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THEMATIC ISSUE

Temporal stability of soil water storage and its influencing factors on a forestland hillslope during the rainy season in China's Loess Plateau

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Abstract Large-scale vegetation restoration in China's Loess Plateau has been initiated by the central government to control soil and water losses since 1999. Knowledge of the spatio-temporal distribution of soil water storage (SWS) is critical to fully understand hydrological and ecological processes. This study analysed the temporal stability of the SWS pattern during the rainy season on a hillslope covered with Chinese pine (*Pinus tabulaeformis* Carr.). The soil water content in eight soil layers was obtained at 21 locations during the rainy season in 2014 and 2015. The results showed that the SWS at the 21 locations followed a normal distribution, which indicated moderate variability with the coefficients of variation ranging from 14 to 33%. The mean SWS was lowest in the middle slope. The spatial pattern of SWS displayed strong temporal stability, and the Spearman correlation coefficient ranged from 0.42 to 0.99 ($p < 0.05$). There were significant differences in the temporal stability of SWS among different soil layers ($p < 0.01$). The spatial patterns of SWS distribution showed small differences in different periods. The best representative locations of SWS were found at different soil depths. The maximum RMSE and MAE at 0–1.6 m soil depth for the rainy season were 4.27 and 3.54 mm, respectively. The best representative locations determined during a short period (13 days) can be used to estimate the mean SWS well for the same rainy season, but not for the next rainy season. Samples of SWS collected over a fortnight during the rainy season were able to capture the spatial patterns of soil moisture. Roots were the main factor affecting the temporal stability of SWS. Rainfall increased the temporal stability of the soil water distribution pattern. In conclusion, the SWS during the rainy season had a strong temporal stability on the forestland hillslope.

Keywords Soil water storage · Forestland · Rainy season · Root · Wangmaogou watershed

Introduction

The Loess Plateau is situated in a large arid and semi-arid region of China, and water is an important factor affecting the ecological diversity and socio-economic development of the region. In recent years, many huge projects have been implemented in the Loess Plateau, with the aim of changing the landscapes, water circulation, and many other environmental features of the region (Chen et al. 2010; Li et al. 2014a). The Loess Plateau is a hot site for various fields of research, because the area is an important part of the Silk Road, i.e. the international cooperation strategy proposed by China (Li 2016). Many studies have been conducted in the arid and semi-arid areas of China, investigating features such as water management and protection (Qian and Li 2011; Qian et al. 2012; Li et al. 2013a, b, 2016a, b; Xu et al. 2015), soil and water pollution (Li et al. 2014b, c; Wu et al. 2014), and human health risk assessment (Li and Qian 2011; Wu and Sun 2016).

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Soil water storage (SWS) is one of the most important influencing factors of surface and sub-surface hydrological processes in loess areas at different temporal and spatial scales, including infiltration, runoff, soil erosion, solute transport, vegetation dynamics, and evapotranspiration (Entin et al. 2000; Heathman et al. 2009; Hou et al. 2013, 2015; Chaney et al. 2015; Gao et al. 2015). The determination of SWS and its spatio-temporal distribution is essential to fully understand hydrological and ecological processes (Beven 2001; Western et al. 2002; Biswas and Si 2011). In semi-arid areas, it is one of the most important limiting factors for vegetation restoration and crop productivity (Hu et al. 2009; de Souza et al. 2011; Gao et al. 2015; Xu et al. 2017). Soil moisture displays substantial variability at different spatial and temporal scales and is mainly controlled by topography, vegetation, solar radiation, soil properties, meteorological forcing, and the depth to the water table, as well as the interaction of these parameters (Western and Blöschl 1999; Hu et al. 2010; Wang et al. 2012; 2015). However, the soil water pattern has a temporal stability. Vachaud et al. (1985) first reported that the spatial patterns of soil water changed slightly with time. This phenomenon has been called the temporal stability of soil moisture pattern (Vachaud et al. 1985; Kachanoski and De Jong 1988; Schneider et al. 2008; Jia et al. 2013). The temporal stability concept can be used to determine representative locations of the mean soil moisture for a particular area (Vanderlinden et al. 2012; Penna et al. 2013), and it can reduce the time and labour costs to assess the status of soil moisture in a particular area (Jia et al. 2013).

Temporal stability is useful when analysing the spatio-temporal patterns of SWS (Brocca et al. 2010; Martinez et al. 2013). Various studies have used the concept of time stability to analyse the temporal dynamics of SWS under different conditions including different regions, sampling times, soil depths, and land uses (Vachaud et al. 1985; Kachanoski and de Jong 1988; Martínez-Fernández and Ceballos 2003; Jacobs et al. 2004; Cosh et al. 2008; Brocca et al. 2010; Biswas and Si 2011). The "Grain to Green" large-scale revegetation programme in China's Loess Plateau was implemented in 1999 to control soil and water losses. The programme has converted 16,000 km^2 of rain-fed cropland to planted vegetation, resulting in a 25% increase in vegetation cover over the last decade (Feng et al. 2016). However, several forest tree varieties, with a high water consumption rate, can cause soils to dry up, resulting in ecological degradation in arid and semi-arid regions (Li 2001; Yuan and Xu 2004; Yaseef et al. 2009; Cao et al. 2011; Chen et al. 2010; Jian et al. 2015). Hence, a determination of the temporal stability of the SWS pattern and the factors that influence it are particularly important to understand soil moisture changes on slopes. However, few studies have researched the temporal stability of SWS patterns in forestland hillslopes. There have been few studies of the minimum monitoring period or monitoring times that can be used to analyse the temporal stability of soil water patterns. Furthermore, there have been no studies on the effects of roots on the temporal stability of SWS. Information on the characteristics of the time stability of SWS at different soil depths after rainfall is also scarce.

In this study, the temporal stability of SWS during the rainy season on a hillslope with Chinese pine (*Pinus tabulaeformis* Carr.) was analysed. The effect of monitoring times on the best representative location and the accuracy of predictions was evaluated. The relationships between the temporal stability of SWS and selected environmental variables were also studied. The main objectives of the study were to: (1) analyse the temporal stability of SWS at different soil depths during the rainy season; (2) evaluate the accuracy of prediction of the representative locations calculated based on different time periods; and (3) determine the main factors affecting the temporal stability of SWS.

Materials and methods

Soil sampling and analysis

The study was conducted on a semi-arid hillslope, with a mean gradient of 28° located in the Wangmaogou watershed (110°20′26″–110°22′46″E, 37°34′13″–37°36′03″N), Suide County, Shaanxi Province, China (Fig. 1). The details of the study area were reported by Gao et al. (2012). A total of 21 polycarbonate tubes (2 m/Φ44 mm) were installed along a hillslope covered with Chinese pine (*P. tabulaeformis* Carr.). The whole hillslope area was approximately 3200 m^2, and the aspect was north-east. The mean spacing of Chinese pine was 1.95 m, and the forest age was 29 years. The elevation ranged from 964 to 997 m. Soil samples with roots were taken from each location at intervals of 0.2 m. The soil depth was 0–1.6 m. The root density, soil particle size distribution, soil organic carbon (SOC) content, and volumetric soil water content (SWC, %, v/v) were determined using a plant root measurement and analysis system (WinRHIZO, Regent Instruments Inc., Québec, Canada), a Mastersizer 2000 particle size analyser (Malvern Instruments, Malvern, UK), a multi N/C 3100 analyser (Analytik Jena AG, Jena, Germany), and a time domain reflectometry sensor (TRIME-PICO IPH, IMKO GmbH, Ettlingen, Germany), respectively. The soil particles were defined as follows: clay (<0.002 mm), silt (0.002–0.05 mm), and sand (0.05–2.0 mm). SWC was measured approximately every day (without rainfall) from 19 July to 3 September 2014 and from 1–31 August 2015. The distribution of rainfall during the rainy season is shown in Fig. 2.

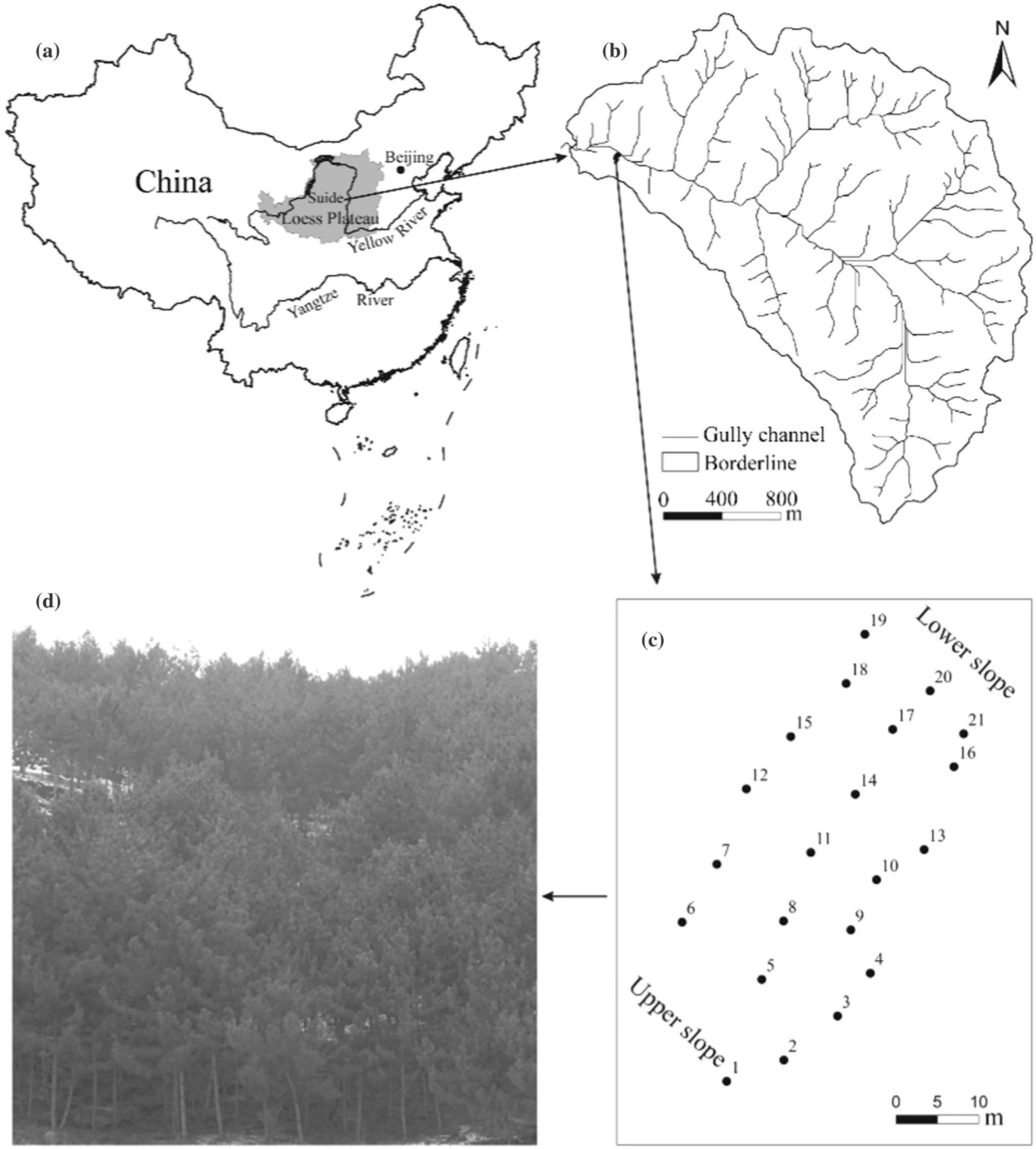


Fig. 1 Location of the study area (**a**, **b**) and 21 polycarbonate tubes across the hillslope (**c**, **d**)

Data analysis

When the SWC is collected on more than 13 occasions within 1 year, it can be used to analyse the spatial pattern of soil moisture (Martínez-Fernández and Ceballos 2005). The SWS data were collected from 19 July to 2 August 2014 and used to analyse the representative locations of mean SWS during the rainy season. In addition, the SWS data from 19 July to 3 September 2014 and from 1–31 August 2015 were used to assess the estimation accuracy of mean SWS using representative locations. The last two of the three periods mentioned represent the rainy season in

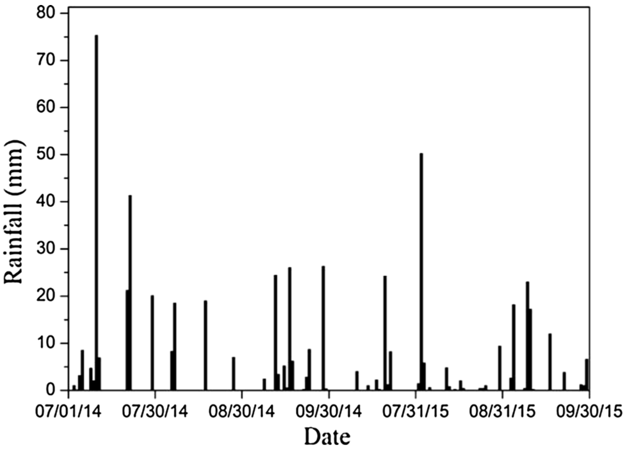


Fig. 2 Rainfall distribution during July–September in 2014 and 2015

2014 and the following rainy season in 2015, respectively. A Spearman's rank correlation test and relative difference analysis were used to evaluate the temporal stability in this study (Vachaud et al. 1985; Douaik 2006).

A mean relative difference (MRD) close to zero indicates representative locations for the spatial mean SWS. Temporal stability might be assumed if the standard deviation of relative difference (SDRD) is sufficiently small at all locations with respect to the spatial variation of the MRD (Douaik 2006). The locations with an MRD closest to zero and with the associated SDRD less than the mean SDRD were considered temporally stable locations (Cosh et al. 2008; Martinez et al. 2013; Xu et al. 2015).

Results

Descriptive SWS statistics

The descriptive SWS statistics for the different periods are shown in Table 1. The rainfall resulted in a higher mean SWS in period 1 (19 July to 2 August 2014) than in period 2 (19 July to 3 September 2014) and period 3 (1–31 August 2015). The SE values of SWS in periods 2 and 3 were lower than in period 1. The SE at each depth was relatively small and showed an upward trend with the increase in soil depth. The coefficients of variation (CV) in the 0–0.6, 0–1.0, and 0–1.6 m soil depths ranged from 14 to 33%. According to Nielsen and Bouma (1985), the variability of SWS in the three soil depths is subject to moderate and variable increases with increasing depth. Moreover, there were significant differences in SWS among the 21 locations for the three periods ($p < 0.01$). The spatial distribution of SWS followed a normal distribution ($p > 0.05$).

The temporal stability of SWS using the Spearman correlation test

The Spearman rank-order correlation is a nonparametric (free distribution) test that can indicate the strength and the direction of the same variable observed on different dates (Douaik 2006). The *rs* values for each soil depth for periods 1, 2, and 3 were analysed (Table 2; Fig. 3). The *rs* values for period 1 and the entire monitoring period ranged from 0.70–0.99 to 0.42–0.99, respectively. The lowest mean *rs* values for each soil depth of period 1 and the whole experimental period were 0.81, 0.88, 0.84 and 0.65, 0.59, 0.68, respectively. The *rs* values had a high level of statistical significance ($p < 0.01$), which indicates that the spatial distribution of SWS at various depths had a strong temporal stability. The mean *rs* values generally followed the order: 0–0.6 < 0–1.0 < 0–1.6 m. The SWS spatial distribution at a depth of 0–1.6 m depth was more stable than at the other two soil depths ($p < 0.01$). The correlation between the periods of 19 July to 3 September 2014 and 1–31 August 2015 for corresponding soil depths was not significantly different ($p > 0.05$). However, the *rs* values of the period of 19 July to 2 August 2014 were significantly larger than those of the periods of 19 July to 3 September 2014 and 1–31 August 2015 ($p < 0.05$).

Table 1 Soil water storage (SWS) summary statistics for the three periods

Dates	Depths (m)	Mean (mm)	Min. (mm)	Max. (mm)	SE (mm)	CV (%)
July 19 2014–August 02 2014	0–0.6	74.66	28.64	114.76	1.07	24
	0–1.0	119.98	66.64	187.36	1.48	20
Period 1	0–1.6	189.27	127.82	300.06	2.09	18
July 19 2014–September 03 2014	0–0.6	61.28	12.36	114.76	0.70	33
	0–1.0	105.17	50.4	187.36	0.93	26
Period 2	0–1.6	174.56	109.28	300.06	1.28	21
August 01 2015–August 31 2015	0–0.6	55.23	20.14	124.96	0.70	28
	0–1.0	93.79	55.58	162.48	0.78	18
Period 3	0–1.6	153.75	97.52	226.12	0.97	14

Min. minimum value, *Max.* maximum value, *SE* standard error, *CV* coefficient of variation

Table 2 Spearman correlation coefficients for the soil water storage (SWS) on different sampling dates from 19 July to 2 August 2014

Dates	0–0.6 m			0–1.0 m			0–1.6 m		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
July 19 2014	0.81	0.97	0.71	0.88	0.95	0.83	0.88	0.95	0.83
July 20 2014	0.82	0.97	0.70	0.91	0.96	0.82	0.91	0.95	0.84
July 22 2014	0.83	0.98	0.70	0.90	0.98	0.82	0.88	0.97	0.80
July 23 2014	0.83	0.98	0.73	0.92	0.98	0.87	0.91	0.97	0.82
July 24 2014	0.87	0.93	0.71	0.94	0.97	0.83	0.93	0.97	0.83
July 25 2014	0.88	0.95	0.80	0.95	0.99	0.90	0.94	0.97	0.89
July 26 2014	0.88	0.97	0.77	0.95	0.99	0.89	0.93	0.98	0.86
July 27 2014	0.91	0.97	0.83	0.95	0.98	0.91	0.94	0.97	0.89
July 28 2014	0.90	0.97	0.85	0.94	0.98	0.87	0.93	0.97	0.85
July 30 2014	0.89	0.96	0.73	0.94	0.97	0.86	0.94	0.98	0.88
July 31 2014	0.90	0.97	0.80	0.95	0.97	0.88	0.94	0.98	0.86
August 01 2014	0.91	0.97	0.80	0.94	0.97	0.85	0.94	0.98	0.87
August 02 2014	0.88	0.97	0.76	0.93	0.97	0.86	0.90	0.96	0.80

Correlations are all significant at $p < 0.01$ (two-tailed)

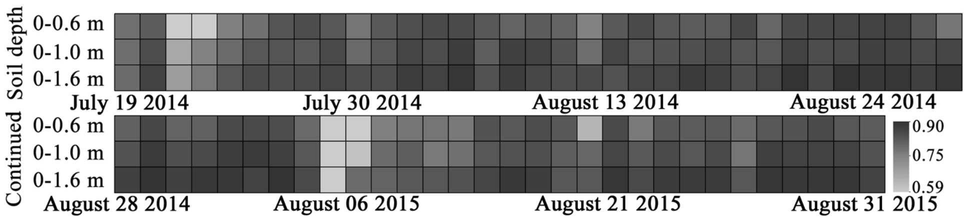


Fig. 3 Spearman correlation coefficients for the soil water storage (SWS) on different sampling dates. Correlations are significant at $p < 0.01$ or $p < 0.05$

Representative locations of SWS

A relative difference analysis was used to determine the representative locations of the mean SWS of the whole hillslope. The MRD of SWS and the best representative locations at various layers are shown in Fig. 4. The MRD ranges at the three depths for periods 1, 2, and 3 were −0.42 to 0.45, −0.29 to 0.49, and −0.25 to 0.52; −0.50 to 0.65, −0.31 to 0.63, and −−0.24 to 0.60; and −0.42 to 0.40, −0.26 to 0.24, and −0.24 to 0.23, respectively. The range of the MRD decreased with increasing soil depth. The range of the MRD was smallest at a depth of 0–1.6 m. This shows that the difference in SWS decreased with increasing soil depth. The mean SDRD at the three depths for periods 1, 2, and 3 were 0.06, 0.04, and 0.03; 0.09, 0.06, and 0.04; and 0.07, 0.05, and 0.03, respectively. The mean SDRD decreased as soil depth increased, which was consistent with the CV values. The best representative locations were not the same at different soil depths. The best representative locations of periods 1, 2, and 3 were locations 18, 14, and 18; locations 12, 5, and 18; and locations 10, 5, and 5, respectively. Locations 18, 14, and 18 also represented the mean SWS of the corresponding soil depth for the period 2, but not for the period 3. Therefore, the best representative locations of SWS existed difference for different depths and periods.

Estimation of mean SWS using the representative locations

The estimated accuracy of mean SWS using the best representative locations of SWS for the different periods is shown in Fig. 5. A linear function was fitted between the mean SWS and the predicted values based on the best representative locations. All fitting equations were significant ($p < 0.01$). The regression coefficient R^2 for the relation between mean SWS and the predicted values were all >0.92. For period 2, the estimated accuracies of the best representative locations determined for periods 1 and 2 at depths of 0–0.6 and 0–1.0 m were slightly different. The RMSE and MAE values were the same due to their having the same representative location at a depth of 0–1.6 m. The differences in the RMSE values and MAE values were no more than 0.09 and 0.37 mm, respectively. For period 3, the predictive accuracies of the representative locations determined for periods 1 and 3 at depths of 0–0.6 and 0–1.6 m were relatively large. The differences in the RMSE and MAE for 0–1.6 m were 12.14 and 12.62 mm,

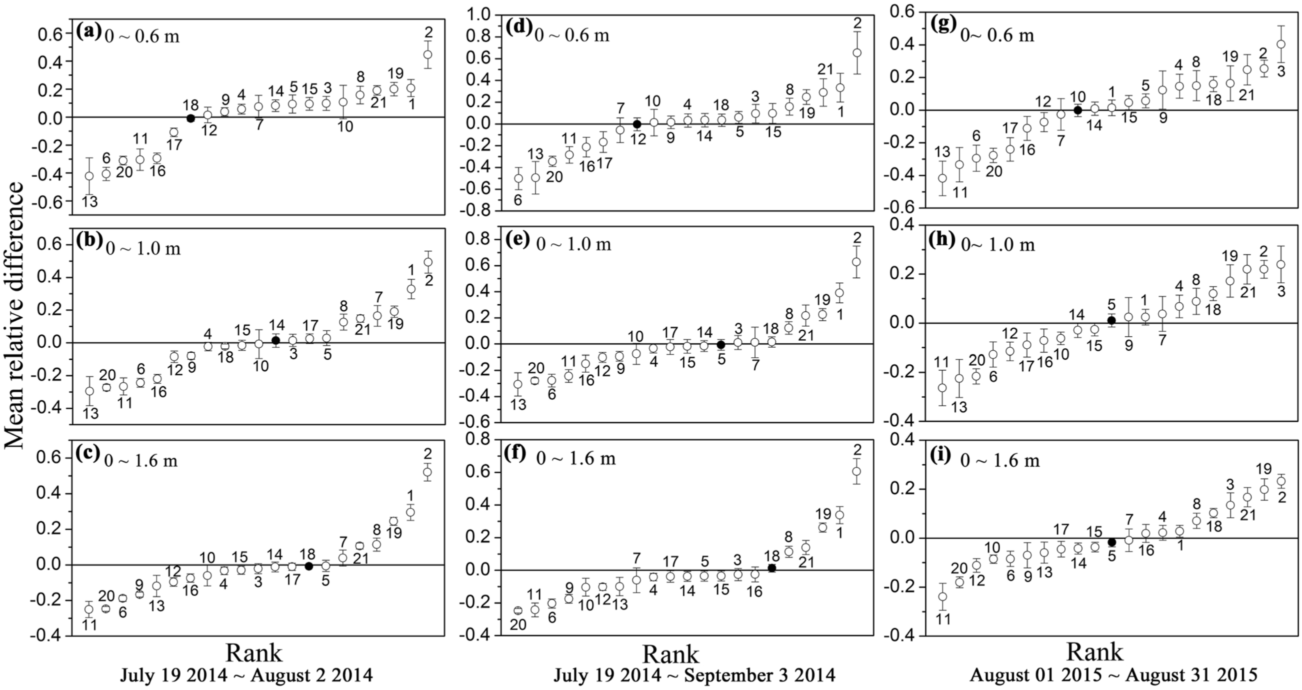


Fig. 4 Plots of the mean relative difference of soil water storage (SWS) at each depth. *Vertical bars* correspond to ± standard deviation of the relative difference. The best representative locations are marked in *black*

respectively. Small values of the RMSE and MAE represent small differences and a high predictive accuracy between predicted and observed values. The percentage RMSE at 0–0.6, 0–1.0, and 0–1.6 m soil depths for periods 2 and 3 were 6, 4, and 2% and 4, 3, and 3%, respectively. The percentage MAE was 4, 3, and 2% and 3, 2, and 2%, respectively. The predictive accuracies were consistent with those of other studies (Cosh et al. 2008; Brocca et al. 2010; Gao and Shao 2012; Liu and Shao 2014).

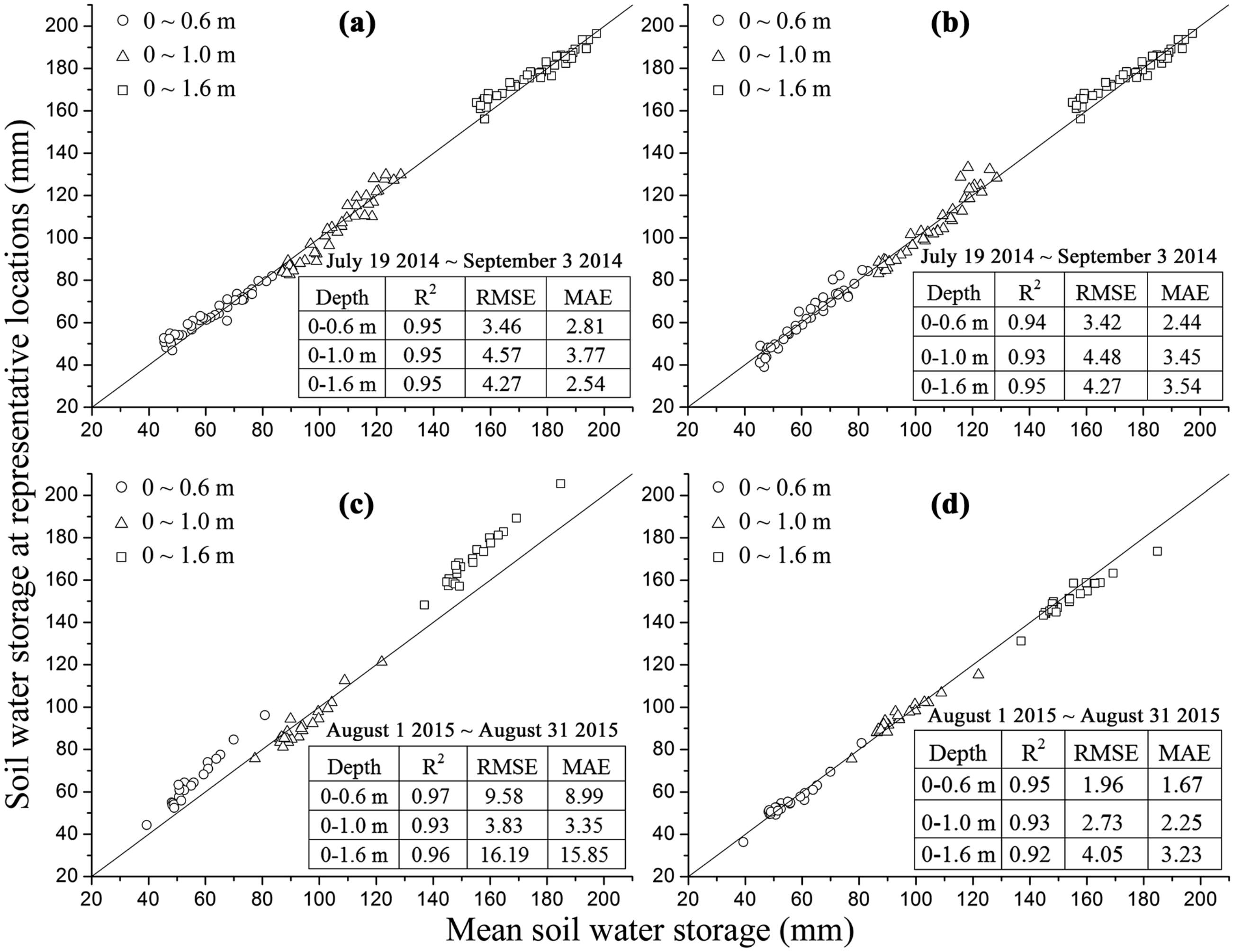
Spatial distribution of SWS

Considering the edge effect and slope position, locations 1, 2, and 9 were not used to analyse the SWS distribution along the hillslope. Table 3 gives the mean SWS and some influencing factors at the 21 locations. Locations 3–8 (upper slope), 10–15 (middle slope), and 16–21 (lower slope) represent different slope positions. The mean SWS of the middle slope was lowest, but the total root length was largest. The mean SWS in the upper slope was slightly lower than in the lower slope. The mean SOC and silt content decreased with decreasing altitude, whereas the other soil particle size category displayed the opposite trend. The relationship between MRD, SDRD, and the related factors are indicated in Table 4. MRD was significantly negatively correlated with sand content and significantly positively correlated with silt content. There were no significant correlations with elevation, root density, and SOC. SDRD was significantly positively correlated with root density, but was not significantly affected by elevation and SOC.

Discussion

Temporal stability of SWS pattern

The SWS was significantly different between the periods of 19 July to 2 August 2014 and 7 August to 3 September 2014 and 1–31 August 2015 ($p < 0.01$). However, the SWS temporal stability at corresponding soil depths was not significantly affected by the rainfall ($p > 0.05$). The mean range of SDRD, CV, and MRD revealed that the difference in SWS decreased as the number of soil layers increased. Datasets with higher kurtosis had fatter tails or more extreme values, and those with lower kurtosis have fatter middles or fewer extreme values. The kurtosis values of SWS at soil depths of 0–0.6, 0–1.0, and 0–1.6 m in the rainy season were −0.415, 0.256, and 1.553 ($n = 840$), respectively. This indicates that the SWC was more concentrated at deep soil depths. The soil water at a depth of 0–1.6 m had the greatest temporal stability. This result was consistent with those of other studies, where the temporal stability has been reported to be higher in the deep soil layers than in the shallow layers (Hu et al. 2010; Liu and Shao 2014). This was because the soil water in deep soil layers was less affected by environmental factors. The



(a) July 19 2014 ~ September 3 2014

Depth	R^2	RMSE	MAE
0-0.6 m	0.95	3.46	2.81
0-1.0 m	0.95	4.57	3.77
0-1.6 m	0.95	4.27	2.54

(b) July 19 2014 ~ September 3 2014

Depth	R^2	RMSE	MAE
0-0.6 m	0.94	3.42	2.44
0-1.0 m	0.93	4.48	3.45
0-1.6 m	0.95	4.27	3.54

(c) August 1 2015 ~ August 31 2015

Depth	R^2	RMSE	MAE
0-0.6 m	0.97	9.58	8.99
0-1.0 m	0.93	3.83	3.35
0-1.6 m	0.96	16.19	15.85

(d) August 1 2015 ~ August 31 2015

Depth	R^2	RMSE	MAE
0-0.6 m	0.95	1.96	1.67
0-1.0 m	0.93	2.73	2.25
0-1.6 m	0.92	4.05	3.23

Fig. 5 Estimated accuracy of the mean soil water storage (SWS) during the rainy season using the best representative locations of SWS. The best representative locations were calculated from 19 July to 2 August 2014 (**a**, **c**), from 19 July to 3 September 2014 (**b**) and from 1–31 August 2015 (**d**)

Table 3 The relationship between mean soil water storage (SWS) and influencing factors of different slope positions over the whole study period

Depth (m)	Locations	Soil water storage (mm)	SOC (g/kg)	Sand (%)	Silt (%)	Clay (%)	total root length (cm)
0–0.6	3–8	59.44	14.54	31.37	68.43	0.20	712.53
	10–15	52.59	13.70	32.69	67.09	0.22	1031.73
	16–21	57.61	9.67	37.20	62.56	0.25	831.90
0–1.0	3–8	101.14	13.83	31.33	68.48	0.19	917.20
	10–15	88.57	13.30	32.50	67.30	0.21	1225.95
	16–21	101.57	10.06	38.28	61.49	0.24	1033.75
0–1.6	3–8	163.55	13.56	31.49	68.33	0.19	1146.33
	10–15	150.25	13.00	33.01	66.79	0.20	1542.51
	16–21	171.16	9.55	38.96	60.81	0.22	1259.64

temporal stability of the SWS pattern in period 1 was significantly larger than in periods 2 and 3 ($p < 0.05$). This was because the rainfall on 20, 21, and 29 July resulted in a higher mean SWS in period 1 than those in periods 2 and 3. The soil moisture patterns were stronger during the wet period than during the dry period (Williams et al. 2009;

Table 4 Pearson correlations between the mean relative difference (MRD), standard deviation of relative difference (SDRD), and some related factors

SWC	Period	Elevation (m)	Root density (cm/cm^3)	Clay (%)	Silt (%)	Sand (%)	SOC (g/kg)
MRD	July 19 2014–September 03 2014	0.20	−0.22	0.22	0.32*	−0.32*	0.07
	August 01 2015–August 31 2015	0.02	−0.22	0.21	0.26*	−0.26*	0.04
SDRD	July 19 2014–September 03 2014	0.25	0.26*	0.15	0.29*	−0.29*	0.19
	August 01 2015–August 31 2015	0.02	0.33**	0.14	0.04	−0.04	0.17

* Correlation is significant at the 0.05 level (two-tailed); ** correlation is significant at the 0.01 level (two-tailed)

Zhao et al. 2010; Penna et al. 2013). However, the depths of soil moisture studied by Williams et al. (2009), Zhao et al. (2010) and Penna et al. (2013) were less than 105 cm and the soil layers were not at a fine scale.

The accuracy of prediction of the representative locations

The best representative locations at different depths changed over time due to the strong impact of climatic, biological, and hydrological factors. The only differences were the level of errors associated with the mean SWS, although the RMSE and MAE values were acceptable. Rainfall increased the temporal persistence of the soil water distribution pattern. The estimated accuracies of the representative locations calculated for periods 1 and 2 were high. The best representative locations calculated from 19 July to 2 August 2014 could be used to analyse the mean SWS during the rainy season. This was because the spatial pattern of SWS indicated the temporal persistence. The best representative locations could represent the mean SWS during the rainy season. Soil water measured more than 13 times in a year can be used to analyse the spatial pattern of SWS (Martínez-Fernández and Ceballos 2005). However, the estimated accuracies of the representative locations determined from 19 July to 2 August 2014 at depths of 0–0.6 and 0–1.6 m for the period 1–31 August 2015 were larger than 10%. The best representative locations determined during the short study period led to a large error in estimating the mean SWS for the non-current rainy season. The temporal stability of the SWS pattern was influenced by roots, rainfall, and soil particles. However, roots, rainfall, and soil particles changed over a period of time. Therefore, the best representative location at each soil depth was not absolute. The estimated accuracy of mean SWS using the representative locations of SWS for the different periods changed.

The main factors affecting the temporal stability of SWS

The total root length was largest, and the mean SWS was lowest in the middle slope, indicating that roots exerted intense competition and absorbed more water in the middle slope. The occurrence of the highest mean SWS in the lower slope was likely due to the downward migration of soil water. Elevation, roots, and SOC were not significant influencing factors on the rank order of soil moisture. Similar results have also been reported in many previous studies, where SWC was only impacted slightly by elevation (Hébrard et al. 2006; Zhao et al. 2011) and SOC (Schneider et al. 2008; Gao and Shao 2012). The weak influence of elevation on soil moisture could be due to the relatively small differences in elevation. Gao and Shao (2012) also reported that there was no significant correlation between SOC and MRD, which disagreed with other studies (e.g. Biswas and Si 2011). This could be caused by the scale of the study. The study by Gao and Shao (2012) and the present study were both conducted at slope scale. A significant relationship was observed between MRD and soil texture, which indicated that soil texture was the dominant influencing factor for SWS. The finding that the soil moisture and temporal stability characteristics of SWS had a significant correlation with soil texture agreed with the results of some other studies (Vachaud et al. 1985; Biswas and Si 2011; Manns et al. 2015). In this study, there was a negative correlation between MRD and root density during the rainy season, but the correlation was not significant. A significant positive relationship was observed between SDRD and root density for the two rainy seasons in 2014 and 2015. Soil texture was the dominant influencing factor for MRD, but it was not the dominant influencing factor for SDRD. Root density was the main factor affecting the temporal change of soil water. Therefore, soil texture and root density were the main factors affecting the spatial and temporal pattern of soil water at the hillslope scale during the rainy season. Soil texture was the main factor affecting the representative location of SWS. Root density, which has seldom been studied, was the main factor affecting the temporal stability of the soil water pattern. The soil water pattern in similar regions (soil texture, vegetation, climate, etc.) should be similar. The replenishing of soil water and factors influencing evapotranspiration should study in different regions for describing the spatial patterns of soil water.

Conclusions

The SWS on the hillslope with Chinese pine followed a normal distribution and displayed a moderate level of variability. The mean SWS was lowest in the middle slope. The temporal stability of the soil water pattern during the rainy season was strong at various soil depths. The best representative locations at different depths varied among the different periods. Samples of SWS collected for a fortnight during the rainy season were used to capture the spatial patterns of soil moisture. The best representative location of the current rainy season may lead to a large error in estimating the mean SWS for the non-current rainy season. Soil texture and root density were the main factors affecting the temporal stability of SWS. Consequently, the SWS at different soil depths during the rainy season indicated a strong time stability. Rainfall increased the temporal stability of the SWS pattern.

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