1 Responses to the Reviewer #2

Main remarks:

The manuscript attempts to quantify the effects of land use change and vegetation phenological change on evapotranspiration in a shrubland ecosystem in China using eddy covariance measurements. Evapotranspiration is a critical ecosystem variable but the controls on ET and particularly its interaction with vegetation processes remain relatively poorly quantified. As the authors point out, ET changes are critical for water resources in dry regions and as such the study addresses an important aspect of coupled hydrological and land surface processes.

However, despite much effort in analyzing the data, the authors do not clearly explain their findings and present somewhat conflicting conclusions. The authors state seasonal vegetation greening increases ET but so does the clearing of natural vegetation. In particular, the reported increase in ET due to land clearing is somewhat counterintuitive. However, the authors need to discuss this in more detail to propose specific mechanisms for why this would be the case in their study site. More generally, the authors need to clarify why vegetation is the main control on ET if ET at the study site is dominated by soil evaporation and why both seasonal greening and vegetation clearance appear to increase ET.

Response: The conclusions are actually not contradictory, because the mechanisms of these two conclusions are different. Due to the unclear statements of Method part and less explanations of Results and Discussion part that may be confusing, we have rewritten the Method part (2.3.3) and Results (3.3 and 3.4) and Discussion part (4.1 and 4.2).Please see lines 269-270, 287-300, 349-353, 364-371, 400-401, 424-430, 445-450, 459-461, 488-490 and the following detailed explanations.

The first conclusion was that normalized ET increased along with the vegetation greening. We demonstrated this conclusion by using the data of 2011-2012 (lines 400-401), since in this period, the vegetation type was stable and there was not any land use change. Seasonal NDVI during 2011-2012 could reflect the vegetation phenology (lines 269-270), such as when the vegetation entered the growing season and so on (349-353). In this case, normalized ET increased along with the vegetation greening (lines 424-430). The mechanism of this increase of normalized ET is due to the increase of leaf stomata, and more water will be transpired to the atmosphere during the vegetation greening and growing process (lines 449-461).

The second conclusion was found in the case of land use change. Land use change represented the conversion of vegetation type, and in this study, this conversion was from vegetation to bare soil. To discuss the impact of land use change on normalized ET, we treated the land use condition of zone A (land use condition was not changed) as the reference, and the differences of vegetation coverage between zone A and zone B ($D_{lu}=M_A-M_B$) as the measure of land use change (lines 287-300). D_{lu} represents land use change most exactly in summer than in winter, because M is a measure of the fraction of green vegetation and D_{lu} in winter is meaningless. So we selected D_{lu} of July—September in each period as the measure of land use change (lines 364-371, Fig.1). We found that with land use change, the normalized ET increased (lines 445-450, 488-490, Fig.2). When the area of land use change was ΔS, normalized soil evaporation and transpiration changed $+\Delta E_N$ and $-\Delta T_N$, respectively. The normalized evapotranspiration changed ΔET_N and was the sum of $+\Delta E_N$ and $-\Delta T_N$. We found ΔET_N increased during the three study periods, indicating that $|+\Delta E_N|$ was more than $|-\Delta T_N|$.

Therefore, the normalized soil evaporation from each unit ($|+\Delta E_N|/_{\Delta S}$) was larger than transpiration from each unit ($|-\Delta T_N|/_{\Delta S}$). Therefore, the mechanism of this increase of normalized ET is that the normalized soil evaporation from each unit of increased bare soil is larger than normalized transpiration from each unit.

Therefore, our results imply that when vegetation type is table, vegetation phenology is the main control factor on the seasonal variation in ET. However, when land use changed from vegetation to bare soil, much larger of soil evaporation from each unit of increased bare soil than transpiration may also make the ET increase.

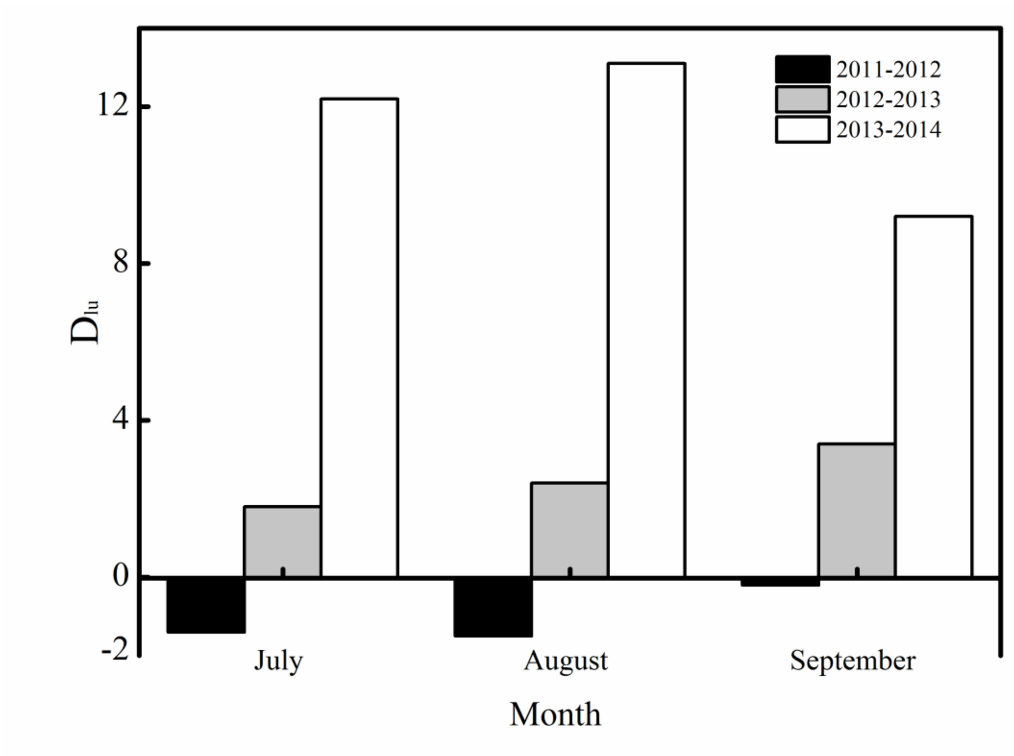

Figure 1 The D_{lu} of July, August and September in each period.

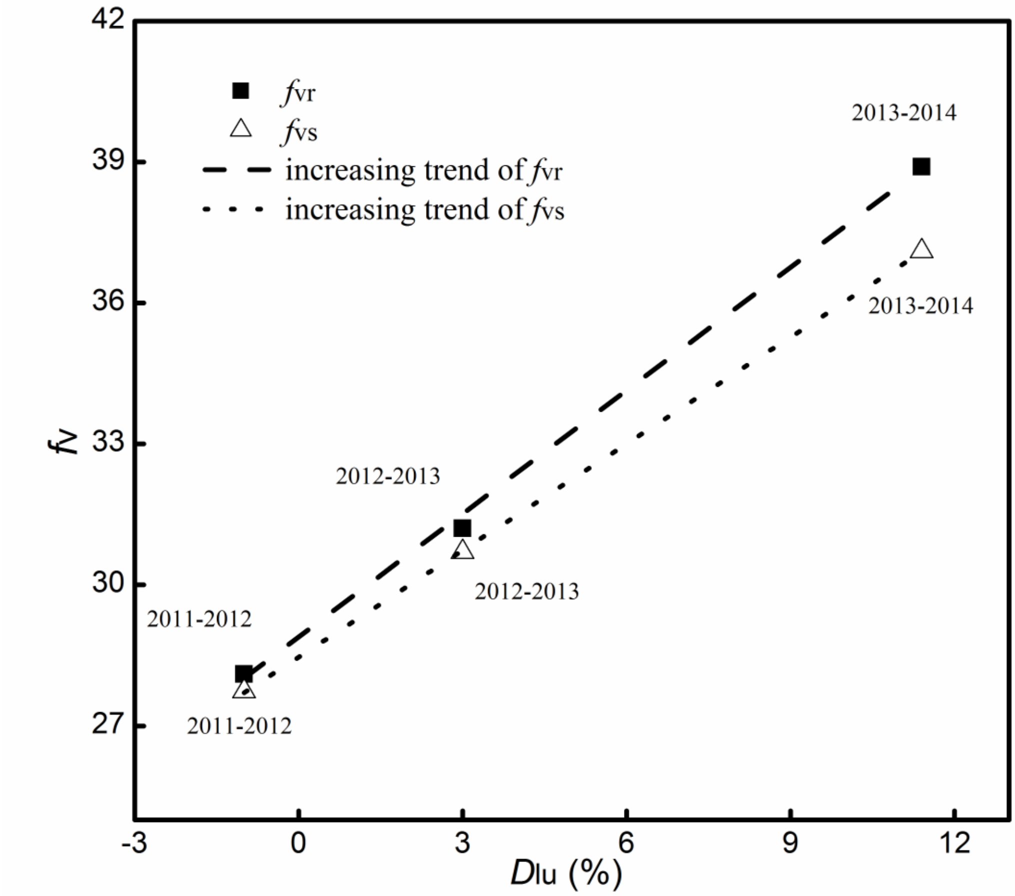

Figure 2 Quantitative analysis between D_{lu} by human activities and ET ($f_{vr} = ET/(E_{TP} \times f_{sr})$, $f_{vs} = ET/(E_{TP} \times f_{ss})$) in July—September of each period.

Studies generally report a decrease in ET when vegetation is cleared or reduced (e.g. Bosch and Hewlett, 1982; Gordon et al., 2005) due to declining transpiration. Furthermore, transpiration usually forms the greater proportion of total ET and as such declines in vegetation would likely reduce total ET.

Response: We agree with the reviewer's comments about the decrease of ET when land clearing happened. But we think this phenomenon is applied to the much higher dense vegetated ecosystems such as forests and grasslands. Just as the reviewer said, in these higher dense vegetated ecosystems, transpiration takes greater proportion than soil evaporation. Some other researchers have also demonstrated this conclusion (Huang et al., 2010; Hu et al., 2013; Wang and Yakir, 2000).

However, in the sparse vegetated ecosystems such as our study site with the xeric vegetation, some studies have also demonstrated that soil evaporation was more than transpiration (Kurc and Small, 2004; Zhang et al., 2005).

We have added the aforesaid statements into the revised manuscript. Please see lines 490-495.

Clearing of vegetation should also lead to reduced access to groundwater, diminishing water supply for ET and resulting in decreased ET in a water-limited area such as the study site.

Response: The groundwater is not accessible by the vegetation roots at our site. Because the maximum root depth of vegetation was measured as less than 160 cm, and the mean groundwater level was 3.4 m. Therefore, we considered the impact (f_{sr}) of soil water content of root zone on ET, and it is expressed as (lines 241-245),

$$f_{sr} = \begin{cases} = 1 & \theta_r > \theta_k \\ = 0 & \theta_r < \theta_w \\ = \frac{\theta_r - \theta_w}{\theta_k - \theta_w} & \theta_w \le \theta_r \le \theta_k \end{cases} \quad (1)$$

Before we compared the normalized ET of three periods, we have excluded the impact of f_{sr} on ET (lines 206-218).

We agree with the reviewer's comments. When the vegetation of our study site was cut-off, transpiration decreased, but soil evaporation increased more than the transpiration decreased, so we found evapotranspiration increased.

Minor comments

P13575 L12: What do you mean by "vegetation coverage"? Foliage fractional cover or something else?

Response: In our study, vegetation coverage is regarded as the fraction of green vegetation (Gutman and Ignatov, 1998).

P13576 L5: The FLUXNET network now comprises of 650 towers (fluxnet.ornl.gov/), the authors should consider replacing "several" sites.

Response: we have replaced the "several" as "a number of". Please see line 131.

P13579 L9-15: Why was this particular potential evapotranspiration (PET) formulation chosen? PET is a key variable in the study to estimate actual ET and as many equations for PET exist, the authors should clearly justify the choice of PET formulation. The equation appears (near) identical to the Penman formulation (Penman, 1948) but this is not clear from the text.

Response: Yes, this formulation is a transformation from Penman formulation. The differences are the estimations of the aerodynamic resistances (r_a) and the aerodynamic roughness of surface (Z_0). The form of the aerodynamic resistances (r_a) was estimated as the following formulation (Penman, 1948 and 1963),

$$r_a(\mathrm{s/m}) = \frac{4.72[ln(\frac{Z_m}{Z_0})][ln(\frac{Z_m}{Z_0})]}{1+0.536U_2} \quad (2)$$

where Z_m is the height at which meteorological variables are measured (2 m), and Z_0 is the aerodynamic roughness of surface (0.00137 m)

We have added these explanations into the revised manuscript. Please see lines 218-232.

P13579 L18-20: Why was MODIS Terra chosen? The Terra satellite is known to have suffered from sensor degradation in recent years (e.g. Wang et al., 2012), including the current study period. Why was MODIS Aqua data not used or a combination of the two sensors to overcome data quality issues (e.g. cloud) and Terra limitations?

Response: We actually downloaded the MODIS/Terra and MODIS/Aqua surface reflectance data from the reverb (http://reverb.echo.nasa.gov). We found there were not obvious differences between these two data series in our study site (Fig.3), so we just select MODIS/Terra surface reflectance data to use. Now that according to the reviewer's suggestion, therefore, in the revised manuscript (lines 272-274, 285-286), we calculated the daily mean NDVI by the mean of MODIS/Terra and MODIS/Aqua, which was expressed by the following equation,

$$NDVI = \frac{NDVI_{Terra} + NDVI_{Aqua}}{2} \quad (3)$$

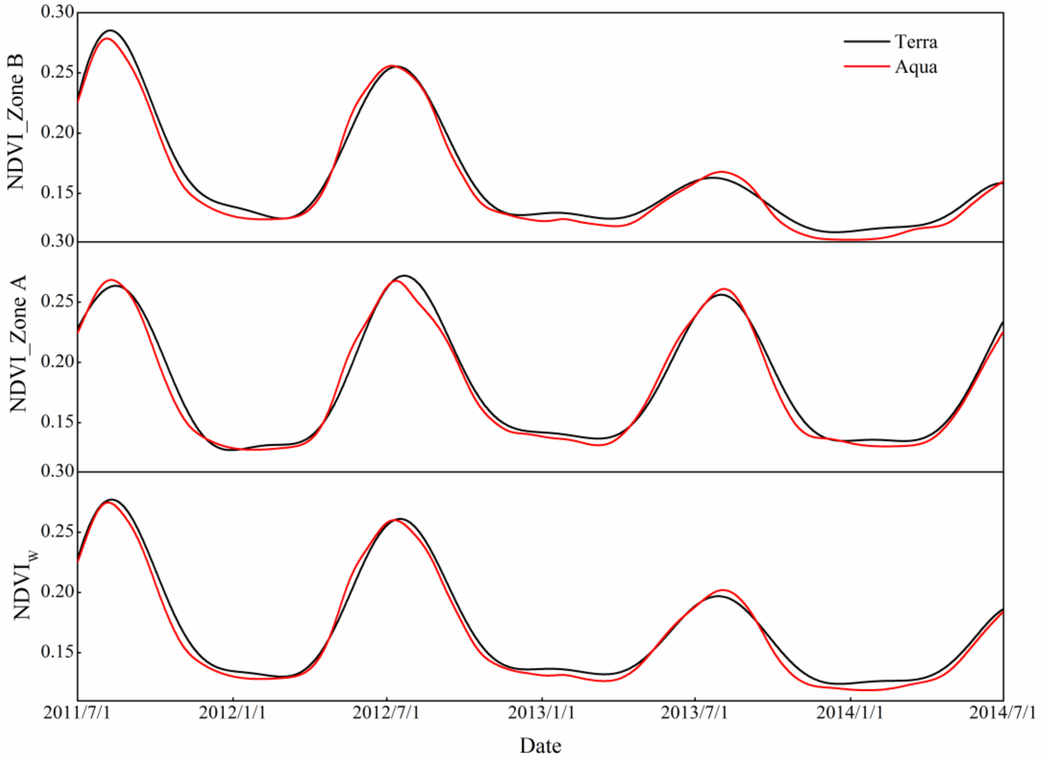

Figure 3 Comparisons of MODIS/Terra and MODIS/Aqua NDVI of zone A, zone B and weight-averaged within the whole footprint.

P13582 L5-9: This information should be stated in the figure caption, not the main text.

Response: Thank you. We have removed the information from the main text, and stated in the figure caption. Please see line 733-737.

P13582 L11-12: The authors state the area of zone B changed over time but was fixed in the study. Was the mean or maximum extent of cleared area used for analysis and how much did the area vary?

Response: In our study, the area of zone B was the maximum extent of land clearing. Because we measured the boundary of land clearing zone (zone B) until October 2013, when the land use condition of zone B has stopped to change. We have added these statements into the revised manuscript. Please see lines 310-311.

Land clearing happened in zone B while land use condition of zone A was not changed during the three periods. Therefore, we came up with a method to obtain the process of land use change. We regarded the vegetation coverage of zone A as reference, and introduced an indicator of D_{lu} to be the measure of land use change, which was calculated by the differences of vegetation coverage (M_A-M_B) between the reference and zone B. D_{lu} represents the land use change most exactly in summer than in winter, because M is a measure of the fraction of green vegetation and D_{lu} in winter is meaningless and nearly zero (lines 297-298). So we selected the mean D_{lu} of July—September in each period to analyze the impacts of land use change on normalized ET (lines 299-300, 364-371). The results are shown in the following Fig.4. Compared to 2011-2012, D_{lu} of 2012-2013 and 2013-2014 both increased. Taking August of each period as example, in August of 2011-2012, D_{lu} was -1.5% due to the tiny differences in spatial distributions of natural vegetation, while in August of 2012-2013 and 2013-2014, D_{lu} were 2.4% and 13.1%, respectively. This phenomenon represented that compared to the August of 2011-2012, the percentage of land use change of 2012-2013 and 2013-2014 increased 4.5% and 14.6%, respectively.

Therefore, despite we did not measure the exact land use changing process of zone B, our method can reflect this process as well. Vague statements in the Method part may make the reviewer confused, so we have rewritten the Method part to state our method more clearly. Please see lines 287-300.

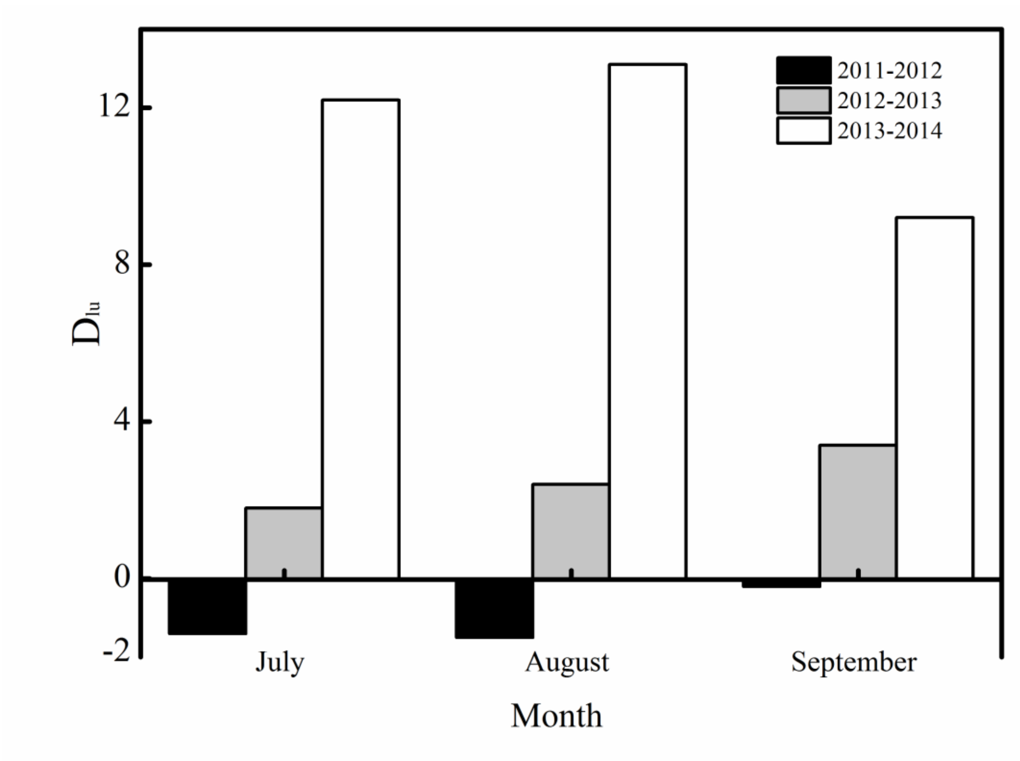

Figure 4 The D_{lu} of July, August and September in each period.

P13584 L26: I don't think Ss and Sr are defined anywhere in the main text.

Response: We have added the definition in the revised manuscript, and revisions are marked as red in 2.3.3. Please see lines 241-245. In the revised manuscript, we have replaced the S by f_s to reflect the impact of soil water content on ET.

In this study, f_{sr} and f_{ss} were defined as impacts of soil water content of root zone and surface on ET, respectively, and were calculated as the following formulations

$$f_{sr} = \frac{\theta_r - \theta_w}{\theta_k - \theta_w} \quad (\theta_w \le \theta_r \le \theta_k) \tag{3}$$

$$f_{ss} = \frac{\theta_s - \theta_w}{\theta_k - \theta_w} \quad (\theta_w \le \theta_s \le \theta_k) \tag{4}$$

P13585 L21-23: The normalization parameter appears to be an important method for attributing ET changes to specific drivers; a clearer explanation for what it represents and why it is adopted would be useful. The meaning of the parameter is not immediately clear (to the reviewer at least) and the authors should spend more time explaining the method.

Response: We have rewritten the Method part (2.3.3) to make it clear. We have changed the "normalized parameter" to "normalized ET" in the revised manuscript, making our conclusions more clear.

The normalization ET in our study represented the effects of vegetation change on ET (lines

216-217).

The reason for why we adopted the normalization method is that we need to eliminate the effects of meteorological condition and soil water condition (lines 206-218), in order to discuss the impact of vegetation change on ET. So we transformed the Eq.3 (line 212) by dividing PET and f_s from ET (lines 214-217).

P13587 L7: What is the unit of increase?

Response: The unit of increase was "mm". We have added the unit in the revised manuscript. Please see line 449-450.

P13588 L16-20: The two sentences appear to contradict each other. On one hand, the authors state vegetation cover *above* a certain threshold can increase ET but on the other, vegetation cover *under* a threshold can also increase ET.

Response: After thinking about the reviewer's comments, we found we have misunderstood the meaning of this finding of Li et al. (2009). Thus, we removed the sentences from our revised manuscript.

Figure 3 caption: Needs clarification and further details on what the different lines and symbols represent.

Response: We have added more expressions below the figure 3 caption. Please see line 733-737.

In Fig.3 caption of the revised manuscript, we revised and added the following explanations: "the black line of Fig.3b is the simulated footprint; the long axis is 1682m, and the short axis is 1263m; the background is the MODIS Surface Reflectance (250 m × 250 m) on 3 January 2011. Square white dots were measured points on 25 October 2013, and the white line is the maximum boundary of bare soil area"

Figure 9 caption: In the main text *M* signifies monthly mean vegetation coverage but in the figure caption is represents "land use change". This is somewhat confusing. Parts of the manuscript are poorly written and hard to follow, for example (but not exclusively) P13572 L8-10, P13588 L4-5 and Discussion in general.

Response: we thought the unclear statements of Method part may make the reviewer confused, therefore, we have rewritten the Method part (2.3.3). Please see lines 287-300.

We have revised the caption of Fig.9 with the following statements: "Quantitative analysis between D_{lu} and normalized ET ($f_{vr} = ET/(E_{TP} \times f_{sr})$, $f_{vs} = ET/(E_{TP} \times f_{ss})$) in July—September of each period". Please see lines 769-770.

According to the reviewer's comments and suggestions, we have revised this manuscript substantially to make our conclusions more clear. All revisions are marked as red in the revised manuscript. Please find the revised manuscript in the attachment.

Technical corrections

13572 L1: grammatical error.

Response: We have revised the first sentence in the abstract part.

The new sentence is “Evapotranspiration (ET) is an important process in the hydrological cycle, and vegetation change is a primary factor that affects ET”. Please see line lines 10-11.

13573 L19: typo.

Response: We have revised the ‘penological’ to ‘phenological’ in the revised version of manuscript. Please see line 58.

References:

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