

| | | | | |
|--|----|---|---------|------|
| POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.) | 57 | 3 | 495–502 | 2009 |
|--|----|---|---------|------|

Regular research paper

Shixiong LI^{1,2}, Qiji WANG^{1*}, Zengchun JING¹, Wenying WANG³

¹ Northwest Plateau Institute of Biology, The Chinese Academy of Science, Xining, 810001, China

² Graduate School of the Chinese Academy of Sciences, Beijing, 100039, China

³ College of life Science, Qinghai Normal University, Xining, 810008, China

*e-mail: wqj@nwipb.ac.cn (corresponding author)

THE EFFECTS OF PROTECTIVE ENCLOSURE ON VEGETATION DIVERSITY, AND PRODUCTIVITY OF DEGRADED ALPINE *KOBRESIA* MEADOW (QINGHAI-TIBETAN PLATEAU)

ABSTRACT: Grassland degradation due to anthropogenic and natural factors and their interactions is one of the worldwide ecological and economic problems because it reduces grassland productivity and diversity and leads to desertification. The objective of this study was to assess the influence of protective enclosure on vegetation composition and diversity and plant biomass of an alpine degraded meadow. The experiment was conducted at center of Qinghai-Tibetan Plateau with two degraded (caused by overgrazing) alpine meadows: the lightly and severely degraded ones (LD and SD) and their enclosed areas with iron net (LDE and SDE, respectively). The areas 200 m × 150 m for each of four degraded alpine meadow treatments at average altitude 3,960 m a.s.l. were set for research. The lightly degraded plots were dominated by *Scirpus distigmaticus* (Kukenth.) Tang et Wang, *Elymus nutans* Griseb. and *Oxytropis ochrocephala* Bunge. The dominating plants in severely degraded plots were: *Artemisia sieversiana* Ehrhart ex Willd., *Ajania tenuifolia* (Jacq.) Tzvel, *Lonicera minuta* Batal. The results showed: (1) the vegetation cover of two degraded plots (LD and SD) has increased after taking the enclosure measures and the forbs dominated both plots. (2) Species richness has also increased in two enclosed degraded plots, respectively. There no significant differences in evenness and diversity between LD and LDE, and SD and SDE, respectively. (3) Enclosure may promote aboveground biomass, particularly grass and forb biomass in LD, and forb biomass in SD plots.

KEY WORDS: alpine steppe meadow, land degradation, enclosure, species diversity, productivity

1. INTRODUCTION

The general problem of the dry grassland damage in lowland and highland regions was due to overgrazing, land management, water shortage, and climate change (Liniger and Thomas 1998, Muller *et al.* 1998, Zhou *et al.* 2005, Bilotta *et al.* 2007). The main effects are: plant cover decrease, biological productivity drop, soil nutrients and water conservation capacity loss and desertification.

The Qinghai-Tibetan Plateau occupies 2.5 million km² in the southwest of the People's Republic of China, approximately 25% of the country's area with an average elevation > 4000 m. An estimated 70% contains high altitude grassland and pastoralism is the primary land use (Miller 1995). The alpine meadow, steppe meadow, and alpine steppe are three main vegetation types distributed in the Qinghai-Tibetan Plateau.

The alpine grasslands of the Qinghai-Tibetan Plateau have supported pastoralism of domesticated yaks (*Bos grunniens* L.) and Tibetan sheep (*Ovis aries* L.) for approximately 2200 years (Miller 1995). In recent

decades, numbers of livestock have increased rapidly (Jing *et al.* 1991, Dong *et al.* 2004) and grassland degradation characterized by reduced above-ground plant biomass, loss of the hard turf layer leading to exposure of subsoil and an increase in the prevalence of toxic plants have become a major problem on the plateau (Lang *et al.* 1997, Zhou *et al.* 2005). Overgrazing has resulted in serious degradation of the grassland, with an annual rate of degradation of 6.6–34.5% (Wang and Chen 2001). Besides overgrazing, increasing rodent population (Li *et al.* 1999, Liu *et al.* 1999), cryoturbation, and climate change have also accelerated the deterioration of plateau grassland (Ma 1999). There is about 42.51 million ha of degraded grassland, which constitutes 33% of the available grassland area in the Qinghai-Tibetan Plateau. Severely degraded grassland area of approximately 7.03 million ha, accounts for 16.5% of the degraded grassland (Wang 1997, Ma 1999).

Alpine meadow degradation not only leads to changes of plants composition, dramatic drop in plant production and loss of diversity, but also in soil C and N loss (Wang *et al.* 2005). Enclosure is a countermeasure for regeneration of the natural vegetation through protection of the areas from human and animal interference. In this regard, the practice of establishing the enclosures has emerged as a prevalent practice for natural regeneration of the native plants in degraded grassland in Qinghai-Tibetan Plateau (Ma *et al.* 2002, Zhou *et al.* 2003). The seedling measures for the severely degraded alpine meadow rehabilitation were reported (Wang *et al.* 2006). However, not much research work has been done in the typical area of the plateau to investigate the effects of enclosure from an ecological perspective.

The aim of the present study was to examine the influence of enclosures on the community structure and vegetation productivity in the lightly and severely degraded alpine meadow and to provide more scientific information for the rehabilitation of the degraded grasslands, on the example of Qinghai-Tibetan Plateau.

2. MATERIAL AND METHODS

The study was carried out at Geduo pasture area in Maqin county of Qinghai province, China. The study site located at latitude 34°21'–34°30'N, longitude 100°26'–100°30'E (elevation 3,950–3,970 m). The annual precipitation changed from 420 to 560 mm, which was concentrated from May to September. Mean monthly temperature is –2.6°C, and the annual cumulated temperature, beyond 0°C is 9143.3°C, the sunlight time, is 2576.0 h (Wang *et al.* 2004). The vegetation type is alpine *Kobresia* meadow, and principal soil types are Mat Cryic Cambisols and Mol Cryic Cambisols (CSTC 1995).

About 10 ha areas of the lightly and severely degraded land were selected based on the difference of the vegetation cover, dominance species composition and forage quality and enclosed with iron net in March 2002, respectively. The plant cover of the lightly degraded plot amounted to 82%, and was dominated by *Scirpus distigmaticus* (Kukenth.) Tang et Wang, *Elymus nutans* Griseb. and *Oxytropis ochrocephala* Bunge. The plant cover of the severely degraded plot amounted to 65%, and was dominated by *Artemisia sieversiana* Ehrhart ex Willd, *Ajania tenuifolia* (Jacq.) Tzvel, *Lonicera minuta* Batal.

Four treatments, each of size 200 m × 150 m, representing the lightly degraded land with enclosure (LDE) and the adjacent open land (LD), and the severely degraded land with enclosure (SDE) and the adjacent open land (SD), were set for research in 2004. All treatment areas were grazed in winter. Grazing intensity was approximately 4.13 heads of Tibet sheep per ha.

For each treatment three plots (50 m × 50 m) were established for measurements. All of the plant and root samples were collected in August 2004. Plant community characteristics were determined from two transects (50 cm × 500 cm) containing ten continuous quadrates (50 cm × 50 cm) in each plot. Plant species were identified and recorded, and total ground cover, species cover, and height were determined from 0.25 m² quadrates. The number of plant species was assessed for each plot. In each plot, five 0.25 m² quadrates were selected randomly and above-ground plant materials were clipped at the ground. The

harvested plants were separated into grasses, sedges and forbs. Root biomass was sampled in ten soil cores (diameter 5 cm) per plot at 0–30 cm depths. The soil cores were crumbled by hand to pass through a 4-mm diameter sieve to separate large segments from the soil. Large root fragments and the associated soil were then washed over a 0.25 mm sieve to retrieve fine roots. All vegetation materials were oven-dried (48 h, 70°C), and weighed.

Importance Values (IV) (Wang et al. 2006) for individual species were calculated as averages of their relative abundance in terms of relative canopy cover, relative height, and relative frequency and expressed in %:

$$IV = \frac{(RC + RH + RF) \times 100}{3} \quad (1)$$

Where:

RC = canopy cover of individuals of a given species in a quadrat (in % of total cover for all species in a quadrat), *RH* = height of individuals of a given species in a quadrat (in % of total height of individuals for all species in a quadrat), and *RF* = frequency of individuals of a given species in a quadrat (as % of total frequencies for all species in a quadrat).

Plant species were classified into four groups based on functional type: grasses, sedges, annual forbs, and perennial forbs. Diversity [Shannon-Weiner index

$$H' = - \sum_{i=1}^s P_i \ln P_i$$

and evenness [Pielou index ($J' = H'/\ln S$)] were calculated (Poole 1974) using species-important data. Species richness (*S*) was considered as the number of species identified in each plot.

Calculations and statistical analyses were performed with MS Excel and SAS 8.2. An independent *t*-test was used to check the effect of enclosures on biomass of above-ground vegetation and root biomass.

3. RESULTS

A total of 53 species were recorded in LD treatment plot, of which 28 were recorded both in LD and LDE plots while only one, *Trollius pumilus* var. *tanguticus* Bruhl was recorded outside of the sample plots. Among the species en-

countered, 4 sedge and 4 grass species were found both in LD and LDE plots. Similarly, a total of 41 species were found in two severely degraded plots, of which 18 species representing both the SD and SDE plots. Two shrub species were found in the severely degraded meadow plot.

The total ground cover of LD plot was equal to 77% and the species: *Scirpus distigmaticus* (Kukenth.) Tang et Wang, *Lagotis brachystachy* Maxim and *Oxytropis ochrocephala* Bunge were dominating. Their *Important Values (IV)* (formula 1) were 11.7, 8.2 and 7.6% respectively. LDE treatment resulted in 96% of total ground cover and the plot was dominated by *Ajania tenuifolia* (Jacq) Tzvel., *Elymus nutans* Griseb, *Pleurospermum pulzkyi* Kanitz, *Poa crymophila* Keng and *Leontopodium nanum* (Hook.f. et Thoms.) Hand.-Mazz. Their *Important Values* (formula 1) were 8.4, 8.2, 5.7, 5.4 and 5.2%, respectively. SD and SDE treatment resulted in 65 and 73% total ground cover. The dominating species in SD plot were *Ajania tenuifolia* (Jacq) Tzvel, *Ligularia virgaurea* (Maxim.) Mattf, and *Artemisia sieversiana* Ehrhart ex Willd with *important values* (formula 1) of 12.8, 11.7 and 9.3%, respectively. The species *Artemisia sieversiana* Ehrhart ex Willd, *Lonicera minuta* Batal and *Ajuga lupulina* Maxim were dominating in SDE plot and their *Important Values* were 14.8, 14.3 and 12.1%, respectively.

Importance Values (IV) for sedges in LDE treatment were lower than that in the LD, while *IV* for grasses and perennial forbs in the lightly degraded plot increased largely after established the enclosures (Table 1). *Importance values* for sedges, grasses and perennial forbs in SDE plot were lower than that in SD, and enclosure measurements increased the *Importance Values* for annual forbs in the severely degraded land.

Richness, diversity, and evenness of above-ground vegetation for different treatments were showed in Table 2. Enclosure measure could improve the species richness both in the lightly and severely degraded plots, while the diversity and evenness value of the community inside the enclosures were lower than in open areas. Some sedge and grass species like: *Kobresia pygmaea* (C.B. Clarke) C.B. Clarke, *Scirpus distigmaticus* (Kukenth.) Tang et Wang, *Deschampsia caespitosa* (Linn.) Beauv and *Stipa purpurea* Griseb typical for

natural alpine meadow had disappeared from the severely degraded meadow, and forb species became dominating in this meadow.

Establishment of enclosures enhanced the total aboveground biomass compared to the plots not enclosed ($P < 0.05$) (Figs 1 and 2). Enclosure measurements increased the biomass of grasses ($P < 0.05$) and forbs ($P < 0.05$) significantly. No significant differences were found for sedge biomass ($P > 0.05$) between LD and LDE plots. Forb biomass was enhanced significantly in the severely degraded

meadow within enclosure, and no significant differences were found for sedge and grass biomass between SD and SDE plots ($P > 0.05$).

In the lightly degraded land, the proportion of sedge, grass and forb biomass was 2.5:1:4 and after three years of enclosure it was 1:2:5 and the total biomass was enhanced significantly. Forbs were the dominants in community for both enclosed and open area of the severely degraded land, and measurement of enclosure enhanced largely the forb biomass in the severely degraded plot.

Table 1. Number of species and average *Importance Values* (*IV*) (formula 1) of different plant groups for the lightly degraded alpine meadow (LD), the lightly degraded alpine meadow with enclosure measures (LDE), the severely degraded alpine meadow (SD) and the severely degraded alpine meadow with enclosure measures (SDE).

| | LD | | LDE | | SD | | SDE | |
|-----------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|
| | No. of species | Average <i>IV</i> | No. of species | Average <i>IV</i> | No. of species | Average <i>IV</i> | No. of species | Average <i>IV</i> |
| Sedges | 4 | 5.5 | 4 | 2.1 | 2 | 0.8 | 1 | 0.3 |
| Grasses | 5 | 4.2 | 5 | 3.8 | 3 | 3.3 | 3 | 1.4 |
| Annual forbs | 3 | 0.4 | 7 | 1.7 | 5 | 3.4 | 10 | 3.4 |
| Perennial forbs | 27 | 2.1 | 26 | 1.8 | 23 | 3.1 | 13 | 3.9 |

Table 2. Richness (number of species), evenness (Pielou index) and diversity (Shannon-Wiener index) of the plant community for the lightly degraded alpine meadow (LD), the lightly degraded alpine meadow with enclosure measures (LDE), the severely degraded alpine meadow (SD) and the severely degraded alpine meadow with enclosure measures (SDE).

| | Richness | Pielou index | Shannon-Weiner index |
|-----|----------|--------------|----------------------|
| LD | 39 | 0.9 | 3.2 |
| LDE | 42 | 0.8 | 3.0 |
| SD | 27 | 0.8 | 3.0 |
| SDE | 33 | 0.8 | 2.8 |

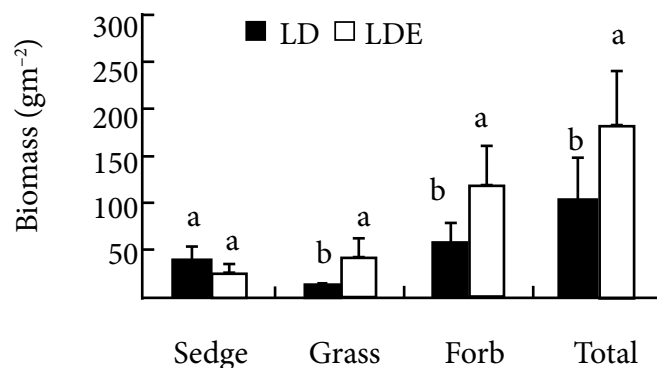


Fig. 1. Mean sedge, grass, forb, and total biomass of the lightly degraded alpine meadow (LD) and the lightly degraded alpine meadow with enclosure measures (LDE). Each composite column marked with different letters are differed significantly at $P = 0.05$.

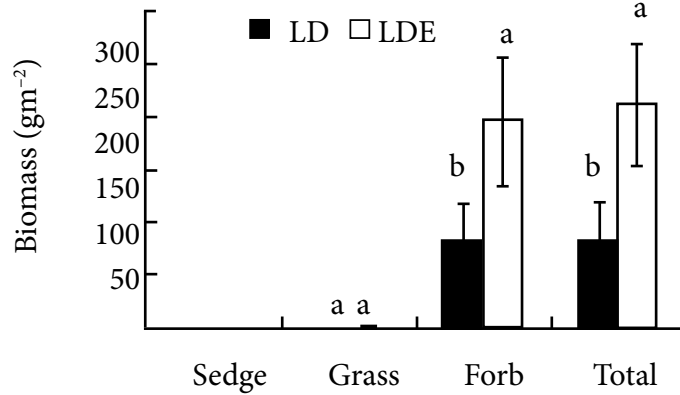


Fig. 2. Mean sedge, grass, forb, and total biomass of the severely degraded alpine meadow (SD) and the severely degraded alpine meadow with enclosure measures (SDE). Each composite column marked with different letters are differed significantly at $P = 0.05$.

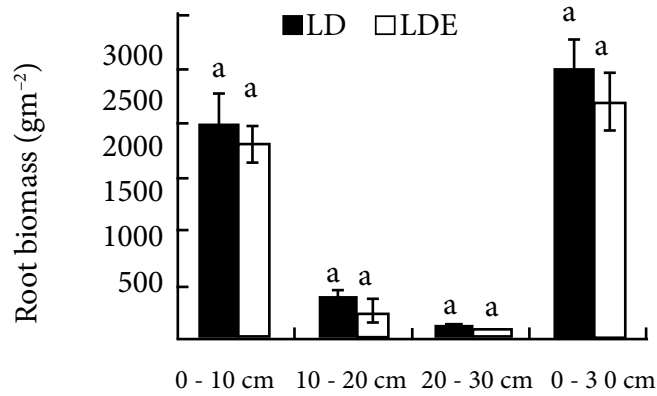


Fig. 3. Root biomass in different soil depth of the lightly degraded alpine meadow (LD) and the lightly degraded alpine meadow with enclosure measures (LDE). Each composite column marked with different letters are differed significantly at $P = 0.05$.

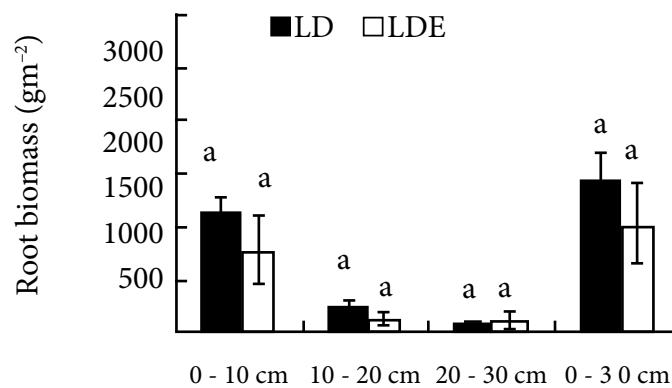


Fig. 4. Root biomass in different soil depth of the severely degraded alpine meadow (SD) and the severely degraded alpine meadow with enclosure measures (SDE). Each composite column marked with different letters are differed significantly at $P = 0.05$ level.

The average root biomass (0–30cm) in LD, LDE, SD and SDE plots was 2492.8 g m⁻², 2138.1 g m⁻², 1453.9 g m⁻² and 1041.1 g m⁻², respectively (Figs 3 and 4). No differences were found in the root biomass of all depths between two degraded lands and their enclosed treatments.

4. DISCUSSION AND CONCLUSIONS

Degradation of alpine grassland is caused by anthropogenic and natural factors and their interactions (Du *et al.* 2004). Anthropogenic factors include seasonal overgrazing by domestic mammals, conversion of grassland to cropland, and mining exploitation (Wang and Fu 2004). Natural factors include rodent and insect pests and wind erosion (Wang and Zheng 1999). The principal analysis shows that overgrazing initiates alpine meadow degradation (Wang *et al.* 2006), causing important changes in the composition and structure of the plant community (Pierre 1998). Understanding of these changes is essential because they have become the focal points for monitoring grassland degradation and they provide the useful information for vegetation restoration. The results of this study confirm that in the early phases of degradation dominating plants disappear and some native plants are lost, like the results observed from alpine steppe (Li *et al.* 2006) and from steppe dominated by *Stipa* sp. in the Mongolia Plateau of China (Mouat and Hutchinson 1995). This study partly supports an emerging global pattern that grassland is replaced by shrub land along with the process of grassland degradation. For example, in the arid regions of southwestern North America, Brown *et al.* (1997) found shrubs such as *Potentilla fruticosa* L. in severely degraded plant communities. In the process of alpine meadow degradation, the biomass proportion of sedges decreases and the unpalatable forb plants gradually invade. The landscape denudation in grassland areas become obvious due to low vegetation cover, and further increase of wind erosion. At this time, rodents frequently damage vegetation by excessive excavating and gnawing (Zhou *et al.* 2005).

Changes in plant biomass may be an important measure of alpine meadow degrada-

tion, and have been used to monitor grassland degradation (Wang and Chen 2006). Net primary productivity of alpine meadows varies with plant community composition, climate (temperature and precipitation), disturbance (grazing), topography, and the interaction of these factors (Wang 2001). One of main feature of severely degraded land was the loss of the originally dense sod layer in the native *Kobresia* meadow and the establishment of large amount of forbs. Establishment of enclosure enhanced aboveground biomass, particularly the grass biomass in the lightly degraded meadow, and forb biomass in severely degraded land.

The results from the present study clearly demonstrated the importance of enclosures in the restoration of degraded alpine lands. The comparison made between the enclosures and open grazing lands of two degraded alpine meadows showed that the composition, diversity of vegetation were higher in the enclosures suggesting rehabilitation of degraded alpine lands in relatively short periods of time by avoiding or minimizing interference of people and domestic animals in the degraded lands with establishing enclosure measures. The same results have been reported from studies made on the other areas of the Qinghai-Tibetan Plateau (Li *et al.* 2006).

Sustainable conservation and utilization of the alpine meadow vegetation resources and the rehabilitation of degraded grassland needs to provide economic, social and ecological benefits. This requires taking different restoration measures for alpine meadow based on the different state of degradation. Establishment of enclosures is very advantageous over other methods because it is fast, cheap and lenient method for the rehabilitation of degraded land (Mengistu *et al.* 2005). This study also demonstrated the importance of enclosures in the restoration of the lightly degraded alpine meadow. It is difficult for the severely degraded alpine *Kobresia* meadow with establishment of enclosures to rehabilitate to the original native vegetation prior to the loss of *Kobresia* plants. The native alpine meadow is characterized by the dominance of *Kobresia* plants that are perennial geophyta rhizomatosa (Zhou and Li 2001). Reproduction of sedge plants such as *K. pygmaea* and *K. humilis* K.Y. Pan in an

alpine environment takes place mainly by cloning. *Kobresia* plants may produce mature seeds, but the rate of germination of these seeds was nearly zero in the field experiments (Deng and Zhou 2001). Grassland degradation mainly caused by the overgrazing, and forage absence is a conflict between degraded grassland recovery and livestock husbandry development. Therefore, cultivars of native grasses with high germination rate such as *E. sibiricus*, *P. crymophila*, and *E. nutans* are seeded usually to rehabilitate severely degraded lands on the Tibetan Plateau (Wang and Chen 2006).

ACKNOWLEDGEMENTS: This research was founded by Chin's National "Tenth Five-Year" Scientific and Technology Key Programmers (No. 2001BA606A-2) and National Natural Science Foundation of China (No. 30660120).

5. REFERENCES

- Bilotta G.S., Brazier R.E., Haygarth P.M. 2007 – The impacts of grazing animals on the quality of soils, vegetation, and surface waters in intensively managed grassland – *Adv. Agron.* 94: 237–280.
- Brown J.H., Valone T.J., Curtin C.G. 1997 – Reorganization of an arid ecosystem in response to recent climate change – *Proc. Natl. Acad. Sci. USA* 94: 9729–9733.
- CSTC1995 – Chinese Soil Taxonomic Classification System. Revised Proposal. Chinese Soil Taxonomic Classification Research Group – Chinese Agricultural Science and Technology Press, Beijing. (in Chinese).
- Deng Z., Zhou X. 2001 – Reproductive strategies of major plant populations in *Kobresia* meadow (In: Chinese *Kobresia* meadow, Ed. X. Zhou) – China Science Press, Beijing, pp. 95–130. (in Chinese).
- Dong Q., Zhao X., Li Q., Ma Y., Wang Q., Shi J., Li Y. 2004 – Responses of contents of soil nutrient factors and water to stocking rates for yaks in *Kobresia parval* pine meadow – *Acta Bot. Boreali-Occidentalia Sin.* 24: 2228–2236. (in Chinese with English abstract).
- Du M., Kawashima S., Yonemura S., Zhang X., Chen S. 2004 – Mutual influence between human activities and climate change in the Tibetan Plateau during recent years – *Global Planet Change*, 41: 241–249.
- Jing Z., Fan N., Zhou W., Bian J. 1991 – Integrated management of grassland rodent pest in Panpo area – *Chinese J. Appl. Ecol.* 2: 32–38. (in Chinese with English abstract).
- Lang B., Huang S., Wang Y. 1997 – Report on the pasture and livestock survey in Hainan IFAD Project Area – International Funds for Agricultural Development, Xining, Qinghai, China. (in Chinese).
- Li X., Jia X., Dong G. 2006 – Influence of desertification on vegetation pattern variations in the cold semi-arid grasslands of Qinghai-Tibet Plateau, North-west China – *J. Arid Environ.* 64: 505–522.
- Li Y., Lai D., Zhou M. 1999 – Rat and insect controls in grassland of Guoluo prefecture – *Chin. Qinghai J. Animal Vet Sci.* 29: 16–17. (in Chinese with English abstract).
- Liniger H.P., Thomas D.B. 1998 – Grass: ground cover for the restoration of the arid and semi-arid soils – *Adv. GeoEcol.* 31: 1167–1178.
- Liu W., Wang Q., Zhou L. 1999 – Ecological process of forming "Black-Soil-type" degraded grassland – *Acta Agre. Sin.* 7: 300–307. (in Chinese with English abstract).
- Ma Y. 1999 – Review and prospect of study on "Block Soil Type" degraded grassland – *Pratacultural Sci.* 16: 5–8. (in Chinese with English abstract).
- Ma Y., Lang B., Li Q., Shi J., Dong Q., 2002 – Study on rehabilitation and rebuilding technologies for degenerated alpine meadow in the Changjiang and Yellow river source region – *Pratacultural Sci.* 19: 1–5. (in Chinese with English abstract).
- Mengistu D., Teketay D., Hulten H., Yemshaw Y. 2005 – The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia – *J. Arid Environ.* 60: 259–181.
- Miller D.J. 1995 – Herds on the move: winds of change among pastoralists in the Himalayas and on the Tibetan plateau – International Centre for Integrated Mountain Development, Kathmandu, Nepal.
- Mouat D.A., Hutchinson C.F. 1995 – Desertification in developed countries – *Environmental Monitoring and Assessment* 37: 1–137 (special issue).
- Muller S. Dutoit T. Alard D. Grevilliot F. 1998 – Restoration and rehabilitation of species-rich grassland ecosystem in France: a review – *Restor. Ecol.* 6: 94–101.
- Pierre H. 1998 – Effects of grazing on plant species composition and spatial distribution in grasslands of the Sahel – *Plant Ecol.* 138: 191–202.
- Poole R.W. 1974 – An introduction to quantitative ecology – McGraw-Hill Inc., New York.

- Wang G., Cheng G. 2001 – Characteristics of grassland and ecological changes of vegetations in the source regions of Yangtze and Yellow rivers – *J. Desert Res.* 21: 101–107. (in Chinese with English abstract).
- Wang Q. 1997 – The study of grassland resource, ecological environment and sustainable development on Qinghai-Tibet Plateau – *Qinghai Prataculture* 6: 1–11. (in Chinese with English abstract).
- Wang Q. 2001 – Biomass and productive mechanism of *Kobresia* meadow (In: Chinese *Kobresia* meadow, Ed. X. Zhou) – China Science Press, Beijing, pp. 131–167. (in Chinese).
- Wang Q., Shi H., Jing Z., Wang Ch., Wang F. 2004 – Recovery and benefit analysis of ecology on degraded natural grassland of the source region of Yangtze and Yellow Rivers – *Pratacultural Sci.* 21: 37–41. (in Chinese with English abstract).
- Wang W., Wang Q., Wang Ch., Shi H., Li Y., Wang G. 2005 – The effect of land management on carbon and nitrogen status in plants and soils of alpine meadow on the Tibetan Plateau – *Land Degrad. Dev.* 16: 405–415.
- Wang W., Wang Q., Wang H. 2006 – The effect of land management on plant community composition, species diversity, and productivity of alpine *Kobresia* steppe meadow – *Ecol. Res.* 21: 181–187.
- Wang X., Fu X. 2004 – Sustainable management of alpine meadows on the Tibetan Plateau: problems overlooked and suggestions for change – *Ambio*, 33: 153–154.
- Wang X., Zheng D. 1999 – Sustainable use of alpine meadow grassland resource on the Qinghai-Tibet Plateau – *Res. Sci.* 21: 38–42. (in Chinese with English abstract).
- Wang J. Chen G. 2006 – Vegetation index and biomass estimation for grassland – *J. Yunnan Agri. Univ.* 21: 372–375. (in Chinese with English abstract).
- Zhou H., Gu S., Zhao X., Zhou L., Yan Z. 2005 – Alpine grassland degradation and its control in the source region of the Yangtze and Yellow rivers – *China-Japanese Society of Grassland Sci.* 51: 191–203
- Zhou H., Zhou L., Liu W., Wang Q., Zhao W., Zhou Y. 2003 – The influence of fencing on degraded *Kobresia humilis* meadow and non-degraded – *Grassland of China*, 25: 15–22. (in Chinese with English abstract).
- Zhou X., Li Y. 2001 – Ecological conditions affecting *Kobresia* meadow (In: Chinese *Kobresia* meadow, Ed. X. Zhou) – China Science Press, Beijing, pp. 1–23. (in Chinese).

Received after revision March 2009