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EFFECT OF PASTURE ENCLOSURE AND DUNG DROPPINGS ON SOIL NUTRIENTS AND ABOVEGROUND BIOMASS IN ALPINE GRASSLAND IN THE NORTHERN TIBETAN PLATEAU

Zengrang Xu[1], Chunxia Lu[1], Shengkui Cheng[1] and G. C. Dhruba Bijaya[1,2]

[1]Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, 11A Datun Road, Chaoyang District, Beijing 100101, PR China
[2]University of Chinese Academy of Sciences, No.19A Yuquan Road, Beijing 100049, China
Corresponding author's E-Mail:gc10dhruba@yahoo.com

ABSTRACT

Pasture enclosure to prevent from grazing and dung droppings are the two widely-used options for degraded grasslands to restoration. The effects of pasture enclosure and dung droppings on soil nutrients and aboveground biomass were evaluated in plot scale in alpine meadow in the northern Tibetan plateau in this study. A plot with 10 m ×15 m was set up in July 2012. We have conducted three treatments: dung droppings within enclosures (DF), enclosures only (F), and open grazing (CK). Samples of soil and aboveground biomass were collected in subplots during the growing seasons of 2013 and 2014. The lab analysis and statistical analysis are also applied. Both pasture enclosures and dung droppings were found to improve soil nutrients and enhance aboveground net primary production in different degree. However, pasture enclosure remained effective through the second year after their construction, while the fertilization benefits of dung droppings were lasting no more than a year. It's suggested that: 1) pasture enclosure should be properly used to recover the degraded grassland, especially the rational duration of pasture enclosure should be explored further in the alpine grassland; 2) increase the proportion of dung droppings on grassland with advocating the growth of renewable energy, thereby promote nutrient cycling, improve soil conditions, and enhancing net primary production.

Key words: pasture enclosure; dung droppings; alpine meadow; soil nutrients; aboveground net primary productivity.

INTRODUCTION

The Tibetan Plateau is suffering from over-grazing and pasture degradation (Guo *et al*., 2014). Restoration of degraded grassland is always important for maintaining the sustainable development of pastoral lands. Currently, pasture enclosures that prevent from grazing are considered the most cost-effective method of grassland restoration, as they can enhance aboveground net primary productivity (ANPP) (De *et al*., 2010; Zhou *et al*., 2004; Zhou *et al*., 2005; Zuo *et al*., 2009) and reduce grazing pressure (Li *et al*., 2009; Liu and Nie, 2012; Yan and Tang, 2007; Zheng and Yu, 2013). Too long extended periods without grazing, for example, more than 8 years enclosure, however, may also negatively impact grassland biomass (Gu and Li, 2013) and biodiversity, particularly in the grazing-dependent bunchgrasses (Weber and Horst, 2011).

The application of herbivore dung as fertilizer is another method to improve soil quality (Tayyab and McLean, 2015) and enhance the primary production of grasslands (Adak *et al*., 2014; Jia *et al*., 2014). Dung is rich in organic matter, nitrogen (N), phosphorus (P), potassium (K) and other nutrients. Of the total feed consumed, approximately 75% of N, 80% of P and 90% of K are excreted, with 30%, 95% and 20% of the excreted N, P and K remaining in the dung, respectively (Tamin, 1992). For example, Yak (*Bosgrunniens* Linnaeus) dung in the northern Tibetan plateau was found to contain 28.32% organic carbon (C), 2.11% total N, 0.29% total P, and 1.35% total K in dry weight (Xu *et al*., 2015). Compared with the national average level by dry weight of cattle dung (CATE, 1999), the yak dung had lower organic C and P, but higher N and K content. Most organic C and nutrients in dung can be returned to soil (Omaliko, 1981; Hoffmann *et al*., 2001; Holter and Hendriksen, 1988; He *et al*., 2009b; Wu and Liu, 2010), increasing soil content of organic C, N, P and K, and thus increasing grassland productivity (Janzen *et al*., 1998; Jones *et al*., 2005; Shimizu *et al*., 2009; Bougnom *et al*., 2012; Lan *et al*., 2012). Dung decomposes quickly during the first 3 months of the growing season, although it can take as long as 3–5 years to fully decompose in grassland in north China (Jiang and Zhou, 2006). Yak dung increases soil nutrients within a 30 cm radius around its deposition (He *et al*., 2009a). The decline in the proportion of yak dung combustion for fuel as renewable energy developed (TAR, 2008) is likely to increase the quantity of dung remaining in grassland and improve soil quality. Although some studies have been conducted on ecological effects of pasture enclosures and chemical fertilizer on soil nutrients and grassland biomass (Yan and Tang, 2007; Zuo *et al*., 2009; Li *et al*., 2009; De *et al*., 2010; Zheng and Yu, 2013), the impacts of natural dung droppings and pasture enclosures, which are the two primary management options, remain unknown especially in alpine grassland (Raza *et al*, 2015). This study investigated the effects of pasture enclosures and dung droppings on soil nutrients and ANPP of alpine grassland in northern Tibetan Plateau, with the aim of providing information for the optimization of grassland restoration.

MATERIALS AND METHODS

Study area and plot design: The study was conducted near to the Experimental Station (92°0′1.72″E, 31°38′56.28″N) of alpine grassland ecosystem in Nagqu county of Northern Tibetan Plateau, affiliated with the Institute of Geographic Sciences and Natural Resources, Chinese Academy of Sciences. In July 2012, a 10 m × 15 m plot was erected with iron mesh enclosure in area of open grazing in *Kobresia pygmaea* alpine meadow (Fig. 1). It located at the moderate degraded alpine meadow for the over-grazing in the last 30 years. The plot was subdivided into 6 subplots (5 m × 5 m), and three treatments were set up within and around the plot: (i) 3 DF subplots: each of the subplots had a 2 kg of fresh dung dropping within enclosure. Referenced from the Shimizu *et al*.(2009) and He *et al*. (2009a), the fresh yak dung was piled up as a circle with 10 cm of radius in each of the subplots to simulate the effect of dung droppings on grassland; (ii) 3 F subplots: each just has enclosure without dung dropping. The enclosure treatment simulated fenced-in pasture, which represented the enclosure pasture situation of preventing from grazing and without dung droppings (Liu and Nie, 2012); and (iii) 3 CK subplots: each locates in open grazing pasture without enclosure. The open grazing treatment represented a pasture grazing freely, simultaneously, where most of the dung droppings were collected by herders for fuel (Xu *et al*., 2013). The aboveground biomass and soil samples were collected during the growing season in August 2013 and September 2014. The samples were then taken back to laboratory to weigh the aboveground biomass and to analysis the content of N, P and K in soil.

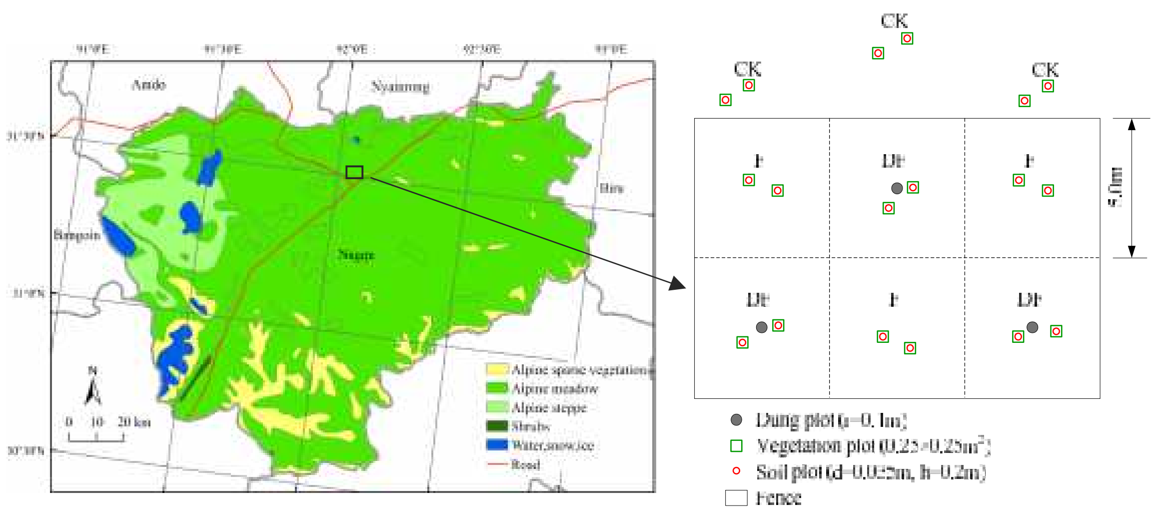

Fig 1. Study area and the plot design

Note: Treatment abbreviations: DF, dung droppings within enclosure; F, enclosure only; CK, open grazing without enclosure

Surveys and laboratory analysis: Within each subplot, two quadrats were established in which aboveground biomass and soil nutrients were monitored (Fig.1). Because the fertilization effect of dung was found to extend only 30 cm (He *et al*., 2009a), quadrats were located within 30 cm around dung in dung dropping treatments. Aboveground biomass samples were taken in 25 cm × 25 cm, which were around the dung lump. Aboveground biomass samples were mowed, cleaned, dried and weighed to the nearest 0.01 g (Guangzheng YP-B electronic scale, Shanghai, China) to determine the ANPP. The differing impacts of grassland management by pasture enclosures and dung droppings could then be assessed on grassland aboveground production.

After the aboveground biomass being cut, each of soil samples has been collected within the biomass sampling quadrat. Soil was sampled by digging at 0–20 cm depth using an auger borer with 3.5 cm inside diameter. Soil samples were dried naturally and screened with a 2 mm sieve. Soil organic matter (SOM) was measured with the potassium dichromate titration. Total N (TN) and total P (TP) were analyzed with the semimicro-Kjeldahl and NaOH fusion-Mo-Sb colorimetric methods, respectively. Available P (AP) was determined by the 0.5 mol.L^{-1} $NaHCO_3$-Mo-Sb colorimetric method and alkali-hydrolyzable N (AN) by the alkaline hydrolysis diffusion method. Total K (TK) determination used the NaOH fusion-flame photometric method, while available K (AK) was measured with the NH_4OAc-flame photometric method (Bao, 2000). The differences in soil nutrient content among treatments were then analyzed.

Statistical analysis: Differences in mean soil nutrients and ANPP among three treatments (DF, F, and CK, n = 6 per treatment) were determined using Duncan's multiple range test with a significance level of α = 0.05. The calculated F-value was then compared with F 0.05 in the F threshold table, where F calculated > F 0.05 indicated a significant difference among treatments. All analyses were conducted in the software of Statistical Package for the Social Sciences (SPSS) 16.0 (Norusis M., 2008).

RESULTS

Effects of pasture enclosures and dung droppings on soil nutrients and ANPP in 2013: We have focused on the effects of pasture enclosures and dung droppings on SOM, nutrients (TN, TP, TK, AN, AP, AK) and ANPP. Samples collected in the growing season of 2013 showed an increasing trend of SOM associated with restoration effort (CK < F < DF), although differences were not significant ($p > 0.05$) (Fig. 2). The differences among treatments in TN and TP were also insignificant. However, the TK was significantly difference among treatments, with the dung within enclosure treatment less than that in the other two treatments. There were no significant differences in AN or AK among treatments, while AP was greatest in the treatment of dung within enclosure among the treatments. It's worth to note that: ANPP differed significantly among treatments ($p < 0.001$), with an order of DF > F > CK. The largest difference in ANPP was observed between the dung within enclosure treatment and the open grazing treatment, where the ANPP of the former was nearly four times larger than the latter. The dung within enclosure treatment was nearly double that of the enclosure treatment. These results demonstrated that both the pasture enclosures and dung droppings have improved ANPP dramatically during the period of one year since the fences erection and dung droppings.

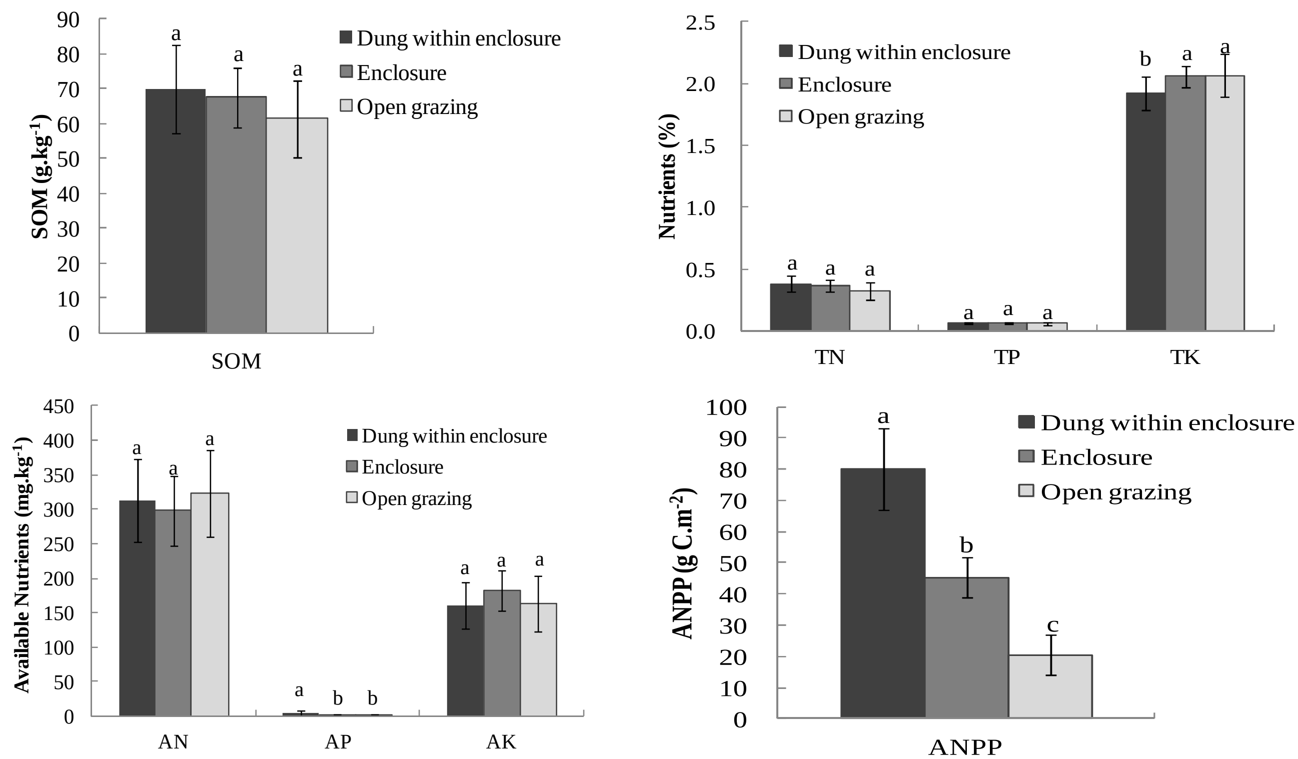

Fig. 2. Effects of pasture enclosure and dung droppings on soil nutrients and ANPP of the alpine meadow in the northern Tibetan plateau in 2013. Different letters indicate significant differences at $p < 0.05$

Note: SOM, soil organic matter; TN, total nitrogen; TP, total phosphorus; TK, total potassium; AN, alkali-hydrolyzable nitrogen; AP, available phosphorus; AK, available potassium; ANPP, aboveground net primary production

Effects of pasture enclosure and dung droppings on soil nutrients and ANPP in 2014: Like 2013, soil samples collected in 2014 showed no significant differences in SOM among treatments. All of TN, TP or TK had no significantly different among the three treatments ($p > 0.05$; Fig. 3). Although AN and AP did not differ significantly among treatments, AK was significantly greater in the dung within enclosure treatment and enclosure treatment than in the open grazing treatment ($p < 0.05$). Enclosures have increased litter accumulation evidently, which could increase AK during decomposition process. The ANPP among various treatments was sequenced as DF > F > CK still. There was significantly difference ($p<0.05$) between enclosure treatments and the open grazing treatment. The significant level of difference between the dung within enclosure treatment and open grazing treatment was $p = 0.007$, as well as that between the enclosure treatment and open grazing treatment was $p = 0.027$. There was no significant difference in ANPP between the dung within enclosure treatment and enclosure treatment. It's induced that, the enclosures still significantly increased ANPP in the second year after the pasture fence erection, whereas the fertilizing effect of dung droppings disappeared after 2 years' decomposition (Table 1). It is suggested that more dung should be returned to soil to sustain nutrient cycling and thereby increase net primary production. Thus the quantity of dung combusted for fuel should be reduced.

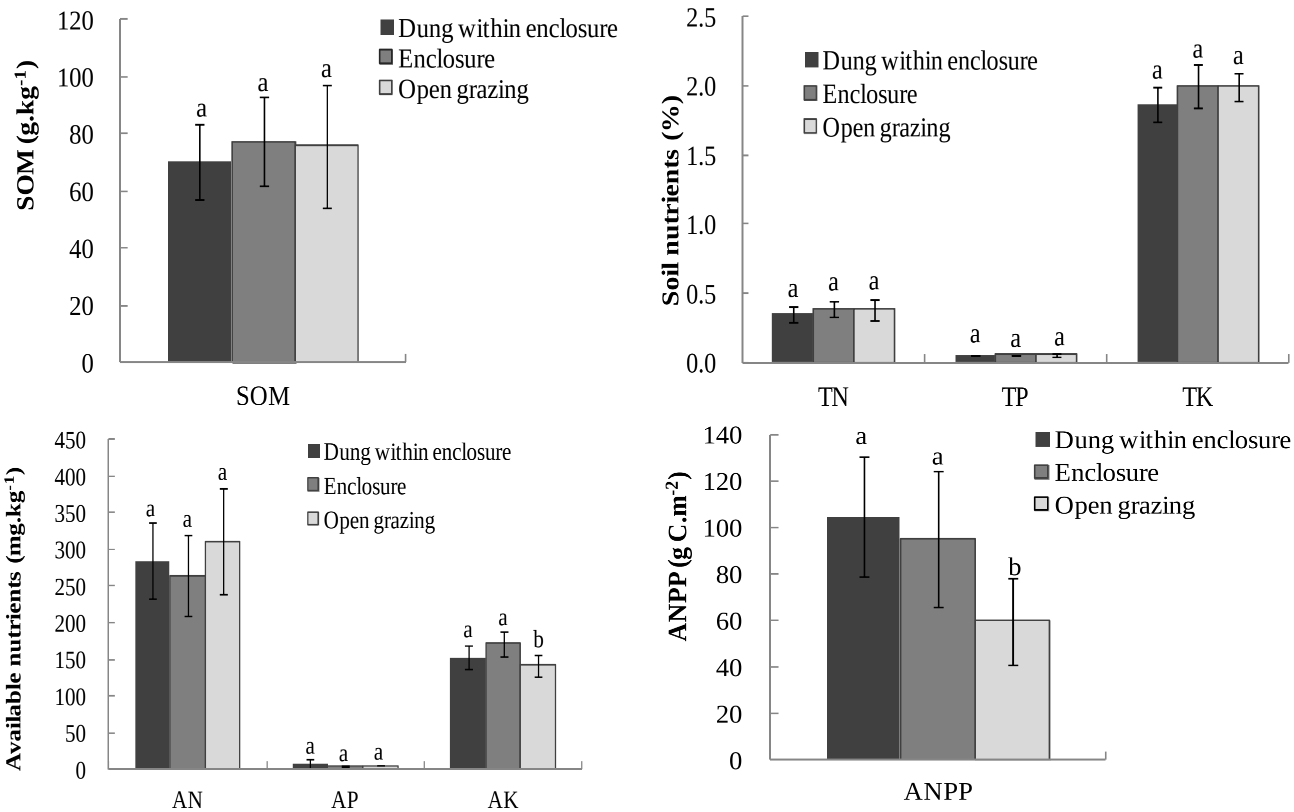

Fig. 3. Effects of pasture enclosure and dung droppings on soil nutrients and ANPP of the alpine meadow in the northern Tibetan plateau in 2014. Different letters indicate significant differences at $p < 0.05$.

With the Duncan's multiple range tests, the significant differences of measurements among various treatments can be illustrated clearly. Table 1 shows the Duncan's multiple range tests on soil nutrients and ANPP among the DF, F, and CK treatments conducted in the year 2013 and 2014. As per the results, the measurements of SOM, TN, TP and AN among various treatments had no differences at significant level $p<0.05$ during the period of 2013-2014. The TK, AP in 2013 were significant differences between the dung within enclosure treatment and other treatments. The AK was significant difference between the enclosure treatments and the open grazing treatment in 2014. The ANPP was significant difference among various treatments in 2013, while the significant difference between the dung within enclosure treatment and enclosure treatment disappeared in 2014. It's inferred that the effect of enclosure with fences can sustain two years at least, while that of dung can only sustain no longer than one year in the alpine grassland.

Table 1. Duncan's multiple range tests on soil nutrients and ANPP among the DF, F, and CK treatments in 2013 and 2014 (n = 6).

Indicators	Treatments	2013		2014	
		Mean	SD	Mean	SD
Soil organic matter ($g.kg^{-1}$)	Dung within enclosure	70.04	12.66	70.40	13.08
	Enclosure	67.53	8.51	77.22	15.51
	Open grazing	61.42	11.10	75.67	21.51
Soil total nitrogen (%)	Dung within enclosure	0.38	0.06	0.35	0.06
	Enclosure	0.36	0.05	0.39	0.05
	Open grazing	0.32	0.07	0.38	0.08
Soil total phosphorus (%)	Dung within enclosure	0.06	0.00	0.05	0.00
	Enclosure	0.07	0.01	0.06	0.00
	Open grazing	0.06	0.01	0.06	0.01
Soil total potassium (%)	Dung within enclosure	1.92^b	0.13	1.87	0.13
	Enclosure	2.06^a	0.08	2.00	0.16
	Open grazing	2.07^a	0.17	1.99	0.10
Soil alkali-hydrolyzable nitrogen ($mg.kg^{-1}$)	Dung within enclosure	312.78	60.63	284.50	52.20
	Enclosure	297.67	49.88	264.50	54.91
	Open grazing	323.11	62.47	310.83	72.41
Soil available phosphorus ($mg.kg^{-1}$)	Dung within enclosure	5.32^a	3.95	7.87	6.73
	Enclosure	2.15^b	0.56	4.31	0.65
	Open grazing	2.26^b	0.52	5.42	0.60
Soil available potassium ($mg.kg^{-1}$)	Dung within enclosure	159.89	33.76	153.00^a	16.59
	Enclosure	182.22	29.12	171.50^a	17.24
	Open grazing	164.22	40.27	142.00^b	15.39
ANPP ($g\ C.m^{-2}$)	Dung within enclosure	80.09^a	13.05	104.53^a	25.81
	Enclosure	45.29^b	6.34	94.93^a	29.25
	Open grazing	20.48^c	6.48	59.73^b	18.40

Note: 1) SD: standard deviation. 2) The treatments including: dung droppings within enclosure (DF), enclosure only (F), and open grazing (CK). 3) According to the conventional regulation of the Duncan's multiple range tests, the same letter means no significant difference among treatments, while the different letters means significant difference among treatments. For example, if treatments of a specific indicator was denoted by *a*, *b* and *c*, that means the treatment labeled *a* was significantly greater than the treatment labeled *b*, as well as the treatment labeled *b* was significant greater than treatment labeled *c*. If there was no letters labeled, means no significant difference among treatments.

DISCUSSION

Although ANPP was significantly greater in the enclosure treatments after 2-years fenced than in the open grazing treatment according to this study, further investigation is required to determine the optimal period of alpine pasture enclosure. According to Gu and Li (2013), the effect of pasture enclosure was not so optimism as expected. The biomass production fluctuated dramatically over the 4 years in the enclosed pasture and it was not greater significantly in enclosed pasture than in the open grazing pasture. It's mainly because that prevention from grazing can disturb the interactions between livestock and pasture and thus may negatively affect the grassland ecosystem balance. Weber and Horst (2011) also claimed that a prolonged recovery period without grazing may prevent the degraded grassland from restoring process, particularly for grazing-dependent bunchgrasses. In future, it is essential to determine the suitable duration of rangeland rest for grassland restoration.

Yak dung is a kind of energy resource in pastoral areas of northern Tibetan Plateau. It has been combusted for fuel by resident herders for thousands of years. However, much of dung combustion has altered nutrient cycling, arising to soil nutrients loss and primary production decrease in the alpine grassland ecosystem in north Tibetan plateau (Xu *et al*., 2013). During the last decade, the rapid development of renewable energy including solar energy, wind electricity and hydropower remarkably reduce the demand for dung as fuel, resulting in more dung droppings on ground to return soil. Yet, a recent study on alpine meadow in the northeastern Tibetan plateau found that dung did not significantly increase soil TN, TP or SOM during the growing season (He *et al*., 2009a). We have also found an insignificant effect of yak dung on SOM, TN and TP, although AP and ANPP were enhanced by dung for the first year after dropping in this study. In contrast, both TK and AK declined in the dung within enclosure treatment comparing to the enclosure treatment, which may have been caused by the transfer or absorption processes under the condition of the net primary production increasing. In addition, the accumulation of organic matter in the soil can negatively affect TK content (Gao, 2004), which may have been another reason for the decrease in K in the treatment of dung within enclosure.

Conclusions: Pasture enclosures to prevent from grazing and dung droppings, two widely options for degraded grasslands to restoration, affected soil nutrients and ANPP of alpine grassland in the northern Tibetan plateau. Soil available phosphorus (AP) was significantly greater in the dung within enclosure treatment than in the other two treatments (enclosure treatment, and open grazing treatment) in the first year (2013) after fences erection and dung droppings. Soil available potassium (AK) was greater significantly in the enclosure treatments than in the open grazing treatment in the 2nd year (2014). The ANPP in the dung within enclosure treatment was greater significantly than that in the enclosure treatment, again that in the enclosure treatment was greater significantly than that in the open grazing treatment in 2013. The ANPP in the two enclosure treatments were greater than that in the open grazing treatment, while the significant difference in ANPP between the dung within enclosure treatment and the enclosure treatment disappeared in 2014. We found that both pasture enclosures and dung droppings had the potential to improve the soil quality and increase primary production, although the duration of these effects varied. The benefits of pasture enclosures remained in the second year after their erection, while the fertilization effect of the dung was only sustained for one year after its dropping. Future management efforts should allow pasture to be grazed after the duration of enclosure to avoid negative effects of prolonged rest. Moreover, the reduction of dung combustion for fuel with the development of renewable energy and increasing the proportion of dung droppings returned to soil, can promote nutrient cycling, improve soil conditions and enhance primary production in alpine meadow ecosystems.

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