Analysis on the exchange of water resources between atmosphere and land in Yongcui River Basin

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Abstract: The analysis and calculation of water resources depend on the equation of water balance, in which the exchange of water resources between surface and atmosphere is usually the main source of water resources in the basin. In this paper, the elements of annual rainfall, annual distribution of rainfall and distribution of basin precipitation in Yongcui River flow area are analyzed in detail. According to the geological and geomorphological conditions and river state in the basin, the distribution of evaporation in the basin and the relevant indicators of drought and waterlogging are analyzed and calculated. Finally, through the analysis of precipitation and evaporation, the exchange of water resources between the basin atmosphere and land is evaluated and summarized.

1. Introduction
The Yongcui River Basin is under the jurisdiction of Yichun City in Heilongjiang Province. It belongs to Shanxi River in Dailing region. The source of Yongcui River is located in the Hanyue Forest Farm, Mingcuyuanggou, coordinates 128°43′12.4″ East longitude; 47°19′10.3″ North latitude. The estuary is located in the southeast of Bailing District. The coordinates are 129°03′46.8″ East longitude and 47°01′19.3″ North latitude. It flows into the Southwest Weihe River and is a tributary of the left bank of the Southwest Weihe River. The drainage area is 706 km\textsuperscript{2}, the catchment area is 677 km\textsuperscript{2}, and the river length is 67 km. In the basin, there are 6 trenches such as Songlinggou, Liangshuihe, Heizhuigou, Cuiyuanggou, and Nanli Gully, which are dendritic in shape. The main components of riverbed are coarse sand and pebbles.

There are 6 rainfall stations and 1 hydrological station in the basin for the period 1960-2011. The exit control station is Dailing Hydrographic Station. The length of the river above the section is 61 km, the distance from the estuary is 6.0 km, and the catchment area is 677 km\textsuperscript{2}. The main underlying surface
is forests, and the main form of production is agriculture. The distribution of river basins and station networks is shown in figure 1

![Figure 1](image-url)

**Figure 1. Distribution of water system and hydrographic station network in Yongcui River basin**

2. Characteristics of basin rainfall and evaporation analysis

Under the normal water balance equation of the basin, the upstream inflow flow, the atmospheric precipitation and the groundwater lateral inflow are the main recharge water. The excretion amount are mainly the groundwater lateral outflow, downstream outflow flow, and the steam emission. In the closed basin, are mainly consist of annual averaged atmospheric precipitation and runoff and steam emission. In the evaluation and analysis of water resources, the total runoff is often used as an indicator to measure the amount of water resources in the area [2, 3]. The direct acquisition of runoff is very difficult. Therefore, the multi-year water balance equation is usually used to calculate the runoff through the calculation of precipitation and evaporation in the analysis and calculation of water resources, and then the number of water resources in the region is determined. At the same time, the spatial and temporal distribution of water resources can also be reflected by the spatial and temporal distribution of precipitation and steam emissions in the basin.

2.1. Basin precipitation frequency calculation

In the calculation of precipitation frequency, the spatial and temporal distribution of annual precipitation is usually analyzed according to the region's annual precipitation characteristics. The calculation of the average annual precipitation is completed by the following formula:

$$P = \frac{1}{n} \sum_{i=1}^{n} p_i$$

- $P$ - Average annual precipitation (mm) for many years;
- $p_i$ - Annual precipitation (mm);

The average annual precipitation in the basin can be determined by collating and analyzing many years of data. The average annual precipitation can only represent the overall precipitation situation of the basin. Therefore, when studying the spatial and temporal distribution of precipitation in the basin, the precipitation variation coefficient CV and the deviation coefficient CS are generally selected [4, 5]. These eigenvalues are calculated using the following formula:

$$c_v = \frac{\sigma}{p} : \sigma = \frac{1}{n-1} \sum_{i=1}^{n} (p_i - \bar{p})^2$$

$$c_s = \sqrt{\sum_{i=1}^{n} (k_i - 1)^2}$$

$$c_y = \frac{\sum_{i=1}^{n} (k_i - 1)^3}{(n-3)c_v^3}$$

Among them, $p_i$ above, it is the mean variance of the annual precipitation sequence, and $k_i$ is the modulus coefficient of annual precipitation, that is, the ratio of annual precipitation to multi-year average annual precipitation. The spatial and temporal distribution of precipitation in this area can be
clearly shown by the isogram of annual average precipitation and precipitation variation coefficient. By fitting the frequency of precipitation through the frequency fit-line software, the precipitation frequency curve can be obtained, and the annual precipitation at the required frequency can be obtained. This is an important reference for water Conservancy projects and hydrological surveys.

The method of selecting representative station was used to calculate the average annual rainfall in the basin. Due to the limitations of data and calculation conditions, the initial value of the required parameters is calculated by the moment method using the fit-line software, and then the statistical parameters are determined by the soft graph method. The results are shown in Table 1. The maximum annual precipitation in the basin is 1036mm, the minimum value is 382.6mm, and the maximum annual precipitation ratio is 2.70.

Table 1. Calculated results of annual rainfall design frequency in Yongcui River basin

| Project name         | Statistical parameters | Design frequency(%) |  |
|----------------------|------------------------|---------------------|---|
|                      | $\tilde{p}$            | $C_v$               | 20 0 10 | 5 2 1 |
| Annual rainfall design frequency | 695.7                 | 0.19                | 2.0 | 797 | 862 | 919 | 985 | 1030 |

2.2. Mapping of annual precipitation and coefficient of variation lines in the basin

Based on the measured data and its distribution of the long series of high-precision rainfall stations in the surrounding river basins, the precipitation characteristic values of each rainfall station in the basin are calculated, and then the equivalent lines of annual precipitation and variation coefficient are drawn based on the conditions of the lower cushion and the surrounding basin data. See figure 2, 3.

From figure 2 and figure 3, it can be seen that the average annual precipitation in the Yongcui River basin gradually decreases from upstream to downstream, and the precipitation in the downstream is greater than 600mm. It belongs to the area rich in precipitation and is in line with the characteristics of rainfall in the main supply source of the Yongcui River basin. The rainfall stations with large annual average precipitation during the flood season are Chaoyang Station and Qinglin Station. The rainfall variation coefficient increases first and then decreases, and the $C_v$ value near Bishui Station is greater than 0.25. It belongs to the abundant water area, which is in line with the changing characteristics of the gradual increase of precipitation from the Northwest to the southeast of the Yongcui River basin, and the annual change increases first and then decreases.

Figure 2. Analogous chart of annual precipitation in Yongcui river basin

Figure 3. Line of $C_v$ value of annual precipitation in Yongcui river basin

2.3. In-year distribution of precipitation in the basin

The annual distribution of precipitation in the basin uses the ratio of annual average monthly precipitation and annual average annual precipitation as parameters. After statistics, the results of rainfall stations in the basin are shown in Table 2. From the table, it can be seen that 73% of the total precipitation is concentrated between June and September, that is, before and after the flood season.
### Table 2. Statistics on the distribution of precipitation in the Yongcui River basin  Unit: mm

| Station name | Average annual precipitation | Items                             | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | Precipitation in flood season |
|--------------|-----------------------------|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----------------------------|
| Dailing      | 640.7                       | Monthly                           | 5.6 | 6.2 | 15.6| 28.9| 58.0| 104.6| 154.2| 141.4| 70.0| 36.3| 13.1| 10.4| 470.2                      |
|              |                             | Annual (%)                        | 0.9 | 1.0 | 2.4 | 4.5 | 9.1 | 16.3 | 24.1 | 22.1 | 10.9| 5.7 | 2.0 | 1.6 | 73.4                       |
|              |                             | Monthly                           | 7.0 | 7.0 | 21.2| 38.5| 62.6| 118.2| 179.3| 165.8| 86.7| 41.4| 15.7| 12.0| 550                        |
|              |                             | Annual (%)                        | 0.9 | 0.9 | 2.8 | 5.1 | 8.4 | 15.8 | 24.0 | 22.2 | 11.6| 5.5 | 2.1 | 1.6 | 73.6                       |
| Chaoyang     | 747.2                       | Monthly                           | 6.8 | 7.1 | 21.0| 38.3| 60.5| 119.9| 170.1| 148.5| 81.1| 43.9| 16.0| 12.1| 519.6                      |
|              |                             | Annual (%)                        | 0.9 | 1.0 | 2.9 | 5.2 | 8.3 | 16.4 | 23.3 | 20.3 | 11.1| 6.0 | 2.2 | 1.7 | 71.1                       |
|              |                             | Monthly                           | 5.9 | 7.1 | 17.3| 35.0| 60.1| 117.5| 170.9| 162.1| 73.8| 41.0| 14.7| 8.7 | 524.4                      |
|              |                             | Annual (%)                        | 0.8 | 1.0 | 2.4 | 4.9 | 8.4 | 16.5 | 24.0 | 22.7 | 10.4| 5.7 | 2.1 | 1.2 | 73.5                       |
| Nanlie       | 731.3                       | Monthly                           | 5.4 | 6.4 | 18.0| 29.5| 48.7| 109.9| 158.0| 146.8| 69.6| 33.8| 13.8| 10.6| 484.3                      |
|              |                             | Annual (%)                        | 0.8 | 1.0 | 2.8 | 4.6 | 7.5 | 17.0 | 24.5 | 22.7 | 10.8| 5.2 | 2.1 | 1.6 | 75.0                       |

### 3. Analysis of basin evaporation

In the process of exchanging water resources between the atmosphere and the land in the basin, precipitation is the process of transporting water resources from the atmosphere to the land, and steam is the process of returning water resources from the land to the atmosphere. Evaporation is also the main item of expenditure in the calculation of water volume in the basin. It is generally divided into surface evaporation and land evaporation.

#### 3.1 Water surface evaporation

According to the Hydrographic calculation specifications for Hydrographic water Conservancy projects[5], when calculating the evaporation of the water surface, the observations of evaporation observation devices with an area less than 20m$^2$ should be converted to the evaporation of the water surface of the 20m$^2$ evaporation pool. Among them, the 20cm caliber version of the E-601 evaporator has a specific specification conversion coefficient. Therefore, evaporation is calculated from the observation value of water surface evaporation of different types of evaporators to the E601 20cm caliber evaporator value.

The evaporation observation station in the Yongcui River stream area uses a 20cm diameter evaporator to observe on weekdays and uses the E-601 evaporator to observe from May to September in part of the year. Taking this into account, a long series of 20cm evaporating dish data is used in the calculation. The observed value of evaporator data is converted by using the observed 20cm diameter E-601 evaporator data in parallel, and then the commutation coefficient of the evaporator value of E-601 is used. The characteristic value of evaporation is the same as that of precipitation, which is convenient for analysis. The results show that the average annual water evaporation in the basin is 479.7 mm and the CV value is 0.09. After conversion, the annual change process curve of the evaporation of the water surface of the basin is shown in figure 4, where the maximum value is 559mm, the minimum value is 385mm, and the extreme value ratio is 1.45.
3.2 Land evaporation

Land evaporation is the evaporation of the basin. It consists of evaporation of surface water bodies, evaporation of soil, and evaporation of plants. It is the main component of evaporation during precipitation. The main influencing factors of land evaporation are land evaporation capacity and precipitation, of which precipitation accounts for the main part. The land evaporation cannot be obtained by observation and measurement, and can only be obtained indirectly by the water balance equation. The average annual land evaporation is the difference between the average annual precipitation and the average annual net flow. The formula is:

$$E = \overline{p} - \overline{R}$$

It has been calculated that the average annual land evaporation in the basin is 361.1 mm. Due to the average conditions of the lower surface of the basin, the distribution of land evaporation isobars is similar to that of precipitation isobars. See figure 5 for details.

3.3 Drought index and drought and waterlogging analysis

The main production form of the Yongcui River basin is agricultural production, and the law of drought and waterlogging is the main law that guides agricultural production and land protection in the changing laws of water resources. Therefore, drought and waterlogging analysis can be used as a reference for sustainable development and rational allocation of water resources.

The index method of drought and waterlogging is a simple and practical method in the analysis of drought and waterlogging. Its essence is the standard difference method. The formula is:

$$\beta = \frac{p - \overline{p}}{\sigma}$$
Among them, the drought and flood index for the time period; P is the time precipitation(mm); For multi-year average precipitation; It is the mean variance of the annual precipitation sequence. The results of the analysis of drought and waterlogging in the basin are shown in table 3.

The drought index is an indicator that reflects the degree of dry and humid climate. It is usually expressed as the ratio of annual evaporation capacity to annual precipitation. Under normal circumstances, the regional land evaporation capacity and the water surface evaporation of natural water bodies are relatively close, the water surface evaporation of the Yongcui River basin for many years is significantly greater than the land evaporation of the basin, indicating that the evaporation capacity of the basin is also significantly greater than the land evaporation. Due to the lack of the measured data, the calculation results of the E-601 evaporator are used to replace the evaporation capacity of the water surface of the basin. Water surface evaporation capacity and annual precipitation can be calculated to obtain a drainage drought index of 0.69 & less than 1.0, which means that during the exchange of atmospheric and terrestrial water resources in the basin, the main flow of water resources is from the atmosphere to the land, and it also indicates that the basin is a humid area.

Table 3. Results of drought and waterlogging analysis in Yongcui river basin

| Extent of droughts and floods | Index criteria | Number of occurrences(years) | Frequency of occurrence(%) |
|-----------------------------|---------------|-------------------------------|---------------------------|
| Great drought               | β< -2         | 0                             | 0                         |
| Drought                     | -2<β<-1       | 6                             | 12                        |
| Normal                      | -1<β<1        | 34                            | 68                        |
| Waterlogging                | 1<β<2         | 8                             | 16                        |
| Otaru                       | β>2           | 2                             | 4                         |

4. Conclusion

The maximum value ratio of the total annual precipitation in the basin is 2.70, indicating that the annual precipitation in the basin varies greatly. The difference in the annual distribution of precipitation is obvious, which is in line with the monsoon climate. 73% of the total precipitation precipitation is concentrated between June and September, that is, before and after the flood season. The annual change of the total evaporation of the basin is smaller, with an extreme value of 1.45 and a CV value of only 0.09. From the basin drought index and drought and flood analysis, it can be seen that the basin is a humid climate zone. The main direction of water resources transportation is the transport of the atmosphere to the land, but the peak precipitation is low, and the flood discharge ability is strong, and the probability of droughts and floods is small. According to precipitation frequency and evaporation analysis, the probability of occurrence in normal years in the basin is 68%, which is more favorable for agricultural production.

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