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Effects of land use intensity on the restoration capacity of sandy land vegetation and soil moisture in fenced sandy land in desert area[1]

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ABSTRACT

Effects of different land use intensity (phytomass semi-cutting and all-cutting) on structure characteristics of plant community and soil moisture in a natural vegetation enclosure and an artificially-aided enclosure were investigated in a sandy grassland in Northern China. No-cutting (phytomass kept nomal) was taken as the control treatment (CK). Analyzes showed that: 1) Importance value of the dominant species of different cutting treatments was in the range of 0.47–0.75. The influence of different cutting intensities on species composition was not significant for the same fenced method; 2) Both the diversity indices and the evenness index of shrub layer for the two enclosures were in the order: CK > semi-cutting > all-cutting; the similar indices of the plots of same cutting intensity and different fenced methods were smaller than 0.3; 3) The above-ground biomass of all-cutting treatment was significantly less than that of semi-cutting treatment, and CK had no significant difference from semi-cutting treatment; 4) There were significant differences in soil moisture between all-cutting and semi-cutting. The soil moisture of different layers within 80 cm increased with the increase of cutting intensities. In 0–30 cm, the soil moisture in different cutting intensities was increased with depth; however, in 30–70 cm, it decreased quickly with the increase of soil depth. Soil moisture under different cutting intensities and CK was in the following order: all-cutting > semi-cutting > CK. It proved that land use has some regulation and improvement effects on soil moisture.

Keywords: two enclosures, land use intensity, vegetation, diversity, biomass, soil moisture.

Desertification is an important environmental problem in China. Many measures to control desertification have been developed and implemented successfully in China [1]. Among these, natural recovery of sandy vegetation without any artificial measures (natural vegetation enclosure) and constructing squared wheat straw checkboard combined with planting sand-fixing shrubs in the most severely degraded land (artificially-aided enclosure) are accepted as common measures for restoring desertified land. The two measures have been confirmed to be successful in accelerating land restoration, decreasing wind erosion, improving soil characteristics and promote vegetation restoration [2]. Therefore, both of them are widely used in China.

However, as the non-equilibria concept was formulated [3–5], as well as long-term changes in plant species composition and biomass production [6–8], grazing of fenced grassland has been regarded as a tendency in grassland management. We could ask whether we can utilize vegetation of natural vegetation enclosure and artificially-aided enclosure in sandy grassland by appropriate methods or not?

The vegetation use associated with the two measures in these regions is poorly documented, partly because there has worried about

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sandy lands are remobilized. Therefore, it is important to gather information on the relationship between land use and stability of sandy land and the effects of land use intensities on vegetation and soil properties in the two enclosures.

The objective of our study was to evaluate the effects of land use intensity on vegetation and soil moisture of natural vegetation enclosure and artificially-aided enclosure in a sandy grassland in Northern China.

MATERIAL AND METHODS

The study area is located at the south edge of the Tengger Desert at jingtai County (103°33′ ~ 104°43′ E, 36°43′ ~ 37°38′ N) in Gansu Province, China. The region belongs to temperate desert climatic zone with mean annual precipitation of 184.8 mm. Nearly 75 % of the rainfall occurs between March and September. The annual average temperature is 8.2 °C, the maximum and minimum temperatures is 36.6 °C and −27.3 °C, respectively. The annual sunshine duration is about 2725.7 hours and the evaporation is 3038.5 mm; the average wind speed is 3.5 m/s while the highest 21.7 m/s; the number of days with >8 scale wind is 27.9 and number of days with sandstorm is 21.9 in a year; underground water table is 80 m; soils are mostly grey brown desert and sierozem, according to the Chinese Soil Classification System (CSTCRG, 1995).

In the north of the study region, landscape is characterized by relatively more mobile sandy land, dense dunes, and loose soil. The original vegetation was *Artemisia arenaria* DC. and *Agropyron desertorum* etc. and vegetation coverage is < 5 %. In order to promote vegetation restoration and prevent wind erosion, since the 1990s, the county has begun to implement enclosure measures, including natural vegetation enclosure and artificially-aided enclosure. Among these, natural vegetation enclosure (NE) was the measure that completely depends on the natural environmental characteristics to reverse desertification and achieve vegetation restoration; but artificially-aided enclosure (AE) was combined with other measures, i. e., 1 × 1 m squared wheat straw checkboard in shifting sand dunes at first which can increase the entrapment of airborne dust, enhance the fine particle content of topsoil, increase water-holding capacity and soil fertility, and improve other soil physicochemical properties that promote the establishment and spread of plants [9−11], and after sand surface became stable, sand-fixing shrubs, such as *Caragana korshinskii* Kom., *Artemisia arenaria* DC., and *Hedysarum scoparium* Fisch. et Mey. etc., were planted which act as a sink for resources, either actively through root uptake of soil water and nutrients [12−14] or passively by accumulating wind-blown dust and litter [15−17], in a feedback mechanism that facilitates invasion and colonization by other plant species under or near its canopy, and then to achieve vegetation restoration. Both of two measures are widely used around the study site.

Livestock grazing is a major land use type in arid and semi-arid environments. Thus it is necessary and representative to study effect of vegetation utilization on sandy land ecosystem by livestock grazing. However, the implement of grazing experiment is difficult and uncontrollable in limited sampling plots. Therefore, we conducted a field experiment by cutting to model the impact of grazing on vegetation and soil moisture in natural vegetation enclosure and artificially-aided enclosure. Two cutting intensities (semi-cutting and all-cutting) were set up on each site and was treated as moderate grazing and heavy grazing, respectively. Among these, semi-cutting was treatment that vegetation coverage was thined to half of the normal; all-cutting was one that vegetation coverage became zero. No-cutting (vegetation coverage kept nomal) was taken as the control treatment (CK). CK was treated as grazing-excluded (hereafter denoted as ungrazed).

In August 2007, four sampling plots (50 × 50 m) were randomly chosen within each site. Each plot was located at least 25 m from the next nearest replica. Among these plots within each site, three sampling plots (50 × 50 m) were used as treatment plots, the remained as CK. Within each treatment plot, eight quadrats (4 × 4 m) were set for evaluating shrub vegetation, and eight smaller quadrats (1 × 1 m) were used for detailed inventory of herbaceous vegetation. Two cutting intensities (treatments) were set

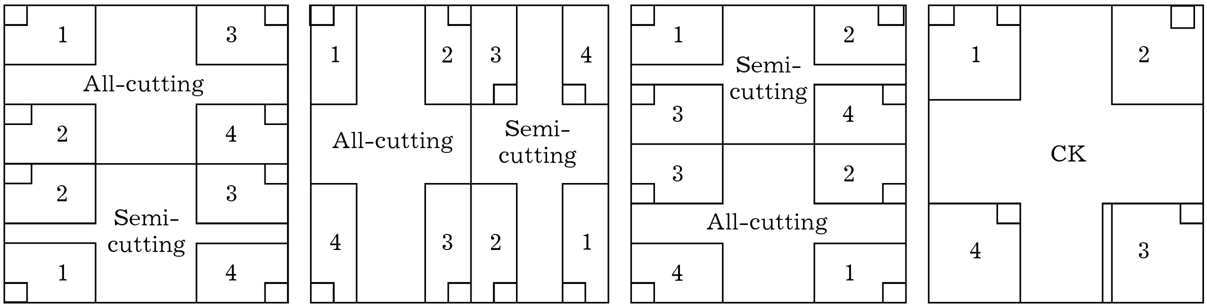

Fig. 1. The measuring point location of the studied plots (NE)

up on eight quadrats (4 × 4 m) within each treatment plot. In one, four quadrats (4 × 4 m) were mechanically chosen for semi-cutting; in the other, the remained used as all-cutting (Fig. 1).

In August 2008, grasses and forbs of the plant communities were identified, counted and height was determined within all the four quadrats (1 × 1 m) of each treatment plot. The aboveground standing biomass was cut in each quadrat, and the dry weight was weighed after being dried at 80 °C for 48 h. Within the four shrub quadrats (4 × 4 m) of each treatment plot, all shrubs were identified, counted, height and crown diameter of the shrubs were measured. The aboveground biomass was clipped, and the fresh and dry biomass were weighed separately.

Soil samples from each treatment plot (semi-cutting and all-cutting) and CK were collected for gravimetric soil water-content analysis to a depth of 1.40 m with 0.20 m increment using an auger (sampling diameter, 0.04 m) during the growing season from March to September, 2008, at approximately 20 day interval. Each complete set of samples was collected within 2 days to reduce the effect of sampling time on our results. Soil samples were oven dried at 105 °C.

Because the enclosures were at one location and not replicated, we followed the approach of Frank et al. [18] and considered each of the three plots a replication of summary statistics. Values from all sampling points within each plot were averaged. Then, one-way analysis of variance (ANOVA) procedures were used to detect the differences in parameters examined between treatments and sites. The least significant difference (LSD) was performed to determine the significance of treatment means at $P < 0.05$. The species richness (S), diversity indexes (H', D) and evenness index (J) were used to describe the plant species diversity. Each parameter was calculated as

$A = n$ (the number of the ith species per quadrat);

$S = N$ (the number of species per quadrat);

$D = 1 - \Sigma P_i^2$;

$H' = -\mathrm{S}P_i \ln P_i$;

$J = H'/\ln S$;

Mountfort (1962) Similar index $I = $
$= 2c/[2ab - (a + b)c]$.

Where i is the ith species; P_i is the relative IV of the ith species; the importance values (IV) of species were calculated using the following formulas: IV = (relative density + relative frequency + relative coverage)/3; and a is the number of species of plot A; b is the number of species of plot B; c is the number of share species of plot A and plot B.

RESULTS AND DISCUSSION

Changes in plant community composition. Difference in plant community composition was observed between the treatments (Table 1). In the AE site, some new species were introduced by artificial planting, such as *Caragana korshinskii* Kom., *Hedysarum scoparium* Fisch. et Mey. and *Calligonum mongolicum* Turcz. in shrub layer; and *Agriophyllum squarrosum* etc. were found in grass layer. The dominant species of different treatment was *Artemisia arenaria* DC. or *Artemisia scoparia* Waldst. et and their importance values were in the range of 0.47–0.75. No significant differences were found be-

Table 1

Effect of utilization intensities on the species composition and the importance value of sandy vegetation community

Mea-sure	Treatment	Shrub layer Species name	IV	Herb layer Species name	IV
NE	CK	*Artemisia arenaria* DC.	0. 56	*Lappula myosotis* V. Wolf	0.81
		Artemisia scoparia Waldst. et	0.32	*Cirsium setosum* (Willd.) MB.	0.47
		Nitraria tangutorum Bobr.	0.20	*Cirsium lanatum*	0.40
				Echinopsgmelini Turcz.	0.30
	Semi-cutting	*Artemisia arenaria* DC.	0.48	*Salsola ruthenica* Iljin.	0.07
		Artemisia scoparia Waldst. et	0.40	*Achnatherum inebrians*	0.62
		Nitraria tangutorum Bobr.	0.31	*Echinopsgmelini* Turcz.	0.54
		A. Parviflora (Grün.) Ling ex Shih	0.26	*Salsola ruthenica* Iljin.	0.43
		Artemisia sphaerocephala Krasch.	0.12	*Echinopilon divaricatum*	0.33
		Oxytropis aciphylla Ledeb.	0.12	*Cirsium lanatum*	0.14
		Caragana roborovskyi Kom.	0.12	*Cirsium setosum* (Willd.) MB.	0.09
	All-cutting	*Artemisia scoparia* Waldst. et	0.47		
		Artemisia arenaria DC.	0.44	*Salsola ruthenica* Iljin.	0.29
		Nitraria tangutorum Bobr.	0.15	*Echinopilon divaricatum*	0.25
		Artemisia sphaerocephala krasch	0.11	*Lappula myosotis* V. Wolf.	0.25
		A. Parviflora (Grün) Ling ex Shih	0.07	*Achnatherum inebrians*	0.16
		Caragana roborovskyi Kom.	0.06	*Echinopsgmelini* Turcz.	0.05
		Scorzonera divaricata Turcz.	0.03	*Thermopsis schischkinii* Czefr.	0.00
				Cirsium lanatum	0.00
				Cirsium setosum (Willd.) MB.	0.00
AE	CK	*Artemisia arenaria* DC.	0.56	*Stipa bungeana* Trin.	0.83
		Caragana korshinskii Kom.	0.30	*Oxytropisglabra* DC.	0.23
		Hedysarum scoparium Fisch. et Mey.	0.24		
		Nitraria tangutorum Bobr.	0.19		
		Oxytropis aciphylla Ledeb.	0.05		
		Calligonum mongolicum Turcz.	0.08		
	Semi-cutting	*Artemisia arenaria* DC.	0.52	*Stipa bungeana* Trin.	0.56
		Atraphaxisfrutescens	0.31	*Cirsium lanatum*	0.46
		Nitraria tangutorum Bobr.	0.28	*Lappula myosotis* V. Wolf.	0.39
		Caragana korshinskii Kom.	0.22	*Agriophyllum squarrosum*	0.34
		Hedysarum scoparium Fisch. et Mey.	0.16	*Salsola ruthenica* Iljin.	0.19
		Oxytropis aciphylla Ledeb.	0.09	*Thermopsis schischkinii* Czefr.	0.07
		Calligonum mongolicum Turcz.	0.06	*Echinopilon divaricatum*	0.06
	All-cutting	*Artemisia arenaria* DC.	0.75	*Lappula myosotis* V. Wolf.	0.44
		Nitraria tangutorum Bobr.	0.32	*Stipa bungeana* Trin.	0.33
		Hedysarum scoparium Fisch. et Mey.	0.22	*Agriophyllum squarrosum*	0.30
		Calligonum mongolicum Turcz.	0.12	*Echinopsgmelini* Turcz.	0.19
		Atraphaxisfrutescens	0.07	*Salsola ruthenica* Iljin	0.16
		Caragana korshinskii Kom.	0.06	*Oxytropisglabra* DC.	0.16
		Oxytropis aciphylla Ledeb.	0.04	*Cirsium lanatum*	0.10
				Echinopilon divaricatum	0.04

Table 2

Effect of land use intensities on diversity indices and evenness index of vegetation community

	Measure	Treatment	D	H'	J
Shrub layer	NE	CK	0.50 ± 0.06	0.80 ± 0.12	0.88 ± 0.03
		Semi-cutting	0.48 ± 0.03	0.77 ± 0.05	0.83 ± 0.04
		All-cutting	0.38 ± 0.07	0.78 ± 0.11	0.78 ± 0.08
	AE	CK	0.43 ± 0.03	0.82 ± 0.17	0.84 ± 0.04
		Semi-cutting	0.49 ± 0.07	0.81 ± 0.13	0.78 ± 0.08
		All-cutting	0.34 ± 0.05	0.60 ± 0.08	0.63 ± 0.06
Herb layer	NE	CK	0.52 ± 0.17	1.01 ± 0.34	0.63 ± 0.21
		Semi-cutting	0.33 ± 0.07	0.51 ± 0.10	0.62 ± 0.11
		All-cutting	0.31 ± 0.06	0.50 ± 0.08	0.56 ± 0.10
	AE	CK	0.27 ± 0.09	0.41 ± 0.14	0.59 ± 0.20
		Semi-cutting	0.44 ± 0.04	0.71 ± 0.07	0.87 ± 0.05
		All-cutting	0.46 ± 0.06	0.83 ± 0.13	0.76 ± 0.08

Note: Data showed as mean ± S.D.

tween the different treatments in same fenced area in term of the dominant plant species and community composition ($P < 0.05$).Therefore, species composition of vegetation community was different with different fenced methods; the effect of different cutting intensities on species composition was not significant for the same fenced method.

Effect of land use intensities on diversity indices and eveness index of sandy vegetation community. Community diversity was one of the important indices that reflected community development level and community function. Results in table 2 indicated that the Simpson index (D) and Shannon-Wienner index (H') of shrub layer for the two enclosures were expressed as following order: CK > semi-cutting > all-cutting. It showed that the diversity indices of shrub layer for the two enclosures were in a decreasing trend with the increasing cutting intensity; namely, cutting decreased the effect of shrub layer coverage of fenced sandy land on community structure and function, which increased environment heterogeneity. The ANOVA analysis (Table 2) identified that there were no significant difference for Simpson index (D) and Shannon-Wienner index (H') between different treatments in the two enclosures ($P < 0.05$).

However, the impact of cutting treatment on diversity of herb layer showed complexity in different plots which had different fenced methods. The diversity indices of herb layer for NE were expressed as in the order: CK >semi-cutting >all-cutting, and it illustrated that diversity indices of herb layer in NE was in a decreasing trend with increasing land use intensity. And the ANOVA analysis identified there were no significant differences among different treatments ($P < 0.05$). The diversity indices in AE were expressed as in the following order: all-cutting > semi-cutting > CK. The reason might be that the planted species were mainly shrubs, such as *Calligonum mongolicum* Turcz., *Caragana korshinskii* Kom., and *Hedysarum scoparium* Fisch. et Mey., which were dominant species in AE; but cutting made these shrubs not achieve the coverage before treatment in short-term, so that provided growth space for herb species.

Community evenness was the distribution proportion of individual number of different species in community, which reflected adaptation situation of different species to environmental factors in community; and to certain number of species, evenness had only related with even degree of distribution of each species individually or community biomass and so on in community, and there was no relationship with the number of species. The more homogeneously each species distributes, the higher the evenness index is. The evenness index of shrub layer for the two enclosures decreased in the following order: CK >semi-cutting >all-cutting; and the evenness index of herb layer for NE decreased in the same or-

Table 3

Similarity index among shrub layer of sandy land vegetation community under different utilization intensities

Similarity index	NE-all-cutting	NE-semi-cutting	AE-CK	AE-all-cutting	AE-semi-cutting
NE-CK	0.5	0.5	0.22	0.18	0.18
NE-all-cutting	–	0.86	0.07	0.06	0.06
NE-semi-cutting	–	–	0.3	0.11	0.11
AE-CK	–	–	–	2	2

Table 4

Similarity index among herb layer of sandy land vegetation community under different utilization intensities

Similarity index	NE-all-cutting	NE-semi-cutting	AE-CK	AE-all-cutting	AE-semi-cutting
NE-CK	0.29	0.22	0	0.29	0.18
NE-all-cutting	–	1	0	0.21	0.27
NE-semi-cutting	–	–	0	0.2	0.17
AE-CK	–	–	–	0.33	0.11
AE- all-cutting	–	–	–	–	0.55

der, but it showed an opposite order in the AE: semi-cutting >all-cutting >CK. By contrast, similar indices of the plots with the different fenced methods on each level of land use were smaller than 0.3 (table 3, 4).

Effect of land use intensities on biomass of sandy vegetation community. ANOVA analysis showed that the above-ground biomass of all-cutting treatment was significantly less than that of semi-cutting treatment in the two enclosures, but CK had no significant difference with semi-cutting treatment ($P < 0.05$) (Table 5). It showed that the above-ground biomass decreased significantly with increased cutting intensity in fenced sandy land community.

Table 5

Effect of utilization intensities on biomass of sandy land vegetation community

Measure	Treatment	Biomass
NE	CK	151.4 ± 15.00 *a*
	Semi-cutting	181.38 ± 26.00 *a*
	All-cutting	88.88 ± 13.89 *b*
AE	CK	231.50 ± 12.00 *a*
	Semi-cutting	222.00 ± 38.55 *a*
	All-cutting	70.63 ± 5.63 *b*

Note: Data showed as mean ± S.D.; values in each column with the same letter are not significantly different among the treatments ($P < 0.05$).

The correlation analysis showed that the species richness and above-ground biomass of different cutting treatments has no significant correlation in the two enclosures.

Changes of soil moisture. Temporal distribution of soil water content. In the two enclosures, mean soil water content in different treatments are shown in Table 6. ANOVA analysis showed that there had significant difference at 0~20, 20~40, 40~60, 60~80 cm soil layers, respectively between semi-cutting treatment and all-cutting treatment, and CK ($P \le 0.01$), but the difference was not significant below 80 cm in NE and AE.

Under different land use intensities, the seasonal changes of the soil water profiles were similar, approximately following the same pattern as that of CK from March to September (Fig. 2). The highest mean of soil water content was found under all-cutting treatment site in the two enclosures, while CK was the lowest. The reason for these differences in soil moisture contents was due to differences in evapotranspiration from different vegetation coverage and soil surface properties such as soil crust [19, 20].

Soil water contents among different treatments changed seasonally, and greater similarities were observed in the period July to September than in March to July (Fig. 2). The

Table 6

Variance analysis for the mean soil moisture in different cutting intensities for the two enclosures

Measure	Treatment	Depth, cm						
		0–20	20-40	40–60	60–80	80–100	100–120	120–140
NE	All-cutting	1.36A	3.81A	4.04A	3.72A	3.05A	2.81A	2.69A
	Semi-cutting	1.29B	3.97A	4.22B	3.46B	2.92A	2.69A	2.74A
	CK	1.06B	3.44B	3.76C	3.11C	2.74A	2.33A	2.64A
AE	All -cutting	0.79A	4.62A	5.18A	4.48A	3.67A	3.15A	3.27A
	Semi-cutting	0.78A	4.59A	4.87B	4.07B	3.84A	2.87A	2.48A
	CK	0.81A	3.71B	4.3C	3.37C	2.65A	2.72A	2.27A

N o t e: Values in each column with the same letter are not significantly different among the treatments ($P < 0.05$).

reason might be that compared with that in the period March to July, rainfall events were more frequent during July and September, leading to a greater degree of soil water recharge. Frequent rainfall decreased the variability of soil moisture [21, 22].

Vertical distribution of soil water content. Figure 3 showed the vertical distribution of the mean soil water content in different treatments in the two enclosures. The trend for the two enclosures showed a low-high-low fluctuation with increased depth and the maximum soil water content mostly occurred in 30 cm layer. Soil water in the upper layers (0 ~ 30 cm) showed lower soil moisture; in 30–70 cm, soil water decreased quickly with the increase of soil depth. The reason for the lower soil mois-

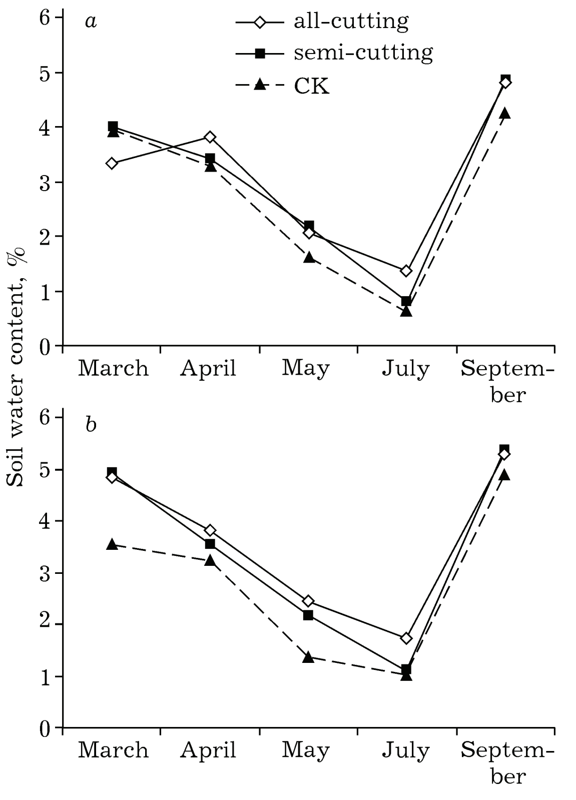

Fig. 2. Seasonal variation of soil water content in NE plots (*a*) and AE plots (*b*)

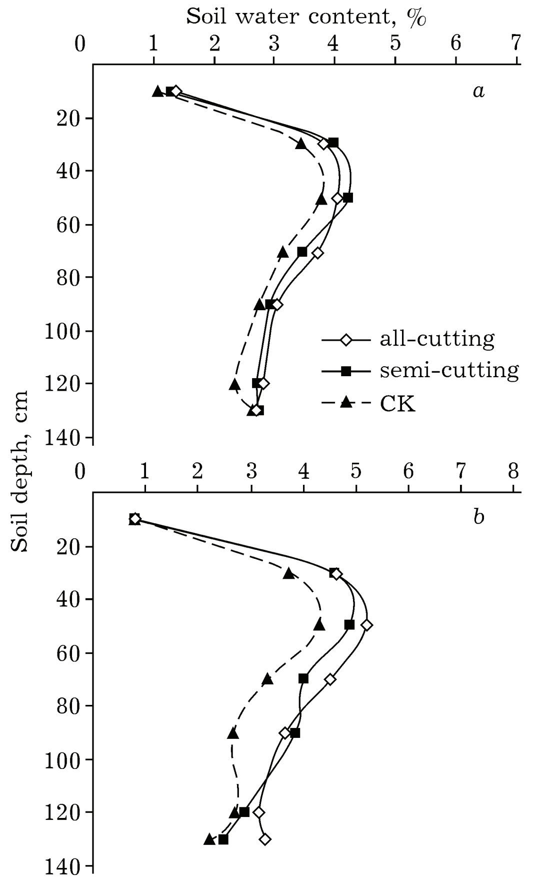

Fig. 3. Depth variation of soil water content in NE plots (*a*) and AE plots (*b*)

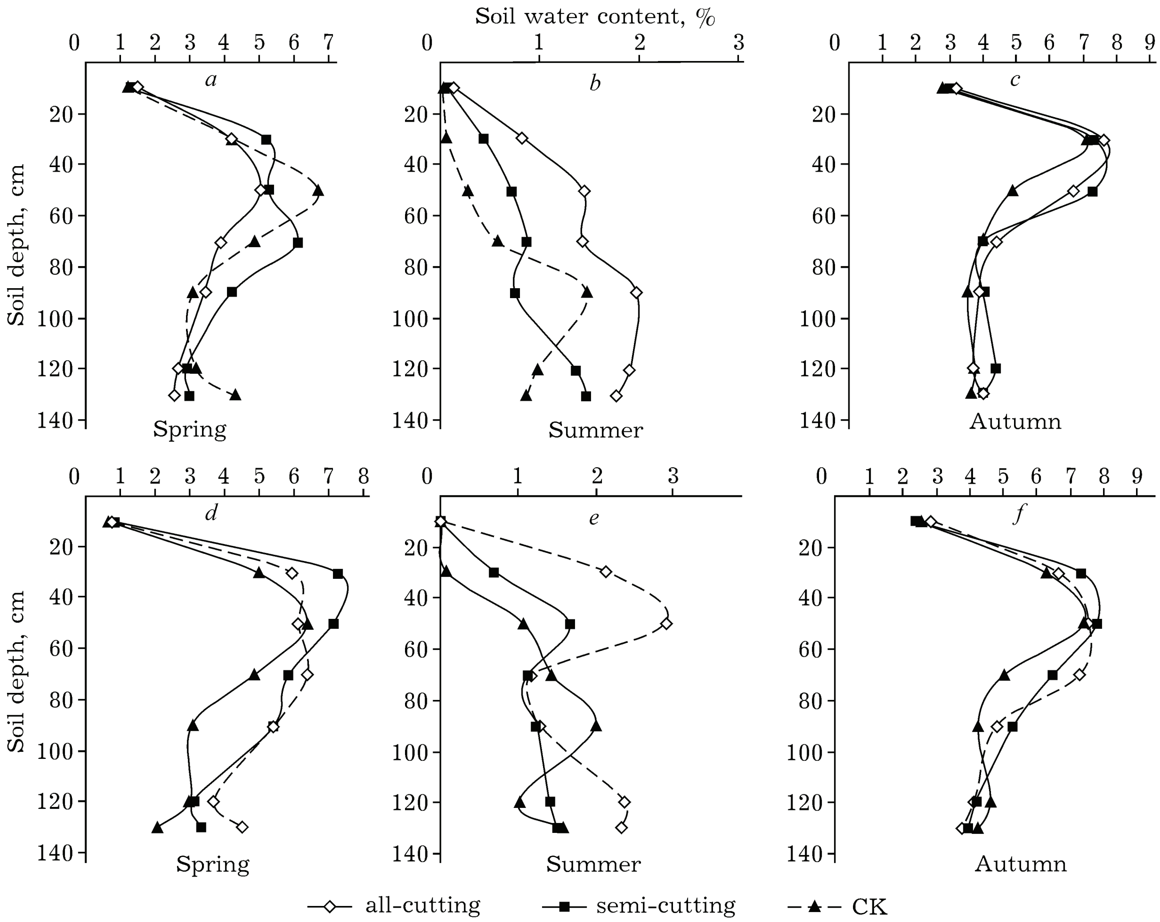

Fig. 4. The effect of land use on soil water content of NE plots (*a*, *b*, *c*) and AE plots corresponding to depth (*d*, *e*, *f*)

ture content in surface soil layer might be contributed to extensive surface evaporation [23]; below 30 cm soil layer, there was main roots distribution of shrubs and herds and soil water was rapidly decreased by root water uptake [24]; below 70 cm depth, soil water content changed slightly with depth increase.

Seasonal variation of the soil water contents was different (Fig. 4). In NE, variations of soil water at the depth of 0-30 cm between the cutting treatment and CK fluctuated greatly during the spring, while the soil water of deeper soil layers at the depth of 30-50 cm decreased slightly with depth increased; in summer, owing to vigorous vegetation growth and extensive evapotranspiration, soil water content within 100 cm depth showed that the nearer to the soil surface, the lower the soil moisture was; in autumn, soil water content change with depth was similar to that of spring, while the difference of soil moisture between the treatments and CK was reduced. The difference between NE and AE was as following: soil water at 30–80 cm depth decreased quickly with depth increased during the spring, while in summer, soil water variation below 80 cm depth was different. Overall, the difference of the soil moisture between different cutting intensity and CK was in the following order: all-cutting > semi-cutting > CK.

Species richness and community diversity are important community characteristics. Studies on the effects of any disturbance on community structures needed to evaluated its species diversity. Desert ecosystem is one of the fragile land ecosystems, and different land use intensity have different influences on its biodiversity. It was shown that decrease in shrub coverage by human impact might lead to decrease of shrub diversity indices in sandy grassland. On the basis of intermediate disturbance hypothesis, however, if fenced sandy land was rarely affected by disturbance factors, community diversity was also not high. Therefore, in practice, when the time of enclosure achieved some years, moderate disturbance would contribute to improvement of community stability.

The effect of grazing intensity (moderate grazing and heavy grazing) on plant community biomass was confirmed. That is, disturbance by heavy grazing was too violent to sandy land vegetation, and made its vegetation show an obvious degenerating trend and community biomass reduced. It illustrated that adaptability of the two enclosures had definite boundary to artificial disturbance, whether sandy land vegetation was kept stable or not, how great extent its occurred and how long returned to original status after disturbance depended on the properties and intensity of artificial disturbance. Only under moderate disturbance frequency and disturbance intensity we can achieve ecological stability of sandy land of natural vegetation enclosure and artificially-aided enclosure.

Zheng et al. [25] reported that the relationships between biodiversity and biomass under different regimes of grassland use (grazing and cutting) in Hulunbeir had no obvious correlation. Our results for the relationship of species richness and above-ground biomass of different grazing intensity in the two enclosures was consistent with the findings in those studies.

In desert ecosystem, there was little precipitation and temperature varied greatly. The variation laws of soil water in sandy land mainly depended on the situation with vegetation development, that is, vegetation evapotranspiration determined use of soil water. In the long-term fenced sandy land, more vegetation coverage inevitably led to excessive consumption and evapotranspiration of soil moisture, which would accelerate gradual drying of soil water environment of community. Therefore, the impact of long-term enclosure on soil eco-hydrological effect of sandy land was negative. The results showed that in the two enclosures there were significant differences in soil moisture between heavy grazing treatment and moderate grazing treatment with CK. It illustrated that grazing had some regulation and improvement effects on soil moisture. But heavy grazing made sandy land surface bared completely and accelerated sandy surface evaporation, and thus soil moisture decreased; while impact of moderate grazing was moderate, soil moisture was well kept.

CONCLUSIONS

In a sandy grassland of natural vegetation enclosure and artificially-aided enclosure, (1) the influence of different grazing intensity (moderate grazing and heavy grazing) on species composition was not significant for the same fenced method?(2) in long-term fenced sandy land, moderate grazing would contribute to improvement of community stability and have no significant influence on biomass?(3) moderate grazing has some regulation and improvement effects on soil moisture of different layers within 80 cm.

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