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Comparison of surface energy budgets and feedbacks to microclimate among different vegetation landscape on the Mongolian Plateau

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CITATION

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HIGHLIGHT

- Vegetation canopy change and vegetation communities types change by warming on the MP.
- Land surface albedo change is significant difference by different vegetation landscapes.
- ET change is more complex by different vegetation landscapes canopy change.

ABSTRACT

The water and heat exchange between the atmosphere and the land surface plays a very important role. The Leaf area index (LAI), land surface albedo (LSA) and evapotranspiration (ET) which play a fundamental role in understanding many causes and consequences of land surface and climate interactions. However, relative contribution from altered albedo and ET to differences in energy budget in contrasting land use types is unclear in temperate climate zones. In this paper, to quantify the land surface water and heat fluxes arising from spatial patterns of land cover in the present climate, as well as enrich the land surface process field observations in the hinterland of Mongolian Plateau (MP) with rapid changes in vegetation growth by warming climate. Here, we focused on the LAI, albedo, ET and their relationships on the different roofing landscapes (the meadow steppe (MDW), the typical steppe (TPL), the desert steppe (DRT), the shrubland (SHB)). Based on the MODIS products 2000-2016, we found that there existed a significant linear negative correlation between LAI and albedo, but not found correlation between LAI and ET.

Among the four vegetation communities, the normalized annual mean Z-score of LAI and ET all showed increased trend, especially for the TPL (slope = 0.091, p=0.036 for LAI and slope =0.086, p=0.050 for ET). However, for the normalized annual mean Z-score of albedo, other three landscapes all showed negative change trend, only for TPL, still showed pocitive change trend (slope =0.105, p=0.029). More importantly, the long-term changes in monthly albedo, ET and LAI values had different contributions to the annual values.

Keyword: Land surface albedo, evapotranspiration, leaf area index, land surface process

INTRODUCTION

The water and heat exchange between the atmosphere and the land surface plays a very important role in ecosystem biophysics processes, biogeochemical cycles, hydrologic, weather variations and climate change (Baldocchi and Ma, 2013; Pielke, 2005; Running et al., 1999; Sellers et al., 1997; Stenseth et al., 2002; You et al., 2017). In the most of the terrestrial-atmosphere models, land surface albedo (LSA) and evapotranspiration (ET) are the vertical factors showing the surface change (Chen and Dirmeyer, 2016; Mu et al., 2011). Based on observations or satellite data of vegetation–atmosphere interaction land surface water and heat flux were quantified in different terrestrial ecosystems (Bathiany et al., 2010; Bright et al., 2015; Chen and Dirmeyer, 2016; Liston et al., 2002; Shao et al., 2017a; You et al., 2017; Zhao and Jackson, 2014). The shifted vegetation growth has resulted in consequences for a range of terrestrial land surface processes that regulate exchange of mass and energy between biosphere and atmosphere.

The albedo is the ratio of the solar shortwave radiation upwelling radiant energy relative to the downwelling irradiance incident upon a surface (Stroeve et al., 2006; Tian et al., 2014). It reflects the amount of solar radiation absorbed by the land surface and control the distribution of solar radiation between the surface and the atmosphere. For example the change of surface albedo by 0.01 is equivalent to the change of solar constant by 1% (Li et al., 2000), a 1% change in albedo at the peak net radiation (i.e., 1000 w m^{-2}) on the Tibetan Plateau means 10 w m^{-2} energy, which is equivalent to or greater than the average soil heat flux of the grasslands on plateau(Shao et al., 2014; Shao et al., 2017b; Sturm et al., 2005; Wang, 2004; You et al., 2017); a 5% increase in surface albedo in tropical forests would reduce local rainfally by 5% (Lean and Rowntree, 1993).

For the ET as the sum of soil evapotration, canopy evaporation, and plant transpiration, also is a key role in planetary hydrologic and energetic cycles (Oki and Kanae, 2006). As regards global climate change owing to biophysical effects, ET generally produces a counteractive energy effect relative to albedo, made the contribution of albedo feedbacks to surface temperature to dissipate significantly more latent energy through ET (Pitman et al., 2011). For example, owing to the global replacement of forests by grassland the surface albedo increase had a cooling effect of 1.36 K (Davin and de Noblet-Ducoudre, 2010), but the decreasing by ET, a surface warming effect of 0.24K. However, this dependence varied for the spatial distribution. Such as in the high-latitude boreal forest zone, deforestation generally cools the land surface because of the high albedo resulting from the snow cover, inducing strong negative radiative forcing (Bala et al., 2007; Bathiany, 2010; Claussen et al., 2001). In arid/ semiarid areas, with high radiation load, but the ET most from rainfall inputs. (Houspanossian et al., 2017; Rotenberg and Yakir, 2010; Santoni et al., 2010). On the other hand, deforestation produces warming effects attributable to the strong evapotranspiration decline in tropical forest zones (Davin and de Noblet-Ducoudre, 2010). However, relative contribution from altered albedo and ET to differences in energy budget and subsequently to surface temperature in contrasting land use types is unclear in temperate climate zones, owing to dissimilarities in surface characteristics and the complex relationship of water and energy fluxes. In addition, in arid/ semiarid areas with high radiation load, the changes in the radiation balance that follows vegetation changes or vegetation community replaces is still not clear (Houspanossian et al., 2017; Rotenberg and Yakir, 2010).

Several recent investigations have further emphasized the rapid changes in vegetation growth in high altitude and high latitude areas in the Northern Hemisphere by warming climate (Brovkin et al., 2013; Lee et al., 2011; Loranty et al., 2014; Tian et al., 2017; Tian et al., 2014; You et al., 2017). The Mongolian Plateau (here after MP) evidence experienced the higher-than-average global warming rate on the plateau during the last decades (John et al., 2018; Shen et al., 2016). Our existing studies had further confirmed the mongolian steppe cover degree increased on the MP by the satellite data (MOD16A1) during 2000-2016 (Tian et al., 2017). Vegetation greenness and community type in the MP driven by climate flux, also change the land– atmosphere hydro-thermal interactions (Chen et al., 2015; Kelley et al., 2015; Lioubimtseva and Henebry, 2009). The mongolian steppe represents over 65% land cover types on the Mongolia plateau, which is largely intact with high biodiversity (John et al., 2013; Khishigbayar et al., 2015). The steppe composed by three steppe types, among the meadow steppe (MDW) accountes 25.1%, the typical steppe (TPL) is of 26.1%, and the desert steppe (DRT) is 27.2% (Hilker et al., 2014; Wesche et al., 2016), with their distribution determined mostly by the precipitation gradient. Although the shrubland (SHB) occupies very little proportion, its change was very significant by our site visit for last over 10 years. At present, these grassland that support face an uncertain future owing to interactions among a warming trend, an increasing frequency in extreme climate events, an varied precipitation in these semiarid ecosystem, and high temporal and spatial variability of vegetation community (Chen et al., 2015; Fernandez-Gimenez et al., 2012; John et al., 2016; Khishigbayar et al., 2015). In order to enrich understand the land surface process by vegetation community effect on the hydro-thermal interactions between land and atmosphere in MP, in this paper, based on the moderate -resolution imaging spectroradiometer data, accurate to extracted the sites of the vegetation community in growing season. Our objectives were limited to: 1) what it the magnitude of the spatial variability in albedo, ET among the different vegetation community on the MP (Table 1). (2) to explote the magnitude of surface energy change resulted from the variation of albedo and ET, during the growing season by the leaf area index (LAI) change direction for the different vegetation community. (3) performing a preliminary analysis of the different vegetation community greenness change and its feedback to the future climate change on the MP.

2. Method

2.1.study area

Our study region is located in the Ulaanbaatar and TOV provinces of Mongolia (Fig. 1). Where corresponds to the subarctic climate in the northeast with cool summers and severe dry winters, with an average annual air temperature of 1.2 °C, annual precipitation of 300-400 mm, and the annual solar radiation of 5200MJm^{-2} (Zhao et al., 2017), mean annual pan-evaporation of $$ mm (). The growing season from May through September is warm and relatively wet registering an annual precipitation of about 88%, while the remaining months (October-April following year) are cold and dry.

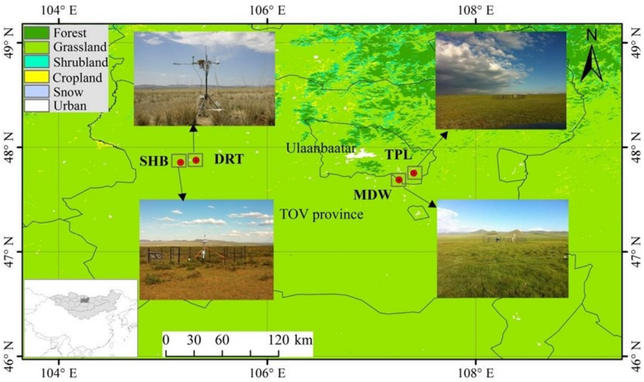

Fig. 1. Geographical position of the study area and distribution of the four land cover types, meadow steppe (MDW), a typical steppe (TPL), dry typical steppe (DRT), shrubland (SHB).

The MP steppe represents a significant proportion of the Eurasian steppe-a major portion of global temperate grasslands and forms a contiguous belt across the continent from the Mediterranean basin to eastern China (Qi, 2017; Wesche et al., 2016). Among the Mongolia steppe, the meadow Steppe (MDW) consists of moist grasslands with high canopy cover of 60 –90% (Liu et al., 2013), and herbaceous species that are less tolerant to drought, dominated by *Leymus chinensis* meadow steppe (Fernandez-Gimenez et al., 2012; Khishigbayar et al., 2015). The typical steppe (TPL) is predominantly herbaceous in nature with a vegetation cover of 25– 100% that is characterized is comprised of short-grass steppe with cool-season perennial C_3 grasses—*Stipa krylovii* and *Artemisia frigida* – as the dominant species (John et al., 2016; John et al., 2013; Liu et al., 2013; Wesche et al., 2016). The desert steppe (DRT) corresponds to the cold desert climate with the annual precipitation of 150–200 mm, and has more open vegetative cover (10–25%), the species is dominated by a perennial grass—*Achnatherum splendens*, a widely distributed cover type with overgrazing. The shrubland (SHB) with the vegetation species is dominated by *Caragana stenophylla* shrub.

For the four vegetation community types sites, we had surved and ensured the distance for each vegetation community is over >10km (Fig. 1). The area of each community in each site is not < 2km×2km, which has lower resolution than MODIS data (500 m resolution for albedo and LAI, 1 km resolution for ET).

All four sites are flat with relatively homogenous vegetation, the elevation is ~1000m. For each community type the dominant species contributes >80% of the cover (Shao et al., 2017b). The soil is classified as chestnut soil (FAO) with a sand loamy texture. For the each vegetation community environment was also experienced strictly observed for last several years, and ensured that the study areas did not experience apparently disturbed by extreme environmental factors (i.g., fire, insects) and anthropogenic activities (i.g., intensive grazing) (Shao et al., 2017a). All the sample sites share a similar background climate, e.g., short-wave radiation, air temperature (Fig.1). But the precipitation was lower in DRT and SHB than in TPL and MDW (Fig.

1).

To confirm the driving effects of vegetation greenness on land surface albedo and ET, we also analyzed the albedo trend for the desert land (DL) on the MP in the same period.

2.2 MODIS data

The land surface products of MODIS onboard NASA's Earth Observing System's satellite Terra (Friedl et al., 2002; Zhang et al., 2003) and the black-sky data set for MOD43A3 (V005) (2000-2016) BRDF/Albedo product (eight days Global 500 m SIN Grid) was used in this study, and the bias was mostly <5% (Liu et al., 2009). The ET product MOD16A2 (2000-2014) at a resolution of 1 km, with the absolute bias being generally <1K (Wan, 2008). The LAI/*f* PAR product is coded as the MCD15A2 (2000–2016), with a 500 m spatial resolution. All the data selected are from day of year (DOY) 153 to DOY 273 (the growing season), with an eight-day interval. In this study, only analysis the albedo, ET and LAI in the growing season in study years, just because in non-growing season, ET is usually small and albedo is substantially and inconsistently influenced by snowpack, it is an other complex progress.

2.3 Data analysis

Based on the deviation between remoting seasion data and the actual site geographic location, we select the site as the center, and made a buffer of 1000m as the extraction range of remote sensing data, for every pixel was extracted to make sure arround has the same vegetation community. For selecting the desert type pixels also like the vegetation community. At last the albedo and LAI dataset have ~12 pixels, ET was ~8 pixels for each land cover type.

For the growing season, we included a total of 20 images produced between day of year (DOY) 121 and 273 (1 May to 30 September). Our initial statistics albedo, ET and LAI in the growing season average monthly values—for example, May was calculated using the sum values of DOY 121, 129, 137, and 145 for each pixel—and then, for the annual value in the growing season, the annual growing season albedo, ET and LAI were calculated using average monthly values with the following formula:

$$M_{annual} = \sum_{i=1}^{5} M_{month,i}$$

where M_{annual} was the albedo, ET and LAI annual mean value of every year, and $M_{month,i}$ was the monthly mean value for albedo, ET and LAI, with i representing the months of May through September.

To explore the inter-annual changes in albedo and LAI, we separated the growing season by month and analyzed the empirical relationships between LAI and albedo, ET. A one-way analysis of variance (ANOVA) was used to examine the statistical significance of the difference in albedo, ET, and LAI among four vegetation communities. For the monthly and yearly albedo, ET and LAI, we applied linear regression models to calculate the coefficient of variation (CV) for the MP by the origin data in order to quantify their inter-annual variations. Finally, we used lined regression to examine the relationship between annual albedo, ET, and LAI on the MP by average annual growing season LAI class.

3. RESULT

3.1 albedo, ET, and LAI for four vegetation community

The long-term mean (±std) of albedo for MODIS (2000-2016) data in growing season was 0.18 (±0.09), 0.21(±0.28), 0.19(±0.29), 0.18(±0.09), 0.26(±0.19) for MDW, DRT, SHB, TPL, DL, respectively (Table 1). There was no significant difference (P > 0.05) in albedo among the four vegetation types.

The growing season mean values of ET from 2000 to 2014 were 24.53(±0.04) mm/Mon in MDW, 17.14 (±0.67) mm/Mon in DRT, 17.37(±2.3) mm/Mon in SHB, 26.01(±1.87) mm/Mon in TPL. For the LAI from 2000 to 2016, the value was 5.69

(±0.12) in MDW, 4.68(±0.09) in TPL, 3.58(±1.03) in DRT and 3.52(±0.13) in SHB (Table 1). Compared with the four vegetation types, the MDW and TPL showed similar LAI and albedo, but the TPL showed higher ET than MDW(Table 1). Compared between DRT and SHB, DRT showed higher albedo and LAI than SHB, but the ET was similar, the resulting have proven further the ET in control of precipitation.

Table 1: Annual mean values of albedo, evapotranspiration (ET), leaf area index (LAI)(Mean±SD) for five land cover types, meadow steppe (MDW), a typical steppe (TPL), dry typical steppe (DRT), shrubland (SHB) and desert land (DL). Significant differences between ecosystems are indicated by different letters (a, and b) at P = 0.05(Duncan's test). SD:standard deviation.

Loc	Albedo	LAI	ET(mm/mon)
MDW	0.18±0.09	5.69±0.12	24.53±0.04
DRT	0.21±0.28	3.58±1.03a	17.14±0.67a
SHB	0.19±0.29	3.52±0.13b	17.37±2.3a
TPL	0.18±0.09	4.68±0.09b	26.01±1.87b
DL	0.26±0.19		

3.2 Inter-Annual Variations of LAI and Albedo, ET

The normalized (*i.e., Z-score*) LAI, albedo and ET showed great inter-annual variations by year and month, as well as the four vegetation types (Figs. 2-3,5). For LAI, the *Z-score* for annual, the mean and variation order was determined as DRT>MDW>TPL>SHB (CV = 0.242, 0.216, 0.191, and 0.166). Additionally, a large deviation in the LAI in 2002 of DRT and SHB(2002), and in 2015 of TPL and MDW (Fig. 2a). But in the monthly, the mean and variation order of the *Z-score* was different, such as in May, the order was determined was TPL> MDW> DRT>SHB (CV = 0.357, 0.284, 0.230, 0.184); then in the June, the order was MDW> TPL> DRT> SHB(CV = 0.432, 0.328, 0.320, 0.258); in the July and August, the order were like in annual, and the value was CV_{DRT} =0.405, 0.356; CV_{MDW} =0.332, 0.304; CV_{TPL} =0.315, 0.280; CV_{SHB} =0.282, 0.206, in July and August, respectively. In the September, the order was TPL >DRT >MDW >SHB (CV =0.282, 0.268, 0.243, 0.178) (Fig. 2b-f). Additionally, a large deviation in the LAI of May in the DRT(2003) and MDW (2005) (Fig.2b); in June was DRT (2006) and SHB(2003), TPL in June (2014)(Fig. 2c); in august was DRT(2003) and SHB(2005) (Fig. 2e). For the four vegation types, the LAI showed increasing trend, especially for TPL, a significant increase was in annual (slope = 0.091, p= 0.036), July (slope = 0.106, p= 0.027) and August (slope = 0.097, p=0.047); and was for MDW in July (slope = 0.095, P= 0.046) and August (slope = 0.091, P= 0.042) (Fig. 2, Table 2). Then for the DRT and SHB, the LAI all did not reach statistical significace level in annual and monthly, even in some month, the slope value showed negative trend. This result worth noting that the vegetation improvement by warming on the MP, that MDW and TPL were more apparent than that in the west DRT and SHB. Over the 17-year study period, there were 9 years when the *Z*-score was below the long-term annual LAI mean in MDW, DRT and SHB; for TPL was 10 years (Fig.2a). In addition, the long-term change of the monthly means also differed for the four vegetation communities (Fig. 2b-f).

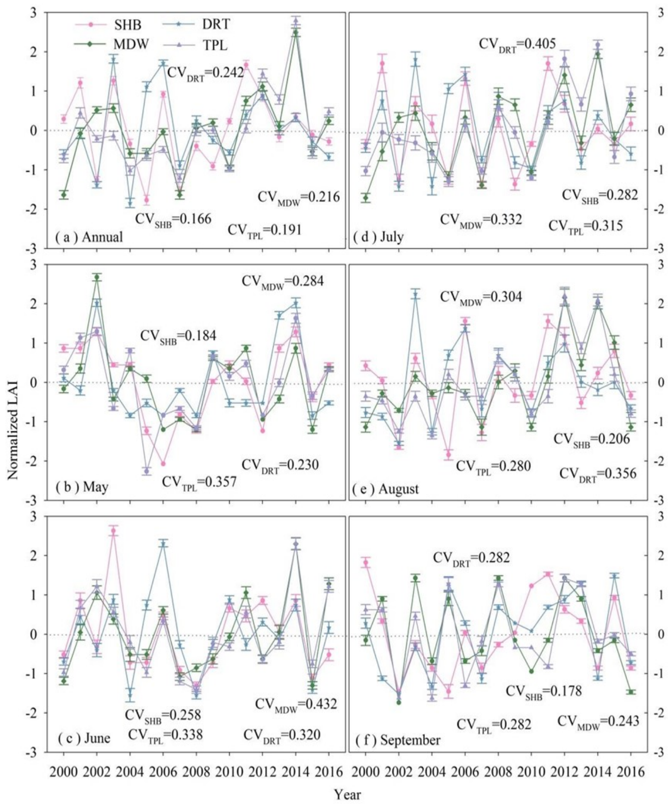

Fig. 2. The trends of the normalized LAI by yearly and monthly through 2000-2016 on the four vegetated types (meadow steppe (MDW), a typical steppe (TPL), dry typical steppe (DRT), shrubland (SHB)) in Mongolian.

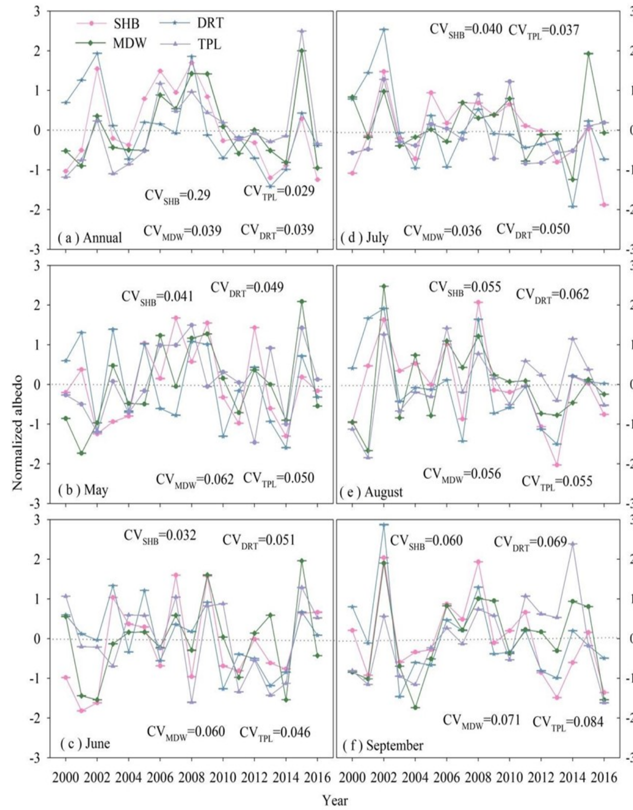

Fig 3. The trends of the normalized albedo by yearly and monthly through 2000-2016 on the four vegetated types (meadow steppe (MDW), a typical steppe (TPL), dry typical steppe (DRT), shrubland (SHB)) in Mongolian Plateau.

Finally, it seemed that: 1) LAI in MDW was in July and Augest showed significant increasing trend, but reduced trend in May and Sept; 2) LAI in TPL all showed increasing trend in annual and monthly, especially in annual, July and August showed significant increasing; 3) but for the DRT and SHB did not show significant increasing trend, even in some month expressed decreasing; 4) for the four study sites, over half years the *Z*-score was below the long-term annual LAI, it means the vegetation canopy cover did not obviously to enhance on the Mongolia plateau.

This not symmetric variability of LAI in zonally and inter-annual variation , which can be critical in driving surface energy balance. In the four vegetation types, the albedo at yearly and monthly time scales showed decreasing or increasing trends and large inter-annual variations over the study period (Fig. 3, Table 2). The albedo Z-score showed not synergistic change (CV_{MDW} = 0.039, 0.062, 0.060, 0.036, 0.056, 0.071; CV_{DRT} =0.039, 0.049, 0.051, 0.050, 0.062, 0.069;CV_{SHB}=0.029, 0.041, 0.032, 0.040, 0.055, 0.060; CV_{TPL} =0.029, 0.050, 0.046, 0.037, 0.055, 0.084 for annual, May, June, July, August, and September, respectively). The line regression of annual albedo showed decreasing trend during study years for MDW, SHB and DRT (Fig. 3, Table 2), especially for the DRT in annual albedo and monthly all showed decrasing trend (Fig. 3, Table 2) , and for annual, July and August reached significant level (slope= -0.106, -0.114, -0.085, p = 0.040, 0.015, 0.047 for annual, July and August, respectively). For the MDW and SHB, although showed negative trend by the result of line regression during study years, but did not reached statistical significance (Fig. 3a,d,e, Table 2). Interesting for the TPL, in annual and some month showed increasing trend, especially in annual and August, the slope was 0.105 (p = 0.029) in annual and was 0.091 (p =0.050) in August (Fig. 3, Table 2), only in the June showed negative trend. The anomaly in annual albedo was generally above the long-term mean before 2009 (2010) for DRT(TPL) and SHB(MDW), an extremely high Z-score was found in 2015. Similar to LAI, the long-term changes in monthly albedo values had different contributions to the annual values, regardless of the decreasing trends for most months (Fig. 3b-f). For example, the low annual albedo on the TPL in 2003 seemed to be related to the extremely low value from July through September, whereas another extremely high value in 2015 was contributed from May through July. Finally, it seemed that: 1) during 2000-2016, the annual growing season albedo showed decreasing trend in the MDW, DRT, and SHB, but in the TPL, appeared significant increasing trend; 2) by monthly, in the different vegetation communities, showed varied change direction, only for the DRT in July and August showed significant decreased trend. For desert areas, the annual growing season albedo followed a flat trend from 2000 to 2016 (p value = 0.629) (Fig. 4).

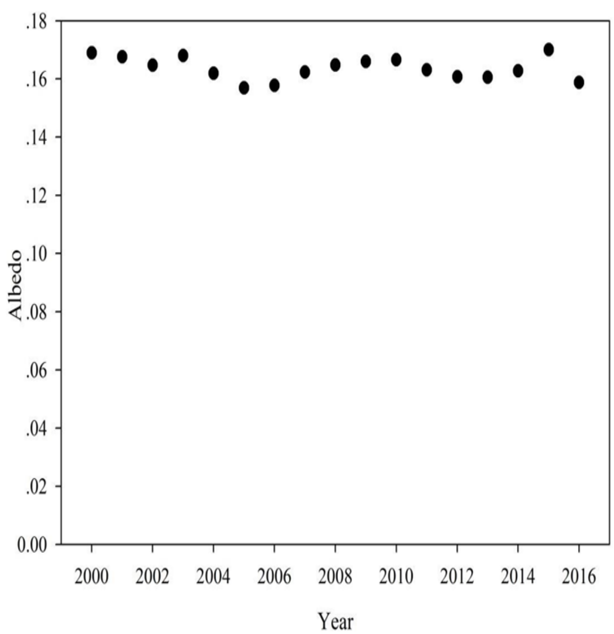

Fig 4. The growing season albedo trend for desert area in the Mongolian Plateau from 2000 to 2016.

For the ET in the four vegetation types at yearly and monthly time scales main showed increasing trends and large inter-annual variations over the study period, but with different range for four vegetation types (Fig 5, Table 2), the decreasing trend only showed in May of MDW, June of SHB and TPL. And the Z-score also showed not synergistic change for four vegetation types (CV_{MDW} = 0.196, 0.221, 0.309, 0.314, 0.280, 0.198; CV_{DRT} = 0.204, 0.247, 0.248, 0.353, 0.306, 0.154; CV_{TPL} = 0.191, 0.230, 0.292, 0.317, 0.260, 0.180; CV_{SHB} = 0.176, 0.242, 0.215, 0.319, 0.283, 0.145 for annual, May, June, July, August, and September, respectively), the inter-annual variation (i.e., CV values) in the DRT in July was highest for the four vegetation types. Although ET showed increasing trend in most annuals and months by the line regression, the significant increasing was only for MDW in July (slope = 0.096, p=0.010) and TPL in annual, July and August (slope = 0.086, p =0.050; slope = 0.116, p = 0.047; slope = 0.108, p = 0.027 for annual, July and August, respectively) (Table 2). Additionally, over the 15-year study period, there were 6 years when the Z-score was over the long-term annual ET mean in TPL, 10 years for SHB, and 9 years for MDW and DRT, however, for the years were not synergy as four vegetation types (Fig. 5a). Additionally, a large deviation for the four vegetation types was found for 2011 and 2014 in May; 2002 in June through September; 2012 in August; and 2003, 2004, 2007 for September. Finally, it seemed that: (1) in the study years, the ET in four vegetation types showed increased trend in annual and some month, especially for TPL in annual, July and August, and MDW in August; (2) in 2002, and 2007, ET for four vegetation types, in annual, June-September was very lower; and in 2014 May – June and of 2004 in September was highest; (3) Over the 15-year study period, there were mostly years when the Z-score was below the long-term annual ET mean four the four types.

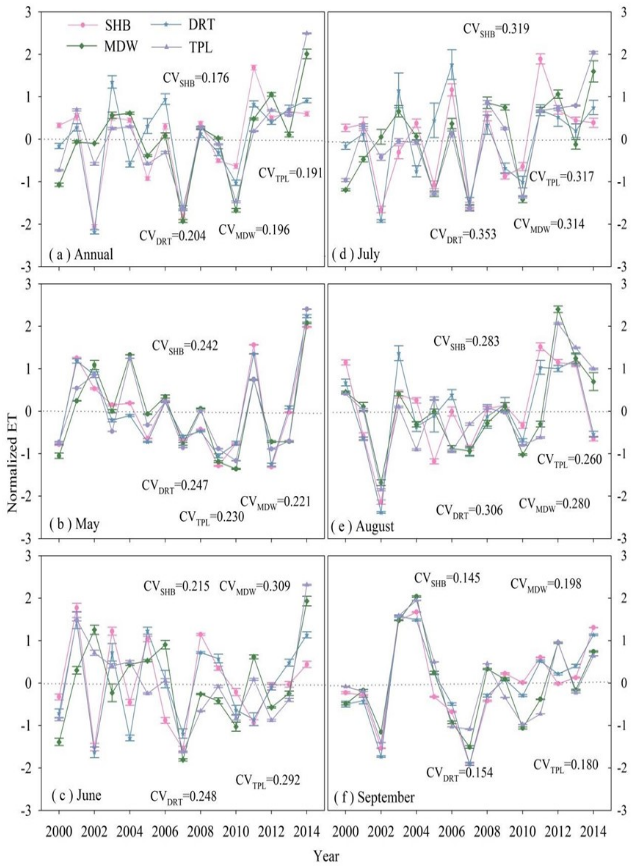

Fig 5. The trends of the normalized ET by yearly and monthly through 2000-2014 on the four vegetated types (meadow steppe (MDW), a typical steppe (TPL), dry typical steppe (DRT), shrubland (SHB)) in Mongolian Plateau.

3.3 The Interdependent Dynamics of Albedo and LAI, ET and LAI, ET, albedo and LST

Significant negative correlations were found in our selected LAI and albedo in four vegetation types (Fig. 6a), when examined by LAI classes, all four albedo measures were higher for lower LAI classes (LAI<0.20) (Fig. 6a), such as SHB and DRT (slope$_{SHB}$ = -0.014, R^2 = 0.274, p = 0.031; slope$_{DRT}$= -0.013, R^2 = 0.194, p = 0.047), were with the higher absolute value for the slope. But albedo were lower when LAI exceeded 2.0 (Fig. 6a), such as in MDW and TPL (slope$_{MDW}$ = -0.012, R^2 = 0.383, p = 0.008; slope$_{TPL}$ = -0.006, R^2 = 0.238, p= 0.047) were with the lower albedo but they were with the higher canopy. Interesting, for the low canopy vegetation types of DRT and SHB, with the similar LAI value range, but the albedo of DRT was higher, maybe because the complex canopy by leaf and limb of shrubland, combined effect on the land surface albedo.

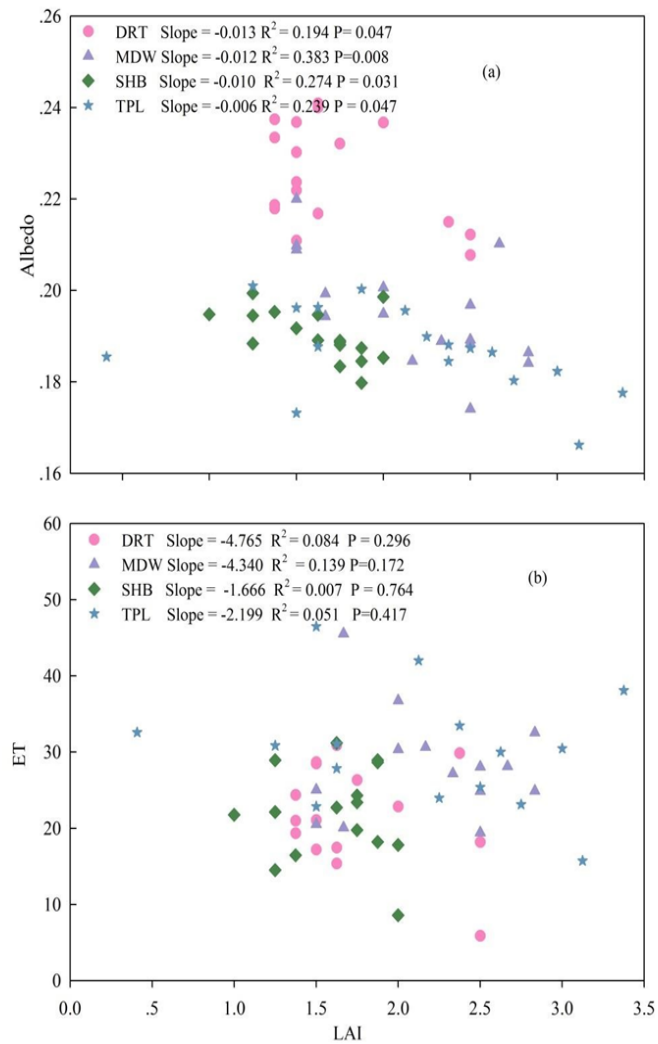

Fig.6. *The line regression of average annual albedo and ET retrieval as a function of estimated LAI classes (0.5 LAI steps), with stratified average data for the four vegetation types.*

For the LAI and ET, in theory, between them should be reason well positive correlated, but our result showed negative correlation and did not showed significant correlation between them in four vegetation types (Fig. 6b). It showed that in the acid/ semiacid region, the correlation of ET with the vegetation canopy was difficult to clear, like other factors soil type, precipitation, temperature and so on, all effect on the hydro-exchange between the atmosphere and the land surface.

4. DISCUSSION

In the Northern Hemisphere, changes in temperature, precipitation and growing season length are likely to have great effects on future vegetation development (Chen and Dirmeyer, 2016; Shao et al., 2017b), resulting in ecosystem feedbacks that may lead to further climatic changes (John et al., 2018). In particular, the biophysical effects of different land cover are receiving attention in recent years (Bathiany, 2010; Bright et al., 2015; Liess et al., 2012; Zhao and Jackson, 2014). This is because land surface process change effect is probably similar or even larger in magnitude than the greenhouse effect on climate. Moreover, they could probably even offset the biochemical climate benefits (Betts, 2000; Bonan et al., 1992; Pitman et al., 2011).

Our results indicate that the annual mean normalized albedo during the 17-years study period ranged from -1.183(2000) to 2.496(2015) for TPL; -1.420 (2013) to 1.936(2002) for DRT; -0.951(2016) to 2.001(2015) for MDW; and -1.248(2016) to 1.697 (2008) for SHB. For the intre-annual change, the *Z-score* for annual, the variation order was determined as DRT>MDW>TPL>SHB (CV = 0.242, 0.216, 0.191, and 0.166). The slope of the long-term annual albedo mean in annual and some month showed decreasing trend, especially for DRT in annual (slope -0.106, p=0.040), July(slope -0.114, p=0.015) and August(slope -0.085, p=0.047). But interesting for the TPL, except in June, for annual and month all showed increasing trend, and significant was in annual (slope =0.105, p=0.029) and August (slope 0.091 p=0.050) (Fig. 3, Table 2). By this different change directions of albedo for the four typical vegetation in the cold, semi-arid climate of MP, confirmed that complex of the region capture of sunlight solar for vegetation canopy at there. Furthermore, the annual growing season albedo for the desert area exhibited a flat trend in the same period, which lends further support on the driving effects of vegetation canopy on the growing season albedo. These abnormal variations for the different vegetation communities are at similar magnitudes as those in different land use at there. Like in Arctic by a tundra-to-shrubland or a tundra-to-forest transition (Eugster et al., 2000; Souther et al., 2014); the South American Chaco (Houspanossian et al., 2017), in the tropical rain forests, and the Swiss Alps mountains in Europe (Rangwala and Miller, 2012), land cover change must be change the absorption active of sunlight. Especially for the human-induced land use changes, such as in forest-cropland and grassland conversion (Carrer et al., 2018; Zhao et al., 2017). Additionally, our result all confirmed that the significant negative correlation between them, such as the slope was 0.012 (p = 0.008) for MDW, was -0.013 (p = 0.047) for DRT and was -0.010 (p = 0.031) for SHB, was -0.006, (p=0.046) for TPL (Fig. 6a). The resulting was consistent with other papers (Bathiany et al., 2010; Bright et al., 2015; Lee et al., 2011; Loranty et al., 2014; Rotenberg and Yakir, 2010; Tian et al., 2017).

For the LAI in the study 17years, the resulting of line regression for four vegetation community types showed increasing trend in annual and most month, especially for TPL in annual, July and August, and for MDW in July and August (Fig.. 2a). This result was conformable with other papers on the MP (Chen et al., 2015; John et al., 2018; Qi, 2017; Shao et al., 2017b; Shen et al., 2015; Tian et al., 2018). However from the month change of slope in the study years in May and September, we did not found the growing season extension over there.

As direct reflection of surface water supply capability, the more soil moisture, vegetation cover degree that more water is avilable for ET(French et al., 2012; Krishnaswamy et al., 2014). Our results indicate that the annual mean normalized ET during the 15-year study period varied from -2.059 to +1.688 for SHB, -2.183 to 1.348 for DRT, -1.927 to 2.011 for MDW, and -1.660 to 2.495 for TPL (Table 2). The value for the four vegetation communities *main* showed *increasing* trends and large inter-annual variations (Fig. 5, Table 2). The resulting of line regression analysis showed that the reached significant change only for MDW in July (slope = 0.096, p=0.010) and TPL in annual, July and August (slope = 0.086, p =0.051; slope = 0.116, p = 0.047; slope = 0.108, p = 0.027), respectively. (Table 2). Although the LAI and ET all showed increasing trend in the study years for the four vegetation communities (Figs. 2, 5, Table 2), the correlation of LAI and ET showed clear negative correlation (Figure. 6). And more resulting support that the vegetation cover degree is a strong control land surface ET(Fatichi and Ivanov, 2014; Garcia et al., 2014). Our result also showed increase sunergistically between them, however, the LAI-ET correlation was negative, it showed more complex relation LAI-ET than LAI-albedo. In arid/ subarid areas with high radiation load, the changes in the radiation balance that follows vegetation changes are likely more important than evapotranspiration contrasts between different vegetation covers because they tend to evapotranspire most from rainfall inputs (Houspanossian et al., 2017; Rotenberg and Yakir, 2010; Santoni et al., 2010). More other factors such as soil, temperature, precipitation all effect the relation for the LAI-ET.

Many land surface process field experiments have been conducted to better quantitatively understand the effect of different terrestrial ecosystem on heat and water fluxes and the impact of land cover change induced alteration in fluxes on local, regional and global climate change (Davin and de Noblet-Ducoudre, 2010; Gibbard et al., 2005; Khishigbayar et al., 2015; Loranty et al., 2014; Zhao and Jackson, 2014) . It was predicted that the vegetation coverage change accompanying the tundra-to-shrubland transition would increase July mean air temperature by +1.5 to +3° in the Arctic (Chapin et al., 2000; Eugster et al., 2000; Frost and Epstein, 2014; Juszak et al., 2014). On the MP, for the occupied the largest area proportion the desert steppe (DRT)(27.2%) significant positive feedback to regional climate change; and for the second area proportion the typical steppe (TPL) (26.1%) on the MP, significant negative feedback to regional climate change, it may look like a offset the energy balance change over there, but for the long-term, it is necessary to clear the magnitude of energy balance among the communities. Due to the greater value of solar irradiance, reduced land surface albedo means more irradiance absorbed, which would further exacerbate climate warming. Compared to the centuries or multi-decades taken by the tundra-to-forest transition or the tundra-to-shrub transition, changes in vegetation greenness and vegetation community in the Mongolia plateau driven by climate flux may take place in a matter of years.

CONCLUSION

The purpose of this study is to quantify the land surface water and heat fluxes arising from spatial patterns of vegetation community in the present climate, as well as enrich the land surface process comprehend in the hinterland of MP.

We choose four vegetation communities (MDW, TPL, DRT, SHB), where the study sites share the same climate conditions defined by the downward radiation. Changes in albedo and ET characteristics of our resulting were directly related to surface characteristics. The LAI and ET were increasing trend for long term mean value in annual growing season for four vegetation types, but for the month change direction was mismatches.

For the albedo, in study 17 years, showed decreasing trend in MDW, DRT and SHB for annual growing season, especially for the DRT in annual and all month was a reduction; but interesting for the TPL, showed significant increasing trend in annual and most month, although its LAI was significant increasing. This is worth further to research. Feel delighted that the correlation between LAI-albedo in the four vegetation types should significant negative correlation. But the correlation between LAI-ET was also negative correlation. Additionally, the interdependent changes in LAI-albedo, LAI-ET on the plateau also showed large variations over time for four vegetation types, we also found some major mismatches between them for some years in different vegetation types.

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