Final Reply of Hess-2013-307 to Y.MA

A) **Material and Methods**

1) The 16 microplots were randomly arranged over the hillslope with the slope gradient ranging from 17.6?(Referee#MA)

Response: Actually, we did not understand the meaning of the question. In our study, all of these mciroplots are randomly distributed along one southwest—northeast aspect 26.8% hillslope which was located in the middle part of Yangjuangou Catchment, and the 60×60cm size design of each microplot area help us distinguish the different land uses/cover more easily and clearly, we also perpendicularly inserted the impervious PVC sheets along the whole slope into the approximate 50cm depth of the soil to form the boundary of each mcrioplot, and made each single-plant being in the middle of fenced microplot.

2) How long have those plants been in each plot, are they natural plants or grown by researchers?(Referee#MA)

Response: The distance between two plants microplot is decided by the distribution of the 16 microplots, the shortest distance between two plants is near three meters, and the longest is about five meters. And all the selected vegetation microplots represents three types land covers such as grassland (plot2), low shrubland (plot3) and tall shrubland (plot4), and these plants experienced approximate 20 years' growth by nature since the implementation of the Grain-for-Green program in the Loess Plateau. All the information was supplemented in Table 2 of revised manuscript.

3) How were a central point and four ambient points distributed in each plot? Were they arranged relative to the main plant in each plot? (Referee#MA)

Response: In every microplot, we determined two soil-moisture-sampling methods, one was central point of sampling (CP), and the other was ambient point of sampling (APs). Specifically, CP was mainly sited in the middle of each plot1 and plot2 which represented bareland and grassland respectively. however CP was sited near the base of each vegetated microplot such as plot3 and plot4 both of which have obvious canopy structure on the ground. 4 APs each of which was near 30cm away from corresponding CP location were distributed around CP in terms of four different directions in each microplot. All the detail information was supplemented in *2.2.1 CP/APs sampling method* of revised manuscript.

4) State clearly the measuring interval during 43 days of experiment, but in figure 4, the experiment was less than 43days, it needs correction (Referee#MA)

Response: This question is related to the period of soil moisture sampling. Because we did not express the relationship between figure 3 and figure 4 clearly, the referee MA may feel puzzle about the experimental period. Actually, figure 3 showed in the manuscript indicated the different hydrological responses of soil moisture in all land uses/cover to the precipitation and radiation over the whole rainy season (from 2012/7/8 to 2012/9/16), it acted as a sketch to show the general dynamics characteristics of soil water content. However, we needed to select some specific hydrological processes in terms of DTW and WTD processes (from 2012/7/8 to 2012/8/20) from the whole rainy season to analyze the TSSM characteristics of different land uses/covers affected by precipitation and radiation. Therefore, we depended on figure 4 to detail the information of figure 3, which could satisfy with the content and objects of the research. The reasons for selecting the time interval from July 8th to August 20th were on basis of two considerations. Firstly, in the selected time interval of figure 4, there existed obvious two different hydrological processes (DTW and WTD) as well as the corresponding soil moisture pulses of different land uses/cover, both of which supplied the TSSM study with reasonable samples; Secondly, compared with the number of soil moisture data logged after August 20th, more soil water content data collected in the selected time interval, which probably more satisfied with the condition of employing statistical analysis. And some supplementary explanations were added in the footnote of figure3 and 4 in revised manuscript.

5) The holes on the ground as a result of every TDR measurement was mended right after, how did you do that? Referee#MA)

Response: With respect to specific sampling process, in each microplot, the selected measuring area of CP or APs location was actually a circle area of 8cm radius whose center was CP or AP (Figure 2b), we employed the FieldScout TDR 300 Soil Moisture Meter (Spectrum Technologies, Inc, Aurora, Illinois, USA) owning two 10cm length probes to insert into the CP or APs circle area and to measure the average volumetric water content in 0~15cm depth soil layer of every microplot.

When the logging processes of soil moisture data was over in some microplot, we carefully filled every disturbing hole formed by probes of TDR with fine soil particle and recovered the former litter layer condition in each vegetated microplot.

Actually, the sharp of every probe was similar to a cylinder with 10cm height and 2mm diameter. Theoretically, the disturbed soil volume was nearly $2\times1^2\times3.14\times100$=628mm^2 after every measuring, which require a little amount of fine soil particles to been filled with. Consequently, the designating the CP/APs circle areas and mending the disturbing holes aimed to reduce the system error derived from the inevitable disturbance of the soil surface layer. And some of related information was supplemented in the *2.2.1 CP/APs sampling method*.

6) I don't understand Eq(13), the i is quite confusing, and explain the Eq (13~15), and carefully check the symbols used in these Eqs, such as (i and k)(Referee#MA)?

Response: According to the suggestion of referee MA, we carefully revised the equations (13~15) and made related interpretation of these revised equations as follow:

Former equations in manuscript	Revised equations in revision
Eq(12) $\bar{\theta}_{CP(i)}=(1/n)\sum_{j=1}^{n}\theta_{CP(i,j)}$	$\bar{\theta}_{CP(i\cdot*)}=(1/n)\sum_{j=1}^{n}\theta_{CP(i,j)}$ $\bar{\theta}_{CP(i\cdot*)}$ is the average soil moisture of the *i* th microplot (*i*=1~16) at CP location over different hydrological processes (if *j*=*n*=1~2, then represented the DTW process; if *j*=*n*=3~7, then represented the WTD process) Dimensionless.
Eq(13) $\theta_{CP(i)}=\sum_{i=1}^{16}\bar{\theta}_{CP(i)}=(1/n)\sum_{j=1}^{n}\sum_{i=1}^{16}\theta_{CP(i,j)}$	$\theta_{CP(*\cdot*)}=\sum_{i=1}^{16}\bar{\theta}_{CP(i\cdot*)}=(1/n)\sum_{j=1}^{n}\sum_{i=1}^{16}\theta_{CP(i,j)}$ $\bar{\theta}_{CP(*\cdot*)}$ the average soil moisture of all microplots at CP location over *n* times, (if *j*=*n*=1~2, then represented the DTW process; if *j*=*n*=3~7, then represented the WTD process), dimensionless.
Eq(14) $p(\bar{\theta}_{CP[1]})=\bar{\theta}_{CP[1]}/\theta_{CP(i)}$ $p(\bar{\theta}_{CP[1]})\in(0,1]$	$p(\bar{\theta}_{CP[1\cdot*]})=\bar{\theta}_{CP[1\cdot*]}/\theta_{CP(*\cdot*)}$; $p(\bar{\theta}_{CP[1\cdot*]})\in(0,1]$ all the different values of $\bar{\theta}_{CP(i\cdot*)}$ should be ranked from lowest to highest, such as $\bar{\theta}_{CP[1\cdot*]}<\bar{\theta}_{CP[2\cdot*]}<\ldots<\bar{\theta}_{CP[16*]}$ in which the number in the square bracket indicates the order of the average soil moisture, dimensionless. And $P(\bar{\theta}_{CP[i\cdot*]})$ is the probability of lowest average soil moisture of some microplots over specific observational times, dimensionless
Eq(15) $Cumup(\theta_{CP[k]})=\sum_{k=1}^{k}p(\theta_{CP[k]})$	$Cumup(\bar{\theta}_{CP[k\cdot*]})=p(\bar{\theta}_{CP[1\cdot*]})+p(\bar{\theta}_{CP[2\cdot*]})+\ldots+p(\bar{\theta}_{CP[k\cdot*]})=\sum_{k=1}^{k}p(\bar{\theta}_{CP[k\cdot*]})$ $Cumup(\theta_{CP[k]})$ the cumulative probability of the *k* th highest average soil moisture of a microplot over specific observational times, dimensionless, abbreviation of TSSM-CumuP

TSSM-CumuP determines whether the rank distribution of soil moisture owned by the same microplot was the same over different hydrological processes which formed different observational times. Actually, TSSM-CumP reflects the rank stability of soil moisture based on the probability density function conforming normal distribution. Moreover, the soil moisture of same-rank-distribution microplot with a 0.5 value of TSSM-CumuP characterizes the mean soil water content of all land uses/cover for both the WTD and DTW processes. Consequently, in contrast to the TSSM-MRD and TSSM-STD both of which describe the dynamic characteristics of the TSSM, the TSSM-CumuP of the soil water content represents a related static feature of the TSSM. And all the interpretations and equation revisions were rewrote in *2.2.2 Quantification of TSSM* of revised manuscript.

7) The three standards you listed here were quite confusing (#MA) "The CumuP should be closer to 0.5 representing the mean soil water content of all land uses/cover for both the WTD and DTW processes, representing what? Also how low can be called "as low as possible"?(Referee#MA)

Response: (1) According to referee MA's suggestion, we changed the confusing expression about the "three standard", and readjusted the former logical structure related to the description of the "three standards" by using two paragraphs to interpret the meaning of three TSSM indices (TSSM-MRD, TSSM-STD and TSSM-CumP) and four principles of TSSM parameter selection respectively. Specifically, a reasonable parameter representing the characteristics of TSSM in the different land uses/cover microplots over DTW and WTD processes should satisfy with four principles as follow:

Principle A: The absolute value of TSSM-MRD in the selected microplot should be lowest than others.

Reason: if we regarded the average soil moisture over the change processes occurred in the spatial patterns of soil moisture as one of indicator to evaluate the characteristic of TSSM, then the TSSM-MRD indicates the fluctuation of every measuring point compared with the average value over a different hydrological processes (DTW or WTD) at distinct positions (CP or APs). And the more closely the absolute value of TSSM-MRD in some microplot approaches to zero over specific hydrological process, the more likely the corresponding soil moisture represented the average soil moisture of all mcrioplots distributing on the whole spatial patterns over the corresponding interval. TSSM-MRD could reflect one of characteristics in TSSM of four different land uses/cover.

Principle B: The absolute value of TSSM-STD should also be lowest.

Reason: TSSM-STD reflects the fluctuation of TSSM-MRD in a specific microplot over specific interval, which represents the fluctuant degree of given specific soil moisture to the average soil moisture derived from the spatial change processes of soil moisture in all microplots during the corresponding hydrological process. If the absolute value of TSSM-STD in a given microplot approaches zero more closely, then it is considered to be better representing the lower fluctuant of TSSM-MRD, and higher stability process over which the corresponding soil moisture gradually closed to the whole-spatial-pattern average soil moisture, TSSM-STD could be another indicator to describe the characteristics in TSSM of four different land uses/cover.

Principle C: The difference between the TSSM-CumP values of the soil moisture in the selected microplot over different hydrological processes should be less than 0.1.

Reason: TSSM-CumuP determines whether the rank distribution of soil moisture owned by the same microplot was the same over different hydrological processes which formed different observational times. In fact, TSSM-CumP reflects the rank stability of soil moisture based on the probability density function conforming normal distribution. The less difference between TSSM-CumP values meant that the corresponding microplot's soil moisture has the more similar rank order distribution over two hydrological processe

Principle D: Based on Principle C, the TSSM-CumP value in the selected microplot should be close to 0.5.

Reason: The soil moisture of same-rank-distribution microplot with a 0.5 value of TSSM-CumuP characterizes the mean soil water content of all land uses/cover for both the WTD and DTW processes.

Consequently, based on the four principles, we determine the TSSM parameter (θ_S) representing the average soil moisture of the corresponding microplot, which could be, theoretically, quantified the TSSM characteristics in different land uses/cover condition and be beneficial to introducing the TSSM concept into specific some hydrological processes.

(2) The expression "as low as possible" was very vague, and we deleted it in revised manuscript. And all the information was supplemented in *2.2.3 Evapotranspiration-TSSM model (ET-TSSM)* and *2.2.2 Quantification of TSSM method* sections of the revised manuscript.

8) According to your statement $t_{s(n)}$ referred to the time when temporal stability condition was reached, but the problem is how did you define the temporal stability, what is the threshold you mentioned? Temporal stability in (Vachaud et al 1985) meant no matter at what time, the rank distribution of soil moisture at each spatial location was almost the same, then, the soil water content at one or two location can always represent the average moisture in the research area, you need more explanation in the section (#MA)?

Response: (1) Explanation o the TSSM concept in Vachaud et al (1985)

The evaluation system of TSSM in *Vachaud et al (1985)* was composed of two parts, one is based on the statistical method to describe the mean relative difference and standard deviation of soil moisture distributing on distinct spatial patterns, and the other is depend on the probability density function to analyze the rank stability of soil moisture spreading on different spatial patterns. In the question, the referee MA mentioned that "temporal stability in (*Vachaud et al 1985*) meant no matter at what time, the rank distribution of soil moisture at each spatial location was almost the same", which was definitely defined by Vachaud et al in 1985. However, after that, in the many other TSSM-related literatures whose authors were *Martinez-Fernandez et al., (2003), Brocca et al., (2009), Coppola et al., (2011), Heathman et al., (2012),* the rank distribution of soil moisture at each spatial location was not the same, especially in extremely conditions—such as wettest and driest condition, the rank distribution was definitely different. And there may be two reasons for the difference of soil moisture rank distribution.

First of all, the complexity of soil condition—such as the different soil textures existing in large spatial scales—could probably lead to the different abilities to the soil water conservation at corresponding spatial scales, especially under the extremely hydrological conditions, the difference was more significance, which probably cause the different rank distributions of soil moisture at each spatial location. Secondly, the different rank distribution of soil moisture maybe as the result of different soil moisture measuring methods. *Vachaud et al* employed neutron scattering methods to measure the soil water content, but other researcher mentioned above mainly depended on the time domain reflectometry to log the soil moisture data. Actually the different measuring apparatus being distinct sensitive to soil water content could also affect the rank distribution

Although the rank distribution of soil moisture at each spatial location was different in later studies, there also existed some of locations with same or similar rank order, which was regarded as one of principles to the selection of TSSM parameter in this paper, and moreover, if the cumulative probability of the selected location with same rank order was close to 0.5, then this soil moisture could characterizes the mean soil water content of all land uses/cover in both the WTD and DTW processes. Essentially, in this paper, we changed the larger spatiotemporal scale focused by former TSSM studies into finer spatiotemporal scale, defined the TSSM concept as the fluctuation between the specific soil moisture of different land uses/cover and average soil moisture of all mcrioplots distributing on the whole spatial patterns over the WTD and DTW hydrological processes, and finally combined the different hydrological functions owned by all of land uses/cover with the TSSM concept, which constructed the ET-TSSM model.

(2) Explanation of the parameter $t_{s(n)}(t_{s(m)})$

In the revised manuscript, we changed the $t_{s(n)}$ into $t_{s(m)}$. The parameter $t_{s(m)}$ represents how quickly the soil moisture of the four different land uses/cover reach the TSSM condition which indicates the soil moisture was most close to the average soil moisture of all mcrioplots distributing on the whole spatial patterns over the WTD with lowest temporal fluctuant.

B) **Results**

9) Only one WTD and one DTW period may not be enough (Referee#MA)

Response: We admitted that a single WTD and DTW process may not be enough, and agreed it was the limitation of the study, which, as the other referee's mention, could hardly generalized to understand the overall soil moisture behavior. However, we had to interpret the reason for analyzing only a single WTD and DTW process, due to some of reasons been caused by some uncontrollable natural factors. There actually existed at least two limitations to our determining more DTW and WTD processes in this paper.

The first limitation is the field experimental condition. The precipitation mainly occurs between June and September which is the rainy season of the study region. The difference distribution of inter-monthly precipitation, to some extent, was difficult for us to acquire a whole DTW/WTD processes by using TDR to measure the soil moisture. As to all of different land uses/cover microplots, we expected to select a series of soil moisture whose hydrological response on precipitation and radiation could form obvious response pulses during an ideal DTW/WTD processes, however, in reality, this expectation was difficult to come true in both WTD and DTW processes. Specifically, on the one hand, due to being lack of enough precipitation or rainfall duration, the hydrological response of soil moisture on precipitation was not obvious during the DTW process; On the other hand, because of being short of enough radiation duration after heavy precipitation or long rainfall duration, the hydrological response of soil moisture on radiation was not obvious over the WTD period. Therefore, the probability to find out a whole and ideal DTW/WTD processes became smaller under the actual field experimental condition.

The second limitation is the CP/APs sampling strategy. We employed the FieldScout TDR 300 Soil Moisture Meter owning two 10cm length probes to insert into the CP or APs in every measuring time. Although we took some ways—designating the CP/APs circle areas, removing and recovering the litter layer condition as well as mending the disturbing holes—at different stages of measuring processes, the inevitable disturbance of the soil surface layer could be intensified if we increased the frequency of soil moisture measuring during other DTW/WTD processes, and finally lead to the increase of the system error. That is the why we reduced the measuring time after a whole and ideal DTW/WTD processes (from 2012/7/8 to 2012/8/20) of soil moisture data logging. Consequently, reducing the frequency of soil layer disturbance was an anther important limitation factor.

Essentially, the determination of WTD and DTW processes represented the downscaling the temporal scale, and the designing of CP/APs sampling was aim to downscale the spatial scale, both of which composed a fine spatiotemporal scale of TSSM study. Due to the scale and content of this study being different from former TSSM studies, especially when we integrated the TSSM concept with WTD/DTW process to analyze the hydrological characteristics of different land uses/cover depended on the construction of ET-TSSM model, this study was probably seemed to have more exploratory characteristics rather than being merely an experiment-driven paper. Therefore, although the one typical WTD/DTW processes could hardly generalize overall soil moisture behavior and supplied limited data with the ET-TSSM model, the seven deduced parameters by means of the ET-TSSM model enriched the implication of TSSM concept and further particularized the time variable of ET functions, which could be regarded as the first step to understand the hydrological processes affected by different land uses/cover from a new aspect. However, we definitely accepted referee #1's suggestion, and in the "*limitation and uncertainties*" of the discussion section of revised manuscript, we mentioned the limitation of one WTD/DTW processes, and point out that increasing the soil moisture data to the application of ET-TSSM model was one of direction of future TSSM-study.

C) **Others:** Language problem and grammatical flaws (#1#2#MA)

Response: We will carefully exam the grammatical flaws and try to make correct and clear expression in this paper.