The process of moisture and temperature change of soil profile in Pisha sandstone area

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Abstract. The Pisha sandstone area in Ordos Plateau is a cross zone of water, wind and freeze-thaw erosion. Freeze-thaw erosion is one of the important erosion modes in this area, and soil moisture and temperature are the two key factors affecting it. In order to reveal the change process of soil moisture and temperature with time in the Pisha sandstone area, we took the small watershed of Erlaohugou in Huangfuchuan as the study area. Two sets of EM50 full-automatic collection systems were set up on a typical slope in the area, and the change process of moisture and temperature of the slope from March to September was continuously observed. The results showed that the changes of soil moisture and temperature in this area were greatly affected by seasons and climate. Soil moisture exhibited significant temporal and spatial differentiation, while soil temperature had significant temporal differentiation but not obvious spatial differentiation.

1. Introduction
The Pisha sandstone is an interlayer of thick sandstone, sand shale, and argillaceous sandstone that gradually formed in the Permian, Mesozoic, Triassic, Jurassic and Cretaceous. It is concentrated in the Ordos Plateau in the Yellow River Basin[1-2]. The area is about 167,000 km². Due to the small thickness and low pressure of the overlying strata on the sandstone, its diagenesis is weak and its structural strength is low[3-4]. It is very hard like the rock when it is dry, but would collapse into sand within one minute when it is immersed in water[5]. Water erosion, wind erosion, and freeze-thaw erosion occur alternately in the Pisha sandstone area[6-7]. The soil erosion is severe and the ecological environment is extremely bad, which makes it a concentrated source area of the coarse sediments of the Yellow River, and severely restricts the sustainable development of the local economy and society[8-9].

Freeze-thaw erosion is a phenomenon that the water in soil and its parent material expands, shrinks, disintegrates and loses due to the drastic change of temperature. Obviously, the freeze-thaw erosion is related to the moisture content, density and temperature of the Pisha sandstone. According to Liu's experimental observations, frost heaving hardly occurs when the moisture content of Pisha sandstone is below 11%. When the water content is 12%~16%, the frost heave rate increases linearly with the increase of the water content, and the frost heave rate increases with the increase of dry density of the Pisha sandstone[10]. Under a certain dry density, the frost heave rate increases with the decrease of the...
cold junction. Therefore, the process of moisture and temperature change of soil profile is important for the study of freeze-thaw erosion in this area.

2. Materials and methods

2.1. Study area
The study area Erlaohugou watershed is a secondary branch ditch which located on the right bank of Nalinchuan, a tributary of Huangfu River. The Erlaohugou watershed is located in Nuanshui Township, Jungar County, Ordos City, with an area of 3.23 km², geographical coordinates of 110°36'2.74"E, 39°47'38.79"N. The geomorphology of the area is loess hilly and gully, which is overlaid with loess or floating soil. It belongs to the typical soil-covering area, and the thickness of the soil on the top of the slope is more than 2 m. Gully density reaches 7 km/km², vegetation coverage is very low, and exposed area of bedrock is more than 30%. The study area is a typical continental semi-arid climate with large annual temperature differences and an average annual temperature of 7.3 °C. The freezing period is from November to March of the following year, and the frozen soil depth is about 1.5 m. The average annual rainfall is about 350 mm. Rain is concentrated from July to September, and most of it is heavy rain. There are many strong winds, the average annual wind speed is 2.2 m/s, and the maximum wind can reach up to 8 degrees. The strong winds are concentrated in April to May and October to November.

2.2. Instrumentation and data collection
Due to the lack of long series of observation data in the study area, two sets of EM50 full-automatic ground temperature and moisture collection systems are embedded in the middle of a typical sunny slope, to monitor soil moisture and temperature changes on the Pisha sandstone slope. The EM50 equipped with 5-channel ground temperature and moisture sensors (ECH2O-5, Decagon Devices Inc., United States; precision: ±3%). Considering that freeze-thaw erosion usually occurs in shallow soil, the buried depth of the sensor along the soil profile are respectively 10, 20, 30, 40 and 50 cm, so as to obtain the soil temperature and moisture dynamics in five layer profiles in real time. The observation period is from March to September 2018. The measurement precision was 0.2 mm and the recording interval was 15 minutes, and more than 60,000 sets of data were collected. Based on statistical analysis of data, the temporal and spatial variation of soil temperature and moisture in different depths were identified.

3. Results and discussion

3.1. Soil moisture change
Figure 1 shows the vertical distribution of soil moisture at P1 and P2. It can be seen from the figure that the distribution of soil moisture along the profile increases first and then decreases. The surface soil moisture content is the lowest, about 15-30%, and then gradually increases with the depth. When it reaches 20-25cm underground, the moisture content reaches the maximum, about 30-45%, and then slowly decreases, about 25-35% when it reaches 50cm underground. Therefore, 20-25cm underground was the largest aquifer of soil.

Fig. 2 shows the change of soil moisture with time at P1 and P2. It can be seen from the figure that the highest value of soil moisture in Pisha sandstone area occurs in July and August, and the lowest in March and April. The variation trend of soil moisture in different soil layers was similar, which is related to rainfall. The rainfall in Pisha sandstone area was mainly concentrated in summer, while the winter was dry and there was little rain.
3.2. Soil temperature change

Figure 3 shows the vertical distribution of soil temperature at P1 and P2. It can be seen from the figure that the soil temperature in March decreases slowly with the increase of soil depth, while the soil temperature in other months keeps basically unchanged with the increase of soil depth, and the difference of soil temperature in different months is obvious, the range of change is from 5℃ to 25℃. It shows that the soil temperature is less affected by the change of soil depth and more affected by the change of external temperature.

Figure 4 shows the change of soil temperature with time at P1 and P2. It can be seen from the figure that the highest value of soil temperature in Pisha sandstone area appears in July and August,
while in March and April was relatively low. The variation trend of soil temperature in different depths was similar, which was related to the temperature change in this area. The average temperature in Pisha sandstone area was 3.5℃ in March, 22.5℃ in August. It can be seen that the soil temperature and the air temperature were generally consistent.

Figure 3. The vertical distribution of soil temperature at P1 and P2.

Figure 4. The change of soil temperature with time at P1 and P2.

4. Conclusions
This paper analyzed the change process of soil profile moisture and temperature with time in the Pisha sandstone area. The results showed that the soil moisture and temperature changes in this area were greatly affected by seasons and climate, and had significant time differentiation. With the increase of
soil depth, the soil moisture increased first and then decreased, and the soil temperature remained unchanged, which indicated that the soil moisture had obvious spatial differentiation, while the soil temperature did not.

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