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An increasing demand for livestock products requires an increase in the productivity and population of Mongolian livestock. One way of achieving this is the development and implementation of efficient means of using natural pasture. Research in mountain-steppe and steppe pastures shows that unsystematic use of pasture causes different kinds of deterioration in primary vegetation compositions and quality, resulting in decreasing pasture yields and digestibility. The specific negative effects vary according to duration, frequency and intensity of grazing, although grazing of less than one month in duration once in each season has little negative impact upon the yield of pastures the following year. Intensive grazing of 2–3 periods on the same area in a season may lead to a decline in pasture yield of upto 72% the following year, with a corresponding change in the primary plant groups. Intensive use of a pasture for continuous grazing over a long period has more far-reaching effects; vegetation coverage decreases annually by 10–15% and the frequency of the species such as Sanguisorba Officinalis, Polygonum Divaricatum, Astragalus Adsurgens, and Vica Amoena, decreases to between 10–30%. Nonetheless there are grazing schemes which make possible recovery in pasture productivity of degraded areas, improving biomass and the structure and composition of the vegetation cover. To develop optimal systems of pasture use, there is a need to integrate the centuries old experience of Mongolian herdsmen with modern scientific research.

Introduction

Increasing demand for livestock raw materials and products in Mongolia makes necessary an increase in the livestock population and especially its productivity. One way to achieve this is the development and implementation of effective methods for the proper use of natural pasture where pastoral animals can obtain about 90 percent of their annual feed intake requirement. The basic condition for effective management of the natural pasture in Mongolia is the development of a grazing system based on interdisciplinary research into species composition of the major types of pasture in different natural and climatic zones, as well as into palatability, bio-ecological characteristics and seasonal growth rates of major fodder grasses. It is important that seasonal, annual and long-term changes in yield and growth capacity after grazing, and the influence of grazing intensity on immediate and long-term productivity and recovery capacity, should be studied.

A new draft of the Land Law will be presented to the State Great Khural (Parliament) in the 1993 autumn session. This Law suggests different forms of pasture use by different ownership categories. This requires that the existing systems of grazing land use be reviewed in order to explore new ways to improve the efficiency of pasture utilisation. Following economic liberalisation there are individual livestock producers, who are interested in investing in pasture land for its improvement. There is also an urgent need to work out methods for conservation of pasture through effective use. Consequently, Mongolian scientists are conducting research on conserving and improving the productivity of natural pasture through rotational grazing regimes which can be monitored by the herders themselves. One way to reach these goals is to study the influence of different grazing regimes on the productivity of pasture in order to develop methods for maintenance and recovery of pasture potential through combining natural growth capability with scientific and traditional herders' approaches.

Ecology and climatic conditions of the research area

The research sites are located in the mountain forest steppe zone. These are the territories of the former Zelter, Nairamdal and Shaamar state farms, and have an average altitude of 630–2200 metres above sea level. The major soil type is mountain steppe and steppe brown supported by chestnut, forest brown and fertile dark brown or real chestnut, old riversides and dry valleys between higher mountain terraces. The research sites belong to the mountain forest steppe region type of vegetation (Yunatov 1950). The mountain steppe community is dominated by Stipa baicalensis, Festuca Lenensis, and the steppe communities by Stipa Krylovii, Leymus chinenses, Koeleria macrantha, Poa attenuata and Agropyron cristatum. The main fodder species of the meadow association are dominated by Leymus chinensis, Bromus inermis and Agrostis mongolica. The area is characterised by an extremely continental climate with long cold winter and belongs to an area with continental, harsh and extremely unpredictable climatic conditions. The average annual temperature is about +0.2°C (-0.3–1.3), average temperature in July is +20.3°C (19.6–22.5), average temperature in January is -23.4°C (-19.9–-27.2). The total sum of temperature above 0 is 2461 (2341–2611). The annual rainfall is about 282.5 mm (174.4–468.6) and about 70–80 percent of precipitation is concentrated in the growing season from June to August.

Phenophase and aspect of natural pasture

A given type of natural pasture has formed by evolution and consists of plants with a very definite inter-relationship. The major stages of vegetative life of any plant are highly correlated with the ecological conditions of the growing environment. This is most clearly determined by the time when it begins to grow or dries back. This gives good criteria on which to base the grazing schedule of a particular area of natural pasture. New growth in drier forest-steppe and dry steppe zones begins in the first decade of April, but plants in wet meadows grow later, in the first decade of May. Due to unstable weather, the growth is slower than its biological potential. Therefore, the grazing of young grass in these zones only becomes possible 30–35 days after the beginning of a new stage of pasture growth in the spring. This means the effective period of spring grazing varies not only between ecological zones, but within zones according to global and micro climatic patterns, including precipitation and warmth. For example, grazing areas lying along the southern slopes of low hills and dry valleys can be used for spring grazing, commencing from the first decade of May, while highland pastures and meadows become available in very late May or early June. This mostly coincides with the time differences in tillering by loose bunch grasses (15–30 May) in the steppe pastures and loose bunch and rhizome grasses in the plains meadow community (15–30 June).

Changes in the colour of pasture can also be a guide to the timing of use of a particular area. The colour of the plant communities changes in close correlation with vegetation stages and changes in colour of different parts of an individual plant during the summer growing season. These visible changes are accepted as criteria for good scheduled grazing management. As an example, in early spring the pastures become blue coloured due to the mass flowering of Pulsatilla ambigua. This time of year is known and used by the herders for early spring *nogoo khoolgokh* (selective grazing of new grass) pasturing of livestock to allow a partial recover of the live weight loss during the winter-spring period. From the scientific point of view, it can be explained that Pulsatilla ambigua contains a number of active substances which are highly effective in restoring body condition, especially rumen degradation activity. A plant of similar characteristics to Pulsatilla ambigua is Wormwood (Artemisia frigida) which begins to grow in early April and

becomes grazeable already at the beginning of May.

Pasture grasses can be divided into 3–4 subgroups according to the time of their flowering. Four subgroups can be identified based on flowering time in the forest-steppe and steppe zones—spring, early summer, summer and late summer—and 3 subgroups in the meadow community: early summer, summer and late summer (Tserendash 1980a). In early summer, minute bunch grasses such as Keoleria gracillis, Poa attenuata and Agropyron cristatum flower, making the pasture light-grey. By this time most grasses are in a more advanced vegetative stage and protein content reaches its maximum; thus pasture productivity and grazing value becomes richer. Livestock grazed on this pasture at this stage regains weight rapidly and are able to put on additional weight. During this time different species of sedge (Carex spp.) in the plains meadow community are in late flowering and seeding stages.

In July many species—about half of the main pasture grasses such as Galium verum, Bupleurum bicaule, Tanacetum sibiricum, Veronica incana in the mountain steppe and steppe pasture and Valerina officinalis, Thalictrum simplex, Geranium protense in the meadow community—flower in sequence, and this leads to a change of colour of the pasture as a whole. Perennial tussock zerophyte species with main and filamentous roots and hemicryptophyte species with subterranean growth shoots play a significant role in forming the pasture community in the forest-steppe and steppe zones, while the major species for continental and plains meadow communities are rhizomatous mesophyte and mesoxerophyte. For example, steppe pastures can be grazed starting when the bunch grasses are at the tillering stage, until the flowering of minute bunch grasses. This makes it possible for the plot to recover and it can be grazed 2 or 3 times for 60–85 days each following the first grazing. The protein content of a regrowing green grass is higher by 11–30 percent than that of continually grazed fields (Tserendash 1980b, 1990) and the regrown young grass is considered more effective for fattening livestock in summer. The heading and flowering of Agrostis Mongolicus, Stipa baicalensis, S. Kirylovii indicates the peak of growth in pasture and hayfields, while the flowering of Bromus inermis signals that the field can be cut for hay.

Regardless of environmental conditions in the second half of August, some grass species reach their final growth stage and show signs of drying. This process is completed by October and nutritive value decreases significantly. However, the dead grass (*khagd*) is excellent standing forage and is used for about 200 days or twice as long as the green grass as a main feed resource of Mongolian native livestock (Tserendash 1980a:32). Under Mongolian conditions, the growth period of pastoral grasses is 3 to 4.5 months.

Seasonal and yearly dynamics of pasture productivity

The productivity and performance of different types of natural pasture in Mongolia varies widely according to annual and seasonal climatic conditions, species composition and growth rate. The results of research carried out over the last 15 years show that the fresh yield of steppe pasture at the end of May is about 10–18 percent of the maximum summer production of the same pasture. But this productive index of pasture composed of intensive species such as Festuca Lenensis and other forbs reaches about 32.1 percent in early summer. In June the index for steppe pasture is 58–66.9 percent, while the meadow pasture has relatively low production estimated at 44.5–46.5 percent. Late growth is caused by thawing of the soil. The highest growth rate occurs as a result of better environmental conditions in July when about 90.0–94.3 percent of the maximum summer fresh yield is accumulated. The summer maximum fresh yield occurs in a period between the first and second decades of August when the dominant species are in the final phase of flowering and early seeding: the real yield of steppe pasture at that time is 11.3–20.5

c/ha, and that of meadows 11.5–34.6 c/ha. The timing of maximum pasture yield in late summer is due to the fact that summer tillering and shooting of bunch and rhizomeous species is closely correlated with the distribution of summer rainfall. Under Mongolian conditions in August two important growth processes are maximised: both the accumulation and destruction of organic matter. The second process become dominant in September when most pasture species are transformed into a so called "speckled" form; in October all plants die completely. By this time 69.9–80.3 percent of the summer maximum yield of pasture is maintained in form of *khagd*. A further decrease in the standing crop of *khagd* follows: 52.2–67.8 percent in February and 34.2–56.1 in April, providing livestock with costless fodder during the hard winter-spring period.

Findings suggest there are phases in the increase of pasture yield: three for steppe and two for meadow pasture. The first phase is the increase in productivity of steppe pasture by 0.2–0.21 c/ha per day in the last decade of May due to the tillering of bunch grasses; the second is in late July, when the above mentioned species flower and the daily increase reaches 0.14–0.2 c/ha; the third phase occurs in the last decade of July at a period of mass flowering of forbs, with an increase of 0.2–0.23 c/ha daily. In the last decade of June there is an increase in the fresh yield of meadow pasture which is related to the shooting-tillering phases of grasses. The daily increase is 0.6–0.74 c/ha. The second period of increased productivity occurs in late July during the flowering of forbs, when the daily increase is estimated at 0.52–0.66 c/ha. Usually in August the increase in yield of different types of natural pasture is 2–5 times less than in June and July.

The maximum yield and its rate of accumulation vary significantly according to the amount of rainfall and its distribution. In dry years when the rainfall was 15.1–38.7 percent less than the long-term average, the productivity of steppe and meadow pasture declined by 8.6–15.1 percent and 5.1–32.2 percent respectively. But, in high rainfall years, yields were higher by 14.7–17.1 percent for steppe and 7.8–152.2 percent for meadow pasture than the long-term average. The large differences in yield variability between the steppe and meadow pastures is basically related to the species composition of these pasture types. For example, the steppe associations are composed of drought-resistant xerophyte plants, while the dominant species in a meadow community are mesophyte grasses which require comparatively high moisture. In our judgement the coefficient of correlation between the yield of steppe and meadow pastures and total rainfall during the growing season is relatively high, varying between 0.51–0.72.

The productivity of a particular type of pasture area depends on the productivity of the dominant and subdominant species. The biological yield of Stipa baicalensis and Festuca Lenensis, the dominant species of a bunch grass steppe pasture, makes up about 23.8–25.8 percent (3.4–4.9 c/ha) of the total fresh yield of this type of grazing. But the contribution of the dominant species (Bromus inermis, Agrostis mongolica) of a forbs-grass plain meadow pasture is estimated as 30.6–36.9 percent (11.3–16.0 c/ha).

The proportion of different naturally formed plant groups is of great importance in evaluating the biological potential and past and current use characteristics, and in defining a management strategy. The proportion of different plant groups is unstable, as the groups change according to vegetative period, weather and intensity of utilisation. There are considerable seasonal and annual variations in the relative abundance of plant groups within different types of natural pasture.

In the very early vegetative period, 35.8–69.4 percent of the yield of mountain steppe and steppe pastures is composed of grasses, 1.5–7.0 percent of sedges, 8.4–19.3 percent of legumes and 19.5–47.0 percent of forbs. At the time of maximum yield in August, this proportion changes to 26.8–48.0 percent; 2.6–13.8 percent; 5.5–23.5 percent; 16.7–46.9 percent, and in October, after drying, to 37.0–60.8 percent; 3.6–10.5 percent; 2.0–12.0 percent; 14.1–41.2 percent

respectively. The share of semishrubs however remains constant in all vegetative periods, varying between 18.5–20.0 percent. One interesting finding is that the share of legumes was higher in steppe communities during years with high rainfall, in contrast to areas of meadow pasture where a high percentage of legumes occurs in dry years.

Influence of pasture use regimes on yield, structure and species composition

Our research findings indicate that improper and unsystematic use of pastures causes different kinds of deterioration in primary vegetation composition and quality, resulting in decreasing pasture yields and digestibility. The negative effect varies according to duration, cycle (repeatedness) and intensity of grazing. However, there was no evidence that short (less than one month) duration single grazing in each season has a negative effect on the yield of mountain steppe and steppe pastures the following year. An intensive regime of 2–3 rotational grazing periods on the same parts of a pasture leads to a decline in pasture yield in the following year down to 37.0–72.0 percent of the yield of a control area. In parallel, there was a considerable change in the primary plant groups. For example, results show that the yield of grass and legume groups in pastures heavily grazed in the previous year decreases by 9 and 4 times respectively. However, the yield of the sedge-forbs group decreases relatively less (by only 1.7–2.0 times) and there was clear evidence that the pasture is likely to change into a type dominated by sedge forbs groups. The same intensity of use of an Artemisia frigida—minute grasses—Stipa Krylovii steppe pasture leads to an increase in the proportion of wormwood. These examples clearly demonstrate that any unadapted use of pasture can easily change not only overall plant group composition but may also cause irreversible domination by a single group or a change in pasture type.

The vegetative composition of a pasture changes when it is allocated to single grazing over 4 consecutive years in early spring. As an example we report the findings of a survey carried out in a Leymus chinensis dry steppe pasture. The vegetation cover became less dense and the number of shoots of the primary plant species were reduced, decreasing the yield. At the end of the fourth year, the density of the vegetation cover was reduced by 20 percent and the proportion of annual grasses had increased remarkably. The height of the dominant species (Leymus chinensis) had decreased by 3 cm and the yield of the pasture at the end of the fourth year of consecutive use had decreased by 40.0–48.8 percent in comparison with that at the beginning of the survey. At the same time, the proportion of forbs had increased by 9.3 times and of grasses decreased from 96.1 percent to 63.6 percent. This phenomena can be explained by the particular features of storage and consumption of nutrients in the root system of Leymus grasses. The sacchrose and starch content in the root of Leymus chinensis grown in areas of regular early spring grazing was 23.2 mg and 15.3 mg respectively, compared with values of 30.3 mg and 18.8 mg in the same plant in an underused pasture. This suggests that early grazing has a negative effect on nutrient content in the root system, which in turn affects the recovery and further growth rate of the plant. Similarly, the vegetation cover of a pasture allocated to a single summer grazing in consecutive years at the same period undergoes irreversible changes, including changes in the vegetation cover and botanic composition and in stems and shoots. Research in a Sanguisorba officinalis-Leymus chinensis-Bromus inermis community show that before grazing the coverage of Bromus inermis within the association was 30.5 percent but that after 10 years it decreased to 6.1 percent. Also, the number of vegetative shoots decreased by 4 times and fruiting shoots had not appeared. This suggests that this regime of pasture use affects both biological performance and capability to grow naturally. Due to these aggregate changes, the coverage and

growth activity of Leymus chinensis, a subdominant species, had increased quickly. Prior to the experiment, the coverage of Leymus chinensis was less than 10 percent, but it doubled reaching 20.6 percent. The number of individual plants counted in 0.1 square meter of the experimental field was 13 at the start, and 9 at the end of the experiment. This suggests a negative influence on productive capability (Tserendash 1990).

Intensive use of a pasture for continuous grazing over a long period in an unchanged manner has more far-reaching negative effects. First, the vegetation becomes less dense. The coverage decreases annually by 10–15 percent, in drier years by up to 20 percent, and the frequency of some species such as Sanguisorba officinalis, Polygonum divaricatum, Astragalus adsurgens, Vica amoena decreases to 10–30 percent. New species often appear in the vegetation cover, most usually Poa attenuata, Keoleria macrantha, Clestogenes squarrose and biannuals such as Heteropappus hispidus and Dontostemon integrifolius. The yield of a pasture area used twice in each of four years consequently decreases by 44.0–62.1 percent in comparison to the ungrazed value.

Where steppe pastures are intensively used, Stipa baicalensis, S. Krylovii, Onobrychis sibirica may disappear and the share of grass decreases by 4–6 times while the amount of forbs increases by 3 times. These changes lead to the complete transformation of the primary plant groups into a seral community dominated by the subgroups.

All these negative changes caused by unsystematic use and repeated grazing over many years strongly suggest the need to develop systems of pasture use based on the centuries-old traditional experience of Mongolian herders as well as on scientific research.

Our research results show possibilities for conserving and improving the primary vegetation composition as well as maintaining and restoring fodder resources by rational pasture use and management. Systematic use of a grazing area improves biomass and the structure and composition of the vegetation cover. Some recovery in species composition has been observed. Resting a mountain steppe and steppe pasture for 3 years from constant grazing allows an increase in the proportion of standing dead litter in the total biomass of the pasture by 4–7 times and grass mass by 5.4–8.0 c/ha. At the same time, the proportion of grasses in the pasture production increases by 3–4 times with a stongly decreased share of forbs (19.2 percent) and Artemisia frigida (15.7 percent). The growth capability of primary species such as Stipa baicalensis, S. Krylovii and Onobrychis sibirica recovers in a short period of the time and natural seeding of these species occurred. Single grazing of a degraded pasture after seeding in early autumn makes it possible to increase the yield by 25–30 percent in the first year and by 35–42 percent in the second year of grazing in comparison with productivity under heavy grazing. This shows that it is possible to recover the primary characteristics of a degraded pasture by reducing the intensity of grazing. Also, good recovery of pasture productivity can be obtained by a rotation of less intensive and intensive grazing. In this case a single grazing period should be allocated each year. Productivity of the pasture under such a grazing regime increases 27.0–202.6 percent compared to areas used intensively and exceptionally for their productivity. Our findings demonstrate that such a grazing schedule improves almost all the basic productivity indices. Several years use can be managed by changing the timing of grazing every year. This means that grazing time and intensity should be chosen in different stages of the growing period so that the pasture has a different pressure in different periods of the year.

Finally, we recommend some possible alternatives to the current system of pasture use in Mongolian extensive livestock production:

(1) Grazing of a pasture which has been used under adequate grazing pressure should be reformulated in the following rotational regime: in the first year, 3 times normal grazing (21–30 days) commencing in May; in the second year, single grazing

in the second half of the summer; and in the third year, single grazing after seeding.

(2) Partly degraded mountain steppe pasture dominated by Stipa baicalensis, S. Krylovii and Festuca Lenensis should be rested in the first year; grazed in late autumn in the second year; a single grazing in mid summer in the third year and twice in the fourth year.

(3) High quality mountain meadow steppe and meadow pastures should be used 3 times, starting in late spring in the first year; in late summer after seeding in the second year; and cut for hay in the third year during heading of Stipa baicalensis, and S. Krylovii or seeding of Leymus chinensis. In the fourth year, these areas can be grazed once or twice starting in the second decade of July.

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