SOIL MOISTURE FLUCTUATIONS AS AFFECTED BY STRAW-MAT MULCH

Wu, Chia-Chun [1]　　Wang, Chien-Han [2]　　Chan, Yu-Ting [3]

INTRODUCTION

Surface mulch has been used as one of the countermeasures for soil and water conservation. The basic functions of mulch include (1) protecting surface soil from raindrop impact, (2) conserving soil moisture, and (3) providing additional organic input through decomposition. Non-organic mulch materials, such as PE cloth, rock fragment etc., also provide similar service to control erosion.

Adekalu et al. (2007) ran 100mm/h simulated rain on remolded soil samples on 6-, 9-, and 12% slopes. Soil samples were covered with different percentage of grass residue, which included 0-, 30-, 60-, and 90%. They found that by increasing the percentage of residue cover, runoff and infiltration could be greatly reduced and enhanced respectively. They also found that residue mulch contributed less noticeably to infiltration at flat slopes; while significantly affected infiltration at steep slopes.

Mupangwa et al. (2007) conducted study on maize yield and soil moisture content with the corn residue application rates of 0.5-, 1-, 2-, 4-, and 8 mt/ha to the treatment plots. Their study indicated that soil moisture content was highly correlated with the mulch application rate. The most beneficial rate was 4 mt/ha. When exceeding 4 mt/ha, the effect of soil moisture conservation became insignificant.

Chakraborty et al. (2008) used rice husk, transparent polyethylene, and black polyethylene as mulch material to study the influence on soil moisture retention. Their study revealed that the soil moisture fluctuated noticeably at 750mm beneath the soil surface without mulch cover. Among all test materials, rice husk at the application rate of 8 mt/ha was found to be the most effective BMP in conserving soil moisture.

Jordan et al. (2010) ran rainfall simulator at 65mm/h to test the effect of wheat residue on infiltration rate. The wheat residue application rates included 0-, 1-, 5-, 10-, and 15 mt/ha. Their study suggested that wheat residue helped increase soil roughness and porosity. The effect of wheat residue reached to the peak at 5 mt/ha application rate, and leveled off when application rate exceeded 5 mt/ha.

Since most of the research results related to surface mulch have not yet addressed specifically the soil water fluctuation before and after the mulch application, therefore, the objective of this study is to focus on soil water fluctuation by continuously monitoring the volumetric soil water content at field condition.

MATERIAL AND METHODS

Experiment Site

This study was conducted at one of the runoff plots located in No. 4 Experiment Station at National Pingtung University of Science and Technology, Taiwan. The runoff plot measured 30m long and 3m wide with average gradient of 40% (Figure 1). The soil at the experiment station was classified as sandy clay loam of Laopei series; mainly weathered from alluvial deposit; with good physical properties, drainage, and ventilation but high acidity

The soil profile as shown in Figure 2 consists of gravels, sand, and silt for the first 450mm beneath the soil surface; whereas, soil texture is more cohesive with less gravel content at depth 450mm and beyond.

Figure 1. Experiment Plot

Figure 2. Soil Profile

Measurement

Daily precipitation was continuously logged on site. Precipitation records were then post-processed to separate effective storms from ineffective ones based upon the standard set by Universal Soil Loss Equation.

A storm is considered effective when accumulated precipitation exceeds 12.7mm with more than 6-hour break between storms. It is also considered effective if more than 6.35mm of precipitation falls within 15 minutes.

Soil moisture smart sensors were used to monitor the soil water content 200mm beneath the soil surface. The entire slope length was divided into three sections, namely Us for upslope, Ms for mid-slope, and Ds for downslope section. Volumetric soil water contents were logged using a digital data logger then brought back to the laboratory for post-processes.

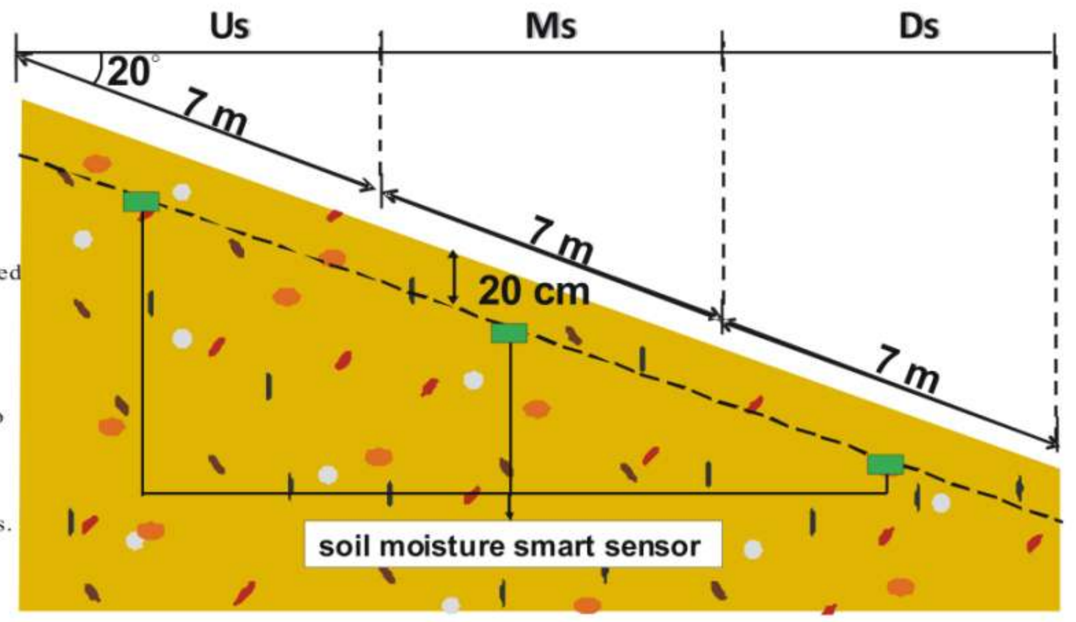

Figure 3. Layout of Soil Moisture Sensors and Locations of Measurement Sections.

Surface Mulch

Snap shots were taken randomly at up-, mid-, and downslope section of the runoff plot. The images were then processed using SigmaScan Pro© image analysis software to calculate the percentage of pixels covered by straw mat within the 600mm² area, which was then used to calculate the percentage of mulch coverage. The averaged mulch coverage along the slope was 68.32%.

RESULTS AND DISCUSSION

Two similar characteristics storms that one before (denoted as Storm A) and the other after (denoted as Storm B) the installation of straw-mat mulch were selected to facilitate the discussion. The primary characteristics of the selected storms including total precipitation, maximum 30-min rainfall intensity, and maximum rainfall intensity as that shown in Table 1.

Table 1. Primary Characteristics of the Selected Storms

Storm event	Storm period	Total Precipitation (mm)	Max. 30-min Rainfall Intensity (mm/h)	Max. Rainfall Intensity (mm/min)
A	05/28~29	141.8	49.2	2.2
B	06/10~11	144.2	69.6	2.2

The initial, maximum, and average soil water contents measured at Us, Ms, and Ds section were summarized in Table 2. Data in the last column of Table 2 was the flow flux per unit length in depth direction; $\left[\frac{L/T}{L}\right]$; calculated one hour prior to the arrival of peak soil water content or one hour during the rising limb toward the peak. The unit length flow flux thus calculated portrayed the speed of soil water flowing through the sensor section.

Table 2. Soil Water Contents before and after Straw-mat Mulch at Different Sensor Locations

Slope location	Storm event	Initial soil water content (%)	Max. soil water content (%)	Unit length flow flux 1-h before peak $\left[\frac{L/T}{L}\right]$
Us	A	53.09	64.59	1.54
	B	54.63	67.70	4.42
Ms	A	45.62	57.71	3.70
	B	46.67	56.35	3.57
Ds	A	49.69	64.58	4.86
	B	49.59	62.36	4.65

Maximum soil water content in Table 2 is the highest water content registered in the course of Storms A and B. We can see clearly that the maximum soil water content is slighter high at the upslope section after mulch application as compared with the reading before the implementation. The trend does not maintain at mid- and downslope sections. In order to reveal the information embedded, we subtract the initial soil water content from all soil water content readings and define the result as 'zeroed' soil water content as that shown in Figures 4 and 5 for before and after mulch application respectively.

When viewing the 'zeroed' soil water content, we get 5.85% volumetric increase in maximum soil water content before the mulch application and 4.45% after at upslope section, 3.83% increase in maximum soil water content before mulch application and 2.63% increase after at mid-slope section, as well as 6.26% increase in maximum soil water content before mulch application and 4.77% increase after at downslope section. The results thus suggest that volumetric soil water content fluctuates in wider range before the implementation of straw mat mulch; i.e. straw mat mulch helps maintain soil water content by shading the ground surface against evaporation.

Another interesting feature embedded in Figures 4 and 5 is the unit length flow flux calculated 1-h prior or 1-h during the rising limb toward the peak soil water content. The unit length flow flux under mulch protection at upslope section appears to be parallel to that at mid- and downslope sections (Figure 5). Nevertheless, the slope of the rising limb without mulch protection at mid- and downslope sections appears to be steeper than that from same sections but with mulch treatment (Figure 4). We believe the reason is mainly due to the runoff retardation caused by straw mat mulch.

Straw mat mulch is capable of absorbing rainwater during storms. The absorbed rainwater is then gradually released to the soil after the storm. Straw mat is also capable of retarding surface runoff by adding material roughness to the bare surface so that unit length flow flux at up-, mid-, and downslope sections is relatively alike with the ratio of 1.24 : 1.0 : 1.3. On the other hand, the ratio of unit length flow flux in depth direction at up-, mid-, and downslope section was 1.0 : 2.4 : 3.2 when soil is left bare.

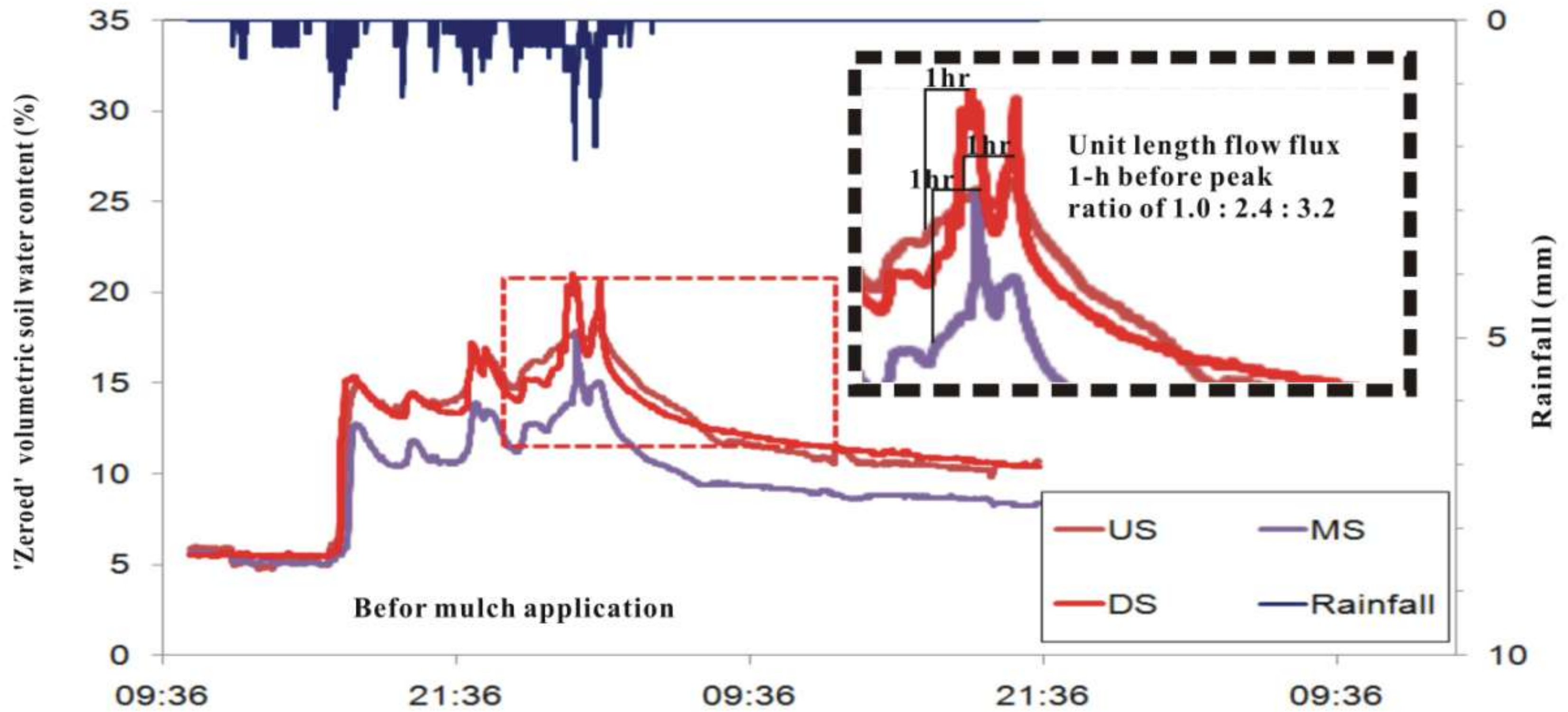

Figure 4. 'Zeroed' (Relative) Soil Water Content with respect to Initial Content before Mulch Application.

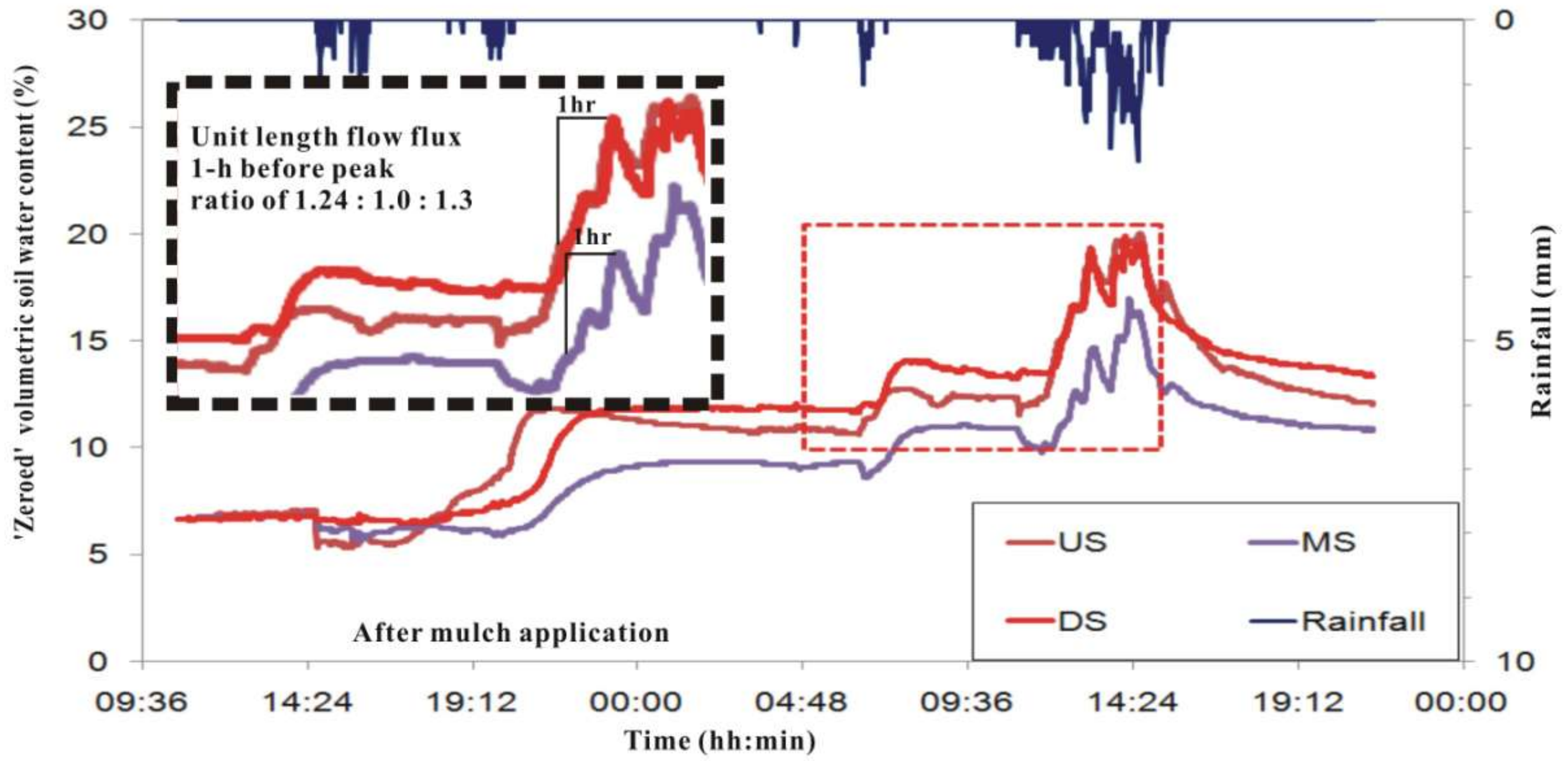

Figure 5. 'Zeroed' (Relative) Soil Water Content with respect to Initial Content after Mulch Application.

CONCLUSION

Preliminary results of this study illustrate the effect of straw-mat mulch in soil moisture conservation. Volumetric soil water content measured 200mm beneath the soil surface reveals the retardation and retention ability of the mulch. When soil is left bare soil water content fluctuates at a wider range and quickly reflects the characteristics of storm with quick rises and rapid drops.

Soil water content measurements reveal three aspects of soil water retardation provided by straw mat mulch; namely (1) less rapid response in soil water content when precipitation arrives, (2) less rapid diminution in soil water content after precipitation ceases, and (3) elongated decay in soil water content during storm breaks. These aspects deserve to be further considered in hydrologic modeling so that the dynamic response in soil water fluctuation can be truly portrayed.

1. Professor, PhD.,Corresponding author
email:ccwu@mail.npust.edu.tw
2.Graduate student,email:bisoto0@gmail.com
3.Graduate student,email:m9837001@gmail.com

NPUST
Dept.of Soil and Water Conservation,National Pingtung University of Science and Technology,Pingtung,TAIWAN

#11121