Postprint: Water Use Characteristics of Poplar in Hunshandake Sandy Land

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Abstract

To investigate the water utilization characteristics of poplar trees in the Hunshandake Sandy Land, this study employed hydrogen and oxygen isotope tracing technology to determine the 18O values of precipitation, soil water, and groundwater, and utilized a multiple linear mixing model to quantitatively calculate the utilization proportions of soil water from different soil layers by poplar trees. The results indicate that: The local meteoric water line for the Hunshandake Sandy Land is: DLWML=7.84 18OLWML +9.12, with a slope smaller than that of the national meteoric water line, reflecting the climatic characteristics of low precipitation and high evaporation in the study area; Soil water content exhibits significant correlations with variations in groundwater table depth, precipitation amount, and plant growing season. During periods with greater precipitation and shallower groundwater table depth, soil water content increases significantly, while during the early and middle stages of plant growth, soil water content is significantly lower; During the rainy season, poplar trees utilize substantial amounts of shallow soil water (0–40 cm), while during the relatively dry season, they utilize large amounts of deep soil water (160–200 cm) and small amounts of groundwater.

Full Text

1.1 Study Area

The study area is located in Zhenglan Banner, Xilingol League, Inner Mongolia Autonomous Region [Figure 1: see original paper]. This region has a temperate continental semi-arid climate, with an average annual temperature of 3.9°C. The mean temperature in January is -17.8°C, in July is 22.2°C, the extreme maximum temperature is 33.7°C, and the extreme minimum temperature is -32.6°C. The average annual precipitation is 396 mm, with 80-90% concentrated in July through September, accounting for 51.8% of the annual total.

1.2 Sample Collection

Soil and plant samples were collected from May to October 2018. Sampling was conducted before and after rainfall events, with a total of eight sampling campaigns throughout the growing season. Soil samples were collected at depths of 0-20, 20-40, 40-60, 60-80, 80-120, 120-160, and 160-200 cm using a soil auger.

1.3 Methods

1.3.1 Isotope Analysis

The D and ^{1} O values of water samples were measured using a liquid water isotope analyzer (DLT-100, LGR, USA). Isotopic compositions are expressed in per mil (‰) relative to the VSMOW standard, with measurement precisions of ±0.30‰ for D and ±0.10‰ for ^{1} O. The isotopic composition is calculated as:

_sa = [(R_sa - R_st)/R_st] × 1000‰

where R_sa and R_st are the D/H or ^{1} O/^{1} O ratios in the sample and standard, respectively.

1.3.2 Soil Moisture Content

Soil moisture content was determined using the oven-drying method [15]. Fresh soil samples were oven-dried at 105°C for 12 hours. The soil moisture content is calculated as:

w = [(m - m_s)/m_s] × 100%

where w is the soil moisture content, m is the mass of the fresh soil sample, and m_s is the mass of the dried soil sample.

2. Results

2.1 Precipitation Characteristics

[Figure 2: see original paper] shows the temporal variations of rainfall and temperature in 2018. The local meteoric water line (LMWL) for Otindag Sandy Land is D = 7.84 ^{1} O + 9.12. The slope of this line is smaller than that of the national meteoric water line, indicating strong evaporation in the study area.

2.2 Soil Moisture Characteristics

presents the soil moisture content at different depths across seasons. [Figure 5: see original paper] illustrates changes in soil moisture content before and after rainfall events. The results demonstrate that soil moisture content is significantly correlated with groundwater depth, rainfall amount, and plant growth stage. When rainfall is abundant and groundwater is shallow, soil moisture content increases substantially. During the early and middle growth stages of plants, soil moisture content is significantly lower.

2.3 Isotopic Characteristics

[Figure 3: see original paper] shows the distribution characteristics of D and ^{1}O values in atmospheric precipitation, rainfall, soil water, and plant water. The isotopic composition of soil water exhibits distinct depth-dependent patterns, reflecting the combined effects of precipitation input and evaporation fractionation.

2.4 Water Source Analysis

A multi-linear mixed model (IsoSource) [16] was used to quantitatively determine the proportional contributions of different water sources to poplar trees. The model results indicate that during the rainy season, poplars primarily utilize shallow soil water (0-40 cm depth). In contrast, during the dry season, they rely mainly on deep soil water (160-200 cm depth) and a small proportion of groundwater.

References

[15] Phillips DL, Gregg JW. Source partitioning using stable isotopes: coping with too many sources. Oecologia, 2003, 136(2): 261-269.

[16] Craig H. Isotopic variations in meteoric waters. Science, 1961, 133(3465): 1702-1703.

[17] Wu Yazun, Wan Junwei, Lin Yun. Hydrogen and oxygen isotope characteristics of atmospheric rainfall in Xilingxia area, Yichang, Hubei Province. Geological Science and Technology Information, 2011, 30(3): 93-97.

[18] Zhang Jiang, Li Guifang, He Yaling, et al. Water utilization sources of Populus euphratica trees of different ages in the lower reaches of Tarim River. Biodiversity Science, 2018, 26(6): 564-571.

[19] Yu Shaowen, Sun Ziyong, Zhou Aiguo, et al. Water characteristics of different ages of Prunus armeniaca plantations in semi-arid region of Western Liaoning Province. Journal of Soil and Water Conservation, 2016, 30(6): 118-122.

[20] Wang Y, Yang J, Chen Y, et al. The spatiotemporal response of soil moisture to precipitation and temperature changes in an arid region, China. Remote Sensing, 2018, 10(3): 468.

[21] Lin G, Sternberg LSL. Utilization of surface water by red mangrove (Rhizophora mangle L.): An isotopic study. Bulletin of Marine Science, 1994, 54(1): 94-102.

[22] Jia Jin, Jia Debin, Guo Shaofeng, et al. Water sources in growing season of Salix gordjevii in the Otindag Sandy Land traced by stable D isotope in 2014. Arid Zone Research, 2017, 34(2): 350-355.

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