Variation Characteristics of Shallow Groundwater Depth in the Terminal Oasis of the Keriya River (Postprint)

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Abstract

The dynamic variation of groundwater depth largely controls desert vegetation. Dariyaboyi is located at the terminal of the Keriya River and represents the largest existing natural oasis composed of desert riparian forests in the hinterland of the Taklamakan Desert. Monitoring the dynamic changes of groundwater depth here facilitates investigation of its influence on surface vegetation, thereby further revealing the mechanisms of natural oasis formation and maintenance. Due to the complex geographical environment and inaccessible transportation, no scholars have previously obtained continuous groundwater depth monitoring data for this oasis. An observation well was established in the hinterland of the terminal oasis in October 2012, obtaining groundwater depth data from 2012 to 2018. The dynamic variation process of water depth in this well over the past 6 years was analyzed from four aspects: distribution characteristics of daily extreme values, daily range, and intra-annual and inter-annual fluctuations of groundwater depth. Additionally, the possible impacts of groundwater depth changes on the ecosystem of the terminal oasis were discussed in combination with the growth habits of Populus euphratica. Preliminary analysis of the observed groundwater depth data in this oasis indicates: (1) The daily minimum groundwater depth in the well mostly occurs at 16:00, 20:00, and 04:00; the daily maximum groundwater depth mostly occurs at 16:00, primarily during April-October, especially in September. (2) The daily range of groundwater depth fluctuates between 0-0.5 m. Daily ranges greater than 0.1 m are mainly distributed in July-August, with 2017 being the most significant. (3) Groundwater depth generally fluctuates between 1.0-3.0 m, with monthly peaks mainly appearing in February-March and August-September. (4) The multi-year average groundwater depth is 2.0 m, and the water depth shows an overall slow rise of approximately 0.08 $m \cdot a^{-1}$. (5) The total number of days per year with water depth between 1.0-2.0 m shows an increasing trend, which is conducive to Populus euphratica seed germination and plant rooting; the total number of

days with water depth between 2.0-4.0 m shows a decreasing trend, which may limit the growth of young and middle-aged Populus euphratica.

Full Text

Variations in Groundwater Table Depth at Daliyaboyi Oasis, Keriya River, China

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Abstract

Dynamic changes in groundwater table depth exert fundamental control over desert vegetation and constrain oasis ecosystems in arid regions. Daliyaboyi, situated in the terminal reaches of the Keriya River, represents the largest natural oasis in the hinterland of the Taklimakan Desert, characterized by its desert riparian forest composition. Monitoring variations in groundwater table depth and analyzing their influence on surface vegetation are essential for understanding the formation and maintenance mechanisms of pristine oases. Due to the complex geographical environment and restricted accessibility, no continuous groundwater monitoring data had been previously obtained for this oasis. In October 2012, our research team established a monitoring well in the hinterland of the Daliyaboyi Oasis and collected groundwater table depth data from 2012 to 2018. This study examines the dynamic changes in water level from four perspectives: daily extreme value distribution, diurnal range distribution, and intra-annual and interannual fluctuations. Combined with the growth characteristics of *Populus euphratica*, we discuss the potential ecological impacts of these groundwater dynamics. Preliminary analysis reveals: (1) Daily minimum groundwater table depths typically occurred at 16:00, 20:00, or 04:00, while maximum depths predominantly appeared at 16:00 during April–October, with September showing the highest frequency (nearly half of the total occurrences during this period). (2) Daily fluctuation ranges varied from 0 to 0.5 m, with most values falling within 0–0.1 m. Larger diurnal ranges (>0.1 m) corresponded to rising water levels, with monthly peaks occurring mainly in July–August. The maximum recorded diurnal range was 0.47 m (August 9, 2017), while the minimum was 0.00 m. (3) Groundwater table depth generally fluctuated between 1.0–3.0 m, with monthly peaks appearing primarily in February–March and August–September. From 2012–2018, water levels gradually rose in winter and fluctuated downward in spring. During 2013–2015, winter levels continuously declined while spring levels rose rapidly by up to 0.5 m. From 2016–2018, both the winter decline and spring rise were weaker (~0.08 m). Summer water level increases were also modest (~0.5 m). (4) The multi-year average groundwater table depth was 2.0 m, showing a slow rising trend of approximately 0.08 $m \cdot a^{-1}$. Additionally, the annual number of days with depths <1.5 m increased, favor-

ing *Populus euphratica* seed germination and seedling establishment, while days with depths of 2.0–4.0 m decreased, potentially limiting the growth of mature trees.

Keywords: Tarim Basin; Taklimakan Desert; Daliyaboyi; pristine oasis; groundwater; dynamic changes

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1. Study Area Overview

The Keriya River originates on the northern slope of the Kunlun Mountains and flows northward into the Taklimakan Desert hinterland, forming the Yutian Oasis in the upper reaches and the Daliyaboyi Oasis at its terminal end. The Daliyaboyi Oasis exhibits a fan-shaped distribution, with a main body approximately 30 km wide from east to west and 15 km from north to south, located at 38°22 N, 81°52 E. The region experiences a warm temperate extreme desert climate, with an average annual temperature of approximately 11°C and annual precipitation below 20 mm. The aridity index is <0.05. Vegetation composition is impoverished, with simple structure and single dominant species, primarily consisting of reeds, *Populus euphratica*, and tamarisk.

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2. Data and Methods

2.1 Observation Methods

On October 19, 2012, we established a monitoring well in the hinterland of the Daliyaboyi Oasis (38°22 N, 81°52 E). An Onset water level logger was suspended inside the well to measure groundwater pressure at a fixed depth below the water table, while an identical logger was placed outside the well to record atmospheric pressure. Data were collected at hourly intervals according to Beijing time. The groundwater table depth (H) was calculated using the formula:

$$H = h + \frac{P_1 - P_2}{\rho g}$$

where h is the height from the logger to the ground surface (m), P_1 is the groundwater pressure data collected by the internal logger (kPa), P_2 is the atmospheric pressure data from the external logger (kPa),   is water density ($kg \cdot m^{-3}$), and g is gravitational acceleration ($9.8\ N \cdot kg^{-1}$). Seasons were defined using standard meteorological classifications: March–May as spring, June–August as summer, September–November as autumn, and December–February as winter.

2.2 Data Processing

A total of 2,112 days of data were published (with 38 days missing). Daily maximum and minimum groundwater table depths were extracted to calculate daily ranges (difference between maximum and minimum). These ranges were arranged chronologically to produce a diurnal range time series.

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3. Results

3.1 Daily Variation Characteristics

Statistical analysis of daily groundwater table depths revealed that minimum values most frequently occurred at 16:00, 20:00, or 04:00. Maximum values predominantly appeared at 16:00, primarily during April–October each year, with September showing the highest occurrence frequency—nearly half of the total occurrences during this period. From November–March, maximum values were distributed across 08:00–14:00, with relatively few occurrences (Table 1, Figure 3).

3.2 Diurnal Range Distribution

During the monitoring period, daily fluctuation ranges varied from 0 to 0.5 m, with most values concentrated in the 0–0.1 m interval. Monthly peaks occurred mainly in July–August. The smallest diurnal range was 0.00 m, while the largest was 0.47 m (recorded on August 9, 2017). Larger diurnal ranges (>0.1 m) were associated with rising water levels (Figure 4). The annual maximum diurnal range increased year by year.

3.3 Intra-Annual Dynamics

Groundwater table depth generally fluctuated between 1.0-3.0 m, with monthly peaks appearing primarily in February–March and August–September. In 2012–2018, water levels gradually rose in winter and fluctuated downward in spring. During 2013–2015, winter levels continuously declined while spring levels rose rapidly by up to 0.5 m. From 2016–2018, both the winter decline and spring rise were weaker (~0.08 m). Summer water level increases were also modest (~0.5 m). The intra-annual fluctuation amplitude near the monitoring well was approximately 1.5 m (Figure 4, Table 2).

3.4 Interannual Variations

Over the monitoring period, groundwater table depth showed a slow rising trend of approximately 0.08 $m \cdot a^{-1}$, with a multi-year average of 2.0 m. Small fluctuations in the depth curve gradually diminished, while short-term intense rising and falling events increased. The timing of water level rise periods showed a delayed pattern. Standard deviation and coefficient of variation indicated small interannual fluctuations, with amplitude variations in 2017 being more pronounced than in other years. During spring, agricultural activities in the Yutian Oasis intercept substantial river flow, sharply reducing water volume reaching the terminal oasis and increasing flow cessation frequency, which threatens the ecological security of this pristine desert oasis [27,32]. Under such conditions, groundwater becomes the most fundamental resource sustaining natural vegetation, making continuous monitoring of groundwater table depth variations critical for desert vegetation development.

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4. Discussion

4.1 Causes of Groundwater Dynamics

The alternating rising and falling pattern of groundwater table depth 1-3 times annually appears related to surface runoff variations in the Keriya River' s terminal reaches. During winter, surplus water upstream of the Yutian section is intercepted to compensate for spring irrigation deficits, leaving primarily groundwater discharge from below the Yutian Oasis to reach the terminal oasis. The river channel between Yutian and Daliyaboyi freezes, storing some water. When daytime temperatures exceed 0°C in February–March, the channel thaws, releasing stored water and causing rapid water level rises in the monitoring well. In March–May, when water delivery to the lower reaches drastically decreases and flow cessation becomes frequent, combined with evapotranspiration in the terminal oasis, spring groundwater levels continuously decline. Summer floods reaching the terminal oasis cause sharp water level rises, exhibiting a rapid-rise slow-fall pattern [27,32]. Autumn declines and recoveries likely relate to flood season termination and reduced water interception during the Yutian Oasis fallow period.

The disappearance of winter water replenishment after 2015 and subsequent spring recovery require further analysis with additional data. According to field investigations, oasis channel floods are artificially regulated, meaning our data primarily represent local variations near the monitoring well. However, through complementary discharge and recharge relationships between surface water, groundwater, and different groundwater sections, the data generally reflect oasis-wide groundwater changes. Negative groundwater table depth values occurred during the monitoring period, with maximum daily ranges reaching 0.47 m, showing rapid-rise slow-fall patterns. A field survey in August 2017 revealed the monitoring well was nearly buried by sediment; local residents confirmed this anomaly coincided with the extraordinary summer flood of 2017, suggesting negative depth values were flood-related.

4.2 Ecological Implications for the Terminal Oasis

The growth season for *Populus euphratica* extends from March to October, with optimal depths for growth being 2–4 m [36]. At our monitoring site, the annual number of days with 2–4 m depth is decreasing, potentially limiting mature tree growth. Conversely, seed germination and seedling establishment occur primarily in June–August, requiring depths of 1–2 m [36]. The annual number of days with 1–2 m depth is increasing, gradually improving conditions for seedling recruitment. These changing groundwater conditions are altering the ecological environment for vegetation development (Table 4).

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5. Conclusions

During the monitoring period, interannual groundwater table depth fluctuations were relatively small, showing a slow rising trend of approximately 0.08 $m \cdot a^{-1}$. Intra-annual depth varied between 1.0–3.0 m, with monthly peaks occurring primarily in February–March and August–September. Two distinct water level rise periods occurred annually. From 2012–2014, winter water levels gradually rose while spring levels fluctuated downward. From 2013–2015, winter levels continuously declined while spring levels rose rapidly by up to 0.5 m. From 2016–2018, rising amplitudes were weaker (~0.08 m). Summer water level increases were modest (~0.5 m). Daily minimum depths typically occurred at 16:00, 20:00, or 04:00, while maximum depths appeared most frequently at 16:00. Diurnal ranges varied from 0–0.5 m, with most values in the 0–0.1 m range; larger ranges (>0.1 m) corresponded to rising water levels. The increasing number of days with depths <1.5 m favors *Populus euphratica* seed germination and seedling establishment, while the decreasing number of days with 2.0–4.0 m depths may restrict mature tree growth.

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