Research on the Detail Time of Grassland Water Deficit for the Qinghai-Tibetan Plateau

Shuan QIAN¹*, Fei-fei PAN² and Men-xin WU³

¹National Meteorological Centre, China Meteorological Administration, Beijing 100081, China
²Department of Geography, University of North Texas, Denton, TX 76203, USA
³National Meteorological Centre, China Meteorological Administration, Beijing 100081, China

*Corresponding author

Keywords: Precipitation, Potential Evapotranspiration, Grassland water deficit, Qinghai-Tibetan Plateau

Abstract. The detail variations of precipitation, potential evapotranspiration (PET) impact the terrestrial ecosystem. The grassland water deficit or surplus status (GWDS) from 1961 to 2010 were systemically studied for the Qinghai-Tibetan Plateau (QTP) using daily data of all meteorological stations. The results indicated that the temporal variations of precipitation were not corresponding to those of PET in a year. The maximum monthly precipitation occurred in July, while the maximum monthly PET appeared in June, the spring precipitation was ranked the second, but its PET was ranked the first in a year. The total water deficit (PET-precipitation) from March to June was more, 51.4% of the total annual value. Therefore, the drought more frequently occurred in Spring and June in the QTP. The grassland can be protected in a year, especially in Spring and June.

Introduction

The Qinghai-Tibetan Plateau (QTP) is the largest and highest plateau in the world, with an area of about 2572.4x10³ km²[1,2]. The grassland covers about 67% of land area in this region. Climate not only decides the grassland vegetation distribution and type, but also influences the grassland productivity[3]. Understanding of impacts of climate on grassland is very important for making the grassland protection policy and restoring degraded grasslands.

The impacts of climate and its change on vegetation have been studied intensively in the recent years[4-13]. But the past researches were focus on annual temperature, precipitation and its trends for the QTP. Although above researches had important significance, the detail temporal variations of precipitation, potential evapotranspiration (PET), and difference between PET and precipitation (i.e., water deficit or surplus status) on grassland have not been studied for the Qinghai-Tibetan Plateau. Specific time to be better protected have not been known for the QTP grassland. This study is to systematically assess the detail temporal distributions of precipitation, PET, and water deficit or surplus status in a year using daily meteorological data of all stations from 1961 to 2010 in the QTP, to find more easily happening drought time, and know when to needed to better protect for making ecological protection policy and restoring degraded grassland ecosystems.

Materials and Methods

Study Area Description

The grassland ecosystem is main terrestrial ecosystem of the QTP, decides the ecological environment and animal husbandry. Affected by climate factors, the spatial distribution of the QTP grassland appears zonal patterns from southeast to northwest[3]. The alpine meadow is the largest and counts for about 41.2% of the QTP grassland area. The second largest is alpine steppe, accounted for 32.4%. The grassland ecosystem of the QTP was the study area.
Meteorological Data

Daily meteorological data were collected at all meteorological stations across the QTP from 1961 to 2010. At each station, a study dataset including daily maximum, minimum and mean air temperatures, precipitation, relative humidity, total cloud cover, wind speed, sunlight hours, and vapor pressure was constructed. Annual, monthly, and seasonal (spring: March-May, summer: June-August, autumn: September-November, winter: December-February) and the grass-growing season (April-September) meteorological elements were calculated.

In addition, the 1:4 million digital map of grassland type from Institute of Geographic Sciences and Natural Resources Research of Chinese Academy of Sciences was used to determine grassland and non-grassland.

Estimation of Daily Grassland Potential Evapotranspiration

Many processes of the grassland ecological system are influenced by evapotranspiration. Therefore, Penman-Monteith formula recommended by FAO is one of the best formulas for computing potential evapotranspiration\([14,15]\). Daily potential evapotranspiration was calculated using formula (1) and daily meteorological elements at all meteorological stations from 1961 to 2010 in the Qinghai-Tibetan Plateau.

\[
\text{PET} = \frac{0.408\Delta(R_n - G_n) + \gamma \frac{900}{T + 273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}
\]  

(1)

Where \(R_n\) is the net radiation reaching the earth’s surface (MJ m\(^{-2}\) day\(^{-1}\)); \(G_n\) is the soil heat flux (MJ m\(^{-2}\) day\(^{-1}\)), in the estimation of daily evapotranspiration, \(G_n=0\); \(T\) is air temperature (°C) at 2 meters above ground; \(U_2\) is the wind speed at 2 meters high (m s\(^{-1}\)); \(e_s\) is the saturation vapor pressure (kPa); \(e_a\) is the actual water vapor pressure (kPa); \(e_s - e_a\) is the saturated vapor pressure difference (kPa); \(\Delta\) is the saturation vapor pressure temperature curve slope (kPa °C\(^{-1}\)); \(\gamma\) is the humidity constant (kPa °C\(^{-1}\)).

Estimation of Grassland Water Deficit or Surplus Status

Water balance between inflow and outflow reflects water deficit or surplus status in the grassland. Precipitation, melt of glacier and snow, inflow of runoff are water sources for the QTP’s grassland ecosystems. Evapotranspiration and outflow of runoff are water outputs in the same region. Generally, since glacier and snow melt, and runoff were far less than precipitation and evapotranspiration\([16,17]\), more deficient in the spatial observation in the QTP, and they are not considered in this study. Therefore, the water balance is mainly controlled by precipitation and evapotranspiration in grasslands.

A multi-year average difference between precipitation and potential evapotranspiration reflects climate water deficit or surplus status\([18-20]\). The climate heterogeneity is noticeable in a year. In different climate periods, the grassland water deficit or surplus status (GWDS) was expressed as the difference of precipitation and potential evapotranspiration during the same period. GWDS during the stage j in year \(i\) is computed as follows:

\[
\text{GWDS}_{i,j} = P_{i,j} - \text{PET}_{i,j}
\]  

(2)

where \(P_{i,j}\), \(\text{PET}_{i,j}\) are respectively precipitation and potential evapotranspiration during the stage j of year \(i\). If \(P_{i,j} \geq \text{PET}_{i,j}\), \text{GWDS}_{i,j}\) indicates the grassland water surplus (GWS), and zero means that precipitation meets the atmospheric demand of grassland evapotranspiration. If \(P_{i,j} < \text{PET}_{i,j}\), \text{GWDS}_{i,j}\) shows the grassland water deficit (GWD).
Results and Discussion

Temporal Variation of Precipitation

Monthly precipitation increased from January of every year, reached over 10 mm in March, peaked in July, i.e., 93 mm, began to fall in August, quickly dropped below 10 mm up to November in the QTP grassland (Fig.1). Total precipitation from April to September reached 363 mm, accounting for 89.4% of the annual precipitation. Among four seasons, summer precipitation was the most abundant, reached 248 mm, and 61.2% of the annual precipitation, followed by precipitation in autumn and spring (Fig.1). The precipitation mainly occurred in the grass-growing season from April to September, especially in the summer, which was consistent with grassland vegetation growth rhythm over the Qinghai-Tibetan Plateau.

Figure 1. Temporal variation of mean monthly, seasonal precipitation from 1961 to 2010 for the Qinghai-Tibetan Plateau grassland.

Temporal Variation of Potential Evapotranspiration

Monthly PET had a single peak and was above 30 mm from January to December (Fig.2). Starting from February as temperature rising, the grassland PET also increased gradually, reached the highest value in June, then in July it began to decline to the lowest value in December. Among four seasons, summer grassland PET was the highest, up to 393 mm. Spring PET was the second highest, up to 311 mm. Winter PET was the lowest. PET in the grass-growing season reached 700 mm, accounting for 68.1% of annual PET.

Figure 2. Temporal variation of mean monthly, seasonal PET from 1961 to 2010 for the Qinghai-Tibetan Plateau grassland.

Temporal Variation of the Grassland Water Deficit or Surplus Status

The grassland vegetation growth needs main water supply from precipitation, while evapotranspiration is main water expenditure. The difference between these two variables can reflect the grassland water deficit or surplus status (GWDS). Figure 3 shows monthly and seasonally mean GWDS from 1961 to 2010. The monthly grassland water deficit (GWD) was above 30 mm for January to December, therefore, the grassland has been in the water deficit condition all year round in the QTP. Starting from January of each year, the GWD increased gradually. The GWD in March,
April, May, and June reached more than 70 mm and the highest occurred in May that was up to 90 mm. From March to June (spring to early summer), the GWD was more severe. After May, the GWD decreased rapidly. The lower value reached below 40 mm from July to September, and the lowest value happened in September. The GWD from July to September was smaller, especially in September because of more precipitation. The GWD in October rebounded, but the monthly GWD was only 54 mm that was lower than the values from March to June. The GWD of November and December were 46 mm and 35 mm, respectively, which also were in the lower level in a year. It is thus clear that higher GWD from March to June could more easily cause drought in the QTP grassland.

Seasonal precipitation was also less than the corresponding PET in the QTP grassland (Fig. 3). Among four seasons, the order of the GWD from the highest to the lowest is spring (up to 244 mm), summer (145 mm), autumn (130 mm) and winter (124 mm). From January to June, the GWD accounted for 64.6% of annual water deficit, from March to June accounted for 51.4%. The GWD for the first half of year was higher than the second half of year. Especially, the GWD from March to June (spring to early summer) was half of annual water deficit. But from spring to early summer every year, the grassland vegetation is going into vigorous growth, demands more water, the more GWD causes the drought more easily and frequently.

![Figure 3. Temporal variation of mean monthly, seasonal GWDS from 1961 to 2010 for the Qinghai-Tibetan Plateau grassland.](image)

**The Main Time to be Better Protected for the QTP Grassland**

Our results revealed the detail temporal distributions of precipitation, PET, the grassland water deficit or surplus status (GWDS). The out of change steps between precipitation and PET, and the time of more water deficit and easily happening drought were found so that we knew the main time with protection for the QTP grassland, which are very important for making ecological protection policy and restoring degraded grassland ecosystems in the QTP.

The precipitations from January to December were all less than PET in the QPT grassland, the grassland water is deficit and the drought could occur all of year. Meanwhile, the temporal variations of monthly and seasonal precipitation were not corresponding well to those of PET. The peak times of precipitation and PET did not coincide, which indicates water supply and demand were not at the same pace and thus drought could more easily occur. The grassland water deficit (GWD) was higher in March, April, May, and June than other months, and the highest in May. Therefore, the grassland drought more easily happens in spring and June. However, the grassland vegetation starts to regreen in spring and grows vigorously from June, demands more water in this period, we must take measures to strongly protect the QTP grassland from March to June.

**Acknowledgements**

The research was funded by the Special Program of NMC, funded in part by the University of North Texas (UNT) Research Initiative Grant (RIG).
References


