Analysis of Precipitation Effectiveness in the Desert Steppe of Inner Mongolia: Based on Monitoring of Process Precipitation in Sonid Right Banner Postprint

Authors: Fang Tingting, Yongzhi Yan, LIU Qingfu, Zhu Ling, Han Fang, Zhang Qing, Han Fang

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Abstract

This study was conducted in Sonid Right Banner, Inner Mongolia, where daily precipitation data from May 2015 to December 2016 and concurrent daily continuous observations of soil water content at various depths (0–10 cm, 10–20 cm, 20–30 cm, 30–40 cm, and 40–50 cm) were analyzed to investigate the effects of precipitation events on soil water content in desert steppe. The results indicated: (1) Precipitation exerted the most pronounced influence on surface soil layers (0–10 cm and 10–20 cm), with a significant positive correlation between precipitation amount and water content in these two layers, whereas the water content in the remaining three layers showed no significant response to precipitation events. (2) The minimum effective precipitation thresholds for the 0–10 cm and 10–20 cm soil layers were 6.4 mm and 8.33 mm, respectively. (3) Further derivation of the effective precipitation conversion rates for the 0–10 cm and 10–20 cm soil layers, based on the minimum effective precipitation, revealed that the maximum effective precipitation conversion rate for the 0–10 cm soil layer could reach 95%, though it mostly remained around 70%; for the 10–20 cm layer, the maximum rate could reach 90%, though it mostly remained around 50%.

Full Text

Precipitation Effectiveness in Desert Steppe in Inner Mongolia: Based on Monitoring of Storm Precipitation in Sonid Right Banner

FANG Ting-ting[1], YAN Yong-zhi[1], LIU Qing-fu[1], ZHU Ling[1], HAN Fang[2], ZHANG Qing[1]

[1]College of Ecology and Environment, Inner Mongolia University, Hohhot 010021, Inner Mongolia, China
[2]Inner Mongolian Ecological and Agrometeorological Center, Hohhot 010051, Inner Mongolia, China

Abstract

Climate change has become a global issue of common concern. Water is one of the main limiting factors in semiarid grasslands. The change in precipitation pattern results in changes in soil moisture status. The effect of precipitation events on soil moisture content in desert steppe was studied based on the analysis of daily precipitation data from May 2015 to December 2016 and daily continuous observation data of soil moisture content at different depths (0–10 cm, 10–20 cm, 20–30 cm, 30–40 cm, and 40–50 cm). The results showed that: (1) The effect of precipitation on topsoil (0–10 cm and 10–20 cm) moisture content was the most significant, and there was a significant positive correlation between the soil moisture content of these two layers and precipitation. The response of soil moisture content of the other three layers to precipitation events was not significant; (2) The minimum volumes of effective precipitation to 0–10 cm and 10–20 cm soil layers were 6.4 mm and 8.33 mm, respectively; (3) When inferring the minimum effective precipitation, it was found that the conversion rate of effective precipitation to soil moisture in the 0–10 cm layer could be as high as 95%, but it was mostly about 70%; it could be as high as 90% in the 10–20 cm layer, but it was mostly about 50%.

Keywords: soil moisture content; effective precipitation; storm precipitation; Sonid Right Banner; Inner Mongolia

1 Study Area and Methods

1.1 Study Area Description

The study area is located in Sonid Right Banner, Inner Mongolia (112°40 25 E, 42°46 52 N, 1079 m). The region is characterized by a typical desert steppe ecosystem with vegetation dominated by *Stipa klemenzii*, *Cleistogenes songorica*, and *Allium polyrrhizum*. The climate is semiarid, with a mean annual temperature of 4.4°C and mean annual precipitation of 177.2 mm. Data collection began in May 2015.

1.2 Data Collection and Analysis

Daily precipitation data and continuous soil moisture measurements at five depth intervals (0–10 cm, 10–20 cm, 20–30 cm, 30–40 cm, and 40–50 cm) were collected from May 2015 to December 2016. Statistical analysis was performed using SigmaPlot 10.0 and SPSS 22.0 software.

2 Results

2.1 Soil Moisture Dynamics

Figures 2-5 illustrate the dynamic changes in soil moisture content at various depths. The 0-10 cm and 10-20 cm layers showed the most pronounced responses to precipitation events.

2.2 Minimum Effective Precipitation

The minimum precipitation required to significantly increase soil moisture was determined to be 6.4 mm for the 0–10 cm layer and 8.33 mm for the 10–20 cm layer. The relationship between effective precipitation and soil moisture increase can be expressed as:

For the 10 cm layer:

$$y_{10} = 0.0476x^{2.0574}$$

For the 20 cm layer:

$$y_{20} = 0.6698x^{0.4959}$$

When accounting for the minimum effective precipitation threshold, the equations become:

For the 10 cm layer:

$$y_{10} = 0.0476(x - 6.4)^{2.0574}$$

For the 20 cm layer:

$$y_{20} = 0.6698(x - 8.33)^{0.4959}$$

2.3 Conversion Rate of Precipitation to Soil Moisture

The conversion efficiency of precipitation to soil moisture varied by depth. For the 0–10 cm layer, the maximum conversion rate reached 95%, though typical values were around 70%. For the 10–20 cm layer, the maximum rate was 90%, with typical values near 50%.

The exponential form of the relationship is given by:

For 10 cm:

$$\frac{0.09793224e^{2.0574\ln(x-6.4)}}{x - 6.4}$$

For 20 cm:

$$\frac{0.3345382e^{0.4959\ln(x-8.33)}}{x-8.33}$$

3 Discussion

Precipitation effectiveness is a critical factor in arid ecosystem processes. The minimum effective precipitation values identified in this study (6.4 mm for 0-10 cm and 8.33 mm for 10-20 cm) indicate the threshold required for soil moisture recharge in desert steppe environments. These findings are consistent with previous research on water limitation in semiarid grasslands.

The high conversion rates observed in the topsoil layers demonstrate the importance of surface soil in capturing and retaining precipitation, particularly during storm events. The rapid response of the 0–10 cm and 10–20 cm layers to precipitation, compared to the weaker response of deeper layers, highlights the role of shallow soils in regulating water availability for herbaceous vegetation in desert steppe ecosystems.

The study results provide a quantitative basis for understanding soil moisture dynamics and precipitation effectiveness in desert steppe regions, which is essential for ecological restoration and sustainable land management practices under changing climate conditions.

References

[The references section contains citations that were preserved in the original text, including works on spatiotemporal variation of precipitation, climate characteristics of desertified grasslands, and atmospheric water cycle factors in arid regions.]

Note: Figure translations are in progress. See original paper for figures.

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