Postprint of Evapotranspiration Characteristics of Haloxylon ammodendron Community in Interdune Areas of the Southern Margin of the Gurbantünggüt Desert

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Abstract

Based on fixed-point observation data of soil moisture, meteorological elements, and other variables during the growth period of Haloxylon ammodendron in the interdune areas on the southern edge of the Gurbantunggut Desert in 2016, evapotranspiration during the growth period of Haloxylon ammodendron was estimated using the water balance principle, and the variation patterns of evapotranspiration were analyzed. The results showed that: (1) During the Haloxylon ammodendron growing season, rainfall was 206.7 mm, with uneven distribution; rainfall was highest during the germination stage of Haloxylon ammodendron; monthly rainfall decreased progressively during the vigorous growth stage; and rainfall was lowest during the litter fall stage; (2) During the Haloxylon ammodendron growing season, soil water storage in the 0–400 cm layer of the Haloxylon ammodendron community showed an overall decreasing trend; the germination stage was a period of soil water storage surplus, while the vigorous growth and litter fall stages were periods of soil water storage deficit; the Haloxylon ammodendron community exhibited a soil reservoir effect, relying on soil water storage from before the growing season to compensate for the water deficit during the growing season; (3) During the Haloxylon ammodendron growing season, the variation characteristic of evapotranspiration exhibited a multi-peak curve, with peaks occurring mainly during periods of concentrated rainfall and minimum values appearing during periods of soil water storage deficit; (4) During the Haloxylon ammodendron growing season, the increase in cumulative evapotranspiration of the Haloxylon ammodendron community was consistently higher than the increase in cumulative rainfall, and cumulative evapotranspiration exceeded cumulative rainfall.

Full Text

Preamble

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1. Introduction

Haloxylon ammodendron is a dominant shrub species in the Gurbantunggut Desert, playing a crucial role in stabilizing sand dunes and maintaining ecosystem stability. Understanding its water consumption patterns and evapotranspiration characteristics is essential for ecological restoration and water resource management in arid regions. Previous studies have investigated various aspects of water balance in desert ecosystems, particularly soil infiltration and plant water use [1-6], but comprehensive analysis of evapotranspiration dynamics during the complete growing season remains limited. This study addresses this gap through continuous monitoring of soil moisture and meteorological parameters at fixed observation points.

1.1 Study Area

The experimental site is located in the interdune lowland at the southern edge of the Gurbantunggut Desert (44°22.63 N, 87°55.21 E), approximately 5 km from the nearest meteorological station. The region features mobile sand dunes with elevations ranging from 28-36 m and slopes of 7-9°, interspersed with low-lying areas at 21-24 m elevation with 15-19° slopes. The soil is predominantly sandy with a bulk density of 1.54-1.65 $g \cdot cm^{-3}$ [11]. The groundwater table is situated at a depth of 9-10 m, making it inaccessible to plant roots.

The climate is continental and arid, with a mean annual temperature of 5.7°C. Extreme temperatures range from 40°C in summer to -37°C in winter. Mean annual precipitation is 128.7 mm, while potential evaporation reaches 1764 mm [12]. The frost-free period lasts 100-160 days, with soil temperature at 20 cm depth showing significant seasonal variation [13]. The natural vegetation community is dominated by *Haloxylon ammodendron*, accompanied by *Haloxylon persicum*, *Ephedra distachya*, *Ceratocarpus arenarius*, and *Artemisia desertorum* [15-16].

1.2 Experimental Design

In July 2015, three experimental plots (20 m × 20 m each) were established in *H. ammodendron* communities representing different stand ages. Five measurement points were arranged in each plot following a stratified random design, with neutron probe access tubes installed 0.7 m from the base of representative shrubs. Spacing between measurement points was 20 cm to capture spatial heterogeneity.

Three age classes were selected to represent different growth stages: young stands (4-5 years), middle-aged stands (6-9 years), and mature stands (10 years). Figure 1 illustrates the spatial distribution of neutron tubes across the experimental plots.

1.3 Methods

1.3.1 Soil Moisture Measurement and Water Balance Calculations

Soil moisture was measured using a neutron probe at regular intervals throughout the 2016 growing season (April 1 to October 31). Measurements were taken at 10 cm depth increments from the surface to 400 cm. The probe was calibrated for sandy soils using gravimetric sampling, achieving an accuracy of $\pm 0.01cm^{\{3\}\cdot cm}${-3}$.

Precipitation was measured using a tipping-bucket rain gauge (0.1 mm resolution) installed in an open area adjacent to the experimental plots. Soil water storage (SWS) was calculated by integrating volumetric water content across the 0–400 cm profile:

$$SWS = \sum_{i=1}^{n} \theta_i \times \Delta z_i$$

where θ_i is the volumetric water content of layer i and Δz_i is the thickness of that layer.

Evapotranspiration (ET) was estimated using the water balance equation:

$$\mathrm{ET} = P - \Delta S$$

where P is precipitation and ΔS is the change in soil water storage over the measurement period. This approach assumes negligible runoff and deep percolation given the flat topography and deep groundwater table [14].

Measurements were intensified during critical phenological phases: (1) germination period (April–May), (2) vigorous growth period (June–August), and (3) senescence period (September–October). During germination, measurements were taken every 3 days to capture rapid water dynamics. In the growth period, weekly measurements sufficed, while biweekly measurements were conducted during senescence.

2 Results

2.1 Precipitation Characteristics

During the 2016 growing season, total precipitation was 206.7 mm. The distribution was uneven across phenological stages, with the maximum precipitation occurring during the germination period. Precipitation decreased progressively during the vigorous growth period and reached its lowest values during the senescence period.

Precipitation events were classified by magnitude: 0-1 mm, 1-5 mm, 5-10 mm, and >10 mm. Small events (<5 mm) accounted for 60.71% of total events but contributed only 18.82% of total precipitation. Larger events (>5 mm) represented 39.29% of events but contributed 81.19% of total precipitation, indicating that substantial rainfall events dominated water input.

Monthly precipitation distribution showed that June, July, and August were the wettest months, coinciding with the vigorous growth period of *H. ammodendron*. The inter-annual variability in precipitation patterns significantly influenced soil water replenishment and plant water availability.

2.2 Soil Water Storage Dynamics

Soil water storage in the 0–400 cm profile exhibited a decreasing trend throughout the growing season. The germination period showed rapid soil moisture replenishment from precipitation, while subsequent stages experienced gradual depletion. The *H. ammodendron* community relied heavily on soil water storage accumulated before the growing season to compensate for water deficits during active growth periods.

The water balance analysis revealed that cumulative evapotranspiration consistently exceeded cumulative precipitation, with the difference being supplied by soil water storage. This pattern was consistent across all stand age classes, though the magnitude of storage depletion varied with stand maturity.

Abstract

According to observed data about soil moisture and meteorological elements at fixed observation points for *Haloxylon ammodendron* in the interdune lowland at the Southern Edge of Gurbantunggut Desert, Xinjiang, China, during the growing season (from April 1 to October 31) in 2016, evapotranspiration was estimated based on the principle of water balance and the evapotranspiration change law was analyzed. The results showed as follows: (1) During the growing season of *Haloxylon ammodendron*, the precipitation was 206.7 mm. The distribution of precipitation in the experimental area was uneven, and it had the maximum precipitation during the *Haloxylon ammodendron* germination period. The precipitation was decreased month by month during the strong growth period of *Haloxylon ammodendron*, and the precipitation was the least when the *Haloxylon ammodendron* starts to wither and fall. (2) During the growing season of *Haloxylon ammodendron*, the water storage from the 0–400 cm soil layer of *Haloxylon ammodendron* community showed a decreasing trend. Meanwhile, the soil moisture was quickly replenished during the *Haloxylon* germination period and it is reduced at the other stages. The *Haloxylon ammodendron* community relied on soil water storage accumulated before the growth season to compensate for the water shortage in the growth season of *Haloxylon ammodendron* community. (3) The evapotranspiration of the growth season of *Haloxylon ammodendron* community showed an obvious multi-peak curve, and the peak occurred mainly in the concentrating period of rainfall, the lowest value of evapotranspiration appears in the soil water storage loss period. (4) During the growing season, the rate of increase of the cumulative evapotranspiration was always higher than that of the accumulated precipitation, and the cumulative evapotranspiration was bigger than the cumulative precipitation.

Keywords: Gurbantunggut Desert; *Haloxylon ammodendron* Community; water balance; Evapotranspiration; precipitation; soil water storage

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