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Pasture Productivity Depending on the Method of Pasture use in the Steppe Zone of Northern Kazakhstan

Balzhan Akhylbekova, Nurlan Serekpayev, Adilbek Nogayev and Bakhytbek Zhumabek

LLP "Scientific and Production Center of Grain Farming Named after A.I. Barayev", Kazakhstan

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Corresponding Author:
Adilbek Nogayev
LLP "Scientific and Production Center of Grain Farming Named after A.I. Barayev", Kazakhstan
Email: adilbek_nogaev@mail.ru

Abstract: Unsystematic grazing of animals and continuous use of pastures leads to their degradation and, accordingly, to a shortage of pasture forage for the production of competitive environmentally friendly livestock products. The proportion of productive grasses in grass covers is decreasing; therefore, there is an urgent need to preserve valuable plant species in pasture grass, restore the productivity of natural vegetation and enrich it with valuable grasses. This study evaluated the impact of the unsystematic grazing method and a developed pasture rotation scheme on the height of the herbage and the productivity of seasonal pasture plots. The study was conducted as an experiment in the Arshaly district of the Akmola region located in the northern part of Kazakhstan. In 2019, unsystematic grazing of animals was carried out on the studied contours of the pasture. The animals grazed without alternating pastures and, as a result, the plants were subjected to intensive grazing for long periods or without sufficient recovery periods. In 2020, there was rotational grazing, where cattle grazed in different areas according to the seasons using a certain pasture rotation. As a result of the conducted study, it was found that with pasture rotation, the height of the herbage increased from 9.56±2.94 to 16.42±5.65 cm. The productivity of pastures after grazing decreased sharply but in the following season, the grassland recovered from 0.77±0.22 to 0.91±0.4 t/ha and exceeded the indicators of unsystematic grazing.

Keywords: Herbage, Seasonal Pastures, Pasture Biomass, Grazing, Pasture Rotation

Introduction

Pastures are one of the most widespread terrestrial ecosystems, accounting for approximately 32% of the natural vegetation of the world (Adams *et al*., 1990). Up to 40% of the earth's surface is covered with pastures, where domestic and wild ungulates graze (White *et al*., 2000).

As of 2020, according to the CLMMA (2020), pastures accounted for more than 18 4.3 million ha, or 83.9% of all agricultural land in Kazakhstan, which puts the country in fifth place in the world in terms of pasture land area. The potential productivity of pasture lands of the Republic of Kazakhstan reaches 25 and more million tons of forage units (FAO, 2020). Moreover, it is believed that the greatest provision of forage lands per person falls on Kazakhstan (Kuliev *et al*., 2013). Kazakhstan's pastures vary greatly in relief: 77% of pastures are located on plains, including 25% in sandy areas, 18% in mountains and hills, and 5% in valleys and lowlands. The natural pastures of Kazakhstan are an important source of cheap forage production. In the forage balance, their products account for 40%, meeting the need for green forage by 80%.

As a result of intensive grazing near settlements and villages, degradation of pasture lands is observed. Overgrazing and the irrational use of pastures in the steppe zone lead to a reduction in biodiversity and degradation of pastures (Hammouda *et al*., 2019; Zhang *et al*., 2021). This leads to a decrease in vegetation cover and the destruction of the soil structure, reducing the content of organic carbon and, accordingly, the productivity of pastures (Kemp *et al*., 2020; Wang *et al*., 2020).

Compared to the 1980s-1990s, the area of degraded pastures in Kazakhstan has increased to 27.1 million ha, which is 15% of the total pasture area. In particular, in the Akmola region, it has increased by 1.9 million ha, or 29.6% (CLMMA, 2020).

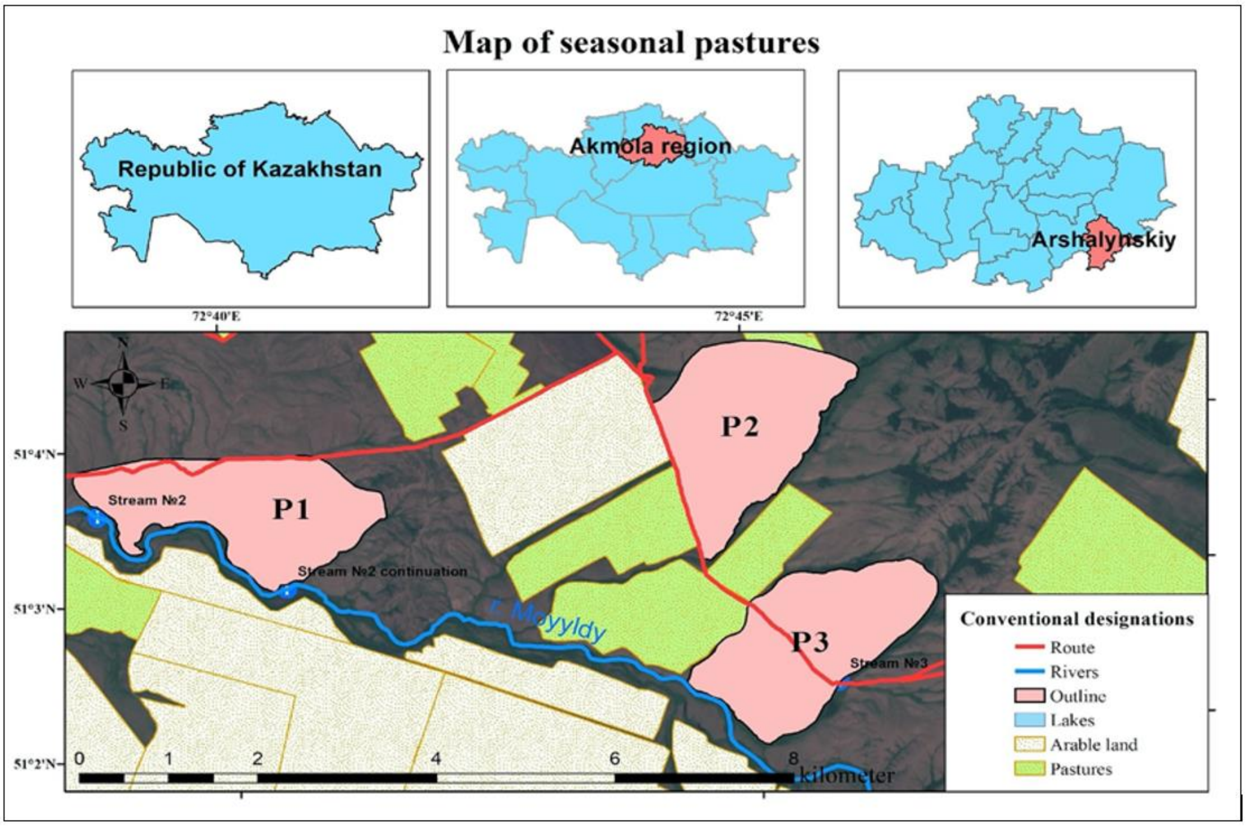

Fig. 1: Location of the studied plots

The yield of natural pastures has decreased by 30-40% compared to the same period.

Unsystematic exploitation has led to the fact that currently the yield of pastures and hayfields has decreased almost everywhere to 3-4 c/ha and the area of degraded land has increased to 15%. In this regard, it is essential to observe grazing loads and seasonality of pasture use, which are the main factors in regulating the use of pastures (Chen *et al*., 2015; Jordan *et al*., 2016).

In this regard, the aim of the study was to assess the impact of the Unsystematic Grazing (USG) method and the developed scheme of pasture rotation on the grass height and productivity of seasonal pasture areas of the steppe zone of Northern Kazakhstan.

Materials and Methods

Scope of the Study

The study was conducted in the Arshaly Breeding Farm LLP (50°50'03"N, 72°10'18"E) located in the Akmola region in the north of Kazakhstan. The territory of the pasture in the district is 5.8 thousand km^2, or 580 thousand ha, which is 4% of the region's territory. The territory of the district is located within the Central Kazakhstan upland. The relief in the east is low; in the central part a hilly plain is located and in the north and west, slightly undulating plains can be observed. The district is located in a zone of dry steppes. The study was conducted in 2019-2020 during the pasture period (spring, summer, and autumn). In 2019, we used USG and in 2020, we applied the pasture rotation scheme (Table 1). Grazing was observed in the example of a herd of 400 heads of cattle of the Aberdeen Angus breed; the daily forage rate was 29 kg/day.

Pasture Territory Observation, Field Research, and Sampling

1. We collected materials on the farm (land and cartographic maps, identification numbers of farmland plots in the national land cadastre Automatic Information System (AIS GZK) (http://www.aisgzk.kz/aisgzk/ru), land area, breed of grazed cattle, livestock number)
2. The obtained coordinates of the points were superimposed on the map in the Geographical Information System (GIS) center of the Kazakh

Agrotechnical University (KATU) named after S. Seifullin. Satellite images were processed using ArcGIS and QGIS software

3. The boundaries of seasonal pastures and contours were recorded using the Garmin Montana 610 GPS navigator with GPS/GLONASS satellite data
4. After the establishment of the boundaries of the pasture lands of the Arshaly Breeding Farm LLP, the pasture area of the farm was divided into three areas of use for the second year of grazing, depending on the type of pastures: P1, P2, and P3, where P1 (51°3'35.672"N, 72°40'8.360"E, 3.34267 km^2) was the plot for spring use, P2 (51˚3'58.464"N, 72˚44'59.495"E, 3.374689 km^2) was the plot for summer use, and P3 (51˚2'33.691"N, 72˚45'31.801"E, 3.304026 km^2) was the plot for autumn use for grazing animals (Fig. 1)
5. Afterward, each seasonal pasture, according to the method of experimental work on pastures, was divided into several contours according to the landscape and groups of plant associations. In 2019, grazing was carried out everywhere, that is, unsystematically and in 2020, we used the developed scheme of pasture rotation according to the seasons of the year. Thus, in spring the cattle grazed on the spring plot P1, in summer on the summer plot P2 and in autumn on the autumn plot P3

Analysis of the Botanical Composition

To determine the botanical composition of the herbage, samples were taken from 1 m^2 of the plot. The selected samples were weighed and divided according to the botanical composition. The botanical description of the herbage was carried out according to the determinants (Dmitrieva *et al*., 1982) and the method of botanical weight analysis of hay and pasture forage samples (Aleksandrova, 1971; Rusanov, 2015). In the case of species botanical analysis, fractions were weighed on technical scales with an accuracy of 0.1 g. The results of the weighings were recorded in a worksheet with the following columns: "name of fractions (plants)", "weight in grams", "percentage of participation" and "remarks on the composition of fractions". In the "name of fractions" column, the fractions of plants successively accepted for analysis by species or groups were recorded, in the "weight in grams" column, the mass by species of a certain plant was recorded, after which the percentage of each plant species in the sample was calculated. The calculation was performed for each fraction separately according to formula 1:

$$X = \frac{(100 - K) \times C}{100} \quad (1)$$

where:

X = The desired percentage of this fraction in the entire forage
K = The sum of percentages of fractions of large plants isolated before taking the average sample
C = The percentage of this fraction in the average sample taken after the selection of large plants

Determination of the Height of Pasture Plants

The herbage height was determined in the main phases of the development of perennial grasses by decades. When determining the height (at least on 10 model plants), the following factors were measured: The height of generative shoots, for which bent plants are straightened along a ruler, and vegetative shoots, which usually coincides with the greatest development of herbage leaves. The data of plant height measurements during the observations of the development of phenophases were recorded in a journal. We used a measuring ruler with a zero mark at the very end. The end of the ruler was installed on the soil surface. The sample size was 50-100 plants, selected in different places along the diagonal of the accounting area. The stem was measured from the soil surface to the top of the plant.

Determination of Pasture Productivity

The productivity of pasture dry mass was determined by the cutting method. Productivity accounting on pastures was carried out seasonally, in each contour on 10 accounting sites with a size of at least 2.5 m^2 (1 × 2.5 m) each at a height of 5-6 cm from the ground on high-grass pastures and 3-4 cm on low-grass ones. The cut green mass from each accounting site was weighed on the spot (with the subsequent conversion from g/m^2 to t/ha; the conversion factor from g/m^2 to t/ha equaled 100). An average sample was also taken to determine the dry substance and then the dry mass yield from 1 ha.

Data Analysis

Statistical analysis was carried out by grazing methods, where the following samples were used: 2019-USG and 2020-pasture rotation (by pasture seasons: Spring-May 25, summer-July 25, and autumn-September 28 of each year). Before statistical analysis, the indicators of green (above-ground) mass and height of herbage according to grazing methods were checked for the normality of the sample distribution. Shapiro-Wilk and Kolmogorov-Smirnov tests were carried out to verify the obtained data on repetitions and variants of the surveyed areas for normal distribution (Slepko *et al*., 2015). In addition, the Levene test ($p>0.05$) was performed to determine the homogeneity of data dispersion by grazing methods. Paired t-tests were performed to determine differences between grazing practices. The influence of pasture use methods on the yield by pasture seasons (spring, summer, autumn) on P1, P2, and P3 plots was analyzed using the single-factor analysis of variance. All statistical analyses were performed using SPSS 23 (SPSS, Los Angeles, CA, USA, 2016).

Table 1: Pasture rotation scheme

	Year	Plots	Seasons		
			Spring	Summer	Autumn
1: USG	2019				
2: Pasture rotation	2020	P1	Grazing		
		P2		Grazing	
		P3			Grazing

Results

Botanical Composition

The surveyed areas of pastures were mainly dominated by perennial grasses, such as Volga fescue (*Festuca valesiaca*), needle grass (*Stipa capillata*), and also such plants as ruddy clover (*Trifolium rubens*), Kaufman's lousewort (*Pedicularis kaufmannii*), field cotton rose (*Filago arvensis*), Russian knapweed (*Rhaponticum repens*), yellow alfalfa (Medicago falcata), dropwort *(Filipendula vulgaris*), large plantain (*Plantago major*), tarragon (*Artemisia dracunculus*) and crested wheatgrass (*Agropyron pectinatum*).

Height of the Herbage

The height of the herbage on P1 during the grazing season ranged from 12.83 to 15.56 with the USG method. When using pasture rotation, the height of the herbage at the beginning of the pasture period was 23.16 cm, and in the summer period after grazing, it decreased to 9.56 cm. In the following season, we noticed the restoration of the height of the herbage to 16.42 cm. On the summer plot P2, the height of the herbage before grazing was 23.1±1.51 cm, and after grazing, the height decreased by 19.92± 3.24 cm. With USG, the height in summer was 19.75± 2.92 cm, and by autumn the plants grew to 26.0± 4.35 cm (Table 2). The results of the Shapiro-Wilk and Kolmogorov-Smirnov tests in terms of herbage height showed that all groups were comparable with the normal observed distribution and the variables obeyed the law of normality (Tables 3). The results of checking the uniformity of variances by grass height are presented in Table 4, which were carried out using the Levene test.

Pasture Productivity

Pasture productivity was analyzed by seasons (spring, summer, autumn) depending on the methods of pasture use (Table 5). The results of the Shapiro-Wilk and Kolmogorov-Smirnov tests in terms of pasture productivity showed that all groups were comparable with the normal observed distribution and the variables obeyed the law of normality (Table 6). The results of checking the uniformity of variances in terms of green (above-ground) mass are presented in Table 7 and were carried out using the Levene test.

With the USG method, the productivity of pastures on P1 in spring equaled 1.19 t/ha, in summer this indicator was 0.39 t/ha higher, but by autumn the productivity of this site had decreased almost 3 times and amounted to 0.57 t/ha. When using pasture rotation on this plot, productivity in the spring was 1.24 t/ha, which is 0.05 t/ha more than with the USG method. After summer grazing, it decreased by 0.47 t/ha, and by autumn there was an increase of 0.14 t/ha. Compared with the USG method, when using pasture rotation, productivity was higher in May by 0.05 t/ha and in September by 0.34 t/ha.

On P2, with USG, the yield in May was 2.43 t/ha, which increased by 0.18 t/ha by summer, and by autumn there was a decrease of 0.44 t/ha compared to the summer indicators. During the use of pasture rotation, the average yield in spring was 2.23 t/ha, in summer it was 0.82 t/ha more and after summer grazing on this plot, by autumn the yield was 1.04 t/ha, which is 1.19 t/ha less than in May.

The average yield for the whole year of USG on P3 was 3.64 t/ha, which is more than on other plots. This is explained by the fact that seeded pastures are located on this site. With the use of pasture rotation in the autumn use area (P3), the yield by the summer period increased by 1.74 t/ha and by the autumn by 0.98 t/ha compared to the spring data.

Based on the results of ANOVA variance analysis by seasons, we accept the null hypothesis for P2, that is, the samples do not differ (Table 8).

Discussion

The density of the grass cover and the high yield of plants leads to an increase in the density of grass shoots due to cattle grazing (Ganche *et al*., 2014), as well as a decrease in the amount of non-grass vegetation (Stybayev *et al*., 2021). Besides, in our studies, after grazing, the yield and, accordingly, the height of plants decreased (Tables 2 and 5).

However, there are studies where higher pasture yields were formed, despite the low plant height (Bell *et al*., 2020; Kunrath *et al*., 2020). This is explained by the fact that there may be a high projective coverage of 80-89% on this plot (Austrheim *et al*., 2014).

Since in 2019, cattle grazing was carried out unsystematically and everywhere, the height and yield indicators on this plot were low seasonally, despite the overall average for the year, and on plots using the developed pasture rotation scheme, the yield, despite a sharp decrease in productivity, was subsequently restored (Fig. 2). In this regard, we can plan and predict the yield of pastures for

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certain areas, which gives us the opportunity for efficient and rational use of natural pastures without the risk of degradation. This is confirmed by the studies conducted by foreign scientists who have come to the opinion that irrational use of pastures and intensity of use, such as overgrazing, will accelerate the degradation of pastures, which will lead to a decrease in aboveground biomass (pasture yield) and the quality of herbage (Gao *et al*., 2007; Imani *et al*., 2010; Badgery *et al*., 2020). In our studies, this was also confirmed with USG.

If we are talking about the aggregate yield with USG, then we can notice a gradual decrease in all areas by the end of the year (Fig. 2). If we analyze by seasons of the year and by plots, the data differs and obeys the law of normal distribution (Table 8). A similar situation is observed in the studies of Michele Scotton and Crestani (2019) conducted in the Venetian Alps, where no variable of the site or animal significantly distinguished grazing methods from free-range methods. For example, with USG, the yield of the summer plot was 2.43 t/ha, 2.61 t/ha, and 2.17 t/ha and it did not significantly differ at the level of p = 0.05, since cattle were grazed unsystematically. However, when using pasture rotation, there was a significant difference in grazing seasons at the level of 0.05 (Table 2).

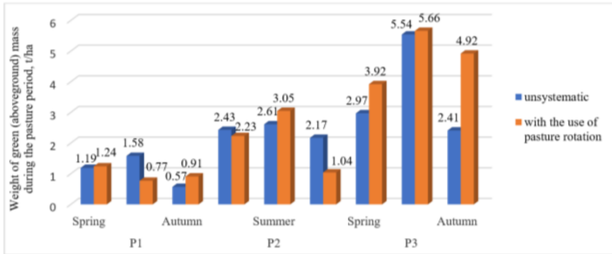

Fig. 2: Productivity of pastures by season, depending on the grazing method

Table 2: Herbage height depending on the methods of use, cm

Seasonal pasture plots	Methods of use	Herbage height during the pasture period, cm: Spring	Summer	Autumn
P1 (spring)	Unsystematic	12.830±2.64	15.740±1.72	14.970±1.36
	With the use of pasture rotation	23.160±6.30	9.560±2.94	16.420±5.65
	p-value	0.004	0.000	0.404
P2 (summer)	Unsystematic	15.810±3.57	19.750±2.92	26.000±4.35
	With the use of pasture rotation	19.540±5.59	23.100±1.51	19.920±3.24
	p-value	0.060	0.137	0.139
P3 (autumn)	Unsystematic	19.730±2.95	40.120±4.76	39.300±7.65
	With the use of pasture rotation	56.670±25.28	44.400±4.10	40.810±9.57
	p-value	0.000	0.040	0.707

Table 3: Criteria for normal distribution concerning herbage height

		Herbage height during the pasture period					
		Spring, 25.05		Summer, 25.07		Autumn, 28.09	
Seasonal pasture plots	Methods of use	Kolmogorov-Smirnov	Shapiro-Wilk	Kolmogorov-Smirnov	Shapiro-Wilk	Kolmogorov-Smirnov	Shapiro-Wilk
P1	Unsystematic	0.200	0.669	0.162	0.290	0.200	0.964
	With the use of pasture rotation	0.024	0.016	0.200	0.362	0.200	0.908
P2	Unsystematic	0.200	0.354	0.200	0.712	0.200	0.302
	With the use of pasture rotation	0.131	0.442	0.007	0.011	0.200	0.423
P3	Unsystematic	0.200	0.133	0.200	0.809	0.200	0.625
	With the use of pasture rotation	0.051	0.041	0.200	0.186	0.164	0.161

Table 4: Checking the uniformity of variances by grass height

	Spring, 25.05				Summer, 25.07				Autumn, 28.09		
Seasonal pasture plots	Levene test	df1	df2	Sig	Levene test	df1	df2	Sig	Levene test	df1	df2	Sig
P1	2.585	1	38	116.000	14.427	1	38	0.001	1.726	1	38	0.197
P2	1.142	1	38	0.292	5.487	1	38	0.024	10.403	1	38	0.003
P3	10.462	1	18	0.005	0.004	1	18	0.952	0.905	1	18	0.354

Table 5: Pasture productivity depending on the methods of use, t/ha

Seasonal pasture plots	Methods of use	Weight of green (above-ground) mass during the pasture period, t/ha		
		Spring	Summer	Autumn
P1 (spring)	Unsystematic	1.190±0.49	1.580±0.64	0.570±0.29
	With the use of pasture rotation	1.240±0.32	0.770±0.22	0.910±0.40
	p-value	0.719	0.000	0.001
P2 (summer)	Unsystematic	2.430±0.48	2.610±0.43	2.170±1.30
	With the use of pasture rotation	2.230±0.48	3.050±0.49	1.040±0.23
	p-value	0.185	0.001	0.001
P3 (autumn)	Unsystematic	2.970±0.42	5.540±0.84	2.410±0.42
	With the use of pasture rotation	3.920±0.70	5.660±0.48	4.920±1.38
	p-value	0.003	0.576	0.000

Table 6: Criteria for normal distribution in terms of pasture productivity

Seasonal pasture plots	Methods of use	Test for the normality of the weight of the green (above-ground) mass					
		Spring, 25.05		Summer, 25.07		Autumn, 28.09	
		Kolmogorov -Smirnov	Shapiro-Wilk	Kolmogorov-Smirnov	Shapiro-Wilk	Kolmogorov-Smirnov	Shapiro-Wilk
P1	Unsystematic	0.073	0.016	0.200	0.029	0.185	0.060
	With the use of pasture rotation	0.200	0.321	0.200	0.146	0.200	0.185
P2	Unsystematic	0.200	0.014	0.200	0.083	0.036	0.072
	With the use of pasture rotation	0.011	0.186	0.200	0.984	0.136	0.263
P3	Unsystematic	0.200	0.752	0.200	0.453	0.200	0.109
	With the use of pasture rotation	0.200	0.934	0.200	0.132	0.027	0.019

Table 7: Checking the uniformity of variances by green (above-ground) mass

Significance	Significance	Sig	Significance							
			Levene test	df1	df2	Sig	Levene test	df1	df2	Sig
Significance	Significance	0.054	3.520	1	38	0.068	6.735	1	38	0.013
Significance	Significance	0.879	0.089	1	38	0.767	16.555	1	38	0.000
Significance	Significance	0.197	5.955	1	18	0.250	14.779	1	18	0.001

Table 8: Indicators of the standard deviation of pasture productivity by grazing methods

Plots and seasons of		USG	Significance (ANOVA)	Grazing by pasture rotation areas (SG)	Significance (ANOVA)
P1	Spring	1.191 a	0.000	1.244 a	0.000
	Summer	1.5855 b		0.771 a	
	Autumn	0.57 c		0.906 b	
P2	Spring	2.434 a	0.267	2.232 a	0.000
	Summer	2.61 a		3.052 b	
	Autumn	2.17 a		1.042 c	
P3	Spring	2.974 a	0.000	3.925 a	0.001
	Summer	5.536 a		5.659 a	
	Autumn	2.408 b		4.927 b	

Pasture mass can be used for effective daily management of pastures by allocating an area of pasture with an acceptable norm that can be grazed on 1 ha without compromising pasture ecosystems, to meet the daily forage needs of pasture animals. In our studies, 334 ha of pasture area were allocated for 400 cattle in spring, 337 ha of pasture were used in summer, and 330 ha of pasture in autumn. In this regard, one of the main tasks in our study was to identify the influence of the unsystematic method and the developed scheme of pasture rotation on the height of the herbage and the yield of pastures.

The use of optimal schemes of pasture rotation developed for specific conditions allows for producing a positive effect for the timely restoration of the vegetation cover of pasture areas and grazing livestock.

Conclusion

The results of the conducted study allow us to conclude that the developed grazing scheme, in comparison with USG, has a positive effect on the height of the herbage and the productivity of pastures, increasing productivity by the end of the pasture season by 0.34 t/ha and by 1.45 cm of herbage height, despite grazing at the beginning of the season. When using the developed scheme of pasture rotation on semi-arid pastures of Northern Kazakhstan, the productivity of pastures recovered after grazing from 0.77 to 0.91 t/ha and the height of the herbage from 9.56 to 16.42 cm, which prevents further pasture degradation.

The contribution of our research lies in the fact that our scheme of pasture rotation developed can be applied by researchers and specialists involved in the conservation, restoration, and improvement of the efficiency of pasture lands, which will lead to the production of competitive and environmentally friendly livestock products.

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Author's Contributions

All authors equally contributed in this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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