Postprint: Relationship between Soil Moisture and Temperature under Different Land Uses during Freeze-Thaw Period in the Loess Plateau

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Abstract

To investigate the variations and relationships between soil moisture and temperature during the freeze-thaw period, soil moisture and temperature data were monitored from runoff plots under different land use types in the field, the spatiotemporal variation patterns of soil moisture and temperature across different soil depths were analyzed, and the correlation between soil moisture and temperature in the study area was elucidated. The results indicated that during the freeze-thaw period, the 20 cm soil layer in sloping cropland exhibited the greatest variation amplitude in water content, while both grassland and forestland showed the maximum variation amplitude in the 40 cm soil layer; the 20 cm soil layer in sloping cropland had the highest degree of variability in water content, whereas the most active layers for grassland and forestland were 30 cm and 10 cm, respectively; grassland entered the freezing and thawing periods earliest, with freezing and thawing times showing a progressive lag with depth; soil water content and temperature in all three land use types (sloping cropland, forestland, grassland) exhibited a quadratic functional relationship. Forestland demonstrated the strongest correlation between soil moisture and temperature, which is more conducive to soil water-heat conservation in the loess region. These findings can provide a scientific basis for research on the impacts of soil moisture on vegetation restoration and for environmental construction and protection in the Loess Plateau region.

Full Text

Preamble

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Abstract: To study the changes in soil moisture and temperature during a freezing-thawing period, the space-time change law of soil moisture and temperature of different soil depth layers were analyzed by monitoring the soil moisture and temperature data of different land use runoff plots in the field. The relationship between soil moisture and temperature in the study area was then clarified. The results showed that the variation degree of the 20 cm soil layer in sloped farmland was the largest, while the strongest active layers in the grassland and woodland were 30 cm and 10 cm, respectively. The 20 cm soil layer in the sloped farmland had the largest dispersion of water content, while the active layers in grassland and forest land were 30 cm and 10 cm, respectively. The grassland first entered the freezing period and the thawing period, and freeze and melt time lags layer by layer, and the soil moisture content and temperature of the three land types followed quadratic functions. The hydrothermal relationship of the soil in forest land was the strongest, which is more conducive to the soil water-heat retention in the loess area. This study provides a scientific basis for the research of soil moisture on vegetation restoration and the protection of the environment from construction in the loess area.

Keywords: freezing-thawing period; land use; soil moisture; soil temperature; correlation; Ansai County

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1. Study Area and Methods

1.1 Study Area

The study area is located in Ansai County, Shaanxi Province (36°51 N, 109°19 E) [Figure 1: see original paper]. The region has a temperate semi-arid climate, with an elevation ranging from 1068 to 1309 m. The mean annual temperature is 8.8°C, with an average of 20.6°C in the warmest month (July) and -4.37°C in the coldest month (January). Annual precipitation averages 505.3 mm, with 645 mm in rainy years and 296.6 mm in dry years. The annual sunshine duration is 2395.6 hours, with a frost-free period of 157 days and relative humidity of 54%. The terrain consists of hilly gullies with slopes typically between 100–200 m.

The study examined three land use types: sloped farmland, grassland, and woodland. Monitoring was conducted from November 15, 2016, to April 20, 2017. Soil moisture and temperature were measured at 10 cm intervals from the surface to a depth of 100 cm. Data were collected on December 20, 2016, at 14:00 during snow cover conditions [TABLE:N]. Statistical analysis was performed using SPSS 22.0, with graphical representations created using Origin 9.0 and Excel 2010. Pearson correlation analysis was employed to examine relationships between soil moisture and temperature.

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2. Results and Analysis

2.1 Soil Temperature Characteristics During Freezing-Thawing Period

Soil temperature dynamics during the freezing-thawing period were analyzed based on field measurements. The freezing period was defined as when soil temperature remained $ $0°C, while the thawing period represented the transition above 0°C [24]. Temperature variations at different depths revealed distinct patterns across the three land use types [Figure 2: see original paper].

Measurements at 10 cm depth intervals showed that temperature fluctuations were most pronounced in the surface layers. The analysis identified five critical temperature thresholds: >0°C, $ $0°C, ≤-5°C, ≤-10°C, and ≤-15°C. Temperature variation amplitudes differed significantly among land uses, with grassland showing the earliest onset of freezing and thawing, followed by woodland and sloped farmland. The freezing process exhibited a clear time lag with depth, progressing sequentially from shallow to deep layers.

2.2 Soil Moisture Characteristics During Freezing-Thawing Period

Soil moisture content exhibited the greatest variation in the 20 cm layer of sloped farmland, while the most active layers in grassland and woodland occurred at 30 cm and 10 cm depths, respectively. The moisture distribution pattern showed that sloped farmland had the highest water content variability, followed by grassland and woodland.

The vertical distribution of soil moisture revealed that grassland maintained higher moisture content in the 10–50 cm layer, woodland in the 10–60 cm layer, and sloped farmland in the 10–70 cm layer. Critical depths for moisture retention were identified at 50 cm for grassland, 60 cm for woodland, and 70 cm for sloped farmland. Below these depths, moisture content stabilized with minimal fluctuations.

The relationship between soil moisture and temperature followed quadratic functions across all land use types. The strongest hydrothermal coupling occurred in woodland, indicating superior water-heat retention capacity in forest soils. This finding suggests that woodland ecosystems provide optimal conditions for soil moisture conservation during freezing-thawing cycles in loess regions.

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