Distribution characteristics of soil moisture of small watershed in gully catchment of the Loess Plateau of China

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Abstract. The temporal dynamics and spatial distribution characteristics of soil moisture in typical slope and gully of Jiulongquangou small watershed were studied in the hilly and gully region of the Loess Plateau of China. The average soil water content of each slope position showed a wave shape with time, and the change trend was: decreasing, increasing, decreasing and increasing. Due to the catchment in the gully, the average soil water content is the largest in the gully, and it changes more with the seasons. The profile soil moisture content characteristics at various slope positions are increased with the soil depth increasing, and the spatial variability of average soil water content in each layer depth is slightly reduced. The spatial variability of soils in different layers under different slopes is slightly fluctuating. However, due to the recharge of interflow and the consumption of roots, there is a large variability in the middle level of the gully and foot of slope, indicating that the interflow in the study area is a factor that must be considered. On the whole, in the small watershed of the gully region of the Loess Plateau, the topographic conditions affect the distribution characteristics of soil moisture, and the gully has obvious water collecting effect.

1. Introduction

Soil moisture is an important variable for understanding and predicting a range of hydrological processes including flooding, erosion, solute transport and land-atmosphere interactions [1-2]. Soil moisture also profoundly affects the ecological environment construction and specific farm planning and management [3-5]. A number of factors such as the interaction of precipitation, soil depth, vegetation and topography lead to high variation of soil moisture in both time and space [6-7].

Spatio-temporal variability of soil moisture effected by precipitation, depth of soil, vegetation and terrain was researched at field scales [8]. Most researchers tend to recognize that the topography and
vegetation are the primary factors which influence the distribution of soil moisture [9-10]. In the Loess Plateau of China there is serious soil and water loss, shortage of water resources and ecological problems. Therefore, research on soil moisture is very important for effective utilization of water and improvement of ecological environment in the Loess Plateau of China.

2. Description of study area and data set

The Jiulongquangou catchment (E: 109°34’, N: 36°19’) is situated on the middle part of the Loess Plateau in Baota district in Yan’an City of Shaanxi province in China. The area of the catchment is 3.98 km² and the altitude is between 1090 and 1200 m. There are significant topographic variations with typical loess hill and gully landforms in the study area. Due to Gully Control and Land Reclamation, the topography and land use types in the gully have been changed. The region has a semiarid continental climate with an average annual precipitation of 573 mm. The 40% of precipitation is mainly concentrated in July and August, while only 3% of precipitation is between December and February when soil and surface water is frozen. The average annual temperature is 9°C with the maximum air temperature of 39.9°C and the minimum air temperature of -22.4°C. In the catchment there are 157-225 frost-free days and 2300-2500 hours of sunshine each year. The soil type is mainly loess, which is developed on the aeolian loess parent material, and the soil thickness is between several meters and several tens of meters. Soil erosion resistance is weak [11].

This study defines six slope positions according to the elevation and location, which are: top of slope, upper slope, middle slope, lower slope, foot of slope and gully (Fig. 1). We repeat 3 times per slope position. The precipitation in the study period is shown in Fig. 2. The soil moisture was measured by TRIME-TDR with different depths from 0 to 100 cm at intervals of 10 cm. The land use type and topographical factors including slope position, slope degree, and elevation were recorded for each site. The sampling time was from May to November, 2016.
3. Results

3.1. Monthly variation of soil moisture content
The data of soil moisture content on top of lope, upper slope, middle slope, lower slope, foot of slope and gully was selected to represent the variation trend of soil moisture from May to December, 2016 (Fig. 3). Due to the plenty of precipitation recharge the soil moisture was abundant from July to August in the catchment during the rainy season. The soil moisture content is maximal with the average value of 15.3% in September. After September the rain reduced and the evaporation played a dominant role, which led to the reduction of the soil moisture content with the value of 12.8% in October. By the weak evaporation and intermittent rain the soil moisture content had a little recovery to 14.7% in the November. From December to March the soil was frozen at the low temperature and the soil moisture was relatively stable. Although the soil moisture content has variations between different time period, the difference is not significant by one-way analysis (p=95%) of variance with 7 months. There is obvious climatic variation in the catchment which doesn’t affect the average soil moisture significantly at the depth of 0 to 100 cm without considering the antecedent precipitation. This could be due to the relatively rich groundwater resources and the water conservation abilities of soil and internal environment in the catchment.
Figure 3. Monthly variation of soil moisture content

Figure 4. Soil moisture content in May and August at different slope positions
The spatial distribution pattern of soil moisture is driven by climatic factors, especially the pre-rainfall plays an important role in the natural factors affecting soil moisture distribution. The soil moisture of different soil depths at each position before and after rain season was shown in the Fig. 4. From the Fig. 4 we can see that generally the soil moisture at gully has a great difference between May and August whether it is in shallow soil or deep soil. The soil moisture content on each slope position is greater than that in May, and the water difference between the two periods gradually increases with the downward movement of the slope position. This difference is more obvious below the lower slope position. The soil moisture of 20 cm at foot of slope varies a lot and changes slightly on deeper depths. Precipitation makes great effection on the soil moisture of gully because of the affluence of water from hillslope and upstream.

3.2. Characteristics of profile distribution of soil moisture

The soil moisture content of each layer depth at different sampling positions was shown in the Fig. 5. Overall, the moisture is increasing with the slope position falling. The soil moisture at top of slope is minimum at the average moisture of 9.8%. The maximum moisture is 15.8% at the gully in the catchment that is 1.6 times as the minimum soil moisture.

![Figure 5. Relationship between average soil water content and soil depth](image)

The variation trend of the soil moisture at different positions is the moisture of gully >lower slope >foot of slope >middle slope >upper slope >top of slope. This is different with the variation trend of soil moisture in desert area where the soil moisture is increasing with the slope position rising. The reason is that in the desert the bare quicksand at top has good permeability and soil biological crusts at the foot prevent water infiltration, however, there is no obvious difference of soil texture between the top and foot of the slope without apparent soil biological crusts. When the rainwater fell on the slope, the water would gather at the lower slope under the force of gravity by the surface runoff and interflow. The gully with the lesser the gradient, the better the soil structure, which accelerate the precipitation infiltration, reduce runoff, increased soil moisture content and enhance water retention capacity. Similar findings have been made on the Loess Plateau. In the vertical of the soil profile, the soil moisture has a little increasing trend with the increase of soil depth except the position at foot of slope. The soil moisture
within the depth of 40 cm at foot of slope has a higher content due to the aggregation of water from upper slope position and its special position at the junction of slope and gully.

4. Conclusion
According to the soil moisture observation and analysis of different slope positions in the Jiuquangou small watershed in 2016, the spatial and temporal distribution and variation characteristics of soil moisture in the small watershed of the Loess Plateau were revealed.

Affected by seasonal rainfall and evaporation, the average soil moisture of each slope showed a trend of decreasing, increasing, decreasing and increasing with time. The soil moisture content is higher in the rainy season than that in the dry season, and the difference is obvious in the lower slope, foot of slope and gully. The soil moisture content increases with the depth of the soil layer. For different slope positions, the soil moisture content at each depth of the gully is the largest. And the average soil water content increases with the depth of the soil layer.

Acknowledgements
This work was supported by the National key research and development plan of China (No. 2017YFC0504700) and Fundamental Research Funds for the Central Universities, CHD (No.300102279502).

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