SPATIOTEMPORAL DISTRIBUTION PATTERN OF SURFACE EVAPOTRANSPIRATION IN GANNAN PREFECTURE, CHINA BASED ON MOD16

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Abstract. Gannan Prefecture, China faces problems of water resource shortage and fragile ecological environment. Exploring the spatiotemporal pattern of ET can provide a basis for regional water resource development. The study analyzes the interannual changes and spatiotemporal characteristics of evapotranspiration based on MOD16, and selects meteorological, LULC data to analyze their impact on ET through trend analysis method and correlation. From 2000 to 2020, the overall AET in Gannan Prefecture showed an upward trend ($P < 0.01$), with an average upward rate of 6.30 mm/a. The PET showed a downward trend ($P < 0.01$), with an average downward rate of 6.24 mm/a. The average change rate of AET in Gannan Prefecture is 6.54 mm/a, mainly concentrated in 5-10 mm/a, and the average change rate of PET is -7.24 mm/a. The AET in Gannan Prefecture is consistent with the interannual change trend of hydrothermal conditions, showing a slow upward trend. The correlation coefficient between AET and rainfall is 0.56, and the correlation coefficient with temperature is 0.69, indicating that the AET in Gannan Prefecture is jointly affected by hydrothermal conditions. The difference in AET between grassland, cultivated land, and wetland in Gannan Prefecture is not significant, and the difference in PET is not significant. Land use type is not the dominant factor for ET changes in Gannan.
Keywords: *AET, PET, climatic conditions, land use, trend analysis method, correlation coefficients*

Introduction

Evapotranspiration (ET) refers to the amount of water evaporated per unit area and per unit time, which includes the evaporation and release of water from surface cover such as vegetation, soil, and water surface. It is an important link in water transfer between the atmosphere and the underlying surface (He and Shao, 2014; Ye et al., 2018). Evapotranspiration is an important factor that affects soil moisture content and surface water resources (Lian and Huang, 2016; Liu et al., 2021). It not only regulates regional precipitation, but also has a cooling characteristic accompanying latent heat effect, playing a decisive role in terrestrial water, heat cycle and energy balance (Han et al., 2017). In recent years, remote sensing data has become the main means of studying regional surface evapotranspiration due to its advantages in multiple temporal and spatial resolutions (Wang et al., 2016). Remote sensing technology has the advantages of wide coverage, fast data acquisition speed, and low data acquisition cost (Velpuri et al., 2013; Boegh et al., 2002). It can dynamically and quickly obtain long-term, large-scale non-uniform surface evapotranspiration, and has become a hot research topic in regional surface evapotranspiration. MOD16 data is an evaporative emission dataset publicly released by National Aeronautics and Space Administration (NASA). MOD16 data uses advanced remote sensing technology and model algorithms to provide high-resolution evaporative emission data, which can accurately measure and analyze water cycle processes at different scales. It has been widely recognized and applied by

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researchers (Wang et al., 2019; Xue et al., 2020). Ma and Chen et al. (2021) explored the spatiotemporal changes and influencing factors of surface evapotranspiration in Henan Province from 2001 to 2019, and used regression models to analyze the correlation between evapotranspiration and influencing factors; Wang and Guo et al. (2016) analyzed the estimation of land surface evapotranspiration in the northwest semi-arid region based on Moderate-resolution Imaging Spectroradiometer (MODIS) remote sensing products, and corrected the model using measured data, providing a new approach for the study of surface evapotranspiration radiation and evapotranspiration; Zhang and Kong et al. (2021) used 500 m resolution MODIS data to drive the PML-V2 model and quantitatively analyzed the impact of vegetation change on global land surface evapotranspiration from 2003 to 2017. The research results are helpful in analyzing the impact of underlying surface change on land water cycle and its potential local climate change. Through existing research, it has been found that studying the spatiotemporal distribution pattern of regional surface evapotranspiration and analyzing its influencing factors can contribute to the rational utilization and optimal allocation of local water resources, and provide theoretical guidance for high-quality development of the ecological environment (Wu et al., 2017; Gu et al., 2021; Zhu et al., 2023).

Gannan Tibetan Autonomous Prefecture, China (abbreviated as Gannan Prefecture, the same below) has a complex terrain structure and belongs to a typical plateau landform. The ecological environment is fragile, and the climate is sensitive and variable. It is an important ecological barrier and the main habitat for many protected animals in northwest China (Feng, 2023). At present, research on surface evapotranspiration in Gannan Prefecture mostly relies on calculating reference crop evapotranspiration based on the scale of national meteorological stations. The research results have a short time series and small space, making it difficult to comprehensively understand the spatiotemporal distribution characteristics of surface evapotranspiration in the entire Gannan region (Wang et al., 2010). Therefore, based on the MOD16A3GF dataset from 2000 to 2020, this study obtained actual evapotranspiration (AET) and potential evapotranspiration (PET) data from the study area. Combined with meteorological data and land use/cover data, trend analysis was used to analyze the spatiotemporal distribution characteristics of surface evapotranspiration in Gannan Prefecture, exploring the impact of hydrothermal conditions on evapotranspiration and to provide scientific basis for ecological environment protection and sustainable development of water resources in Gannan Prefecture.

Research area and research methods

Overview of the research area

Gannan Prefecture, China is located in the southwest of Gansu Province, with coordinates ranging from 100 ° 46 ′ to 104 ° 44 ′ E, north latitude ranging from 33° 06′ to 35° 34′ N, and an altitude ranging from 2500 to 4000 m (*Fig. 1*). It is located on the western edge of the Loess Plateau and the northeast of the Qinghai Tibet Plateau, with a complex terrain structure. The southeast is mainly characterized by undulating mountain landforms with steep slopes; The western, northeastern, and southwestern regions have small terrain fluctuations, with plains, mountains, plateaus, and hills interlaced. The research area belongs to a plateau continental climate, with short summer and long winter. The average annual temperature ranges from 2.9°C to 14.5°C, and the average annual precipitation ranges from 416 to 782 mm. The precipitation is concentrated from May to September (Meng, 2023).

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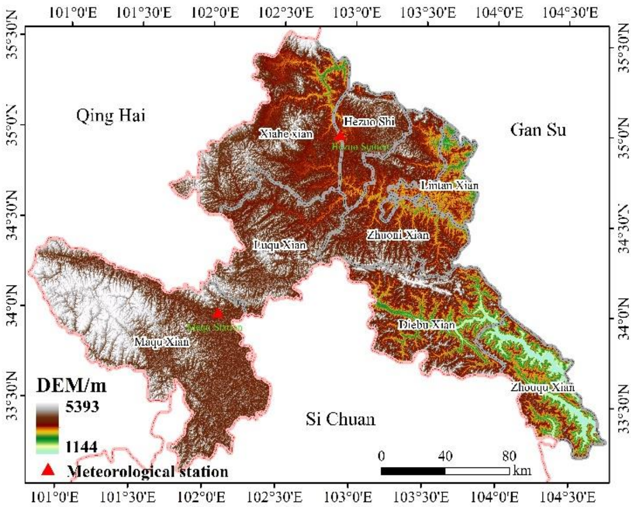

Figure 1. *Digital elevation model map of Gannan experience*

Data source and processing

The data used in this study mainly includes actual evapotranspiration (AET) and potential evapotranspiration (PET) data, meteorological data, and land use/cover data. The AET and PET data are MOD16 products, which were calculated by NASA's improved evapotranspiration algorithm based on the Penman formula proposed by Mu et al. (2007) with a spatial resolution of 500 meters (Penman, 1948; Monteith, 1965; Meng et al., 2020; Wen et al., 2020; Wang, 2022). Among them, the MOD16A3GF dataset（https://search.earthdata.nasa.gov/）This data was synthesized at the L4 level from MOD16 full-year products with a temporal resolution of years (Running et al., 2021). Data processing steps were as follows: (1) Use the MODIS Projection Tool (MRT) tool to convert the MOD16 HDF data format and obtain GeoTiff format data for AET and PET; (2) Preprocessing such as projection conversion, cropping, and embedding based on the geographical location of the research area; (3) Use ArcGIS and ENVI software to eliminate outliers and invalid values.

The meteorological data is sourced from the China Meteorological Data Sharing Service Network's "Daily Value Dataset of Surface Climate Data in China (V3.0)" (https://data.cma.cn/) It mainly includes daily data such as rainfall and temperature. There are two national meteorological stations in the study area, namely the Cooperative Station (station number: 56080) and the Maqu Station (station number: 56074) (*Fig. 1*). The land use/land cover (LULC) data is sourced from the 30 m spatial resolution GlobeLand30 data developed in China (http://www.globallandcover.com/). The data adopts the WGS-84 coordinate system, including 10 types of land use, including farmland, forest land, grassland, shrubland, wetland, water body, tundra, artificial surface, bare land, glacier, and permanent snow cover (Chen et al., 2015).

Research methods

Trend analysis method

The trend analysis method is used to analyze the changing trends of indicators and initial values in different periods. Due to its ability to calculate the changing trends of

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different indicator pixel levels, it is widely used in the study of long-term spatiotemporal distribution of remote sensing data. The trend analysis method can be used to obtain the pixel regression slope K of AET and PET long time series. If the slope is regular, it indicates an upward trend of the indicator over time, while if it is negative, it indicates a downward trend of the indicator over time. The larger the absolute value of the slope, the more obvious the trend of indicator change (Yang et al., 2022). The calculation formula is:

$$K=\frac{n^*\sum_{i=1}^{n} i^*AET_i-\sum_{i=1}^{n} i\sum_{i=1}^{n} AET_i}{n^*\sum_{i=1}^{n} i^2-\left(\sum_{i=1}^{n} i\right)^2} \qquad \text{(Eq.1)}$$

In the formula, K is the slope of the trend of AET change; N is the number of years during the monitoring period; AETi represents the AET for the i-th year. When $K > 0$, the evapotranspiration of this pixel shows an increasing trend; When $K < 0$, the evaporation of this pixel shows a decreasing trend; Replacing the AET in the equation with PET can also be used to analyze the interannual changes in potential evapotranspiration capacity.

Correlation analysis

Correlation analysis is the analysis of two or more parameters with correlation, used to measure the degree of correlation between parameters. The calculation formula is as follows:

$$R=\frac{\sum_{i=1}(Y_i-\bar{Y})(X_i-\bar{X})}{\sqrt{\sum_{i=1}(Y_i-\bar{Y})^2\sum_{i=1}(X_i-\bar{X})^2}} \qquad \text{(Eq.2)}$$

In the formula: R is the linear correlation coefficient; X_i and Y_i are the values of X and Y factors in the i-th year, respectively. $\bar{X}$ and $\bar{Y}$ are the mean values of the study period for X and Y factors, respectively. The correlation coefficient R ranges from -1 to 1. A positive R indicates a positive correlation between indicators, while a negative R indicates a negative correlation between indicators. The larger the absolute value of R, the higher the degree of correlation between indicators.

Results and analysis

Temporal and spatial distribution characteristics of AET and PET in Gannan Prefecture

The distribution of annual average AET and PET in Gannan Prefecture over time is shown in *Figure 2*. From *Figure 2*, it can be seen that the average AET of Gannan Prefecture from 2000 to 2020 was about 592.4 mm, with a fluctuation range of 476.4~643.5 mm. It reached its peak in 2019 and reached its minimum in 2000, showing an overall upward trend with an average rate of 6.30 mm/a. The annual average PET is about 1423.6 mm, with a variation range of 1288.7~1557.7 mm. It reached its peak in 2002 and reached its minimum in 2020, showing an overall downward trend with an average decline rate of 6.24 mm/a. The difference between PET and AET is defined as the degree of drought in the study area. The variation range of the difference is 648.0~1042.5 mm, showing an overall downward trend, with an

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average decline rate of 12.55 mm/a, reaching its maximum and minimum values in 2002 and 2020, respectively. According to the rainfall data from the meteorological stations in the study area, there is an increasing trend in the study area, where the rainfall in 2002 was 180.4 mm, which is the lowest value in the last 20 years. This indicates that the difference between PET and AET can better reflect the drought situation in the study area.

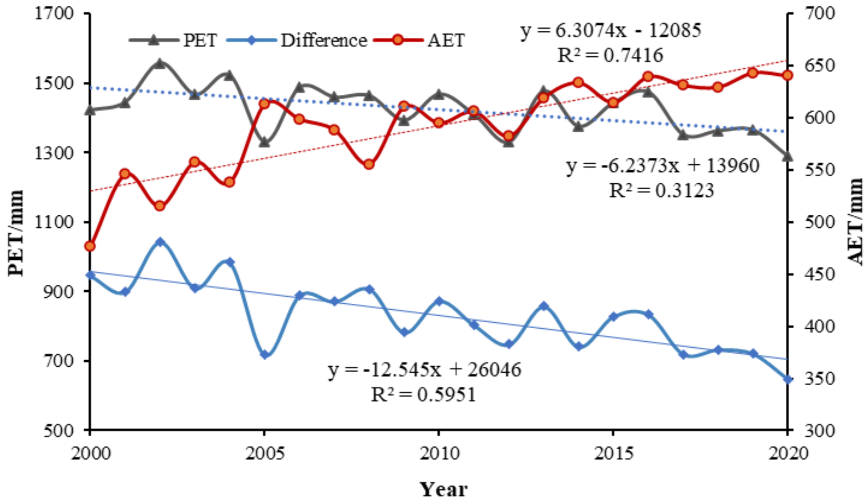

Figure 2. *Interannual changes of AET and PET in Gannan Prefecture*

Figure 3 shows the spatial variation process of AET in Gannan Prefecture in 2000, 2010, and 2020. *Table 1* shows the distribution range and proportion of AET in the study area in 2000, 2010, and 2020. From the chart, it can be seen that the overall regional AET in Gannan Prefecture has been increasing year by year. In 2000, AET was mainly distributed below 500 mm/a, in 2010, the distribution in the area of 550-650 mm/a increased significantly, and in 2020, AET was mainly distributed between 600-700 mm/a.

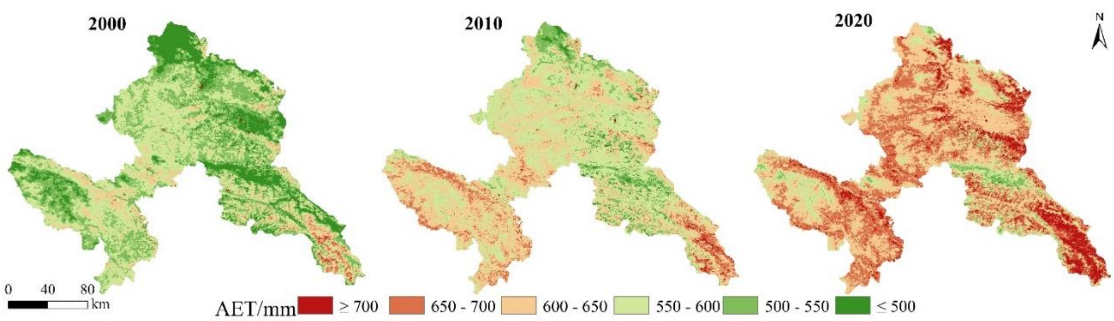

Figure 3. *Spatial change process of AET in Gannan Prefecture in 2000, 2010 and 2020*

Figure 4 shows the spatial variation process of PET in Gannan Prefecture in 2000, 2010, and 2020, while *Table 2* shows the distribution range and proportion of PET in the study area in 2000, 2010, and 2020. From the chart, it can be seen that the annual average PET spatial distribution in the study area is similar to the AET spatial

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distribution, but the extreme value distribution is exactly the opposite. Areas with PET greater than 1500 mm/a are distributed in the northeast. The fluctuation of PET in Gannan Prefecture showed that in 2000, PET was mainly distributed between 1400 and 1500 mm/a. By 2010, areas with a concentration greater than 1500 mm/a had significantly increased, while in 2020, PET was mainly distributed below 1300 mm/a.

Table 1. *Distribution range and promotion of average AET in Gannan Prefecture in 2000, 2010, and 2020*

AET/mm	**Promotion /%**			
	2000	**2010**	**2020**	**Average annual value**
≤ 500	75.8	1.9	0.0	1.3
500-550	19.3	10.3	0.8	9.4
550-600	4.1	44.8	11.2	57.5
600-650	0.8	35.6	54.8	26.3
650-700	0.1	6.8	28.1	4.3
≥ 700	0.0	0.6	5.1	1.2

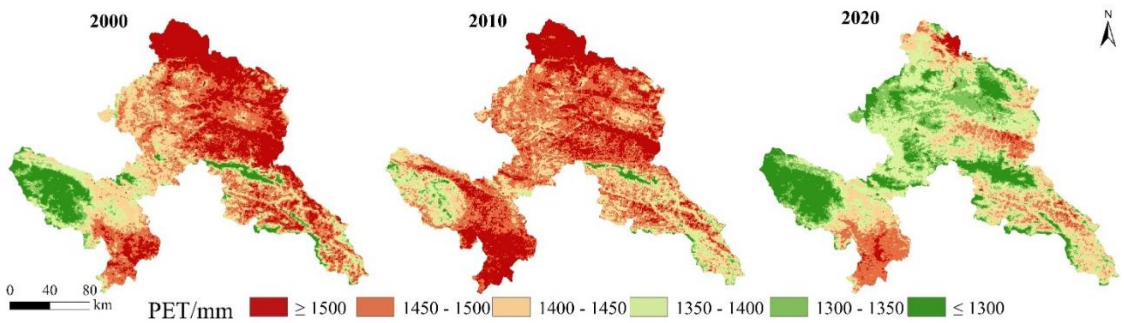

Figure 4. *Spatial change process of PET in Gannan Prefecture in 2000, 2010 and 2020*

Table 2. *Distribution range and promotion of average PET in Gannan Prefecture in 2000, 2010, and 2020*

PET/mm	**Promotion/%**			
	2000	**2010**	**2020**	**Average annual value**
≤ 1300	9.0	1.1	62.5	5.2
1300-1350	7.3	2.4	27.8	5.2
1350-1400	18.5	8.7	8.4	16.7
1400-1450	30.2	24.3	1.2	40.6
1450-1500	23.7	38.5	0.2	25.4
≥ 1500	11.3	25.0	0.0	6.9

The spatial distribution of average AET and PET from 2000 to 2020 is shown in *Figures 5* and *6*. From *Figure 5*, it can be seen that the annual average AET distribution of different pixels ranges from 437 to 756 mm/a. There is a significant difference in the spatial distribution of AET within the study area, with higher AET in the low mountainous areas of the southeast and lower AET in the high

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mountainous areas of the central and northern regions. The average annual PET in different regions ranges from 1077 to 1671 mm/a, with high values distributed in the northern, central, and southwestern regions, and low values distributed in the western regions. The main reasons for this phenomenon are related to the terrain and land use type. The southeast is the lowest point of the study area, and the area is mainly composed of forest land, with abundant water resources, strong vegetation water vapor interception ability, and high canopy surface evaporation; The western region has a higher altitude and lower temperature, and the impact of surface wetness on AET and PET is small, only related to climate change. Therefore, the distribution of the two shows good consistency; The vegetation coverage in the northern region is small, the climate is dry, and the surface water vapor content is low, resulting in the phenomenon of low AET and high PET.

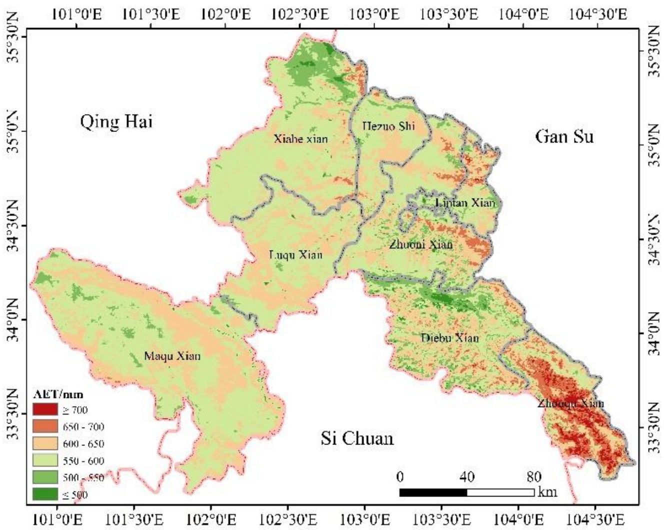

Figure 5. *Spatial distribution of annual mean AET values in Gannan Prefecture from 2000 to 2020*

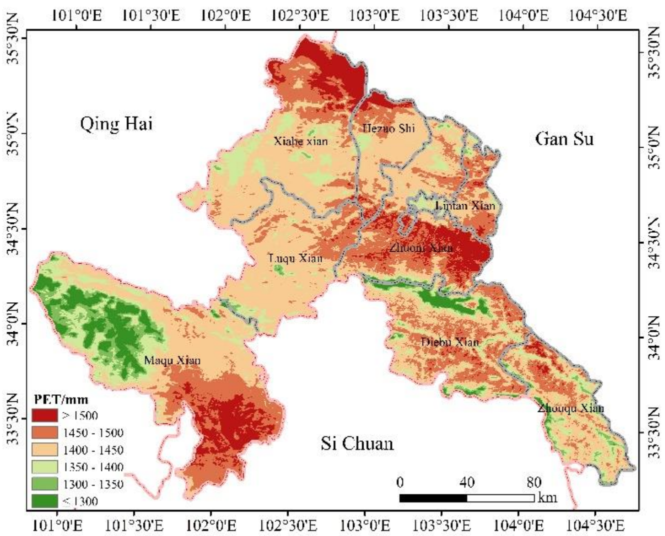

Figure 6. *Spatial distribution of annual mean PET values in Gannan Prefecture from 2000 to 2020*

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Trends in spatiotemporal changes of AET and PET in Gannan Prefecture

Figures 7 and *8* show the interannual changes of AET and PET in Gannan Prefecture from 2000 to 2020. *Table 3* shows the proportion of different levels of trend change rates of AET and PET in Gannan Prefecture from 2000 to 2020. From the chart, it can be seen that AET in the study area significantly increased ($P < 0.01$) and PET significantly decreased ($P < 0.01$). From 2000 to 2020, the average change rate of AET in Gannan Prefecture was 6.54 mm/a. The growth rate of AET was mainly concentrated in 5-10 mm/a, accounting for 82.8% of the study area. The growth rate was 2-5 mm/a, accounting for 15.1% of the study area, showing a rapid upward trend. Areas with $K > 10$ mm/a were distributed in the north and southwest, accounting for 1.9% of the total area of the study area, while areas that remained unchanged only accounted for 0.3% of the total area. From 2000 to 2020, the average change rate of PET in Gannan Prefecture was -7.24 mm/a, with the change rate mainly concentrated in -10~-5 mm/a, accounting for 82.8% of the total area of the study area. The growth rate was -5~-2 mm/a, accounting for 7.3% of the study area. The growth rate was less than -10 mm/a, accounting for 9.3% of the study area, showing a rapid downward trend. The unchanged area only accounted for 0.6% of the total area, mainly distributed in the southwestern mountainous areas.

Table 3. *The proportion of different grades of AET and PET trend change rate in Gannan Prefecture from 2000 to 2020*

Changing trends	**Change rate (mm/a)**	**AET**	**PET**
		Ratio/%	**Ratio/%**
Decline	< -10	0.0	9.3
	-10~-5	0.0	82.8
	-5~-2	0.0	7.3
Basically unchanged	-2~2	0.3	0.6
Rise	2-5	15.1	0.0
	5-10	82.8	0.0
	> 10	1.9	0.0

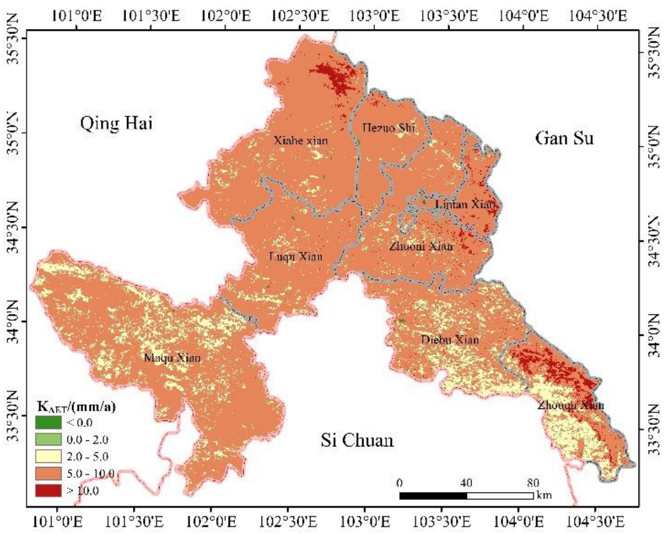

Figure 7. *Spatial distribution of AET trend change rate in Gannan Prefecture from 2000 to 2020*

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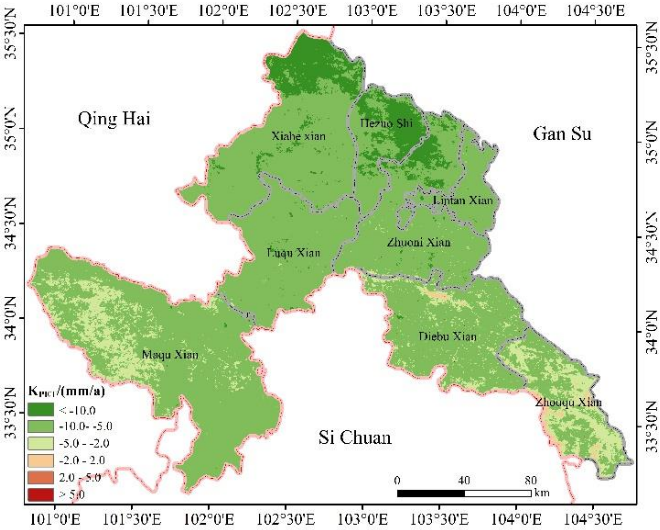

Figure 8. *Spatial distribution of PET trend change rate in Gannan Prefecture from 2000 to 2020*

Analysis of ET influencing factors

The impact of climate change on the spatiotemporal changes of ET in Gannan Prefecture

Climate change is an important factor affecting the spatial distribution of regional hydrothermal conditions, and the changes in ET are closely related to the patterns of regional hydrothermal changes (Ye et al., 2022). In regional research, annual average temperature represents regional thermal conditions, precipitation represents water conditions, and the study of interannual changes in temperature and precipitation helps to explore the driving factors of AET and PET changes in the study area. *Figure 9* shows the interannual variation of AET, temperature, and precipitation in Gannan from 2000 to 2020. The data is obtained from the annual precipitation and daily temperature data of the National Meteorological Cooperation Station and Maqu Station. The average annual rainfall in the research area is 246.8mm, and there are fluctuations in rainfall from year to year, with a slow upward trend of 3.71 mm/a per year ($P < 0.01$). The rainfall in 2018 was the highest at 349.8 mm, while the rainfall in 2002 was the lowest at 180.4 mm. From *Figure 9,* it can be seen that the average annual temperature in the study area is around 3.0°C, showing an upward trend at a rate of 0.03°C/a ($P < 0.01$). The interannual variation of temperature is large, and the temperature fluctuation has slowed down in the past 10 years. The interannual variation trend of AET in the study area is basically consistent with that of precipitation and temperature, showing a fluctuating upward trend. The correlation coefficient between AET and precipitation is 0.56, and the correlation coefficient with temperature is 0.69. The above data indicates that the AET in Gannan Prefecture is influenced by hydrothermal conditions, with temperature being the main driving factor.

The changes in surface evapotranspiration are influenced by the combined effects of climate conditions and human activities, but the scope of human activities in the study area is small and mainly affected by changes in climate conditions. Combined with meteorological data, it is shown that in recent years, the precipitation and temperature in the study area have shown a gradual increase, which has increased the humidity and

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temperature in the study area. AET shows a significant upward trend. At the same time, national policies protect the ecological environment and promote the rational development of land use, promoted vegetation restoration and played a positive role in the AET of the study area.

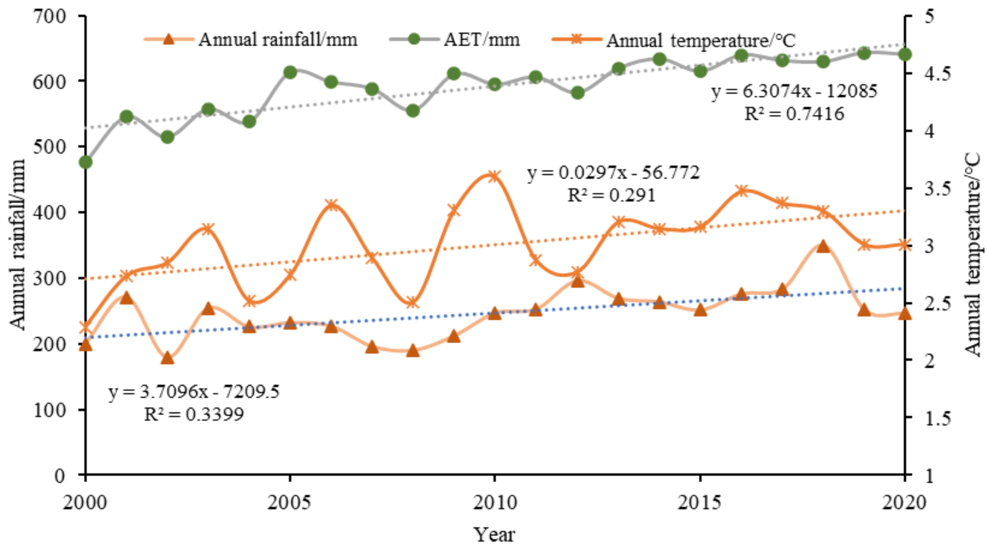

***Figure 9.** Interannual variations of AET, temperature, and rainfall in Gannan Prefecture from 2000 to 2020*

The impact of LULC on the spatiotemporal changes of ET in Gannan

The land use/cover in Gannan is mainly grassland and forest land, followed by cultivated land, wetlands and other types (*Fig. 10*). In 2020, the proportion of grassland, forest land, cultivated land, wetlands, permanent snow cover, water bodies, artificial surfaces, shrublands, and bare land in Gannan Prefecture was 53.53%, 35.04%, 6.69%, 3.03%, 0.63%, 0.51%, 0.45%, 0.07%, and 0.05%, respectively. Grassland is distributed throughout the western part of the study area, forest land is distributed in the east, and cultivated land is distributed near the eastern urban area, Wetlands are distributed in the southwest, while other land use/cover is scattered within the study area. Due to the lack of water evapotranspiration data in MOD16 data and the limited area of bare land and shrubland, this study will no longer analyze the ET changes in water, bare land, and shrubland.

The distribution of different land use types has an important impact on the water cycle process in the study area. In order to further quantify the impact of land use types on evapotranspiration, the ET status of five land use types in Gannan Prefecture, including grassland, forest land, cultivated land, wetland, and artificial surface, will be statistically analyzed. Research has found that the average AET for many years, from large to small, is forest land (652.3 mm) > grassland (634.9 mm) > arable land (631.5 mm) > wetland (624.0 mm) > artificial surface (542.5 mm), with no significant difference in AET among grassland, arable land, and wetland. The average annual PET difference under different land use types is not significant, with the order from large to small being wetland (1476.5 mm) > forest land (1446.1 mm) > cultivated land (1423.3 mm) > grassland (1415.4) > construction land (1401.1 mm), with the maximum difference being only 75.4 mm. In summary, land use type is not the dominant factor for ET changes in Gannan.

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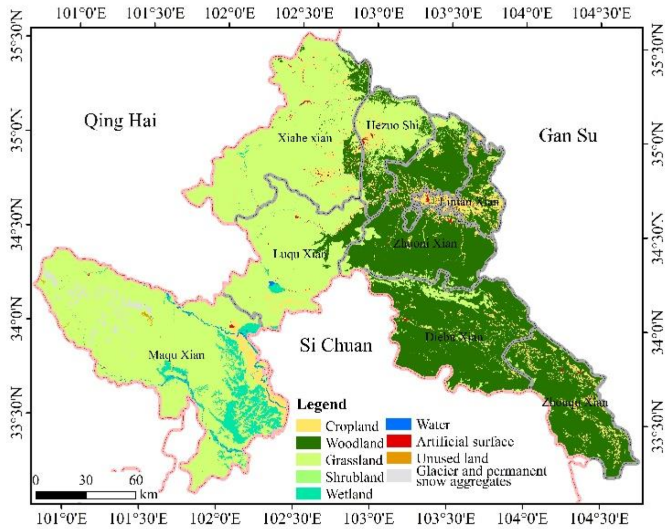

__Figure 10.__ Land use/cover distribution map in Gannan Prefecture

Discussion

Evapotranspiration is an important bridge between surface water and atmospheric water, and exploring the spatiotemporal changes of evapotranspiration plays an important role in the rational development and utilization of water resources and the protection of the ecological environment. The spatial distribution of AET in Gannan Prefecture shows significant differentiation, showing a gradually increasing trend from west to east, consistent with the research results of Feng (2023). The research results indicate that the AET of wetlands and areas with high vegetation coverage is significantly higher, which is consistent with the research results of Zhang et al. in the Huan River Basin (Zhang et al., 2018). The interannual variation trend of AET in the study area is basically consistent with that of precipitation and temperature, but there is a difference in their impact on AET. The degree of influence of temperature on AET is higher than that of rainfall, indicating that in plateau areas, temperature is the main driving factor for AET spatiotemporal changes. This conclusion is consistent with the natural characteristics of the geographical distribution difference of "high in the west and low in the east" of Gannan topography.

The interannual variation of evapotranspiration in terrestrial ecosystems is mainly controlled by radiation (Niu et al., 2019), and also influenced by moisture and temperature (Sheffield et al., 2012). Since the beginning of the 21st century, surface radiation has begun to decrease in the Chinese region (Wild et al., 2012), which explains the decreasing surface PET in Gannan State. In Northwest China, there is a clear trend of warming and drying of the climate (Zhang et al., 2016), which leads to an increase in AET, and the Gannan region has implemented a strict vegetation protection policy, which has led to a significant effect of vegetation restoration and a significant increase in vegetation evapotranspiration (Wang et al., 2023). In addition to this, human activities such as agricultural irrigation and soil and water conservation projects also affect ET.

In this study, in the process of establishing the response relationship between ET and land use and meteorological factors, the nonlinear response relationship between land use and ET as well as the interaction between ET and meteorological factors were fully considered, which reduced the uncertainty of the results to a certain extent. However, in

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fact, there is a complex response relationship between ET and the influencing factors, and the simple response model constructed in this study still made the results of the study have a certain degree of error. MODIS data has outstanding advantages in studying the spatiotemporal distribution patterns of large-scale and long time series surface parameters. This article focuses on the spatiotemporal distribution pattern of surface evapotranspiration in Gannan Prefecture from 2000 to 2020 and explores the impact of hydrothermal conditions on evapotranspiration. However, due to differences in data resolution, high-resolution and measured evapotranspiration data need to be introduced in the future to further verify the reliability of MODIS16 data.

Conclusion

The average annual AET distribution in Gannan Prefecture ranges from 437 to 756 mm/a, and there is a significant difference in the spatial distribution of AET within the study area. The AET is higher in the low mountainous areas of the southeast, while it is lower in the high mountain areas of the central and northern regions. The average annual PET in different regions ranges from 1077 to 1671 mm/a, with high values distributed in the northern, central, and southwestern regions, and low values distributed in the western regions.

From 2000 to 2020, there was a significant increase in AET ($P < 0.01$) and a significant decrease in PET ($P < 0.01$) in Gannan Prefecture. The average change rate of AET in Gannan Prefecture is 6.54 mm/a, mainly concentrated in 5-10 mm/a, accounting for 82.8% of the study area. The growth rate is 2-5 mm/a, accounting for 15.1% of the study area, showing a rapid upward trend. The areas with $K > 10$ mm/a are distributed in the north and southwest, accounting for 1.9% of the total area of the study area. The average change rate of PET in Gannan Prefecture is -7.24 mm/a, and the change rate of PET is mainly concentrated in -10~-5 mm/a, accounting for 82.8% of the total area of the study area. The growth rate is -5~-2 mm/a, accounting for 7.3% of the study area, and the growth rate is less than -10 mm/a, accounting for 9.3% of the study area. The area that remains unchanged only accounts for 0.6% of the total area, mainly distributed in the southwestern mountainous areas.

The average annual rainfall in the research area is 246.8 mm, and there are fluctuations in rainfall from year to year, with a slow upward trend of 3.71 mm/a per year ($P < 0.01$). The average annual temperature in the research area is around 3.0°C, showing an upward trend at a rate of 0.03°C/a ($P < 0.01$). The interannual variation of temperature is significant, and the temperature fluctuation has slowed down in the past 10 years. The interannual variation trend of actual evaporation and hydrothermal conditions in Gannan Prefecture remains consistent, showing a slow fluctuating upward trend. The correlation coefficient between AET and rainfall is 0.56, and the correlation coefficient with temperature is 0.69. The above data indicates that the AET in Gannan Prefecture is influenced by hydrothermal conditions, with temperature being the main driving factor.

The average annual AET of Gannan Prefecture varies under different land use types, with the order from large to small being forest land > grassland > farmland > wetland > artificial surface. The AET of grassland, farmland, and wetland is not significantly different; The difference in PET is not significant, and the order from large to small is wetland > forest > cultivated land > grassland > construction land. The results indicate that land use type is not the dominant factor for ET changes in Gannan.

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REFERENCES

[1] Boegh, E., Soegaard, H., Thomsen, A. (2002): Evaluating evapotranspiration rates and surface conditions using Landsat TM to estimate atmospheric and surface resistance. – Remote Sensing of Environment 79(2): 329-343.

[2] Chen, J., Chen, J., Liao, A. (2015): Global land cover mapping at 30 m resolution: a POK-based operational approach. – ISPRS Journal of Photography and Remote Sensing 103: 7-27.

[3] Feng, S. Y. (2023): Comprehensive Ecological Risk Assessment of Grassland Ecosystems in Gannan Preview. – Lanzhou University, Gansu.

[4] Gu, J. H., Xue, H. Z., Dong, G. T. (2021): Influence of NDVI/land use on spatial and temporary changes of evapotranspiration in the Yellow River Basin. – Arid Zone Geography 44(01): 158-167.

[5] Han, M. W., Zhao, G. J., Mu, X. M. (2017): The spatiotemporal variation of potential evaporation on the Loess Plateau from 1959 to 2015. – Geography of Arid Areas 40(05): 997-1004.

[6] He, T., Shao, Q. (2014): Analysis of changes in spatial and temporal patterns of evapotranspiration in China from 2001 To 2010 Based on MOD16 Products. – Journal of Geo Information Science 16(06): 979-988.

[7] Lian, J., Huang, M. (2016): Comparison of three remote sensing based models to estimate evapotranspiration in an oasis desert region. – Agricultural Water Management 165: 153-162.

[8] Liu, M., Tang, R. l., Li, Z. l. (2021): Research progress on data-driven remote sensing inversion methods and products for evapotranspiration. – Journal of Remote Sensing 25(08): 1517-1537.

[9] Ma, J. Q., Chen, Y., Hao, X. P. (2021): Spatial and temporary variations of surface evolution and its influencing factors in Henan Province from 2001 to 2019. – Soil and Water Conservation Research 28(05): 134-141.

[10] Meng, X. Y. (2023): Remote Sensing Estimation of Carbon Stocks in Grassland Vegetation in Gannan Experience. – Lanzhou University, Gansu.

[11] Meng, Y., Dan, W. H., Wang, H. (2020): Spatial and temporary characteristics of surface evapotranspiration in the Wujiang River basin based on MOD16 and its influencing factors. – Soil and Water Conservation Research 27(06): 139-145.

[12] Monteith, J. L. (1965): Evaporation and environment. – Symposia of the Society for Experimental Biology 19: 205-234.

[13] Mu, Q., Heinsch, F. A., Zhao, M. (2007): Development of a global evapotranspiration algorithm based on MODIS and global meteorology data. – Remote Sensing of Environment 111(4): 519–536.

[14] Niu, Z. E., Hu, K. M., He, H. L., Ren, X. L., Zhang, L., Ge, R., Li, P., Zheng, H., Zhu, X. B., Zeng, N. (2019): The spatial-temporal patterns of evapotranspiration and its influencing factors in Chinese terrestrial ecosystem from 2000 to 2015. – Acta Ecologica Sinica 39(13): 4697-4709.

[15] Penman, H. L. (1948): Natural evaporation from open water, bare soil and grass. – Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences 193(1032): 120-145.

[16] Running, S., Mu, Q., Zhao, M. (2021): MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500m SIN Grid V061 [Data set]. – NASA EOSDIS Land Processes DAAC.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2203_21072120

[17] Sheffield, J., Wood, E. F., Roderick, M. L. (2012): Little change in global drought over the past 60 years. – Nature 491(7424): 435-438.
[18] Velpuri, N. M., Senay, G. B., Singh, R. K. (2013): A comparative evaluation of two MODIS evapotranspiration products over the contiguous United States: using point and gridded FLUXNET and water balance ET. – Remote Sensing of Environment 139: 35-49.
[19] Wang, L. J., Guo, N., Yang, Q. D. (2016): Estimation of land surface evapotranspiration in the northwest semiarid zone based on MODIS remote sensing products. – Plateau Metrology 35(02): 375-384.
[20] Wang, S. P., Zhang, C. J., Han, Y. X. (2010): Characteristics of evapotranspiration and its influencing factors in different climatic zones of Gansu Province. – Desert China 30(03): 675-680.
[21] Wang, S. W. (2022): Spatial and Temporary dynamics of drought in inner mongolia in the last 20 years and its response to changes in climate and evapotranspiration. – Soil and Water Conservation Research 29(04): 231-239.
[22] Wang, T., Tang, R. L., Li, Z. L. (2019): Research progress of daily scale extension method for remote sensing inversion of evapotranspiration. – Journal of Remote Sensing 23(05): 813-830.
[23] Wang, X. L., Jiang, Y. Y., Zhang, Y. F., Chen, J. Z., Ao, Z. J., Ji, Z. J. (2023): Characteristics and driving factors of vegetation changes in the Gannan Plateau from 2001 to 2020. – Pratacultural Science 40(9): 2185-2198.
[24] Wen, Y. Y., Zhao, J., Wang, Y. Q. (2020): Characterization of spatial and temporary variations of surface evapotranspiration in Shanxi Province based on MOD16. – Progress in Geoscience 39(02): 255-264.
[25] Wild, M., Trüssel, B., Ohmura, A., Long, C. N., König-Langlo, G., Dutton, E. G., Tsvetkov, A. (2009): Global dimming and brightening: an update beyond 2000. – Journal of Geophysical Research: Atmospheres 114(D10): D00D13.
[26] Wu, D., He, Q. J., Pan, Z. H. (2017): Application of daily evapotranspiration models for different fertility stages of spring maize in Northeast China. – Journal of China Agricultural University 22(08): 18-29.
[27] Xue, J., Bali, K. M., Light, S. (2020): Evaluation of remote sensing based evapotranspiration models against surface renewal in almonds, tomatoes and maize. – Agricultural Water Management 238: 106228.
[28] Yang, L. Y., Li, Y. N., Fan, H. (2022): Spatial and temporary distribution of evapotranspiration in the Mu Us sand land and analysis of influencing factors. – China Agricultural Science and Technology Bulletin 24(10): 169-178.
[29] Ye, H., Zhang, T., Yi, G. (2018): Temporary and spatial characteristics of ET and its relationship with climatic factors in the Yellow River source area from 2000 to 2014. – Journal of Geography 73(11): 2117-2134.
[30] Ye, L. Y., Lu, H., Qin, S. J. (2022): Evolution of evolution and actual evolution in the Yangtze River Basin from 1960 to 2019. – Advances in Water Science 33(05): 718-729.
[31] Zhang, T., Liu, J., Dong, X. H. (2018): Spatial variation of evapotranspiration in Huan River basin using the MOD16 dataset. – Journal of Irrigation and Drainage 37(8): 121-128.
[32] Zhang, Y. Q., Kong, D. D., Zhang, X. Z. (2021): Impact of vegetation changes on global land surface evapotranspiration from 2003 to 2017. – Journal of Geography,76(03): 584-594.
[33] Zhu, W., Fan, L., Jia, S. (2023): Integration of microwave satellite soil moisture products in the contextual surface temperature vegetation index models for spatially continuous evolution estimation. – ISPRS Journal of Photography and Remote Sensing 203: 211-229.

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