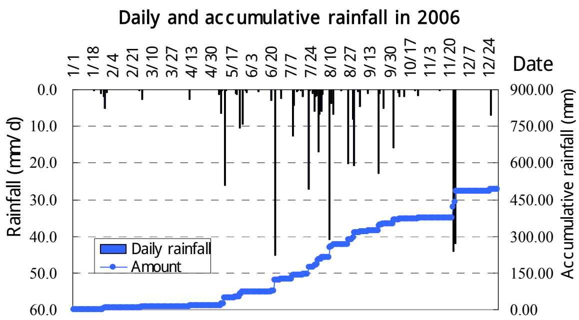


Figure 4 Precipitation in 2006

3.2 Amount of precipitation

For a certain basin, the water income and expenditure occurs at anytime and the water moisture exchange with the external keeps a dynamic condition. And the total water income refers to the amount of precipitation received in the considered period.

With regards to Liudaogou basin, the amount of effective precipitation was 470 mm during the considered time and only trifling snowfall about 20 mm occurred in winter (Figure 4). Therefore, the total water income could be approximately estimated to be 3.37×10^6 m^3.

3.3 Surface runoff

Conventionally, by reason of the complicated topography in Loess Plateau, the surface runoff is hard to be accurately observed and estimated. In the current study we developed a runoff calculation model for the surface runoff by kinematic wave theory and by using hypothetical channel network (Hashimoto, N., 2006, and Kobayashi, K., 2006). Since this type of calculation model has already been verified applicable to the calculation of the surface runoff of the study location, the surface runoff occurred in 2006 was estimated by numerical calculation through this numerical calculation model (Huang, 2008).

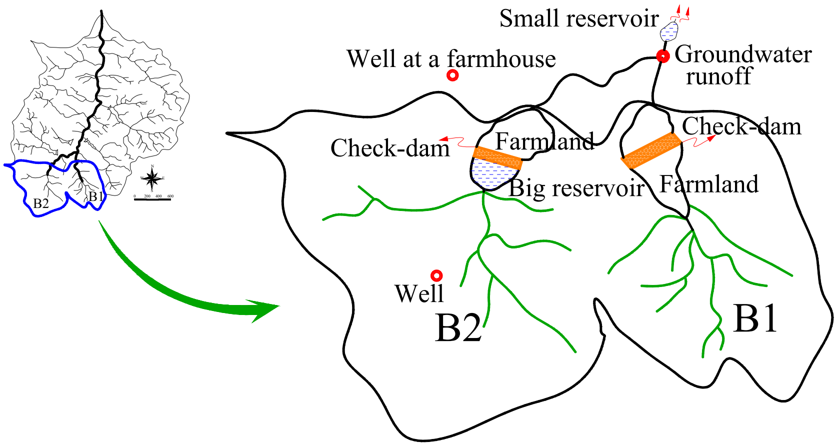


Figure 5 Position and sketch map of B1 and B2

On the other hand, there is no existing digital elevation model (DEM) which is essential to generate the hypothetical channel network for the whole study location, thereupon we could only carry out the runoff calculation of the two tributaries of the upstream. Nevertheless, owing to the ground condition is considerably homogeneous within the whole basin, therefore the total surface runoff was approximately estimated by considering the calculated result of these two-chosen tributaries. Each tributary was respectively named B1 (area: 0.44 km^2) and B2 (area: 0.58 km^2). The sketch map of this area is shown in Figure 5 and the corresponding generated hypothetical channel network is respectively shown in Figure 6.

The numerical calculation of the surface runoff of the two branches is separately carried out and the calculated result was shown in Figure 7. In B1 basin, the amount of surface runoff is 3.87×10^4 m^3 which accounts for 17.9 % of the total precipitation. Meanwhile, total runoff of 5.04×10^4 m^3 occurred in B2 and the runoff percentage is 17.6 %. In view of surface runoff percentage may slightly increase at the downstream of the study basin, consequently for the whole study basin, the runoff percentage of the surface flow was approximately estimated to 18.0 %.

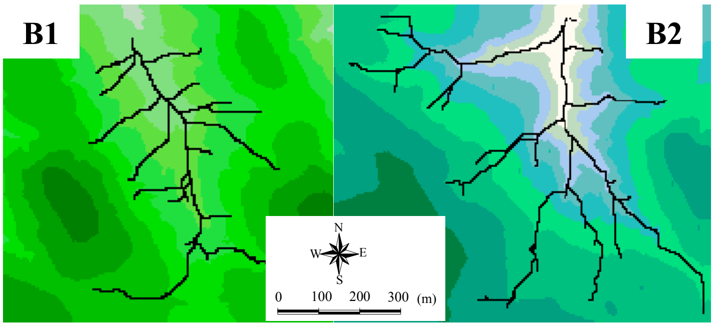


Figure 6 Hypothetical channel networks of B1 and B2

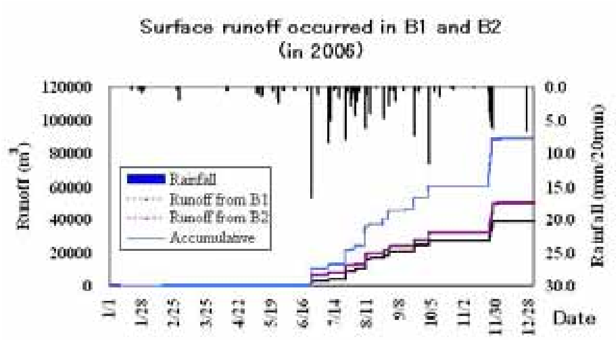


Figure 7 Surface runoff of B1 and B2

3.4 Groundwater runoff

The shallow groundwater runoff exists continuously except winter during which the runoff of this kind is stopped by the upper-frozen ground. The observation of groundwater runoff is hard to be implemented at downstream of Liudaogou basin due to the natural river channel was confused by human factors, whereupon the groundwater runoff was observed at a point as shown in Figure 5. The discharge was observed by a flowmeter several times and the average discharge was about 1.75×10^{-3} m^3 /s in 2006 (Ref: Figure 8). Thus, quantity of groundwater runoff (270 days) was accounted for 8.0 % of total precipitation of the catchment area up to the observed point.

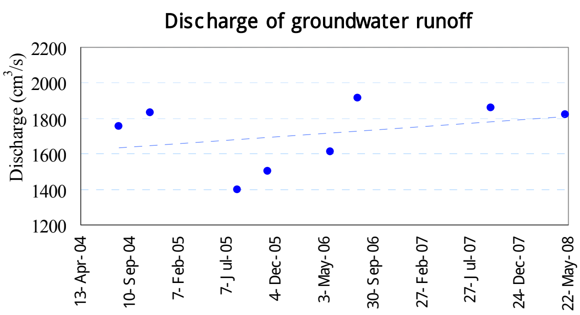


Figure 8 The observed discharge of groundwater runoff

Towards estimating the total groundwater runoff from Liudaogou basin in 2006, we considered the groundwater runoff is uniform in each tributary since the ground shows the homogeneous condition. And because the catchment area of the discharge observed occupies about 15 % of the total basin area, the amount of groundwater runoff from the whole basin may be estimated to 2.8×10^5 m^3 by referring to the observed discharge. Thereby the total groundwater runoff approximately accounted for 8.1 % of the water income.

3.5 Water utilization

Water utilization in Liudaogou basin is mainly composed with two parts. One is the domestics water includes the life water of the habitants and the water consumption by domestic animals, and another is farmland irrigation.

According to the result of targeted survey, the domestic water is taken from an artesian well was located at upstream in B2 (Figure 5), the water in this well belongs to the unconfined groundwater. Normally, daily domestic water was about 200 m^3 but increased in summer (June and August) during which attains approximately 300 m^3/d. Therefore, total domestic water was roughly estimated to be 8.2×10^4 m^3 in the year of 2006.

Another item of water consumption is the irrigative water which was taken from two different-size reservoirs. The big one which water storage area is about 5330 m^2 is at downstream of B2 and the relative-small one is located at lower-side of the groundwater runoff observed point (Figure 5). According to the investigated result, the farmland irrigated area is 20.6 ha, and about 70 % of the total irrigative water was taken from the big reservoir while the left part was taken from the small reservoir. The main function of the big reservoir is the storage of the shallow groundwater. During the rainy season, in order to prevent the check-dam which was built at downstream of B2 from being destroyed by the flood, runoff occurs in B2 is discharged through the artificial channels excavated at both sides of the reservoir. The amount of intake for irrigation from the big reservoir was estimated by analyzing the data of water level fluctuation observed in this reservoir. The water level fluctuation and the accumulative water intake curves are respectively shown in Figure 9.

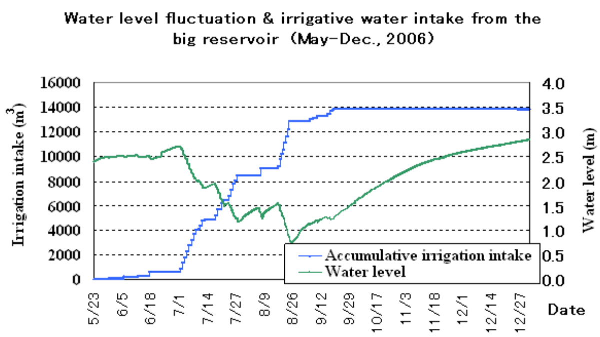


Figure 9 Water level fluctuation and accumulative intake in the big reservoir

From Figure 9 we can understand the irrigative period in the study location is from the late in May to the end of September, and the irrigative water taken from the big reservoir is 1.4×10^4 m^3. Thus the left part supplied by the small reservoir could be approximately inferred to 0.6×10^4 m^3, consequently sum of the irrigative water approximates to 2.0×10^4 m^3. Therefore, the amount of water utilization is around 1.02×10^5 m^3 by summing up the domestic water and the irrigation water,

3.6 Consideration of annual change of the shallow groundwater

On the purpose of considering the annual change of the shallow groundwater, we performed the observation of shallow groundwater fluctuation at two points, one is in the big reservoir and another is in a well at a farmhouse (Figure 5). Since there was nearly no surface inflow that the water level change in the big reservoir could be merely regarded as fluctuation of the shallow groundwater in B2. By analyzing the observed result, the shallow groundwater almost keeps in a same level at annual corresponding time can be realized (Figure 10), for an instance, the water level in May 2006 is similar to the corresponding time in 2007. And in the case of the observed result of another point, the shallow groundwater fluctuation shows similar condition (Huang, 2007). Therefore, we can infer the annual water income and expenditure of the shallow groundwater approximately keeps equilibrium.

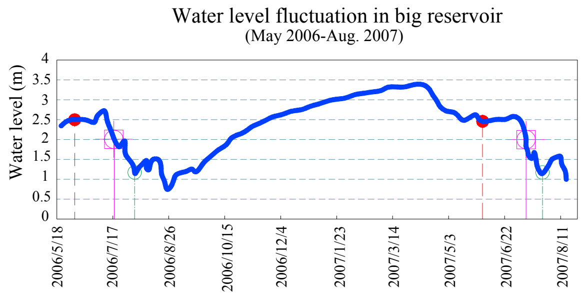


Figure 10 Water level fluctuation in the big reservoir

3.7 Evapotranspiration

Evapotranspiration normally refers to the sum of evaporation, transpiration and interpolation by vegetation. In view of the complicated geomorphological features such as the bare land, the crops, and sparse but diverse vegetation, observation of actual evapotranspiration is extremely difficult to be accurately performed. Because the annual shallow groundwater almost keeps dynamic balance, we roughly estimated the evapotranspiration by subtracting the quantity of the surface runoff, the groundwater runoff and the water utilization from the total precipitation. In the case of the estimated result, evapotranspiration occupied 70.9 % of the total precipitation.

4. ANALYZED RESULT

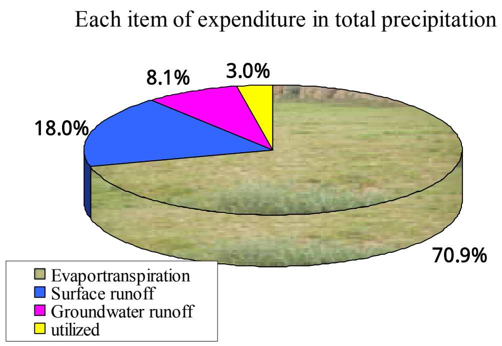


Figure 11 Percentage of each item of water expenditure

Generalized every item of water expenditure and the result is shown in Figure 11 by which the water expenditure of Liudaogou basin in 2006 could be simply realized. The total runoff accounted for about 26 %, and the water utilization only occupied 3.0 % of the total precipitation, whereas the evapotranspiration is in predominant status among all items of water expenditure.

5. CONCLUDING REMARK

Theoretically, the runoff of the surface flow, and the shallow groundwater could be expected as the available water in the study basin. However, due to extensive distribution of the frail-loose loess in upper Loess Plateau, the surface runoff is extremely difficult to be stored and utilized. Therefore the limited shallow groundwater runoff appears extreme significant. For the purpose of putting afforestation into practice on upper Loess Plateau, on all accounts, how to conserve groundwater runoff in every small basin becomes a most considerable problem.

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