EFFECTS OF CUTTING HEIGHT AND FREQUENCY ON YIELD IN A MONGOLIAN RANGELAND

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ABSTRACT

In the past, meadow rangelands in Mongolia were used for summer grazing and hayfields. Nowadays, however, they are grazed throughout the whole year. Changing environmental, economic, and political conditions have had a great impact on Mongolian pastoralism. The consequences are severe degraded rangelands due to overgrazing and climate change, especially during the last 20 years. Therefore, a new grazing system that is adapted to changed climate conditions is needed. -The aim of this research was to determine the effects of cutting frequency and stubble height (simulated grazing) on total yield and regrowth in order to provide information for recommendation for rangeland management. Vegetation was cut to two different stubble heights (base and 3 cm) on up to four occasions (some plots were cut every month during the growing season) over a two year period. The experiment was fully factorial in a randomised complete block design with five replications carried out at the *Agrostis*-forb meadow rangeland in the forest steppe zone of Mongolia. Sampling was carried out in 2006 and 2007. Total yield decreased as the number of cuttings increased. Cutting to the ground (0 cm) gave a significantly higher total yield than cutting to 3 cm during the first year. However total yield and regrowth were lower in the second year. Cutting to the ground three and four times during the growing season strongly affected the yield of the following year. Based on these results, the optimum cutting regime for rangeland management appears to be cutting twice a year (July and August) and leaving a 3 cm sward remaining when cut.

1. INTRODUCTION

In Mongolia, nomadic animal husbandry is still an important part of the Mongolian lifestyle and the main source for the country's livestock products. Therefore, grazing rangelands are seen as one of the main foundations of the Mongolian economy and social development. Livestock production has been and is the main source of income for Mongolia's rural population, and it does have the potential to provide a steady income for the rural population (Havstad *et al*., 2008). In earlier times, herders had a good traditional nomadic rangeland management system, and it has been argued that herders shared knowledge that supported a flexible system of sustainable resource management land use (Fernandez-Gimenez, 2000). From 1921 to 1990, however, Mongolia was governed under a socialist regime with a centrally planned economy and socialist ideology was superimposed on traditional Mongolian extensive livestock farming management (Report Country Gender Assessment, 2005). During the seven decades of the socialist era, the traditional rangeland management system was replaced by central government control (Mearns, 1996). The traditional rangeland management systems were obliterated from that time.

Changing environmental, economic, and political conditions since 1990 have greatly influenced Mongolian pastoralism (Sternberg, 2007). Since 1990, Mongolia has shifted to private ownership in a democratic market economy (Bilskie and Arnold, 2002). Dramatic change over the last 20 years has seen Mongolia fall into the more universal pastoral norms of maximizing livestock production, reduced mobility, increased sedentarization, and concentration on income-producing animals as herder motivation and options changed from meeting quotas to generating income as in other pastoral regions of the world (Bedunah and Harris, 2002; Sorbo, 2003; Lesorogol, 2006). Concurrently government levels of support and control have been slashed, land tenure has evolved towards private possession, and poverty is widespread (Sneath, 2003). The predictable results are the deterioration of the rural water infrastructure, intensified grazing patterns, increased land degradation, and an end to co-operative herding decision-making and implementation (Batjargal, 1997; Janzen and Bazargur, 2003).

Scientists have suggested that the Mongolian rangelands have reached their "carrying capacity" levels and need a better management regime befitting the conditions of the area (Dorligsuren, 2006). Small increases in animal populations or changes in land-use patterns may therefore result in localized degradation. Such changes include the tendency to settle for more prolonged periods around infrastructural facilities, herding by salaried herders, and increasing numbers of inexperienced herdsmen who have fled unemployment in the cities after the socialist era (National Plan of Action to Combat Desertification in Mongolia, 2007).

Mongolian rangelands have experienced degradation over the last 20 years, not only due to overgrazing but also due to global climate change. In Mongolia, the warmest ten years of the last 65 years occurred after 1990 (Natsagdorj *et al*., 2005). Germination and plant growth start earlier in the spring, and peak yield has decreased 20-30% in the total territory of Mongolia, except for the high mountain zone (Bolortsetseg *et al.*, 2005). Report of the Mongolian Ministry of Nature and Environment predicted that in 2020 grazing time over the summer period will be halved due to climate change (MNE, 2007). Therefore, a new grazing system that is adapted to changed climate conditions is needed.

Meadow rangeland, which is 2.1 percent of total rangeland in Mongolia, has primarily been used for summer grazing and for hay fields (Sainkhuu, 1996). The meadow research group of the Mongolian-Russian joint expedition worked in the basin of the Orkhon River in the Shaamar district of Selenge province from 1976-1986. Sainkhuu (1985, 1990, and 1996) presented data on structure, species composition, productivity nutrient status and the effects of grazing on the meadow rangelands. There is a need for better information on the impact of grazing intensity for management recommendation, not least because of the climate change experienced over the last two decades (Bolormaa *et al.*, 2008).

A study called "Green Gold" pasture ecosystem management was initiated in 2004 and carried out in three areas in the basin of the Orkhon River in the Shaamar district, Selenge province in the forest steppe zone of Mongolia. In 2004, *Agrostis*-forb humid, *Carex*-forb swamp and *Elymus*-forb dry vegetation communities and different ecological conditions of the meadow rangeland were selected. Prior to the 1990s these areas were used for hay fields and then grazed during a short period in the autumn (Sainkhuu, 1985). Over the last 20 years this management system has been shown to be unsustainable and herders use these areas for sheep and cattle grazing without any resting time (Baatar *et al.*, 2005).

In this report, I present results of a study aimed at assessing the effect of cutting frequency and stubble height (simulated grazing) on total yield and regrowth yield of the first and second year of cutting in the *Agrostis*-forb humid meadow rangeland. The results should contribute to rangeland management recommendations.

2. MATERIALS AND METHODS

2.1. Study site

The experiment was located in the Territory of the Shaamar district in North Mongolia that covers the area between 105°50'E and 106°56'E and 47°51'N and 47° 56'N. The area is mountainous, from 850 to 1050 m a.s.l. The climate is continental with a long-term average annual precipitation of 293 mm, of which 254.4 mm fall during the growing season (from May to September) (Table 1). The long-term annual average temperature is 0.31°C, minimum temperature is -23°C in January, and the maximum temperature is 19.5°C in July.

The 2006 growing season was more comparable to the long-term climate data than the 2007 growing season. Mean annual temperature and precipitation in 2007 were higher than the long-term data, but varied greatly throughout the growing season (Table 1). June 2006 was both warmer and dryer than the long-term data while July 2007 had values similar to the long term data, although not as dry as June of the previous year (Table 1).

Table 1. *A summary of climate variables at the study site. Monthly mean data of temperature and precipitation are shown for the two study years. Long-term data covering the period 1966 to 2003 are shown for comparison (Data from Sukhbaatar Meteorological Station, 2007).*

Years	Temperature, ˚C (mean)					Average	Precipitation, mm (accumulated)					Sum
	May	June	July	Aug	Sept		May	June	July	Aug	Sept	
Long term data	11.4	17.3	19.5	17.2	10.1	15.1	20.1	51.2	76.3	70.8	36	254.4
2006	10	18.7	20.9	17.6	11.2	15.7	49.5	2.5	84.8	96.2	20.7	253.7
2007	13.9	17.7	23.7	18.6	11.9	17.2	42.8	60.2	48.5	110.4	23.5	285.4

The vegetation at the study site is classified as *Agrostis*-forb rangeland (Agency for Land Administration, Geodesy and Cartography, 2002). The research field is located in a depression, which rests on an old moist fenland. The soil at the study site is classified as black meadow soil (Dorjgotob, 1994). It has sufficient amounts of plant nutrients such as NO_3 and P_2O_5, but is low in K_2O (Baatar *et al.*, 2005). Measurements at the study site during the study period showed that bulk density was 1.05-1.48g cm^{-3}, porosity was 44.7-60.5% and field carrying capacity moisture between 34.9 and 54.7 mm. Maximum water holding capacity and field carrying capacity were higher (Danzan-Osor, 2005). Soil moisture during the growing season of both years was efficient for plant growth (Fig. 1).

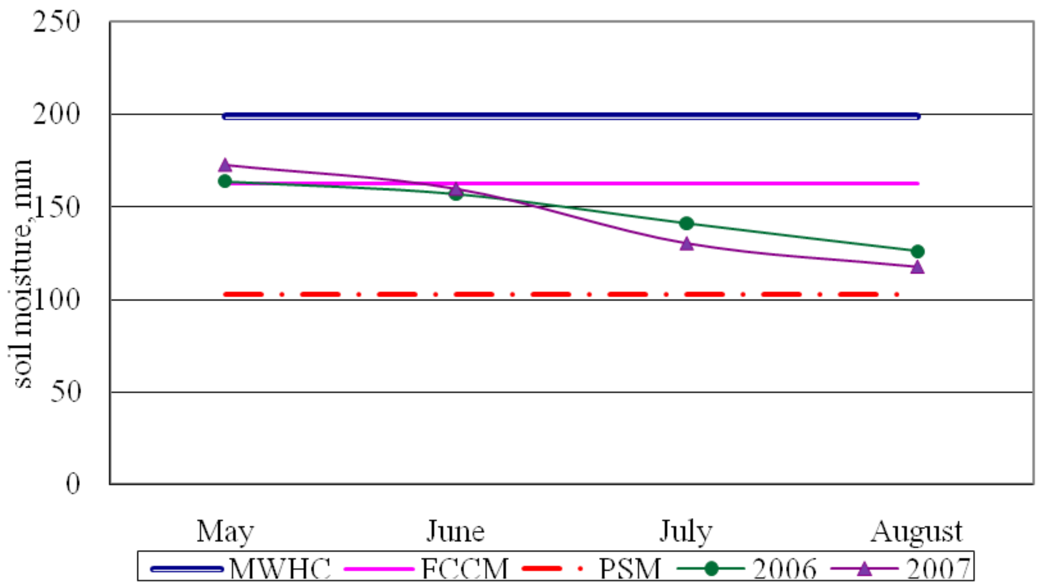

Fig. 1. *Soil moisture during the growing season for the two study years (2006, 2007), maximum water holding capacity (MWHC), field carrying capacity moisture (FCCM), and moisture of the plants to be stunted of the soil (MPS). MWHC, FCCM and MPS were measured by the single ring method of A.Danzan-Osor in 2005.*

Fifty-one plant species were reported at the study site. The most dominating species was *Agrostis mongolica Roshev.*, while subdominants were *Poa pratensis L.*, *P. subfastigiata* Trin., *Calamagrostis purpureus* (Trin.) Trin., *Carex enervis* C.A.Mey., *Carex orthostachys* C.A.Mey. and the forbs, *Sanguisorba officinalis* L., *Potentilla anserine* L. and *Thalictrum simplex* L..

2.2. Experimental design

The experiment was established within a fenced area in spring 2004. A total of 220 (1 x 1 m) plots were laid out in a homogeneous area within the same vegetation type. Plots were separated from each other by 1m buffer strips. Treatments were randomly assigned to the plots.

The treatments included cutting biomass at two different heights (0 and 3 cm), four different cutting frequencies (four different starting times during the growing season, i.e. May, June, July or August), and year of cutting. The design of the experiment was fully factorial. Five plots were randomly chosen each month to be cut for the first time. Plots that were cut the first year were cut again the second year following the same scheme, and, in addition, another set of plots was selected for starting cutting the second year. The procedure is shown schematically in Table 2. In this report I include results from two years, 2006 and 2007.

Table 2. *Experimental scheme with cutting frequencies and stubble heights. Treatments (Tr) 1-3 and 7-9 are new plots for study of 2007 that had rested during the previous three years. Tr 13-15 and 19-21 rested two years until 2006, and then were cut continuously for two years in 2006 and 2007. Tr 1-3 and 13-15 were cut at 3 cm, Tr 7-9 and 19-21 were cut at 0 cm. The names of months represent cutting times. Every treatment was replicated five times.*

Cut only on 2007					
at 3 cm			at 0 cm		
Tr-1	Tr-2	Tr-3	Tr-7	Tr-8	Tr-9
May	-	-	May	-	-
June	June	-	June	June	-
July	July	July	July	July	July
Aug	Aug	Aug	Aug	Aug	Aug
Cut on 2006 and 2007					
at 3 cm			at 0 cm		
Tr-13	Tr-14	Tr-15	Tr-19	Tr-20	Tr-21
May	-	-	May	-	-
June	June	-	June	June	-
July	July	July	July	July	July
Aug	Aug	Aug	Aug	Aug	Aug

2.3. Measurements

In the beginning of April, before the growing season, dead biomass from the previous year was removed. The main field work was carried out during the growing season, from May to September. Biomass was obtained from the plots on the 20th of every month. Cutting was done by hand. The first time a plot was cut in a season, biomass was separated into species, but subsequent cuttings (second, third and fourth) were not separated. In the following months, biomass was cut to the same height as previous cuttings of that plot, obtaining regrowth of a plot between the two cuts. All cuttings of a plot were to the same height. All plant material was dried at air temperature inside a small wooden shed and weighed after drying. Annual yield was obtained by summing biomass from all cuttings of a given plot. Accumulated regrowth was calculated by summing all except the first cut of a year for each plot.

Soil moisture was measured at four different depth levels (0-10 cm, 10-20 cm, 30-40 cm and 40-60 cm) once a month, just before cutting the biomass, using the weighing method used at the Forage Assessment Laboratory, Research Institute of Animal Husbandry. The soil temperature was measured at four different depths (5, 10, 15, and 20 cm) three times a day, at 9 am, 2 pm and 6 pm.

2.4. Data analyses

Prior to analyses accumulated yield data were calculated for different frequencies and years for the two cutting heights. Data from the August 2007 harvested at 0 cm were removed from the dataset due to unexplained difficulties (yield of 0 cm cut less than 3 cm). Thus, no August data were included in the analyses in this report (frequency equals 1).

Analysis of variance (ANOVA) was used to test the effect of cutting frequency, height and year (first year cutting: 2006 and 2007) on total yield. The focus here was on the impact of frequency and height treatments on the first year cuttings. Year is included to assist distinguishing between year differences due to conditions (climate and resting time). ANOVA was also used to test the impact of frequency, height and year on total yield. Here year corresponds to whether a plot was cut in the first or second year. The first year plots had not been cut before and had one extra year of exclusion from grazing compared to the second year plots that had been cut the previous year. Finally, ANOVA was used to test effects of frequency, height and year (first and second years of cutting) on regrowth yield. For all three analyses the design was 3 × 2 × 2.

Statistical analyses were performed using SPSS (version 16.0) for Windows.

3. RESULTS

3.1 Effects of cutting frequency and stubble height on yield

The annual total yield during the experimental period is summarized in Table 3. Cutting frequency had a highly significant effect on total yield during the first year (Table 4) with yield decreasing as the number of cuttings increased (Table 3, columns A and B). Cutting the biomass to the surface (0 cm) gave a significantly higher total yield than when cut to 3 cm (Table 4, Fig. 2).

Table 3. *Annual accumulated yields during the experimental period harvested with different frequencies at 0 cm and 3 cm heights.*

		Annual accumulated yield, kg ha^{-1}					
		First cutting				Second cutting	
		2006 A		2007 B		2007 C	
Stubble heights	Cutting frequency	mean	SE	mean	SE	mean	SE
0 cm	twice	3024	22.4	4037	15.6	2264	38.6
	three times	2531	8.0	3310	29.7	1789	8.1
	four times	2744	27.5	3072	20.3	2129	24.8
3 cm	twice	2975	27.5	2699	37.7	3571	54.4
	three times	2591	18.5	2385	17.7	1895	15.8
	four times	2322	11.8	2282	24.2	1622	8.3

Table 4. *Result of ANOVA on accumulated yield of first year cutting (column A and B in Table 2). The impact of height, frequency and year on accumulated yield was tested.*

Univariate Analysis of Variance	df	F	Significance
Cutting frequency (F)	2	7.156	0.002
Stubble height (H)	1	18.678	0.000
Year (Y)	1	3.974	0.052
Y × F	2	0.241	0.787
Y × H	1	10.879	0.002
H × F	2	0.330	0.720
Y × F × H	2	1.032	0.364
Error	48		

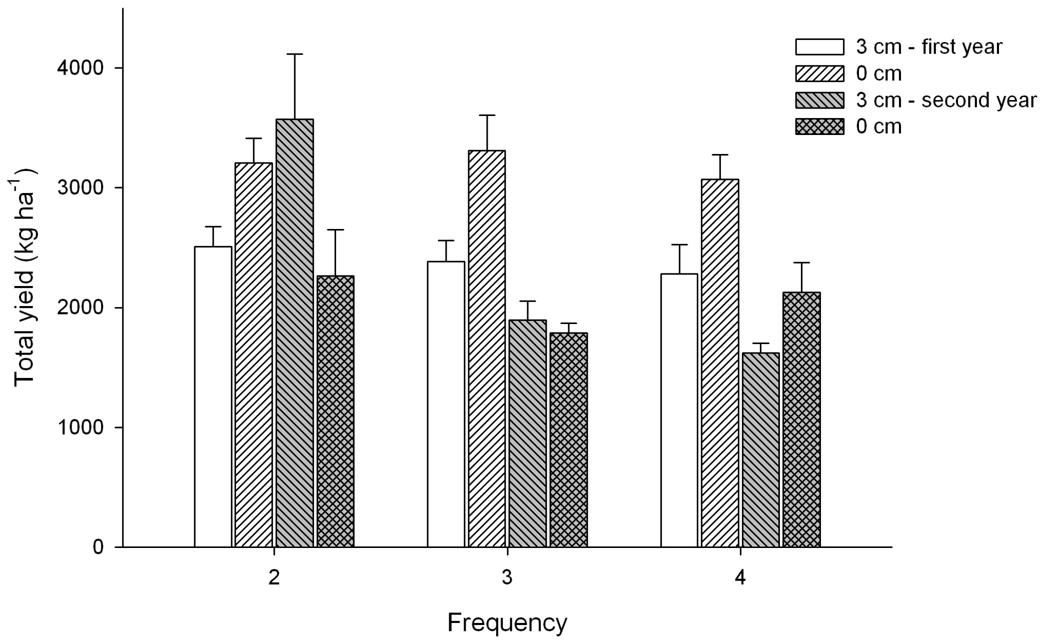

Fig. 2. *Total yield (kg ha^{-1}) for the three different cutting frequencies and two different stubble heights in first and second year.*

3.2. Effect of preceding year's treatment (rested or cut) on total yield and regrowth

For cuttings starting in 2006, accumulated yield was significantly lower in 2007 than comparable treatments cut for the first time in 2007 (Table 5, Fig. 2). This pattern was prominent in plots that were cut three and four times during the growing season; they had 13-30% lower yield in the second year (Table 3, columns B and C). There was a strong significant interaction between stubble height and year of first cutting (Table 5) as cutting at 0 cm strongly reduced the second year's accumulated yield (Table 3, columns B and C, and Fig. 3). Cutting twice a year to 0 cm gave the highest accumulated yield in the first year, but in the following year the yield had decreased 25-44%. The highest yield of a second year cutting was when cut twice at 3 cm (Table 3).

Table 5. *Result of ANOVA for total yield in 2007 for plots harvested at 0 cm and 3 cm heights to different frequencies harvested for the first time in 2006 and 2007 (data from columns B and C in Table 3).*

Univariate Analysis of Variance	df	F	Significance
Year (Y)	1	21.880	0.000
Height (H)	1	4.955	0.031
Frequency (F)	2	11.959	0.000
Y × H	1	16.830	0.000
Y × F	2	1.016	0.370
H × F	2	1.315	0.278
Y × H × F	2	4.694	0.014
error	48		

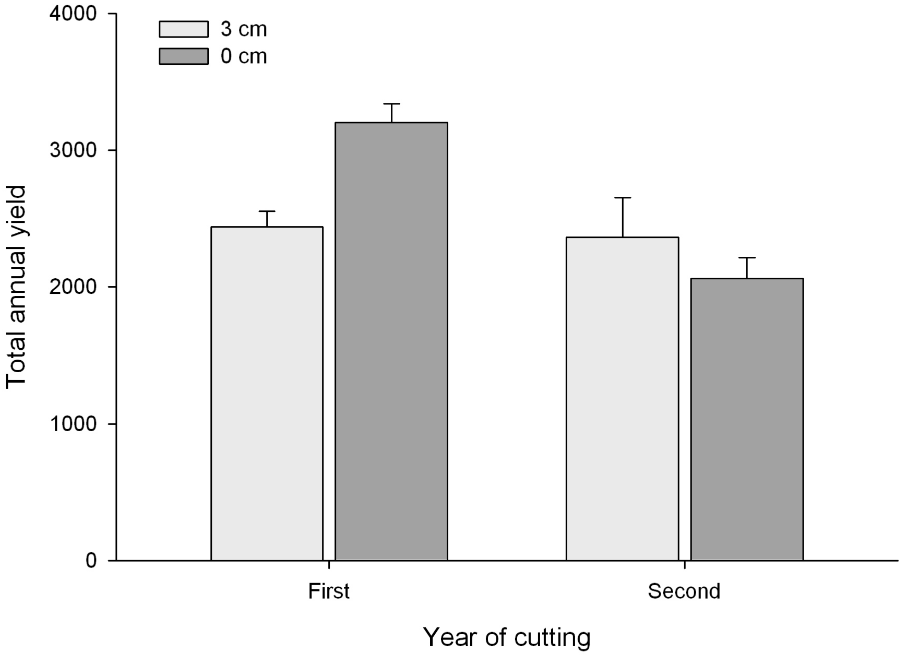

Fig. 3. *Mean accumulated yield of 2007 cutting from plots which were cut for the first time in 2006 and 2007 at two different heights (0 and 3 cm).*

In 2007, plots that were first cut in 2006 had significantly lower regrowth than plots cut for the first time in 2007 (Table 6, Fig. 4). Frequency and stubble height also had a significant effect on regrowth (P<0.001), and the interactions between frequency and year (P<0.001) and frequency and height (P<0.05) were significant.

Table 6. *Result of ANOVA of regrowth yield. The effects of different cutting frequencies and stubble heights on regrowth yield of first and second year.*

Univariate Analysis of Variance	df	F	Significance
Year (Y)	1	26.584	0.000
Frequency (F)	2	248.967	0.000
Stubble height (H)	1	15.598	0.000
Y × F	2	9.043	0.000
Y × H	1	1.473	0.231
F × H	2	4.112	0.022
Y × F × H	2	0.333	0.718
Error	48		

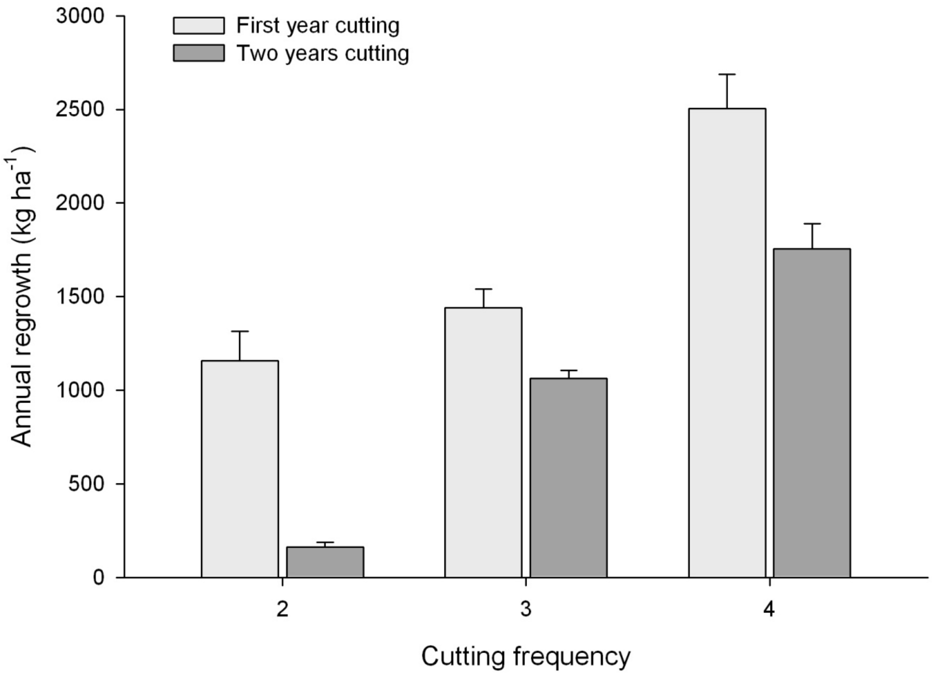

Fig. 4. *Total regrowth yield (kg ha^{-1}) for the three different cutting frequencies in first and second year.*

4. DISCUSSION

This study focused on the short term effect of cutting frequency and stubble height on total annual yield and regrowth yield of first and second years of cutting with the aim of assisting with rangeland management recommendations for Mongolia. A new management system is now needed consistent with current climate change conditions.

4.1. Effects of cutting frequencies and stubble height on yield

Total annual yield was less when cuttings began early and frequency was high (Table 3). Sainkhuu (2006) recorded that tillering and budding were the most sensitive stages for plant growth. If livestock grazing occurs at the time of plant tillering, fewer branches are formed and plant growth would stop. During the budding period, nutrition is not sufficient to support growth of the reproductive parts of the plant. Plants are not capable of supporting rapid growth in shoots and roots simultaneously for an extended period of time. If rangeland is grazed severely, root growth stops and roots may die (Teel, 2000). Hence, rangelands grazed during the tillering and budding period may be expected to experience degradation. This may explain the observed decrease in yield when cut early. The earliest cutting (20th of May) was at the time of tillering, the next cutting (20th of June) coincided with the start of budding and onset of flowering for most species present. Jewiss and Powel (1965) similarly observed a slower recovery of biomass after a first cutting at early heading compared to anthesis on timothy (*Phleum pratensis*. L.). Hoglind et al. (2004) reported regrowth, tillering and leaf area dynamics following spring harvest at two growth stages in Norway. They found consistently higher regrowth rates after late cutting. Whereas early first cutting hampered timothy sward regrowth predominantly by reducing tiller survival and retarding post-cut leaf area development. Halil *et al*. (2006) and Geber (2002) found the same results for lucerne (*Medicago sativa* L.) and reed canary grass (*Phalaris arundinacea* L.) in New Zealand and Sweden. The total yield decreased with more cutting frequency per year, earlier start and increases in the stubble height. Increased height of cutting resulted in increased yield of the regrowth harvested from the four-cut regime. In agreement with Jones and Lazenby (1988) infrequent severe cutting during the first year resulted in a maximum net yield and an increasing number of cuts reduced the accumulated yield and the height of cutting had no influence on accumulated yield.

Cutting at 0 cm gave a significantly higher accumulated yield and regrowth yield than at 3 cm, but this was not a valuable result for the future. Comparable results have been reported for lucerne where yield also increased with the harvest from base (0 cm), but this management caused reduction in hay yield in successive years (Tosun, 1971) because there was decreasing non-structural carbohydrate content in the roots (Halil *et al*. 2006). Cutting with a higher stubble height in the three- and four-cut regimes seemed to compensate for the increased cutting frequency compared with two severe cuttings at lower stubble height (Geber, 2002). In the experiment reported by Kading and Kreil (1990) higher stubble height resulted in an increased accumulated yield in a five-cut regime, but the accumulated yield was lower than with two or three cuts. This agrees with the results of the four-cut regime in the present experiment (Table 3).

With latest cutting times, the regrowth yield was lower compared to earlier cuttings (Fig. 2). The latest cuttings were in August for the all treatments. At that time, plants have started preparation for wintering because day length is getting shorter and changes in day length (photoperiod) regulate the phenological development of rangeland plants. Changes in the day length function as the timer or trigger that activates or stops physiological processes initiating growth and flowering and that starts the process of hardening for resistance to low temperatures in autumn and winter (Llewellyn, 2000). Misley *et al*. (1977) observed similar results that the earlier of two cutting times led to the highest regrowth yield and to the findings by Bonesmo and Skjelvag (1999) that regrowth was not affected by a similar difference in harvest time.

4.2. Effect of preceding year's treatment on yield

Increased cutting frequency negatively affected the total yield in the second year. Lkhagvajav *et al*. (2007) found comparable results on slightly and heavily degraded types of *Festuca*-forb rangeland in Mongolia. Especially cutting at 0 cm was a reason for yield decrease in the following year, which was clearly demonstrated by a strong interaction between year of cutting and stubble height (Table 5). In a study of the moderately degraded type the yield was increased with four annual cuttings (Lkhagvajav *et al*., 2007). The yield was increased with four cutting times a year. In this case *Potentilla acaulis* L., which grows by stolons on the ground, grew very fast after the cutting. Population total biomass in *Potentilla acaulis* L. decreased initially and then increased with increasing grazing intensity. This species is adapted to heavy grazing and increased with intensive cutting (Li Jinhua *et al*., 2005). At my study sites, grasses and sedges, including *Agrostis mongolica* Roshev., *Poa pratensis* L., *P. subfastigiata* Trin., *Calamagrostis purpurea* (Trin.) Trin., *Carex enervis* C.A.Mey., *Carex orthostachys* C.A.Mey dominated in the sward. The short term effect of cutting frequency on the yield may therefore depend on plant community type or the dominant species.

In my study, the total regrowth yield was higher in the first year of cutting and increased with increasing frequency of cutting (Fig 3), but total yield decreased with increasing frequency, especially in the second year (Fig. 2). Stuczynska and Jakubowski (1980) found a close correlation between above-ground crop yield and the root bulk of reed canary grass in a cutting frequency experiment. They reported a decreasing crop yield and root bulk with an increasing number of cuts after two years of three to six cuts a year. Kading and Kreil (1990) also reported that more than two cuts in the first year clearly reduced the yield in the second year in their five-cut regime experiment.

4.3. Recommendations for rangeland management

The experiment was carried out under field conditions. Consequently the treatment effects may have interacted with the climatic conditions. The treatment effects on total yield were fairly consistent between years in spite of the observed differences in temperature and precipitation (Table 1). Plots that were cut for the first time in 2007 had a somewhat higher yield (although not significantly) than plots cut for the first time in 2006 (Table 3, columns A and B and Table 4), which can be attributed to longer resting time and different weather conditions.

Cutting twice a year gave the highest total yield in both first and second year (Table 3). Cutting at 0 cm gave the highest yield in the first year; however, the yield decreased in the second year. Thus I conclude based on my results that two annual cuttings at 3 cm should be recommended for rangeland management. Sainkhuu (1985) recommended that the *Agrostis*-forb rangeland could be grazed such that it would be allowed to regrow three to four times a year. The average peak yield in my study over two years was 37% lower than he reported.

5. CONCLUSIONS

The total yield decreased with high cutting frequency and cutting over a longer period (two years). Cutting at 0 cm with higher frequency was a reason that total yield decreased in the following year. Increased stubble height had less effect on the regrowth yield of the different cutting regimes.

For short-term rangeland management recommendations cutting twice at 3 cm per year may probably be recommended because of the high yield. However, the long term effects of this treatment should be assessed.

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