Land use affects the response of soil moisture and soil temperature to environmental factors in the loess hilly region of China

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Changes in soil moisture and temperature are the result of the combined effects of many environmental factors. Scientific determination of the response characteristics of soil moisture and soil temperature to environmental factors is critical for adjusting the sloping land use structure and improving the ecological environment in China’s loess hilly region. A soybean sloping field, maize terraced field, jujube orchard, and grassland in the loess hilly region were selected as the research objects. The change characteristics of soil moisture and soil temperature, as well as their interactions and statistical relationships with meteorological factors, were analyzed using continuously measured soil moisture, soil temperature, and meteorological factors. The results show that air temperature and air humidity were the main controlling factors affecting soil moisture changes in the 0-60 cm soil layer of soybean sloping field and grassland in the normal precipitation year (2014) and the dry year (2015). Air humidity and wind speed were the main meteorological factors affecting soil moisture changes in maize terraced field. Air temperature had a very significant negative effect on soil moisture in jujube orchard. Soil moisture and soil temperature were all negatively correlated under the four sloping land use types. In the normal precipitation year, air humidity had the greatest direct and comprehensive effect on soil moisture in soybean sloping field, maize terraced field, and grassland; soil temperature had a relatively large impact on soil moisture in jujube orchard. The direct and comprehensive effects of soil temperature on soil moisture under all sloping land use types were the largest and most negative in the dry year. The air temperature had a high correlation with the soil temperature in the 0-60 cm soil layer under the four sloping land use types, and the grey relational grade decreased as the soil layer deepened. The coefficient of determination between 0-20 cm soil temperature and air temperature in the

maize terraced field was low, indicating a weak response to air temperature. The above findings can serve as a scientific foundation for optimizing sloping land use structures and maximizing the efficient and sustainable utilization of sloping land resources in China's loess hilly region.

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Abstract

Changes in soil moisture and temperature are the result of the combined effects of many environmental factors. Scientific determination of the response characteristics of soil moisture and soil temperature to environmental factors is critical for adjusting the sloping land use structure and improving the ecological environment in China's loess hilly region. A soybean sloping field, maize terraced field, jujube orchard, and grassland in the loess hilly region were selected as the research objects. The change characteristics of soil moisture and soil temperature, as well as their interactions and statistical relationships with meteorological factors, were analyzed using continuously measured soil moisture, soil temperature, and meteorological factors. The results show that air temperature and air humidity were the main controlling factors affecting soil moisture changes in the 0-60 cm soil layer of soybean sloping field and grassland in the normal precipitation year (2014) and the dry year (2015). Air humidity and wind speed were the main meteorological factors affecting soil moisture changes in maize terraced field. Air temperature had a very significant negative effect on soil moisture in jujube orchard. Soil moisture and soil temperature were all negatively correlated under the four sloping land use types. In the normal precipitation year, air humidity had the greatest direct and comprehensive effect on soil moisture in soybean sloping field, maize terraced field, and grassland; soil temperature had a relatively large impact on soil moisture in jujube orchard. The direct and comprehensive effects of soil temperature on soil moisture under all sloping land use types were the largest and most negative in the dry year. The air temperature had a high correlation with the soil temperature in the 0-60 cm soil layer under the four sloping land use types, and the grey

relational grade decreased as the soil layer deepened. The coefficient of determination between 0-20 cm soil temperature and air temperature in the maize terraced field was low, indicating a weak response to air temperature. The above findings can serve as a scientific foundation for optimizing sloping land use structures and maximizing the efficient and sustainable utilization of sloping land resources in China's loess hilly region.

Introduction

Soil moisture distribution and variability is a comprehensive reflection of natural conditions such as climate, vegetation, topography, and soil properties, and is the result of multiple environmental factors acting together (Zhu et al., 2014; Huang et al., 2016). Soil moisture variability is primarily controlled by meteorological factors on a time scale (Li et al., 2019; Zhu et al., 2019). Zhong et al. (2014) found that temperature, sunshine, and precipitation are all inversely correlated with the temporal variation of soil moisture in the 0-10 cm layer from March to May and that the meteorological factors of temperature and sunshine are all inversely and highly significantly correlated with soil moisture from June to September in the hilly area of Chongqing, China. Liu et al. (2021) discovered that the absolute change rate value of soil moisture is positively correlated with air temperature, relative air humidity, and rainfall, but negatively correlated with photosynthetically active radiation, vapour pressure deficits, and wind speed in different subtropical plantations of the Yangtze River Delta Region. The response characteristics of soil moisture to meteorological factors are not consistent in different regions due to differences in climate, topography, soil texture, and vegetation, and the dominant driving meteorological factors for soil moisture variation in different periods are also not consistent. Precipitation, solar radiation, and air temperature are the main factors affecting soil moisture variability in water-scarce areas (Liu et al., 2012; Wang et al., 2019; Han et al., 2020). Furthermore, air humidity, wind speed, and other factors will influence soil moisture change by affecting the intensity of soil evaporation (Akinyemi et al., 2007; MacDonald et al., 2018). Soil temperature is another environmental factor that influences soil moisture movement. According to Liu et al. (2020), soil temperature has a direct impact on soil water movement and distribution, which is one of the major influencing factors affecting bare soil evaporation. The temperature of the soil profile, particularly the surface soil, varies with seasons and day-night changes in natural conditions, which has a direct impact on soil moisture infiltration, redistribution, and evaporation, which is especially significant in arid and semi-arid regions (Sarkar et al., 2007; Sypka et al., 2016).

The energy exchange between the soil and the atmosphere causes changes in soil temperature due to the combined effects of solar radiation and precipitation. Many academics have conducted extensive research on the relationship between soil temperature changes and meteorological factors, with promising results. Air temperature has a significant impact on soil temperature throughout Eurasia throughout the season, according to Hu and Feng (2005), and precipitation has an impact on soil temperature as well, especially at high latitudes and during the winter. Sattari et al. (2020) used tree-based hybrid data mining models to estimate soil temperature in Turkey's Sivas Divrigi district, concluding that sunshine duration and air temperature are the most important factors in the prediction of soil temperature, while precipitation is the least important meteorological variable. Dodds et al. (2003) investigated the factors influencing soil temperature in pepper fields under plastic mulches and discovered that mean air temperature and mean radiation are the best predictors of soil temperature, with wind speed and relative humidity being secondary, and rainfall having little or no effect. It can be concluded that differences in the studied regions' geographic environments and ecological factors lead to differences in the effects of the same meteorological factor on soil temperature. Soil temperature is influenced by soil moisture conditions in addition to meteorological factors. Moisture and heat in the soil influence and interact with one another, and changes in soil moisture can change the thermal characteristics of the soil, affecting its temperature (Cheng et al., 2013). Mi et al. (2014) discovered that under the condition of constant soil bulk density during frequent dry-wet alternation processes, soil moisture is the most important factor influencing changes in soil thermal parameters and that the water retention effect of mulching has a direct impact on the dynamic changes of surface soil thermal parameters. In a potato field in Wuchuan County, Inner Mongolia, China, Zhang et al. (2020) discovered an inverse proportional relationship between soil moisture and temperature, whereby as soil moisture increases, soil temperature decreases, and as soil moisture declines, soil temperature rises, under various water level treatments.

Soil moisture and temperature respond differently to environmental factors depending on the land use type. According to Hao et al. (2019), converting grassland to evergreen woody vegetation prolongs the impact of meteorological drought on soil moisture; therefore, restoring prairie that has been heavily encroached by woody species may mitigate the impact of climate change on water resources in the climate transition zone of the United States. Chen et al. (2009) found that although the soil temperature of each soil layer in winter wheat fields in the North China Plain under different tillage methods (ploughing, rotary tillage, and no-tillage with straw mulching) is extremely significant in response to air temperature changes, the tillage methods affect the change range of soil temperature. Complex and changeable landform types, deep loess, and various types of soil developed from it have formed a variety of vegetation types and land use conditions in the loess hilly region, all of which have important effects on soil moisture and temperature. However, there are currently few studies on how soil moisture and temperature respond to environmental factors under various land use types, and the relationship between soil moisture and temperature in response to environmental factors needs to be clarified.

In light of the aforementioned phenomenon, this paper investigated four typical land use types in the loess hilly region (soybean sloping field, maize terraced field, jujube orchard, and grassland). Pearson correlation analysis, path analysis, stepwise regression analysis, and grey relational analysis were used to study the relationship between soil moisture and temperature changes and major meteorological factors (air temperature, air humidity, solar radiation, wind speed, and precipitation) under different precipitation years for the four land use types, as well as the relationship between soil moisture and soil temperature. The goal of this research is to uncover the mechanisms by which various environmental factors influence soil moisture and temperature under different land use types in order to provide a scientific foundation for land use improvement and vegetation construction in the loess hilly region.

Materials & Methods

General situation of the study area

The study area is located in the Yuanzegou watershed (37° 15′ N, 118° 18′ E), Qingjian County, Shaanxi Province, China, in the north-central part of the Loess Plateau, which is a typical loess hilly and gully area. The study area has a temperate continental monsoon climate, with an annual average air temperature of 8.6℃, with the lowest monthly average air temperature of -6.5℃ in January and the highest monthly average air temperature of 22.8℃ in July. The average annual precipitation is 505 mm, but it is unevenly distributed throughout the year, with 70% of the precipitation falling between July and September. The soil in the study area is loessial, with the most silt, followed by sand, and the least clay, which has high infiltration capacity. The field capacity and wilting moisture are about 25% and 7% (volumetric moisture content), respectively. The precipitation in the growing season (from May to October) in 2014 and 2015 was 377.4 mm and 289.2 mm (Fig. 1), respectively, and 2014 and 2015 were considered a normal precipitation year and a dry year, respectively, according to Hao et al. (2003).

Experimental scheme

Since the implementation of returning farmland to forestland and grassland in the loess hilly region, the study area has seen a wide range of land use and vegetation types, including large areas of cultivated land for planting maize, potatoes, and soybeans, grassland from returning farmland, and scattered woodlands (jujube orchard, Caragana woodland, and Robinia woodland, etc.). The experimental plots were chosen from a representative soybean sloping field, maize terraced field, jujube orchard, and grassland with a similar slope aspect (shady slope) and gradient (about 18°). Soybean and maize were sown at densities of 19.5×10^4 and 9×10^4 plants·hm^{-2}, respectively, in late April and early May each year and both were harvested in early October. Lizao was the jujube species used in the experiment, which was planted in 2003 and was in the full bearing period during the experiment. Plant spacing was 2 m and row spacing was 3 m, respectively. The grassland was naturally restored from sloping farmland for more than 30 years. The eugenic plant was *Artemisia gmelinii*, and the associated plants were *Lespedeza daurica* (Laxm.) Schindl. and *Bothriochloa ischaemum* (L.) Keng. During the experiment, none of the plots were irrigated, and the field management followed the local standard.

Two sets of soil moisture and temperature automatic monitoring instruments were installed in the middle of each experimental plot along the same contour line with a 10-meter in April 2014. The monitoring points in the soybean sloping field and maize terraced field were placed between crop rows, and the jujube orchard monitoring points were placed 30 cm away from the trunk. The EC-5 soil moisture sensor (Decagon Devices, Pullman, WA, USA) and the RR-7110 soil temperature sensor (Rainroot Scientific Ltd., Peking, CN) were used to measure the volumetric moisture content and temperature of the soil. The probes of the soil moisture sensor were placed at 10, 20, 60, 100, and 160 cm depths, respectively. The probes of the soil temperature sensor were placed at depths of 10, 20, 40, 60, and 100 cm, respectively. During the vegetation growing season (May to October) in 2014 and 2015, soil moisture and temperature were measured every 2 minutes and the data were recorded every 10 minutes. To characterize the soil moisture and temperature at a certain depth under each sloping land use type, we averaged the soil moisture and temperature at the same depth at two monitoring points under this sloping land use type. An AR5 automatic weather station (Avolon Scientific Inc., Jersey City, NJ, USA) continuously monitored weather variables such as air temperature, air humidity, atmospheric pressure, solar radiation, wind speed, and precipitation in the study area.

Data processing

Path analysis

The statistical method of path analysis is used to decompose correlation coefficients. Its importance lies not only in revealing the direct and indirect influence of x_i on y in correlation analysis of multiple independent variables x_1, x_2,..., x_m, y, but also in obtaining the path information of the best influence on y from the relationship between an independent variable and other independent variables in a complex correlation between x_1, x_2,..., x_m, y. Therefore, the absolute value of the path coefficient can be used to directly compare the important role of each independent variable in the regression equation, which is of great practical value for clarifying key factors and changing the reflection of dependent variables in a multivariable system, and path analysis is more comprehensive and delicate than correlation analysis. SPSS linear regression was used to perform path analysis in this study. Please see Du and Chen (2010) for more information on the specific procedure. It's worth noting that this study used stepwise regression to create a linear regression equation and then calculated the path coefficient. Stepwise regression has the advantage of gradually adding or removing an independent variable from all available independent variables until the best regression equation is found.

Grey relational analysis

The basic principle of grey relational analysis (GRA) is to compare the geometric relationships of statistical sequences to determine the closeness of multiple factors in the system (ie, grey relational grade). The greater the grey relational grade, the closer the geometric shape of sequence curves is, and vice versa. GRA has the advantage over traditional statistical analysis or other analysis methods in that it analyzes factors based on their development trends, does not specify sample size, does not require a typical distribution law, has a small calculation amount, and the calculation results are consistent with the qualitative analysis results.

Before performing GRA, the reference sequence must be determined first, followed by a comparison of the other sequences' similarity to the reference sequence. If the reference sequence is $X_0=\{X_0(k)|k=1,2,\ldots,n\}$, and the comparison sequence is $X_i=\{X_i(k)|k=1,2,\ldots,n\}(i=1,2,\ldots,m)$, then the correlation coefficient of $X_i(k)$ and $X_0(k)$ is calculated as follows:

$$\varepsilon_i(k) = \frac{min_i min_k|x_0(k) - x_i(k)| + \rho max_i max_k|x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho max_i max_k|x_0(k) - x_i(k)|} \quad (1)$$

where ρ is the resolution coefficient, which is usually 0.5; $|x_0(k)-x_i(k)|$is the absolute difference between X_0 and the k-th index of X_i; $min_i min_k|x_0(k)-x_i(k)|$and $max_i max_k|x_0(k)-x_i(k)|$ are the two-level minimum and maximum differences, respectively.

The following formula can be used to calculate the correlation coefficient between $X_i(k)$ and $X_0(k)$:

$$\varepsilon_i(k) = \{\varepsilon_i(k) \mid k = 1,2,...,n\} \quad (2)$$

The correlation coefficient value of each comparison sequence and the reference sequence at each point is obtained from the correlation coefficient calculation. The outcomes are numerous, and the data is dispersed. As a result, the correlation coefficient of each comparison sequence at each point must be reflected collectively in one value, which is the grey relational grade $r(x_0, x_i)$ of the comparison sequence to the reference sequence, commonly abbreviated as r_i. The average method is the most commonly used method for calculating the grey relational grade, and the formula is as follows:

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\varepsilon_i(k) \quad (3)$$

The grey relational grade in this study reflects the proximity of each influencing factor to the soil temperature. The greater the grey relational grade is and the closer it is to 1, the closer the connection between the reference sequence and the comparison sequence is, the greater the influence of the comparison sequence on the reference sequence; otherwise, the farther the connection is, the smaller the influence. When the grey relational grade is greater than 0.80, the factors corresponding to the comparison sequence are thought to be closely related to the soil temperature and to have a significant impact. The surface layer (0-20 cm), middle layer (20-60 cm), and deep layer (60-100 cm) soil temperature in the four experimental sloping land use types were used as parameter variables. To determine the effect of air temperature, air humidity, solar radiation, wind speed, precipitation, and soil moisture on soil temperature under various sloping land use types, the reference sequence and each environmental factor sequence were dimensionless processed, and then the grey relational coefficients between each environmental factor sequence and the reference sequence were calculated.

Data analysis

The binary correlation analysis between soil moisture and environmental factors was conducted using the Pearson correlation analysis method in SPSS software (SPSS Inc, Chicago, Illinois, USA). The stepwise regression method in SPSS was used to screen the independent variables in the stepwise regression analysis of environmental factors affecting soil moisture, and the variables that met the allowable level (0.05) entered the model. The drawing was done with OriginPro 2017 software (OriginLab Corp., Northampton, MA, USA).

Results

Soil moisture response to environmental factors

Binary correlation analysis between soil moisture and environmental factors

According to the authors' previous research (Tang et al., 2019), the soil moisture in the 0-60 cm soil layer fluctuated greatly during the growing season, and the soil moisture in the 60-160 cm soil layer changed smoothly under various experimental sloping land use types. It can be concluded that environmental factors have a significant impact on soil moisture in the 0-60 cm soil layer. Table 1 shows the correlation analysis results for daily mean moisture content in the 0-60 cm soil layer and daily mean air temperature (x_1), daily mean air humidity (x_2), daily mean solar radiation (x_3), daily mean wind speed (x_4), daily precipitation (x_5), and daily mean soil temperature in the 0-60 cm soil layer (x_6) under four experimental sloping land use types.

During the 2014 growing season, the soil moisture in the 0-60 cm soil layer of the soybean sloping field had a significant correlation with air temperature, air humidity, and wind speed, with the correlation between soil moisture and air temperature and air humidity reaching an extremely significant level ($p<0.01$) (Table 1). In the 2015 growing season, the soil moisture of the soybean sloping field was highly correlated with air temperature, air humidity, and solar radiation ($p<0.01$). It can be concluded that, whether in a normal precipitation year or a dry year, air temperature and air humidity were the main controlling factors for soil moisture changes in soybean sloping field at a small catchment scale. The soil moisture of the maize terraced field was significantly correlated with air temperature, air humidity, and wind speed ($p<0.01$) during the 2014 growing season. The correlation between soil moisture in maize terraced field and air humidity, wind speed, and precipitation were extremely significant ($p<0.01$) during the 2015 growing season. According to the findings, air humidity and wind speed were the most important controlling factors affecting soil moisture changes in maize terraced field on a regional scale during various precipitation years. In the 2014 growing season, jujube orchard soil moisture was significantly correlated with air temperature, air humidity, and precipitation, but in the 2015 growing season, it was only extremely significantly correlated with air temperature and wind speed ($p<0.01$). In both growing seasons, the correlation between soil moisture in the jujube orchard and air temperature was extremely significant ($p<0.01$), indicating that among the meteorological factors studied, the air temperature had a significant impact on soil moisture in the jujube orchard, and soil moisture decreased as air temperature rose. During the 2014 and 2015 growing seasons, the correlation between soil moisture in grassland and air temperature and air humidity reached an extremely significant level ($p<0.01$), indicating that air temperature and air humidity were the main factors affecting the change of soil moisture in the grassland, regardless of precipitation differences. In the growing seasons of 2014 and 2015, air temperature, solar radiation, and wind speed were negatively correlated with soil moisture under the four sloping land use types. This was due to increased air temperature, solar radiation, and wind speed, which resulted in increased soil evaporation, which then resulted in a decrease in the moisture content in the 0-60 cm soil layer. Under various sloping land use types, air humidity and precipitation were positively correlated with soil moisture, indicating that as air humidity and precipitation increased, soil moisture increased as well.

In the growing seasons of 2014 and 2015, there was a negative correlation between soil moisture and soil temperature in the 0-60 cm soil layer under various sloping land use types, and all of them passed the significance test ($p<0.01$) (Table 1), indicating that soil moisture and soil temperature affected each other in this soil layer, and as the soil temperature increased, the soil moisture decreased. The dry year had a significantly higher correlation between soil moisture and soil temperature in the 0-60 cm soil layer under the same sloping land use type than the normal precipitation year. The reason for this could be that the dry year caused a severe soil water shortage, and the high soil temperature in the 0-60 cm soil layer increased soil moisture evaporation, resulting in a strong negative correlation between soil temperature and soil moisture. In the 2014 and 2015 growing seasons, the maize terraced field had a lower correlation between soil moisture and soil temperature in the 0-60 cm soil layer than the other three sloping land use types. This is because the soil temperature of the maize terraced field's 0-60 cm soil layer was relatively low, and the average soil temperature of this soil layer did not exceed 20℃ in the two growing seasons, soil moisture evaporation was minimal. Similarly, the average soil temperature of the 0-60 cm soil layer in the jujube orchard was 20.73℃ in the 2014 growing season, which was 0.41, 1.20, and 1.81℃ higher than that of the soybean sloping field, maize terraced field, and grassland. The evaporation of soil moisture in this soil layer was accelerated by the higher soil temperature in the jujube orchard, making soil temperature have a strong negative effect on soil moisture.

Path analysis of the relationship between soil moisture and environmental variables

It is easy to overlook the interaction between environmental factors only by judging the contribution of environmental factors to soil moisture based on the simple correlation coefficient between environmental factors and soil moisture. The correlation coefficients between various environmental factors and soil moisture were divided into direct and indirect effects for path analysis to further explore the direct and indirect effects of various environmental factors on soil moisture.

In the 2014 growing season, air humidity had the greatest direct effect on soil moisture in the 0-60 cm soil layer of soybean sloping field, maize terraced field, and grassland, with direct path coefficients of 0.492, 0.491, and 0.716, respectively, followed by solar radiation (Table 2). Soil temperature had the greatest direct effect on soil moisture in jujube orchard, with a direct path coefficient of -1.101. The direct influence of air humidity and solar radiation on soil moisture under four sloping land use types showed positive effects. The direct impact of soil temperature on soil moisture in the soybean sloping field, jujube orchard, and grassland was negative. The absolute value of the direct path coefficient of soil temperature in soybean sloping field and grassland was greater than the absolute value of the sum of indirect path coefficients, and the sum of indirect effect coefficients of soil temperature was very small, indicating that the influence of soil temperature on the soil moisture of soybean sloping field and grassland in the 0-60 cm soil layer was mainly reflected in the direct effect. The evaporation of soil moisture in soybean sloping field and grassland intensified as soil temperature increased, reducing the moisture content in the 0-60 cm soil layer. As a result, the impact of soil temperature on soil moisture was primarily a direct effect with little correlation to other meteorological factors. The absolute values of the direct path coefficients of air temperature, air humidity, and wind speed were greater than the absolute value of the sum of their respective indirect path coefficients in the maize terraced field, and the sum of these three meteorological factors' respective indirect path coefficients was small, indicating that the influence of these three meteorological factors on the soil moisture of the 0-60 cm soil layer of the maize terraced field was mainly reflected in the direct effect. The evaporation capacity of the atmosphere increased as the air temperature rose, and the increase in wind speed aided the increase in evaporation rate. Because of the aforementioned comprehensive factors, soil evaporation increased in the maize terraced field, reducing the moisture content of the 0-60 cm soil layer. As a result, the influence of air temperature and wind speed on soil moisture is mainly a direct effect, and the correlation with other environmental factors was weak. Soil evaporation was reduced as air humidity increased, and the rate of soil moisture loss slowed. It had a primarily direct influence on soil moisture, with little correlation with other influencing factors. Although solar radiation had a large direct effect on soil moisture under the four sloping land use types, all of which had coefficients above 0.4, it also had a relatively large indirect effect on soil moisture through other environmental factors (such as air temperature, air humidity, and soil temperature), resulting in a small overall impact of solar radiation on soil moisture, so the simple correlation coefficients between solar radiation and soil moisture under various sloping land use types were low.

Soil temperature had the greatest direct impact on soil moisture in the 0-60 cm soil layer under soybean sloping field, maize terraced field, jujube orchard, and grassland in the 2015 growing season, with direct path coefficients of -0.762, -0.861, -0.950, and -0.741, respectively, all of which had negative effects (Table 3). The soil moisture of the soybean sloping field, jujube orchard, and grassland was positively affected by air humidity. The direct path coefficients of soil temperature under soybean sloping field and grassland were greater than the sum of indirect path coefficients, and the sum of indirect path coefficients of soil temperature was very small, only -0.017, indicating that the influence of soil temperature on soil moisture under these two sloping land use types was mainly reflected in the direct effect, with little correlation with other meteorological factors. The evaporation of soil moisture was accelerated by the rise in soil temperature, resulting in soil moisture loss and decline. The direct effect (0.193) of air humidity on soil moisture in jujube orchard was opposite to the comprehensive indirect effect (-0.166) on soil moisture through the influence of air temperature, wind speed, and soil temperature. The simple correlation coefficient between air humidity and soil moisture in jujube orchard was as low as 0.027 due to the superposition of the two effects, indicating that air humidity had little effect on the change of soil moisture in jujube orchard and that it was unnecessary to consider too much. The direct effect of air temperature on soil moisture in maize terraced field and jujube orchard was positive, but the indirect effect on soil moisture by influencing wind speed and soil temperature were negative, and the indirect path coefficient was about 1.5 times that of the direct path coefficient. As a result, the comprehensive effect of air temperature on soil moisture in maize terraced field and jujube orchard was negative, as predicted by its indirect effect.

Environmental factors affecting soil moisture: a stepwise regression analysis

The effect of different independent variables on the dependent variable can be well explained using multiple stepwise regression analyses. Therefore, the dependent variable in this study was soil moisture (y) in the 0-60 cm soil layer under various sloping land use types, and the independent variables were air temperature (x_1), air humidity (x_2), solar radiation (x_3), wind speed (x_4), precipitation (x_5), and soil temperature (x_6) in the 0-60 cm soil layer. The main environmental factors affecting soil moisture were investigated using multiple stepwise regression analyses. Empirical models were developed based on the final regression results to predict the soil moisture content in the 0-60 cm soil layer under different sloping land use types (Table 4).

The regression equations for various sloping land use types all reached extremely significant levels (p<0.01) during the 2014 and 2015 growing seasons (Table 4). Different environmental factors entered the stepwise regression model for different sloping land use types in different precipitation years. In the 2014 growing season, the contribution rates of air humidity and solar radiation to soil moisture under soybean sloping field, maize terraced field, and grassland were higher than other environmental factors, and the total contribution rates of air humidity and solar radiation to soil moisture were 70.91% for soybean sloping field, 67.48% for maize terraced field, and 74.68% for grassland, respectively. It showed that air humidity and solar radiation were the main controlling factors affecting the soil moisture in soybean sloping field, maize terraced field, and grassland in the 2014 growing season. In the jujube orchard, soil temperature contributed more to soil moisture (35.87%) than the air temperature, air humidity, or solar radiation, indicating that the relationship between soil temperature and soil moisture in the 0-60 cm soil layer was closer in the 2014 growing season. During the 2015 growing season, soil temperature was entered into the regression equation of soil moisture in the 0-60 cm soil layer under four sloping land use types, and the contribution rate of soil temperature to soil moisture under all sloping land use types was more than 49%, with more than 81% for soybean sloping field and grassland. Soil temperature had a significant effect on soil moisture change under various land use types in the dry year, and it was the main controlling factor of soil moisture change in soybean sloping field and grassland, according to the findings. The sum of air temperature and soil temperature contributions to soil moisture under the maize terraced field and jujube orchard was 86.45% and 78.29%, respectively, indicating that air temperature and soil temperature were the main factors affecting soil moisture changes in the 0-60 cm soil layer of these two sloping land use types.

Response of soil temperature to changes in environmental factors

GRA was used in this study to examine the impact of different environmental factors on soil temperature, with soil temperature as the dependent variable and air temperature, air humidity, solar radiation, wind speed, precipitation, and soil moisture as the independent variables. The main influencing factors on soil temperature were then screened out for four different sloping land use types.

GRA on the main influencing factors of soil temperature

The grey relational grade between environmental factors and soil temperature is shown in Table 5 for different sloping land use types. The grey relational grade between air temperature and soil temperature in the surface and middle layers under the four sloping land use types was the highest, ranging from 0.8275 to 0.8446, according to the standard of grey relational grade greater than or equal to 0.80, indicating that air temperature was the primary factor affecting soil temperature in the 0-60 cm soil layer under various sloping land use types. The upper soil layer increased the barrier between the lower soil layer and the environment as soil depth increased, and the grey relational grade between soil temperature and air temperature decreased. Using the 2014 growing season as an example, the grey relational grade between the soil temperature in the surface layer and air temperature under soybean sloping field, maize terraced field, jujube orchard, and grassland was 0.8439, 0.8444, 0.8398, and 0.8417, respectively, while the grey relational grade in the middle layer decreased to 0.8394, 0.8388, 0.8318, and 0.8395, indicating that the grey relational grade decreased with the deepening of the soil layer. Furthermore, solar radiation had a significant impact on soil temperature in the surface layer under soybean sloping field and jujube orchard, with grey relational grades of 0.8107 and 0.8006, respectively. During the 2014 growing season, the grey relational grade between soil temperature in the deep layer and air humidity was at its highest, with values of 0.8344, 0.8352, and 0.8356, respectively, under soybean sloping field, maize terraced field, and grassland. Wind speed was closely related to soil temperature in the deep layer of soybean sloping field, maize terraced field, and grassland in the 2015 growing season, with the grey relational grade exceeding 0.82, indicating that wind speed had a significant impact on soil temperature in the 60-100 cm soil layer under these three sloping land use types. The air temperature was the most important factor affecting soil temperature in the deep layer of the jujube orchard in the 2014 and 2015 growing seasons. The grey relational grade between precipitation and soil temperature in the surface layer and deep layer under the four sloping land use types was the lowest in the 2014 growing season, with the grey relational grade in the surface layer ranging from 0.5233 to 0.5605 and the grey relational grade in the deep layer not exceeding 0.6305, indicating that precipitation had little effect on soil temperature in the 0-20 cm and 60-100 cm soil layers. The average grey relational grade between wind speed and soil temperature in the middle layer under the four sloping land use types was as low as 0.54, indicating that it was not closely related to the soil temperature in the 20-60 cm soil layer. The grey relational grade between precipitation, air humidity, and solar radiation and soil temperature in the surface, middle, and deep layers under various sloping land use types in the 2015 growing season was all low, with the average grey relational grade being 0.6161, 0.5980, and 0.5856, respectively, indicating that precipitation, air humidity, and solar radiation had little effect on soil temperature in the 0-20 cm, 20-60 cm, and 60-100 cm soil layers.

There were differences in the grey relational grade between the soil temperature in the same soil layer and the same environmental factor under different sloping land use types under the same external meteorological conditions (Table 5), which may be caused by differences in the underlying surface of the four sloping land use types. When it comes to solar radiation, for example, the more vegetation on the underlying surface, the less solar radiation the ground receives and the slower the soil's response to solar heating. Furthermore, the greater the surface roughness of the underlying surface, the lower the surface albedo and the easier it is to absorb solar radiation. It can be concluded that sloping land use influences the energy exchange between meteorological factors and soil, resulting in different soil temperature responses to meteorological factors. The distribution and changes of soil moisture, as well as the soil temperature, are affected by differences in the properties of the underlying surface under various sloping land use types.

Soil temperature response characteristics to air temperature

According to the findings, the air temperature had a significant impact on soil temperature under various experimental sloping land use types, particularly in the 0-60 cm soil layer. The correlation between soil temperature and air temperature at different depths was investigated using average data from daily observations, as shown in Fig. 2.

The coefficient of determination (R^2) between air temperature and soil temperature in the surface layer under the four sloping land use types ranged from 0.72 to 0.91 in the 2014 and 2015 growing seasons (Fig. 2), indicating a strong correlation. The highest R^2 in the middle and deep layers did not exceed 0.68 and 0.30, respectively, and the lowest was as low as 0.32 and 0.01. It shows that as the soil layer depth increased, the correlation between air temperature and soil temperature decreased, implying that the time it took for the change in soil temperature to catch up to the change in air temperature grew longer. It's worth noting that the maximum R^2 between the soil temperature and the air temperature in the deep layer was less than 0.30, indicating that the deep layer's response to air temperature was rather weak. The primary cause of this phenomenon is that solar radiation heated the surface soil, which was then transferred to the deep soil via heat conduction and convection. As the depth of the soil layer increased, the heat carried by heat conduction and convection decreased, causing the soil temperature to drop. As a result, air temperature changes had a big impact on the surface soil, but not so much on the deep soil.

The R^2 between the soil temperature in the surface layer and air temperature in the jujube orchard and grassland in the 2014 growing season was about 0.83, which was lower than that in the soybean sloping field, and the R^2 in the maize terraced field was relatively low, about 0.72 (Fig. 2). In the 2015 growing season, the coefficient of determination between the soil temperature in the surface layer and air temperature in the soybean sloping field, jujube orchard, and grassland were all around 0.90 and were higher than that in the maize terraced field.

Discussion

The link between changes in soil moisture and environmental factors

The combined effects of multiple influencing factors, such as land use (vegetation, topography, etc.), meteorological factors (precipitation, air temperature, wind speed, etc.), and soil properties, result in temporal and spatial changes in soil moisture. Soil moisture retention, soil moisture diffusion, and soil moisture loss can all be affected by rising air temperatures (Qiu & Ben-Asher, 2010; Chen et al., 2018). Precipitation can raise atmospheric relative humidity and soil moisture content, while solar radiation and wind speed can influence the evaporation of soil moisture.

Changes in soil temperature had a significant impact on soil moisture, affecting both the maintenance and movement of soil moisture. Cho and Choi (2014) investigated the temporal and spatial variability of soil moisture and its relationship with meteorological factors at the regional scale of the Korean Peninsula, they discovered that soil moisture was positively correlated with daily average precipitation but negatively correlated with air temperature. Czarnecka and Nidzgorska-Lencewicz (2006) found that the variability of soil moisture to a depth of 10 cm under rye and potato cultivation is mainly formed by precipitation totals. Whereas, moisture in deeper soil layers under rye depends, first of all, on the air humidity, and under potato cultivation, on thermal conditions of air and soil. In an oasis farmland-shelter forest, Wang (2007) discovered a significant negative correlation between wind speed and soil moisture, but no significant influence on soil moisture content from solar radiation, air temperature, or atmospheric relative humidity. Han et al. (2016) analyzed soil moisture and temperature data from four Qaidam Basin sampling sites and found that soil temperature was closely related to soil moisture, and the relationship between soil temperature and soil moisture at various depths at the Nomhon site was a quadratic function with a parabolic change. The relationship between soil temperature and soil moisture in the shallow layer was also quadratic at the Delingha and Da Qaidam sites, whereas soil temperature and soil moisture in the deep layer was positively linearly correlated. The soil moisture in the 0-60 cm soil layer under different sloping land use types responded differently to environmental factors in this study (Tables 1, 2, 3, and 4), primarily due to differences in vegetation types and coverage, as well as micro-topography, which directly affected the ground receiving precipitation and solar radiation, as well as the meteorological environment near the ground. In general, soil moisture was positively correlated with precipitation and air humidity, while soil moisture was negatively correlated with air temperature, wind speed, solar radiation, and soil temperature (Table 1). The results of this study differ slightly from those of the previous studies, which could be due to the different regions studied (such as humid, arid, and semi-arid regions), as well as the study's scale and time (Wang et al., 2016; Baldwin et al., 2017).

The direct and comprehensive effects of air humidity on soil moisture in the 0-60 cm soil layer under soybean sloping field, maize terraced field, and grassland were at their peak in the 2014 growing season, according to path analysis results (Table 2). In the jujube orchard, the soil temperature in the 0-60 cm soil layer had a significant impact on soil moisture (Table 2). The direct and comprehensive effects of soil temperature on soil moisture under various sloping land use types were the greatest in the 2015 growing season (Table 3). This is because increased plant transpiration and soil evaporation result from lower air humidity and higher soil temperature, resulting in a decrease in soil moisture content (Li et al., 2002; Kidron & Kronenfeld, 2016). The environmental variables entered for the four sloping land use types in the 2014 and 2015 growing seasons were air temperature, air humidity, solar radiation, wind speed, and soil temperature in the 0-60 cm soil layer, according to this study's stepwise regression analysis (Table 4). The above results differ from the findings of Zhang et al. (2013). The input variables are similar in that they include air humidity and wind speed, but the daily mean air temperature is excluded from Zhang et al.'s research results and does not enter the input variable. The difference in input variables is due to the difference in study area and time, and the direct effect of air temperature on soil moisture in Zhang et al.'s study is small, with a direct path coefficient of only -0.0364, and air temperature's comprehensive determination ability on soil moisture is small. The air temperature was entered into the regression model of the soil moisture under the maize terraced field and jujube orchard in this study in the 2014 and 2015 growing seasons (Table 4), especially in the dry year, where the direct path coefficient between the air temperature and the soil moisture under the maize terraced field and jujube orchard was both above 0.54 (Table 3). Despite the fact that the indirect effect of air temperature on soil moisture through other environmental factors (air humidity, wind speed, and soil temperature) was the polar opposite of the direct effect, the combined effect of air temperature on soil moisture under these two sloping land use types was still relatively large (Table 3). In addition, the sum of the indirect path coefficients of solar radiation under the soybean sloping field, maize terraced field, and grassland in the 2014 growing season was high, with values of -0.442, -0.467, and -0.581, respectively, according to Table 2. The absolute value of the indirect path coefficient of solar radiation affecting soil moisture through air temperature, air humidity, and soil temperature was above 0.384, and the maximum was as high as 0.603 (Table 2), indicating that solar radiation had a large impact on soil moisture through air temperature, air humidity, and soil temperature, according to the composition of the indirect path coefficient of solar radiation.

Soil temperature changes in response to environmental factors

Air temperature has been shown in numerous studies to be the most important meteorological factor affecting soil temperature (Paul et al., 2004; Wan et al., 2007). The grey relational grade between air temperature and soil temperature in the 0-60 cm soil layer under the four sloping land use types was found to be the highest in this study, ranging from 0.8275 to 0.8446 (Table 5), indicating that air temperature was the primary factor affecting the soil temperature of the 0-60 cm soil layer under different sloping land use types. The grey relational grade between soil temperature and air temperature decreased as the soil depth increased (Table 5), indicating that the influence of soil temperature by air temperature weakened as the soil depth deepened. As a result, during the 2014 and 2015 growing seasons, the air temperature was not the primary driver of soil temperature change in the 60-100 cm soil layer under soybean sloping field, maize terraced field, and grassland. However, in the 60-100 cm soil layer of the jujube orchard, the air temperature was still the most important factor influencing soil temperature. On the one hand, it could be because the jujube orchard is exposed and the vegetation coverage is low, resulting in poor ground shading. On the other hand, the soil moisture content in the 60-100 cm soil layer of the jujube orchard is low, and many pores in the soil are filled with air. Water has a specific heat capacity of about three times that of air, which means that the temperature of water rising or falling is about one-third that of air when absorbing or releasing the same heat. As a result, the lower the soil moisture content, the weaker the regulating effect on soil temperature is, and the easier it is for external meteorological conditions to affect soil temperature. Due to the aforementioned two factors, the air temperature has a significant impact on the deep soil of the jujube orchard.

The coefficient of determination between soil temperature and air temperature in different soil layers of 0-100 cm under the four sloping land use types was different in the study of the response of soil temperature to air temperature (Fig. 2), and the coefficient of determination in the surface layer under maize terraced field was small (Figs. 2c-2g), indicating that the response was weak. It could be because soybean sloping field and grassland plants are short, whereas maize plants in the terraced field are tall, and the densely covered maize canopy can intercept a lot of solar radiation. At the same time, due to low chlorophyll concentration and a waxy layer on the surface of the leaves, maize leaves have a higher reflectivity than soybean leaves, according to Liu et al. (2012). In addition, the author's previous research found that the soil moisture content in the 0-20 cm soil layer of the maize terraced field was higher than that of the other three sloping land use types in the 2014 and 2015 growing seasons (Tang et al., 2019). Water has a much higher specific heat capacity (4.2×10^3 J/(kg·℃)) than soil (1×10^3~2.5×10^3 J/(kg·℃)), which means that the temperature of water rises less than that of soil when they absorb the same amount of heat; on the other hand, water's ability to lose heat during the cooling process is lower than that of soil. Therefore, soil specific heat capacity increases as soil moisture content increases and the higher the soil moisture content, the slower the soil temperature rises and falls, and the less sensitive it is to air temperature.

Conclusions

The following conclusions are drawn from an examination of the effects of air temperature, air humidity, solar radiation, wind speed, and precipitation on soil moisture in the 0-60 cm soil layer and soil temperature in the 0-100 cm soil layer under various sloping land use types, as well as the relationship between soil moisture and soil temperature:

(1) Air temperature and air humidity were the main controlling factors affecting soil moisture changes in soybean sloping field and grassland during the growing seasons of normal precipitation year (2014) and dry year (2015). The most important meteorological factors affecting soil moisture changes in maize terraced field were air humidity and wind speed. In the jujube orchard, the effect of air temperature on soil moisture was extremely significant ($p<0.01$) and had a negative effect. Under all sloping land use types, there was a negative correlation between soil moisture and soil temperature in the 0-60 cm soil layer ($p<0.01$).

(2) Air humidity had the greatest direct and comprehensive impact on soil moisture in soybean sloping field, maize terraced field, and grassland during the growing season of the normal precipitation year. Soil temperature had a relatively large effect on soil moisture in jujube orchard, and the impact on soil moisture in soybean sloping field and grassland was mostly reflected in the direct effect. The direct effect of air temperature, air humidity, and wind speed on soil moisture in maize terraced field was predominant. Solar radiation had a large direct effect on soil moisture under the four sloping land use types, but it also had a large indirect effect on soil moisture by affecting air temperature, air humidity, and soil temperature, resulting in a small

overall impact on soil moisture small. The direct and comprehensive effects of soil temperature on soil moisture of various sloping land use types were the largest and showed a negative effect during the growing season of the dry year.

(3) In the four sloping land use types, the air temperature had a strong correlation with the soil temperature of the 0-60 cm soil layer, and the grey relational grade decreased as soil depth increased. The air temperature was the most important factor affecting soil temperature in the 60-100 cm soil layer of the jujube orchard during the growing season of normal precipitation year and dry year. There were differences in the grey relational grade between the soil temperature of the same soil layer and the same meteorological factor under different sloping land use types under the same meteorological conditions.

(4) The air temperature had a high correlation with the soil temperature of the 0-20 cm soil layer of the four sloping land use types during the growing season of normal precipitation year and dry year, and the correlation decreased with the increase of soil depth. The R^2 between the soil temperature and air temperature in the maize terraced field's 0-20 cm soil layer was small, indicating a weak response to air temperature.

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Figure 1

Monthly precipitation and average air temperature in the study area during the 2014 and 2015 growing seasons.

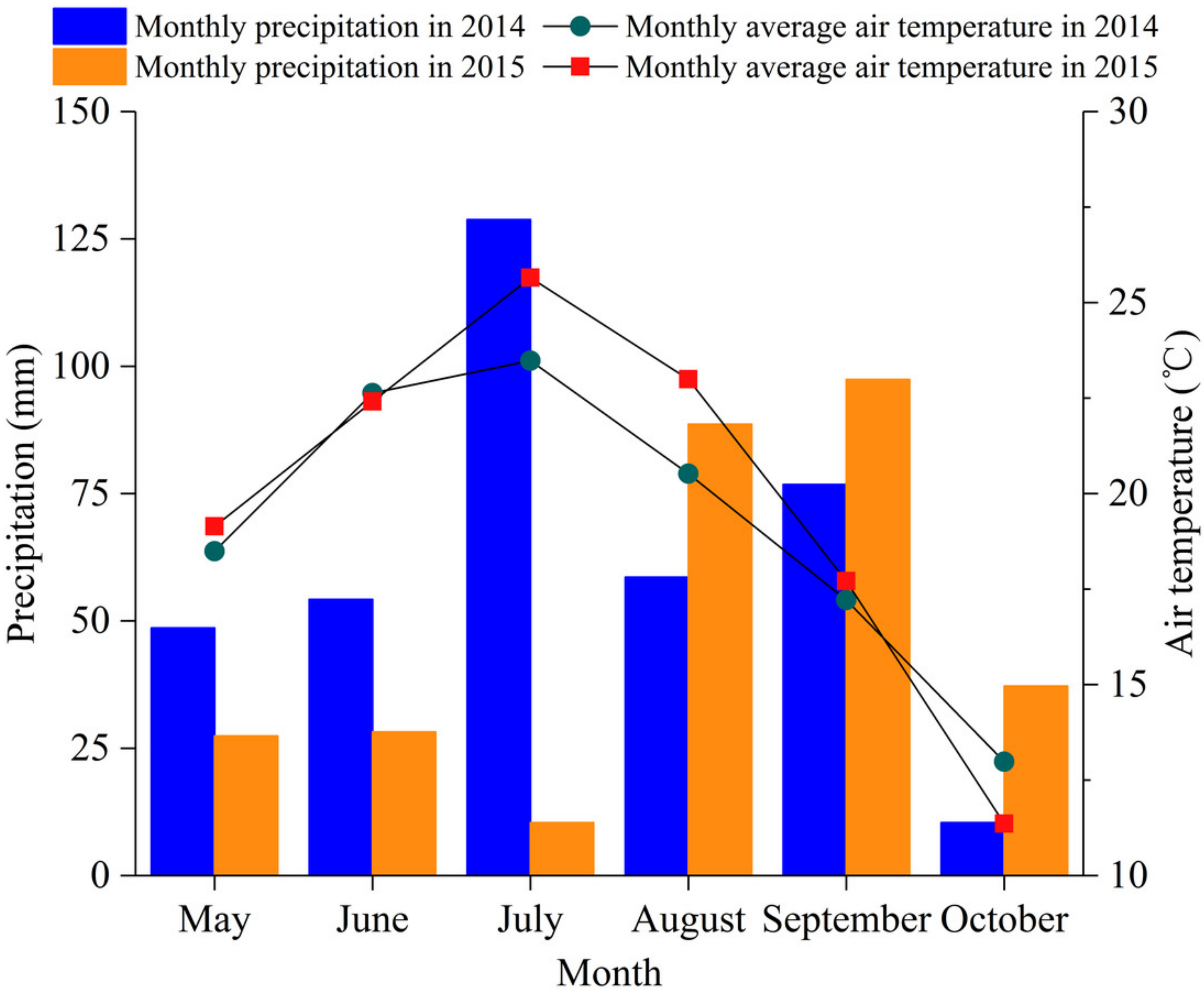
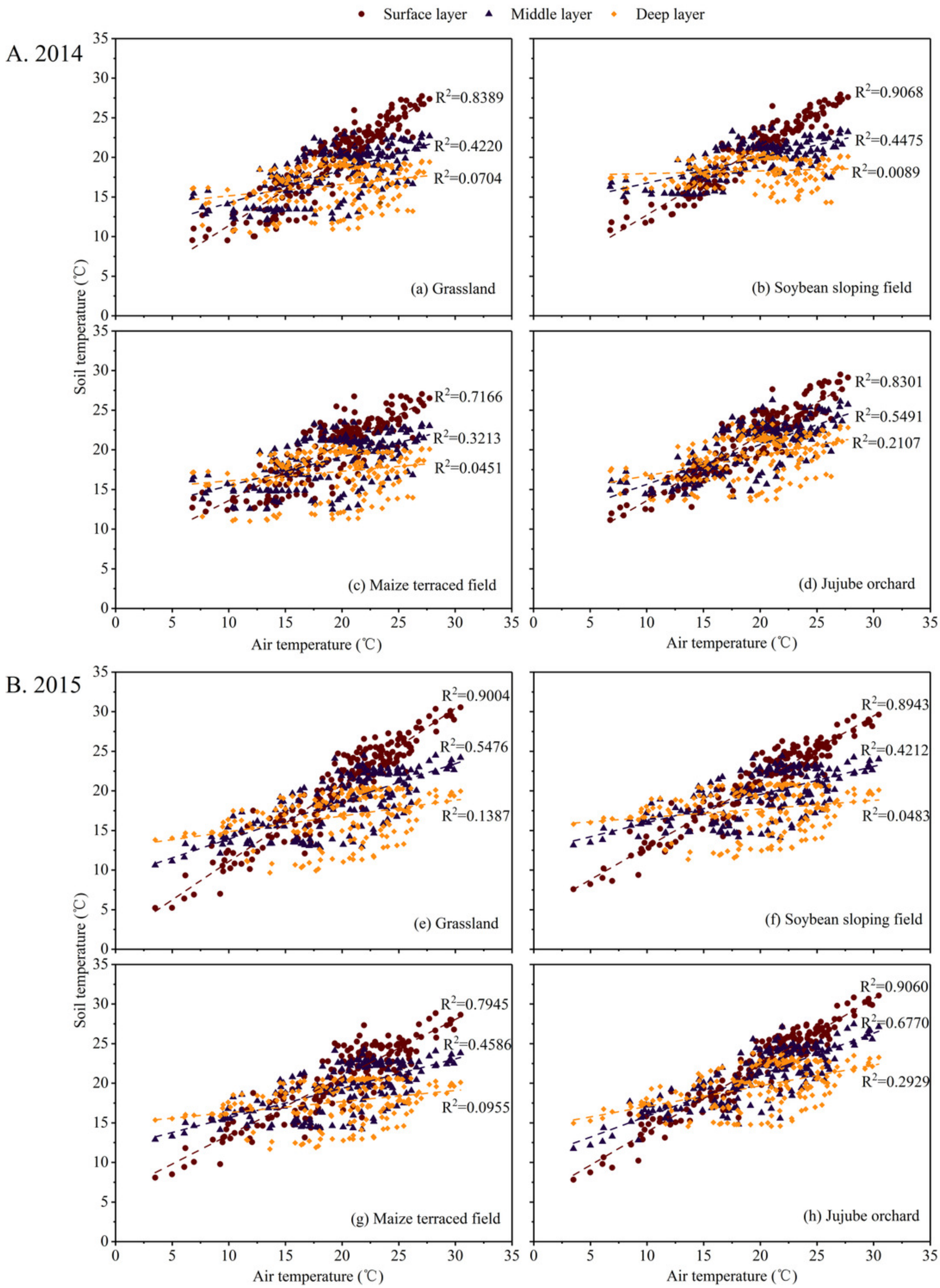


Figure 2

Correlation between soil temperature at different depths and air temperature.



Surface layer
Middle layer
Deep layer
A. 2014
B. 2015
Soil temperature (℃)
Air temperature (℃)
R²=0.8389
R²=0.4220
R²=0.0704
(a) Grassland
R²=0.9068
R²=0.4475
R²=0.0089
(b) Soybean sloping field
R²=0.7166
R²=0.3213
R²=0.0451
(c) Maize terraced field
R²=0.8301
R²=0.5491
R²=0.2107
(d) Jujube orchard
R²=0.9004
R²=0.5476
R²=0.1387
(e) Grassland
R²=0.8943
R²=0.4212
R²=0.0483
(f) Soybean sloping field
R²=0.7945
R²=0.4586
R²=0.0955
(g) Maize terraced field
R²=0.9060
R²=0.6770
R²=0.2929
(h) Jujube orchard

Table 1(on next page)

Tables

Table 1 Correlation analysis between soil moisture in 0-60 cm soil layer and main environmental factors under experimental sloping land use types.

Year	Sloping land use type	Environmental factor					
		x_1	x_2	x_3	x_4	x_5	x_6
2014	Grassland	-0.422**	0.511**	-0.151	-0.222**	0.217**	-0.322**
	Soybean sloping field	-0.294**	0.324**	-0.031	-0.174*	0.15	-0.305**
	Maize terraced field	-0.242**	0.402**	-0.035	-0.265**	0.145	-0.224**
	Jujube orchard	-0.289**	0.361**	-0.003	-0.157	0.172*	-0.378**
2015	Grassland	-0.698**	0.227**	-0.334**	-0.111	0.003	-0.758**
	Soybean sloping field	-0.747**	0.246**	-0.384**	-0.058	0.025	-0.779**
	Maize terraced field	-0.152	0.282**	-0.131	0.375**	0.198**	-0.431**
	Jujube orchard	-0.411**	0.027	-0.075	0.245**	0.025	-0.520**

Note: '*' represents significance at 0.05 level, '**' represents significance at 0.01 level, similarly hereinafter.

Table 2 Path analysis of influencing factors on soil moisture in 0-60 cm soil layer under different sloping land use types in the 2014 growing season.

Sloping land use type	Environmental factor	Simple correlation coefficient with *y*	Direct path coefficient	Indirect path coefficient					
				x_1	x_2	x_3	x_4	x_6	Total
Grassland	x_2	0.511	0.716			-0.603		-0.139	-0.205
	x_3	-0.151	0.429		-0.603			0.384	-0.581
	x_6	-0.322	-0.388		-0.139	0.384			0.065
Soybean sloping field	x_2	0.324	0.492			-0.593		-0.207	-0.167
	x_3	-0.031	0.411		-0.593			0.406	-0.442
	x_6	-0.305	-0.370		-0.207	0.406			0.065
Maize terraced field	x_1	-0.242	-0.266		-0.476	0.591	-0.014		0.024
	x_2	0.402	0.491	-0.476		-0.603	-0.249		-0.089
	x_3	-0.035	0.432	0.591	-0.603		0.075		-0.467
	x_4	-0.265	-0.179	-0.014	-0.249	0.075			-0.086
Jujube orchard	x_1	-0.289	0.801		-0.477	0.597		0.899	-1.090
	x_2	0.361	0.742	-0.477		-0.605		-0.234	-0.382
	x_3	-0.003	0.425	0.597	-0.605			0.415	-0.428
	x_6	-0.378	-1.101	0.899	-0.234	0.415			0.723

Table 3 Path analysis of influencing factors on soil moisture in 0-60 cm soil layer under different sloping land use types in the 2015 growing season.

Sloping land use type	Environmental factor	Simple correlation coefficient with y	Direct path coefficient	Indirect path coefficient				
				x_1	x_2	x_4	x_6	Total
Grassland	x_2	0.227	0.130				-0.131	0.097
	x_6	-0.758	-0.741		-0.131			-0.017
Soybean sloping field	x_2	0.246	0.173				-0.096	0.073
	x_6	-0.779	-0.762		-0.096			-0.017
Maize terraced field	x_1	-0.152	0.576			-0.064	0.830	-0.729
	x_4	0.375	0.225	-0.064			-0.217	0.150
	x_6	-0.431	-0.861	0.830		-0.217		0.429
Jujube orchard	x_1	-0.411	0.549		-0.403	-0.065	0.913	-0.960
	x_2	0.027	0.193	-0.403		-0.505	-0.177	-0.166
	x_4	0.245	0.223	-0.065	-0.505		-0.163	0.022
	x_6	-0.520	-0.950	0.913	-0.177	-0.163		0.431

Table 4 Stepwise regression analysis of environmental factors affecting soil moisture.

Year	Sloping land use type	Multiple regression equation	n	F	p	Total variance explained /%
2014	Grassland	$y=11.997+0.086x_2+0.012x_3-0.234x_6$	157	37.834	0.000**	x_2 (46.68), x_3 (28.00), x_6 (25.32)
	Soybean sloping field	$y=13.187+0.059x_2+0.011x_3-0.256x_6$	156	17.774	0.000**	x_2 (38.61), x_3 (32.30), x_6 (29.09)
	Maize terraced field	$y=14.117-0.069x_1+0.033x_2+0.007x_3-0.629x_4$	157	15.823	0.000**	x_1 (19.45), x_2 (35.92), x_3 (31.56), x_4 (13.07)
	Jujube orchard	$y=9.989+0.392x_1+0.095x_2+0.012x_3-0.724x_6$	150	29.740	0.001**	x_1 (26.09), x_2 (24.18), x_3 (13.86), x_6 (35.87)
2015	Grassland	$y=17.222+0.014x_2-0.393x_6$	184	130.999	0.000**	x_2 (14.89), x_6 (85.11)
	Soybean sloping field	$y=17.946+0.019x_2-0.469x_6$	184	158.103	0.000**	x_2 (18.49), x_6 (81.51)
	Maize terraced field	$y=14.698+0.119x_1+0.550x_4-0.268x_6$	184	34.696	0.000**	x_1 (34.67), x_4 (13.56), x_6 (51.78)
	Jujube orchard	$y=10.964+0.156x_1+0.014x_2+0.749x_4-0.361x_6$	184	21.896	0.000**	x_1 (28.66), x_2 (10.06), x_4 (11.65), x_6 (49.63)

Table 5 Grey relational grade between different environmental factors and soil temperature.

Year	Sloping land use type	Soil layer (cm)	Environmental factor					
			Air temperature	Air humidity	Solar radiation	Wind speed	Precipitation	Soil moisture
2014	Grassland	0-20	0.8417	0.6916	0.7977	0.6218	0.5233	0.7327
		20-60	0.8395	0.6342	0.7889	0.5349	0.6713	0.7081
		60-100	0.6819	0.8356	0.6673	0.7302	0.5679	0.6826
	Soybean sloping field	0-20	0.8439	0.7150	0.8107	0.6249	0.5317	0.7450
		20-60	0.8394	0.6479	0.7742	0.5482	0.6763	0.7040
		60-100	0.6530	0.8344	0.6816	0.7258	0.6305	0.6725
	Maize terraced field	0-20	0.8444	0.6750	0.7952	0.6254	0.5342	0.7132
		20-60	0.8388	0.7083	0.7847	0.5257	0.6742	0.6566
		60-100	0.6670	0.8352	0.6857	0.6938	0.6102	0.7293
	Jujube orchard	0-20	0.8398	0.6864	0.8006	0.6098	0.5605	0.7433
		20-60	0.8318	0.6888	0.6989	0.5522	0.6177	0.7884
		60-100	0.8319	0.7644	0.7069	0.6787	0.5712	0.6419
2015	Grassland	0-20	0.8379	0.6796	0.6992	0.6639	0.6091	0.7271
		20-60	0.8284	0.5574	0.6736	0.6849	0.6608	0.7000
		60-100	0.7002	0.6768	0.5840	0.8235	0.5968	0.7015
	Soybean sloping field	0-20	0.8446	0.6879	0.7102	0.6757	0.6012	0.7411
		20-60	0.8282	0.5711	0.6820	0.6853	0.6452	0.7003
		60-100	0.6562	0.7032	0.5656	0.8268	0.5910	0.6973
	Maize terraced field	0-20	0.8439	0.6753	0.7202	0.6824	0.6060	0.7039
		20-60	0.8301	0.6453	0.6836	0.6970	0.6711	0.7010
		60-100	0.6977	0.6745	0.5834	0.8248	0.6542	0.7098
	Jujube orchard	0-20	0.8320	0.6973	0.7192	0.6780	0.6482	0.7389
		20-60	0.8275	0.6180	0.7111	0.6841	0.6824	0.7125
		60-100	0.8240	0.6716	0.6094	0.6776	0.6186	0.7022