

Changes in the Composition and Diversity of Pasture Grass Due to the Influence of Grazing in the Steppe Zone of Northern Kazakhstan

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Abstract: Overgrazing poses a serious threat to the sustainability of steppe pasturelands in Northern Kazakhstan, where intensifying livestock pressure drives significant changes in vegetation composition, species diversity, and soil fertility. This study investigated the effects of grazing intensity on pasture vegetation and chestnut soil properties in the Zhaksyn district of the Akmola region. Field surveys were conducted in July-August 2024 using 75 m transects with 1 m² quadrats across three treatment plots: intensively grazed, moderately grazed, and ungrazed control. Vegetation parameters assessed included species composition, cover, height, yield, and nutritional and energetic quality across spring and summer seasons. Statistical analyses revealed that intensive early-season grazing significantly reduced species richness and plant biodiversity compared to late grazing and control plots. Intensive grazing also increased vegetation heterogeneity through the destruction of dominant species and contributed to a reduction in plant cover. Soil analysis indicated a slight decline in humus content and significant loss of organic matter under intensive grazing due to trampling and reduced vegetation cover, alongside elevated soil salinity associated with increased exchangeable sodium. Moderate grazing, by contrast, showed less severe impacts across all measured parameters. Overall, unmanaged intensive grazing exerts compounding negative effects on both plant community structure and soil health, with implications for long-term pastureland sustainability. These findings highlight the need for regulated grazing management strategies to preserve steppe biodiversity and maintain ecosystem function in Northern Kazakhstan.

Keywords: Overgrazing, Steppe rangeland, Species richness, Vegetation diversity, Soil fertility, Chestnut soil, Grazing intensity, Northern Kazakhstan

Received: 07-05-2025 | **Revised:** 11-09-2025 | **Accepted:** 22-07-2025 | **DOI:** 10.3844/ojbsci.2026.26.01.019

Introduction

The widespread steppe zone of northern Kazakhstan consists of a range-land ecosystem that increases the significance of the area, which plays a vital role in providing forage for livestock and protecting biodiversity [1]. Rangelands are of great

significance at the international, domestic and regional levels, both in terms of scale and socio-economic impact. When properly managed, rangelands can ensure food security and alleviate poverty for millions of people. They are essential for the livelihoods of people worldwide, providing a range of benefits such as food (milk (yogurt, butter, cheese), meat, fat), fuel, fertilizer, fibers (obtained from wool, hides) draught power, transport, additional security, and opportunities for capital accumulation [2, 3].

In Kazakhstan, pasture lands cover an extensive 183.9 million hectares, accounting for 83.8% of all agricultural land [4]. Of this, 5.8 million hectares are improved, and 103.4 million hectares are irrigated [5]. The geographical distribution of these pastures varies substantially, with 77% located on plains, 25% in sandy regions, 18% in mountains and hills, and 5% in valleys and lowlands. Kazakhstan's natural grasslands are a substantial supplier of economical fodder. A significant number of pasture lands are located in the Karaganda, Almaty, Mangistau, Kostanay and West Kazakhstan regions. These natural pastures are an important source of cheap feed production, contributing 40% to the feed balance, including 80% of the need for green fodder [6].

Notably, it is recorded that in the Akmola region alone, there are million hectares of pastureland of about 6.38, with 4.441 million hectares allocated as agricultural lands. Of these, 969.5 thousand hectares are improved and 1331.7 thousand hectares are flooded [7]. However, the state of natural forage lands is in an extremely unfavorable ecological state. Productivity has declined by 60%, resulting in yields of only 3-5 centners per hectare. In the dry steppe zone, hay yields are even lower, ranging from 2-3 centners per hectare. The degradation rate continues to increase, with the area of completely degraded hayfields and pastures increasing from 1.3 x 10⁶ hectares in 2001 to 1.9 x 10⁶ hectares in 2020 [8].

Despite the large area of pastures in Kazakhstan, only 30% are utilized for grazing due to various problems such as degradation, inadequate watering places, and water sources [9, 10], as well as desertification [11]. To unlock the full potential of pastures and livestock, infrastructure development, such as increasing the number of processing facilities, improving road networks and repairing wells and water sources are pivotal. Pastoralism in northern region of Kazakhstan, plays a vital role in the economy, highlighting the need for pasture grasses diversity and composition analysis. These grasses serve as an important indicator of pasture land strength. Recently, desertification and degradation of pasture lands are pressing environmental problem not only in Kazakhstan and Central Asia, but also throughout the world [12-15].

Restoring natural pastures is a critical issue, targeting not only to develop livestock farming but also to improve the ecological state of large areas [16]. Notably, an objective assessment of pastures for effective use requires monitoring degradation levels, including long-term trends in biodiversity, projective cover, pasture load, livestock numbers, and productivity, as influenced by climate and grazing pressure [17, 18].

Observing the decline in pasture productivity is important, as it is directly linked to the potential risk of instability of pasture lands. Study has shown that intensive grazing negatively impacts species richness, height, projective coverage, and productive vegetative mass [19-21]. Cattle grazing on pastures with poor forage quality exhibit altered behaviour, being more mobile and selective in their forage consumption. Research has also shown that grazing alters the nutrient composition of the grass stand [22], a significant component in effective pasture management and increasing feed production, where grass mixtures are often formulated [23].

In steppe regions, grazing has shown to significantly influence plant communities. Following the collapse of Soviet Union, vegetation was directly affected due to a reduction in livestock, resulting in large steppe areas without grazing [24]. Grazing is considered important in studies because it create disturbances in natural phenomenon and manipulates the structure and composition of grass communities [25]. However, grazing under distinct management styles may not necessarily result in continuous changes in plant variety. Dynamic environmental factors have a huge effect on changes in prevailing varieties as compared to shifting grazing variables [26]. Overgrazing disrupts vegetation structure and diversity, impairing ecosystem function and services [27]. Grazing not only affects plant diversity but also disrupts ecosystem function by impacting plant community structure, carbon and nitrogen cycling.

However, research on the impacts of pasturing on wetland ecosystem functions remains limited [28, 29]. While previous research has thoroughly explored the relationship between plant biodiversity and grazing in different ecosystems, there is still a need to examine the impact of grazing on pasture grasses diversity and structure. This research seeks to shed new light on the economically important pasture zone in Northern Kazakhstan, emphasizing the deep connection between grazing intensity and grassland health. Using field surveys, ecological models, and local knowledge, this study will investigate the broader impacts of pasturing on the environment while conserving variance.

The study evaluated the effects of pasturing on feed composition and diversity, identified its effects on ecosystem like soil fertility, species richness, carbon proportion and biodiversity, and assessed sustainable grazing methods to improve pasture ecosystem resilience and decrease the adverse effects of overgrazing. Ultimately, it seeks to protect the steppe's ecological integrity in Northern Kazakhstan.

Materials and Methods

Study Area

The study on changes in pasture grass composition and diversity as a result of grazing in the steppe zone of Northern Kazakhstan was carried out in 2023-2024 at Zaporozhye-Agro LLP (55.6520°N 37.5080°E), in the Zhaksyn district of the Akmola region. The district's pasture area spans thousands of square kilometers (km²), with a terrain that includes low-lying eastern areas, hilly plains in the central part, and gently undulating plains in the north and west, located in the dry steppe zone. The study employed a Randomized Complete Block Design (RCBD) with three replicates, featuring of three grazing variants: no grazing (control), moderate grazing, and intensive grazing, and with each variant studied in two periods (early and late grazing), resulting in 18 plots (3 variants * 2 blocks * 3 replicates), with each plot measuring 0.5 Hectares (ha) (100 m * 50 m).

Geobotanical studies were conducted to determine pasture vegetation by assessing variance composition, projective cover, height, yield, and quality indicators of pasture vegetation across spring and summer seasons. The studies assessed the nutritional and energy-protein value of the vegetation. A geobotanical survey of pasture contours was conducted following established experimental methodologies on hayfields and pastures. The bioclimatic potential was calculated using D.I. Shashko's method, which takes into account the influence of heat resources and heat-moisture ratio on biological productivity.

The Hydrothermal Coefficient (HTC) calculations were carried out on the basis of the current temperature regime and the amount of precipitation during the warm period, characterized the 2024 meteorological conditions as slightly dry (HTC = 1.05). Specifically, May was excessively humid, June and July were very dry, and August was excessively humid due to the amount of precipitation (Fig. 1).

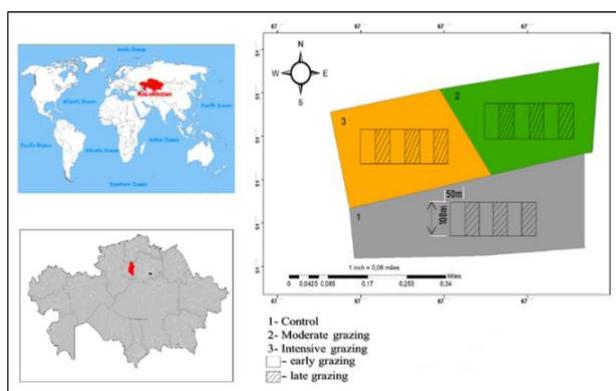


Fig. 1: Experimental plots: 1- no grazing (control), 2-moderate grazing, 3-intensive grazing, with three replicates per treatment, studied during two grazing periods: early grazing and late grazing

The determination of the soils bulk density was carried out using the cylinder method according to N.A. Kachinsky and assessed according to S.I. Dolgov's scale for evaluating soil compaction based on bulk density (g cm⁻³) [30]. Soil nutrient content was determined in layers (0-10 cm, 10-20 cm, and 20-30 cm) before the start of grazing in spring. Sampling of the soil was carried out in accordance with the guidelines set forth in GOST 17.4.3.01-83 Nature Protection (NPP) standards [31].

Farm Structure in Northern Kazakhstan

The size of the farms on which livestock are maintained in Northern Kazakhstan plays a tremendous role in how the livestock are grazed [15]. Northern Kazakhstan's farm structure consists of three main types. Agricultural Enterprises (AE) are the largest, with thousands to tens of thousands of animals, and are frequently linked to Soviet-era farms. They typically contained resources to supply high-quality feed and facilitate extensive grazing migrations. In contrast, Private Farms (PF)

are typically diverse in grazing activities and scale, and have grown rapidly since 2000 [32, 33]. The Households (HH), the smallest farm type, typically manage a small number of animals per unit. However, due to their sheer numbers, they collectively account for a significant portion of the grazing land, approximately 60%. As a result of sedentarization and path dependency, these farms have limited grazing areas. In the context of pre-Soviet era, livestock grazing practices were characterized by large-scale, communal herds, transhumant, and seasonal migrations [34].

Fig. 2 offers a comprehensive overview of the average daily air temperatures throughout 2024, backed up by data from the Standard Meteorological Zone Seasonal Temperature (SMZST) norms. This comparison highlights periods where temperatures deviated from expected seasonal patterns, providing insights into climatic anomalies that may have influenced environmental and agricultural conditions. In the early months of 2024, up to May-June, experienced average daily temperatures consistently higher than the SMZST norms, with deviations reaching up to +5°C. Such unseasonably mild winters can disrupt soil freezing processes and affect the overwintering of pests, potentially leading to earlier pest emergence in the spring.

May and August exhibited drastic temperatures fluctuating around the SMZST values. These variations could influence the timing of soil thawing and the onset of the planting period, affecting planting schedules, and early plant development. The summer months, particularly July and August, showed prolonged periods where temperatures exceeded the SMZST by 3-4°C. These heatwaves can lead to increased soil evaporation rates, reduced soil moisture, and stress on vegetation, potentially impacting crop yields and pasture quality. September and October temperatures dropped below the SMZST norms by approximately 2°C, highlighting an early onset of cooler conditions. This cooling trend may influence the timing of soil sampling and preparation for winter crops, as well as affect the residual warmth in the soil necessary for late-season plant growth.

According to GOST 17.4.3.01-83, "Nature Protection. Soils. General Requirements for Sampling," sampling procedures must account for prevailing climatic conditions, including temperature variations [35]. The standard emphasizes that factors such as soil cover heterogeneity, terrain, and climate should be considered to ensure accurate representation of soil conditions. The observed temperature anomalies in 2024 could influence soil properties, including moisture content, microbial activity, and chemical composition, as also affirmed by recent research by Huang et al. and Ruan et al. [36, 37]. These changes necessitate adjustments in sampling strategies to maintain the integrity and representativeness of soil samples. For instance, recent studies by Nie et al. and Zhang et al., along with earlier work by Zargar et al. revealed that elevated temperatures can accelerate the volatilization of certain compounds or alter microbial populations, thereby affecting analytical results [38, 39, 40].

Also, temperature variations have the potential to significantly affect pasture ecology and grazing management practices, as elevated temperatures are capable of causing higher evapotranspiration, which can influence soil moisture content and consequently impact plant growth, as noted by Wang et al. and Mondal et al. [41, 42]. On the other hand, decreased temperatures have the ability to retard plant growth and reduce the overall productivity of the pasture. This data can be used in making grazing management decisions, for instance, the manipulation of grazing intensity and timing in order to achieve optimum pasture productivity. For example, the high temperatures reported in June and late July 2024 would have promoted plant growth, therefore potentially supplying more forage to grazing livestock. The drastic varying temperatures noted in August 2024 (from 19.9°C to 14.1°C) would have had adverse effects on plant growth and productivity, thus necessitating modifications to grazing management strategies, as also stated by Ghahramani et al., Lee et al., and Polley et al. [43-45].

The Fig. 2 reveals a number of important trends and patterns in the temperature data. Notably, the temperatures in June 2024 showed a dramatic increase towards the latter part of the month, with readings well over 21.0°C. This warming can be attributed to a variety of factors, ranging from changes in atmospheric circulation patterns to increased solar radiation. In contrast, May and August 2024 were characterized by a more fluctuating temperature trends, with readings ranging between 8.0°C and 13.0°C and 14.0°C and 20.0°C, respectively.

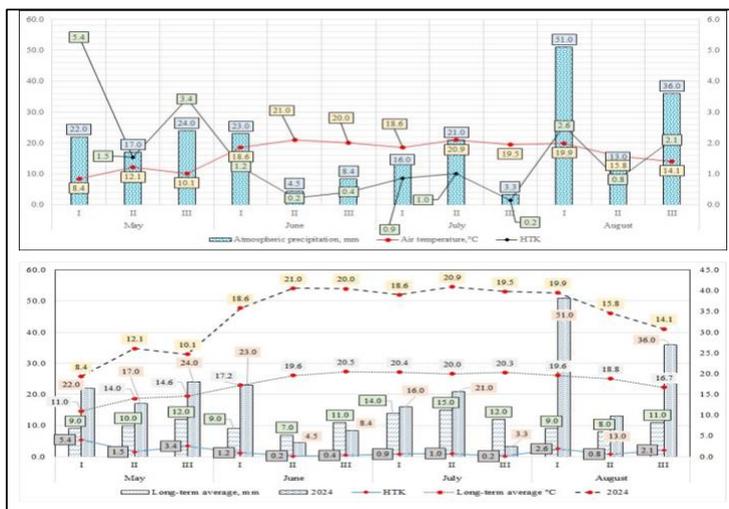


Fig. 2: Average daily air temperature in 2024 compared to SMZST, °C

Biodiversity, Crop Yield, and Pasture Pressure

The plant community surveys were conducted in July-August 2024. These surveys involved 75-Meter (m) transects with 1 m² quadrats sampled every 5 m along the transects to assess vegetation diversity and density. The surveys were carried out in three different treatments: intensively grazed, moderately grazed, and control.

Pasture yield was recorded using the mowing method, where the amount of the main stock or after grass was determined in each variant before each subsequent grazing [46]. The mown mass from each plot was immediately weighed, and an average sample of 1 kg was taken for drying. Additionally, the botanical composition of the grass stand was assessed by identifying plant species present on the plot using botanical identifiers.

The load on 1 ha of pasture, also known as pasture capacity or H, was calculated as the number of animals that can be grazed on 1 ha without causing damage to pasture ecosystems [47]. The calculation provides a conventional unit of measurement for assessing the grazing capacity of a particular pasture. This was determined by (1):

$$H = \frac{E}{K * D} \text{ (Eq. 1)}$$

Where:

H is the permissible load per 1 ha of pasture (heads),

E is the capacity (carrying capacity) of 1 ha of pasture (heads)

Y is the yield of edible green fodder or dry mass during the grazing period (kg or k units)

K is the daily requirement per head of cattle for green fodder or dry mass (kg of k units)

D is the duration of pasture use (days).

To account for pasture yields fluctuations over the years, an additional reserve area (10-20%) was provided. Given that the daily requirement of cattle is 29 kg of pasture fodder and the grazing period lasts averagely 180 days in the Akmola region. Calculations were made to determine the forage deficit in the studied pasture area and the need for additional pasture area.

To develop an optimal scheme of pasture rotation, scientific and methodological manual on grazing loads on restored and degraded pastures was used (taking into account the loads on pastures) [48, 49], along with rules for the rational use of pastures [50], and as well as methods for combating degradation and desertification of pastures [51]. Therefore, the optimal pasture load (load rate) is the number of grazing animals per 1 ha during the grazing period (or a separate season) that prevents the degradation of the grass stand. In other words, it is the number of seasonal feeding rates for one animal with pasture feed per 1 ha. After determining the actual load, the actual need (deficit or surplus of the pastures) was determined by multiplying the actual load by the actual livestock population and subtracting this number from the actual area of pastures, thereby identifying and deficit or surplus.

Statistical Analysis

The average plant species richness, alpha diversity (using the Shannon-Weaver diversity index), and beta diversity (using Bray-Curtis dissimilarity) were calculated to test the hypothesis that grazing intensity and timing influence plant diversity and composition. The Shannon-Weaver diversity index was calculated using Eq. 2:

$$H' = -\sum (p_i \cdot \ln p_i) \text{ (Eq. 2)}$$

Where:

H' = Shannon-Wiener diversity index

p_i = relative dominance of species i

$\ln p_i$ = Natural logarithm of p_i

A two-way analysis of variance was used to determine the significant differences in alpha and beta diversity between grazing treatments. Principal Component Analysis (PCA) was employed to assess differences in plant community composition. Also, Analysis of Similarity (ANOSIM) was used to identify differences between plant communities based on grazing intensity. The null hypothesis (that there are no differences between plant communities) was tested by calculating the Bray-Curtis ranked distances within and between quadrats assigned to the three grazing intensity levels. All statistical analyses were performed using R.

Soil

Soil moisture was determined using the Thermostat-Weight Method (TWM). A special needle auger was used to collect soil samples at given depths, marked on the outer part of the auger to ensure accuracy. The auger was then inserted into the soil, rotated 1-2 times clockwise, and then removed. The soil in the cavity of the auger was placed in a pre-weighed cup, which was quickly sealed, and weighed. When immediate weighing was not possible, the soil-containing cups were tightly sealed and quickly delivered to the laboratory for weighing on a techno-chemical scale with 0.01 g accuracy. The soil samples were then dried in a cabinet at a temperature of 105°C until a constant mass was achieved, indicating that all excess moisture had evaporated. To ensure accurate soil moisture determination, the samples were weighed after 6 hours of drying and then removed from the drying cabinet with tongs, covered with lids and placed in a desiccator with CaCl_2 for cooling.

After cooling them to room temperature, the samples were weighed again. They were then unsealed, placed back in the drying cabinet for control drying, and after 1-2 hours, they were removed, cooled, and weighed again. This process was repeated until the discrepancies in soil mass did not exceed 0.05 grams, indicating that the soil mass had stabilized. Large changes in mass would have indicated insufficient drying or moisture loss during the experiment. Once a constant mass was achieved, weighing was stopped, and the cups were emptied. Soil moisture was determined using Eq. 3:

$$W = \frac{(m_1 - m_2)}{(m_2 - m_0)} \times 100\% \text{ (Eq. 3)}$$

Where:

W is the soil moisture content (% of the mass of absolutely dry soil)

m_0 is the mass of the aluminum cup (g)

m_1 is the mass of the cup with soil before drying (g)

m_2 is the mass of the cup with soil after drying (g)

Productive moisture reserves, mm, were calculated using the formula described in Eq. 4:

$$W = 0.1 \text{ gh} (u - k) \text{ (Eq. 4)}$$

Where:

W is the soil moisture reserves (in mm of water layer)

q is the bulk density of the soil (g cm^{-3})

h is the soil layer (cm) in which the soil moisture reserves are determined

u is the moisture content of absolutely dry soil (in %)

k is the moisture content of stable wilting point (in %)

0.1 is the coefficient for converting the soil moisture reserves into mm of water layer.

The soil moisture reserves are determined in each 10 cm soil layer.

Determination of the Bulk Density of Soil

The bulk density of the soil in connection with soil shrinkage was measured three times during the vegetation period (spring - after snowmelt, summer, and autumn) or at the beginning and end of grazing. Measurements were taken in triplicate at each site, with 10-25 folds per layer (0-10 cm, 10-20 cm, and 20-30 cm). The cylinder method of N.A. Kachinsky was used, and soil compaction was assessed base on of bulk density values (g cm⁻³) according to S.I. Dolgov's scale.

Determination of Nutrients in Soil

For these purposes, soil samples were collected from layers of 0-10, 10-20, 20-30, and 30-40 cm before the experiment started and after grazing. Changes in agrochemical properties of the soils were determined periodically, once every 3 months. The selected samples underwent agrochemical analysis in a specialized laboratory.

Soil sampling was carried out in accordance with GOST 17.4.3.01-83 Nature Protection (NPP). Soils. General requirements for sampling. The analysis included determination of organic matter (humus) according to GOST 26213-91 using the Tyurin method, nitrate nitrogen using the colorimetric method with phenoldisulfonic acid according to Grandval-Lajoux,

total nitrogen content using the Kjeldahl method as described in Eq. 5:

$$\% \text{ of } N = \frac{V \times 1.4 \times N}{W} \text{ (Eq. 5)}$$

Where:

V= volume of the acid used

N= normality of the standard acid

W= weight of the organic compound)

, easily hydrolyzable nitrogen using the method of I.V. Tyurin and M.M. Kononova, mobile phosphorus and potassium compounds using the Machigin method as modified by TsINAO. GOST 26205-91 Soils, and soil pH using the TSINAO method (GOST 26483) [52].

Results

The results of the study revealed 22 plant species belonging to 12 families (poaceae (grasses), asteraceae (daisies), fabaceae (legumes), euphorbiaceae (spurges), convolvulaceae (morning-glories), plantaginaceae (plantains), brassicaceae (crucifers), cyperaceae (sedges), rubiaceae (madders), lamiaceae (mints), amaranthaceae (amaranth), and Ranunculaceae (buttercups). Of these, the most dominant plants were: Wallisian fescue (*Festuca valesiaca* Gaudin), white wormwood (*Artemisia lercheana* Weber ex Stechm), creeping couch grass (*Elytrigia repens* (L.) Nevski), needle grass (*Stipa capillata* L.), alfalfa (*Medicago sativa* L.), spurge (*Euphorbia esula* L.), awnless brome grass (*Bromopsis inermis* (Leyss.) Holub), meadow bluegrass (*Poa pratensis* L.), common dandelion (*Taraxacum officinale* (L.) Wigg) and field bindweed (*Convolvulus arvensis* L.) (Table 1).

Plant species such as alfalfa (*Medicago sativa*) and kentucky bluegrass (*Poa pratensis*), have high nutritional value and are palatable to grazing animals. Those plants have the potential to favor healthy growth and boost productivity in grazing animals. Plants like field bindweed (*Convolvulus arvensis*) and Leafy spurge (*Euphorbia esula*) are regarded as undesirable because of their negative impacts on grazing intensities due to their invasive habit of growth, toxicity, or tendency to overtop desirable forage crops.

Table 1: The most common 10 plant species with the highest average percentage of coverage by grazing intensity (control, moderate, intensive) and timing (early, late) in the steppe zone

Species	Coverage (%)					
	Early			Late		
	Control	Moderate	Intensive	Control	Moderate	Intensive
<i>Achillea millefolium</i> L.	-	-	0.8 ± 2.6	0.3 ± 1.6	-	-
<i>Artemisia absinthium</i> L.	1.5 ± 2.0	6.9 ± 5.9	13.2 ± 10.2	0.9 ± 2.9	13.3 ± 9.4	19.9 ± 11.2
<i>Artemisia lercheana</i> Weber ex Stechm	10.0 ± 5.6	-	-	10.5 ± 5.6	-	-
<i>Artemisia pauciflora</i> Weber	-	-	19.2	-	-	13.5
<i>Bromopsis inermis</i> (Leys.) Holub.	7.8 ± 6.1	-	-	3.8 ± 3.3	-	2.1 ± 2.7
<i>Carex acuta</i> L.	6.3 ± 4.8	4.1 ± 4.3	4.4 ± 4.0	0.6 ± 1.2	8.7 ± 6.4	3.4 ± 3.2
<i>Convolvulus arvensis</i> L.	8.0 ± 6.3	2.6 ± 3.2	-	9.7 ± 4.8	-	-
<i>Descurainia sophia</i> (L.) Webb ex Prantl	-	4.2 ± 4.6	-	-	4.9 ± 5.0	-
<i>Euphorbia esula</i> L.	6.1 ± 4.4	5.4 ± 5.5	0.8 ± 2.7	8.1 ± 4.2	0,0	1.0 ± 3.2
<i>Elytrigia repens</i> L.	8.7 ± 5.3	8.7 ± 6.4	5.6 ± 4.2	10.9 ± 4.4	8.7 ± 5.0	6.4 ± 3.7
<i>Festuca valesiaca</i> Gaudin	8.7 ± 6.5	10, 4 ± 4.6	4.9 ± 2.7	7.1 ± 3.2	14.1 ± 7.1	8.4 ± 4.7
<i>Galium verum</i> L.	1.7 ± 3.6	2.2 ± 2.5	-	0.4 ± 2.0	-	-
<i>Linaria vulgaris</i> Mill.	-	-	0.8 ± 2.5	-	3.9 ± 3.2	0.1 ± 0.8
<i>Medicago sativa</i> L.	5.1 ± 4.3	4.0 ± 3.3	1.7 ± 4.0	2.7 ± 3.0	2.5 ± 4.8	-
<i>Phlomis tuberosa</i> (L.) Moench	-	-	4.1 ± 4.0	-	2.6	3.1 ± 3.4
<i>Plantago lanceolata</i> L.	7.2 ± 5.7	-	3.2 ± 3.0	9.5 ± 3.8	-	-
<i>Poa pratensis</i> L.	10.0 ± 6.1	5.2 ± 4.7	10.6 ± 11.0	10.1 ± 5.7	2.8 ± 5.1	7.4 ± 7.8
<i>Salsola tragus</i> L.	-	-	5.9 ± 5.6	-	-	2.7 ± 3.8
<i>Stipa capillata</i> L.	12.3 ± 8.6	10.4 ± 9.1	2.9 ± 5.7	16.0 ± 8.1	3.5 ± 7.2	2.2 ± 4.9
<i>Stipa lessingiana</i> Trin. & Rupr.	-	-	1.0 ± 2.8	-	8.8	3.9 ± 4.4
<i>Taraxacum officinale</i> Wigg.	4.6 ± 4.2	8.1	-	5.9 ± 3.1	-	-
<i>Thalactrum minus</i> L.	-	-	3.5 ± 3.2	-	-	-

Vegetation such as yarrow (*Achillea millefolium*) and lady's bedstraw (*Galium verum*) have some forage quality but suitability based on variables such as grazing pressure and local ecosystem conditions. The species can be managed carefully in order to reap the most out of their positives while avoiding as much of their potential negatives. Native species such as *Stipa lessingiana* have high quality forage for livestock and can suit particular climatic conditions as well as certain soil types and are thus highly recommended for use in grazing pastures in the same environmental areas (see Table 2).

Effective pasture management involves the selection of a good mix of species, weed control, and the application of best grazing practices. Selection of desired species, according to their nutritional value, palatability, and adaptability to local conditions, is important in increasing pasture productivity and sustainability. Proper grazing practices can help retain a balance of desired species.

Table 2: Characteristics and classification based on suitability of plant species to grazing livestock

Species	Characteristics and classification
Yarrow (<i>Achillea millefolium</i> L.)	The plants have finely divided, aromatic foliage with medium green hue. They produce small, white flowers in compact clusters (2-4 inches across) on 2-3 feet stems, attracting pollinators and offering forage value, but suitability depends on grazing pressure and ecosystem conditions [53].
Common wormwood (<i>Artemisia absinthium</i> L.)	This perennial has an upright growth habit with a woody base and silver-gray foliage with a potent aroma. It produces small, yellowish flowers in dense panicles on stem tips. Due to its bitter taste and toxicity, <i>Artemisia absinthium</i> is not palatable for livestock and is often avoided in pastures [54, 55].
<i>Artemisia lercheana</i> Weber ex Stechm	Mugwort (<i>Artemisia vulgaris</i>) is a rhizomatous perennial growing 2-6 feet tall, with aggressive spreading via underground rhizomes, forming colonies up to 6 feet wide. Its rapid spread can outcompete desirable forage species, reducing pasture quality and productivity for livestock [56].
<i>Artemisia pauciflora</i> Weber	<i>Artemisia pauciflora</i> is a perennial shrub with sparse foliage, found in dry areas. It may serve as a forage species in rangelands or pastures with limited options, though its value varies by location and livestock preferences [57].
<i>Bromopsis inermis</i> (Leyss.) Holub.	This winter-green perennial grass has robust rhizomes, making it ideal for soil stabilization in areas like road verges and riverbanks. It forms dense stands, providing decent livestock forage, but its value varies with grazing pressure and soil quality [58, 59].
<i>Carex acuta</i> L.	<i>Carex acuta</i> is a tufted sedge with slender, flat leaves up to 90 cm tall, featuring three-angled stems and rhizomatous roots. It produces brown flowers in spikes during late spring and summer. This sedge provides valuable forage for livestock in wetland areas, but its suitability as a pasture species depends on grazing pressure and soil moisture [60, 61].
Field bindweed (<i>Convolvulus arvensis</i> L.)	This perennial herb has twining or prostrate stems with distinctive, hairless leaves that vary in shape. It's often considered a weed in pastures, competing with valuable forage plants and potentially harming them. Livestock tend to avoid it due to unpalatability or toxicity [62].
<i>Descurainia sophia</i> (L.) Webb ex Prantl	This plant grows 20-75 cm tall with a grayish hue from short hairs. Its upright stem has bulbous branches and intricately divided leaves. Plants in solonchaks have plump lobes. It's considered a weed, competing with forage species, and has low suitability for livestock [63].
Leafy spurge (<i>Euphorbia esula</i> L.)	This herbaceous perennial grows 1-1.2 meters tall with smooth, mostly hairless stems. Its narrow, lance-shaped leaves have wavy edges. Considered a noxious weed, its toxic sap can harm livestock, reducing pasture quality [64].
Common couch (<i>Elytrigia repens</i> L.)	This plant has a 120 cm stalk with resilient, branchy rhizomes 5-15 cm underground. Its rhizomes can regrow from fragments and produce 200-250 buds, making management challenging. It outcompetes desirable species but provides some forage value [65].
Volga fescue (<i>Festuca valesiaca</i> Gaudin)	<i>Festuca valesiaca</i> (Volga fescue) is a drought-tolerant, cold-hardy perennial grass with a bunch-type growth habit and narrow, rolled leaves. It's valued for erosion control, restoration, and low-maintenance landscaping, providing habitat and food for wildlife, and suits grazing pastures and ecological restoration.
Lady's bedstraw (<i>Galium verum</i> L.)	Lady's bedstraw has charming whorls of leaves and yellow flowers, growing 15-120 cm tall with glossy, hairy leaves. It provides some forage value, but suitability depends on grazing pressure and ecosystem conditions. It's a moderate competitor in pastures.
Yellow Toadflax (<i>Linaria vulgaris</i> Mill.)	<i>Linaria vulgaris</i> is a perennial herb growing up to 1 meter tall with erect, smooth stems and vibrant yellow flowers in terminal clusters. It's considered a weed in pastures, spreading rapidly and having low palatability and nutritional value for livestock.
Alfalfa (<i>Medicago sativa</i> L.)	This plant is a perennial with a deep taproot, making it resilient and drought-tolerant. It fixes nitrogen, promoting sustainable ecosystems. In pastures, it provides excellent forage, improving livestock growth and soil fertility.
<i>Phlomis tuberosa</i> (L.) Moench	<i>Phlomis tuberosa</i> is a perennial herb with sturdy stems, ovate leaves, and tubular flowers in whorls. Its tuberous roots aid survival and regrowth. It attracts pollinators, but its forage value varies by palatability and ecosystem.
<i>Plantago lanceolata</i> L.	This rosette-forming perennial herb has hairy flower stems to 45-100 cm tall, with basal leaves having 3-5 parallel veins. It's a weed competing with forage species, but relatively palatable to livestock, indicating soil compaction or disturbance [66].

Kentucky bluegrass (<i>Poa pratensis</i> L.)	<i>Poa pratensis</i> has boat-shaped leaf tips and smooth texture, with narrow leaves and short ligule. It's desirable for livestock, but sensitive to heavy grazing and intense pasture use.
<i>Salsola tragus</i> L.	<i>Salsola tragus</i> is an annual plant transforming into a spherical mass of intertwined stems (up to 1 m long) with sharp, thorn-like protrusions. Its deep taproot (>1.8 m) and spiny clumps reduce forage quality and harm livestock [67-69].
<i>Stipa capillata</i> L.	One plant's fine foliage and airy plumes suit grazing pastures, offering nutritious feed. <i>Phlomis tuberosa</i> , with its ovate-lanceolate leaves and tubular flowers, adds diversity to ecosystems, though isn't typically used as pasture grass.
<i>Stipa lessingiana</i> Trin. & Rupr.	<i>Stipa lessingiana</i> (Lessing feather grass) is a year-round grass with fine foliage and feathery plumes, providing nutritious forage for livestock. Native to temperate steppes, it's drought-tolerant and suitable for low-maintenance pastures in similar climates [70].
Common Dandelion (<i>Taraxacum officinale</i> Wigg.)	Despite <i>Taraxacum officinale</i> not considered a primary pasture grass, it can be found in pastures and grazing lands, where its leaves can serve as a nutritious, albeit occasional, forage for livestock. However, its presence is often considered more as a weed than a desirable pasture component [71, 72].
<i>Thalictrum minus</i> L.	<i>Thalictrum minus</i> is a year-round herb found in habitats like calcareous grasslands. It's not a primary forage species due to limited palatability and potential toxicity from alkaloids [73].

When calculating beta diversity (Bray-Curtis), we first calculated Bray-Curtis distance matrix, then the average distance to the centroid for each group was also determined (Table 4). Then the significance of differences between grazing options was tested (Table 3-4).

Table 3: Average distance to the centroid

Grazing period	Average distance	Standard deviation
Early	0.409	0.121
Late	0.421	0.099

Table 4: Mean values (± standard deviation) of plant species richness (S), alpha diversity (Shannon-Weaver index, H') and beta diversity (distance to centroid) of plants depending on grazing (control, moderate, intensive) and grazing periods (early, late).

Indicator	Early grazing			Late grazing		
	Control	Moderate grazing	Intensive grazing	Control	Moderate grazing	Intensive grazing
Wealth	8.82 ± 1.86	7.16 ± 1.98	6.98 ± 1.80	7.98 ± 1.47	5.47 ± 1.41	6.2 ± 1.42
Alpha diversity (Shannon-Weaver)	2.09 ± 0.22	1.83 ± 0.33	1.79 ± 0.26	1.99 ± 0.19	1.58 ± 0.26	1.66 ± 0.26
Beta diversity (Bray-Curtis)	0.28 ± 0.12	0.34 ± 0.10	0.37 ± 0.11	0.27 ± 0.11	0.3 ± 0.11	0.34 ± 0.15

Control plots exhibited the highest species richness, especially with late grazing (7.98±1.47), indicating stabilization of vegetation cover in the absence of anthropogenic impact. In contrast, early intensive grazing (6.97±1.80) led to a substantial decrease in richness, highlighting the negative impact of intensive grazing on the plant communities. Late intensive grazing (6.2±1.42) also decreased richness, though less sharply than early intensive grazing. The results indicate that early intensive pasturing substantially reduces species richness, potentially leading to vegetation destruction and community degradation. Also, the vegetation in the control plots, which were protected from grazing, showed stabilization and had the highest species richness.

The highest alpha diversity (Shannon-Weaver index, H') was observed in control plots during the early period (spring), where grazing was absent. With early intensive grazing, the uniformity of species distribution decreased, likely due to the dominance of individual species.

Beta diversity values were lowest in control plots (0.28±0.12), indicating homogeneous vegetation in areas without grazing. However, intensive grazing areas showed higher beta diversity (0.37±0.11 for early grazing, 0.34±0.15 for late grazing). That's why, it can be said that intensive grazing increases vegetation heterogeneity as a result of the destruction of prevalent varieties. Moderate grazing yielded a moderate increase in beta diversity, creating an ecological mosaic

Table 5: Analysis of variance results: ANOVA (species richness and Shannon index) and PERMANOVA (beta diversity)

Indicator	Early grazing			Late grazing		
	Control	Moderate grazing	Intensive grazing	Control	Moderate grazing	Intensive grazing
Wealth	$< 1 \times 10^{-3}$					
Alpha diversity (Shannon-Weaver)	$< 5 \times 10^{-4}$	$< 5 \times 10^{-4}$ (6.01099E-21)				
Beta diversity (Bray- Curtis)	1×10^{-3}					

ANOVA statistically confirmed notable variations in species richness and alpha diversity among grazing treatments ($p < 0.001$) (Table 5). The Bray-Curtis distance-to-centroid analysis revealed that control plots had the lowest vegetation structure variability (0.28 ± 0.12), whereas intensive grazing resulted in the highest variability (0.37 ± 0.11). This confirms that intensive grazing not only reduces species richness but also increases vegetation heterogeneity.

The obtained data indicate that early intensive grazing significantly reduces species richness, suggesting degradation of the plant community and decreased biodiversity. Late grazing also showed that control plots (without grazing) had the highest species richness, implying that grazing reduces species numbers. The Bray-Curtis distance to centroid analysis demonstrated that the control had low beta diversity, which gives an understanding that without grazing, the vegetation is relatively homogeneous.

Aboveground biomass was strongly influenced by grazing intensity and season. Pasturing-exclosure plots (without grazing) had higher aboveground biomass compared to intensively grazed plots, suggesting that grazing pressure inhibits biomass accumulation by plants. Reduction in biomass with intensive grazing is due to the shortfall of dominant varieties and the change in vegetation structure (see Table 6).

Table 6: Aboveground plant biomass (kg ha⁻¹) and pasture feed deficit/surplus (t) under different grazing intensities and periods

Periods	Plots	Aboveground plant biomass, kg ha ⁻¹	Deficit (surplus) of pasture feed, t
Early	Control	1680 ± 412	0.01
	Moderate	1690 ± 518	0.01
	Intensive	1700 ± 422	0.02
Late	Control	1720 ± 531	0.02
	Moderate	1790 ± 490	0.05
	Intensive	990 ± 375	-0.23

The aboveground biomass production differs with various grazing intensities and durations. During the early period, biomass production is comparable in control, moderate, and intensive grazing plots, with values ranging from 1680 to 1700 kg ha⁻¹. During the following period, however, control and moderate grazing plots have increased biomass production, with values of 1720 and 1790 kg ha⁻¹, respectively. In sharp contrast, however, the intensive grazing plots experience a tremendous drop in biomass generation, with a value of 990 kg ha⁻¹.

The values of pasture feed deficit and surplus also indicate important trends. During the first period, all grazing intensities have a slight feed deficit (0.01-0.02 t), indicating that the pasture is slightly underutilized. During the second period, control and moderate grazing plots still have a slight feed deficit (0.02-0.05 t), but intensive grazing plots have a feed surplus (-0.23 t), indicating overgrazing and potential degradation of the pasture. The findings indicate that grazing intensity has a more pronounced impact on biomass yield and feed balance during the latter period; as intensive grazing reduces biomass yield and moderate grazing, however, seems to keep biomass yield and feed balance relatively stable for both periods.

Fig. 3 illustrates the impact of grazing intensity on vegetation structure for both early (A) and late (B) grazing. Intensive grazing is characterized by the greatest scatter of points, indicating the destruction of vegetation structure. A Principal Component Analysis (PCA) biplot (A) shows vegetation composition across three grazing treatments, with PC1 and PC2 explaining 32.14% of total variance. Gray arrows indicate loading vectors, showing clear separation between intensive, control, and moderate grazing treatments. An alternative PCA Biplot (B) captures 36.58% cumulative variance, revealing complementary aspects of vegetation response to grazing treatments, with different clustering patterns suggesting distinct ecological processes affected by grazing intensity. The species vectors in the plot show that fescue (*Festuca valesiaca*) and

couch grass (*Elytrigia repens*) are associated with control and moderate grazing, whereas bluegrass (*Poa pratensis*) and black sagebrush (*Artemisia pauciflora*) dominated under intensive grazing. This shift in species composition indicates a significant change in ecosystem structure. The PCA analysis confirms that intensive grazing leads to significant changes in vegetation structure, favoring species such as *Poa pratensis* and *Artemisia pauciflora*, while *Festuca valesiaca* and *Elytrigia repens* are associated with control plots.

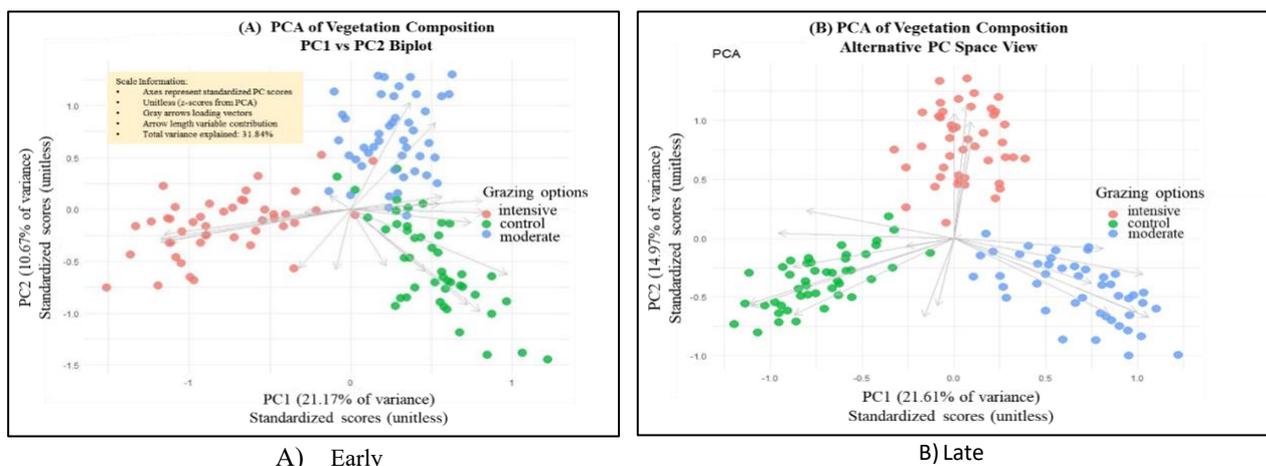


Fig. 3: Principal Component Analysis (PCA) of species composition for early and late grazing in pasture areas (control (no grazing), moderate and intensive grazing)

The humus indicators were at the average level typical for dark chestnut soils. Depending on the period, it remained within the initial values, but its content slightly decreased with intensive grazing (2.38% versus 2.61% in the control with early grazing). This indicates an insignificant decline of organic matter in the soil due to trampling and reduction of plant cover.

Due to the rainy spring, N - NO₃ was leached into the lower horizons and, accordingly, the indicators decreased by late grazing. The P₂O₅ value remained within the initial values for the grazing periods and corresponded to a low content as seen in Table 7.

With intensive grazing, exchangeable sodium increased as a result of trampling, which indicates an increase in soil salinity. Thus, intensive grazing had a negative impact on both the soil and the plant community. Higher soil density may explain the decrease in alpha diversity, as compacted soil makes it difficult for seeds to germinate and for shallow-rooted plants to develop. Dominant deep-rooted species will displace the less resistant species, leading to a decrease in the evenness of species distribution and a drop in the Shannon index

Table 7: Agrochemical and agrophysical indicators of dark chestnut soils in the 0-30 cm layer under different grazing technologies, Zaporozhye-Agro LLP, Zhaksynsky district, Akmolra region, 2024

Indicators	Early Grazing			Late Grazing		
	Control	Moderate grazing	Intensive grazing	Control	Moderate grazing	Intensive grazing
Humus, %	2.61	2.54	2.38	2.60	2.55	2.37
N- NO ₃ , mg kg ⁻¹ soils	8.77	8.33	8.22	8.48	8.05	7.84
P ₂ O ₅ , mg kg ⁻¹ soils	12.42	13.04	11.51	12.40	13.03	11.53
K ₂ O, mg kg ⁻¹ soils	>500	>500	>500	>500	>500	>500
Sum of exchange bases, mg.eq 100 g ⁻¹	9.6	10.1	10.3	9.5	10.1	10.2
Exchangeable sodium, mg.eq 100 g ⁻¹ soil	0.062	0.118	0.129	0.063	0.114	0.124
Density, g cm ⁻³ 0-20 cm	1.21	1.25	1.32	1.31	1.33	1.39

Discussion

Grazing Pattern and Species Richness

Grazing is an ecological process that directly affects natural vegetation, regarded as a discriminating interruption that declines interspecific competition [74, 75]. The research confirms that grazing intensity elicits different response in various grazing variants. For instance, control plots with no grazing were characterized by the species abundance, especially with late grazing. In contrast, early intensive grazing resulted in a significant reduction in species richness, indicating a negative impact on the plant community. This outcome is consistent with previous researches, which found that heavy grazing in high mountain steppe and dry desert reduced vegetation cover, species richness and above ground biomass [76-79].

Late intensive grazing also led to a decrease in richness, although not as sharply as early intensive grazing. According to Herrero-Jáuregui & Oesterheld and McCarthy et al., analysis highlight stocking rate decrease species diversity and richness than increased [80, 81]. The change in plant community diversity is attributed to different grazing practices [82]. The statistical analysis revealed that alpha diversity (Shannon-Weaver diversity) decreased in early intensive grazing due to decreased uniformity of species distribution, potentially indicating the dominance of individual species.

Beta diversity (Bray-Curtis diversity (dissimilarity)) results showed that intensive grazing increased vegetation heterogeneity due to the destruction of dominant species, consistent with Li et al., who found that disorganized grazing reduced pasture productivity and herbage height in the Akmolra region [83]. ANOVA confirmed significant differences in species richness and alpha diversity between grazing treatments (Table 4 and 5). Moderate grazing led to a moderate increase in beta diversity, creating an ecological mosaic. Additionally, Bray-Curtis distance to centroid analysis verified that control plots had the lowest variability in vegetation structure, whereas intensive grazing plots exhibits increased vegetation heterogeneity and reduced species richness.

Moreover, the data confirmed that early intensive grazing with fewer species significantly contributes plant community degradation and decreased biodiversity compared to late grazing and control (without grazing), which had the highest species richness. This means that grazing reduces the number of species.

Soil Indicators and Grazing Pattern

The research data on soil showed that intensive grazing slightly decreased soil humus levels compared to the control plot (Table 7). According to Nasiyev et al., nitrate content is a key indicator of fertility, supplying nitrogen to plants [11]. The study showed a significant decline of organic matter in the soil due to trampling and reduced plant cover. It was also observed that N - NO₃ leach down to lower horizon during spring rains.

The P₂O₅ value remained within initial values for the grazing periods, corresponding to a low content. However, Nasiyev et al. and Dixon et al. discovered that grazing influences the proportion of mobile phosphorous [84, 85]. The results also confirmed that intensive grazing increased soil salinity due to increased exchangeable sodium from trampling. Similarly, Erfanzadeh et al. and Di et al. revealed that there is higher soil salinity in posturized plots compared to un-posturized plots [86, 87].

While this study's findings may not fully represent all steppe region due to weather fluctuation, they provide guidance on managing grazing patterns and. Implementing rotation and monitoring of grassland can help protect biodiversity. In short, the analysis shows that intensive grazing had a negative impact on both the soil and plant community.

Conclusions

The findings highlight the significant effects of posturing intensity on pasture composition and diversity in the steppe zone of northern Kazakhstan. The research data collected on vegetation, species richness and soil parameter revealed that early intensive grazing causes a substantial reduction in species richness, negatively affecting the plant community and biodiversity. However, late grazing and control plots (without grazing) showed higher species richness. Notably, intensive grazing increases the vegetation heterogeneity due to the destruction of dominant species.

The study on chestnut soil showed that intensive grazing slightly decreased soil humus levels and resulted in a significant loss of organic matter due to trampling and reduced plant cover. Furthermore, intensive grazing increased soil salinity because of increased exchangeable sodium increased from trampling. This study concludes that unmanaged grazing not only affects

pasturelands but also poses a risk to sustainability, negatively impacting both soil and plant communities. This research contributes to both the understanding of biodiversity and ecosystem sustainability.

Acknowledgment

We thank the publisher for facilitating the dissemination of our research to a broader audience. We appreciate the editorial board for their thorough review and enhancement of our manuscript. We gratefully acknowledge the support of the Ministry of Agriculture of the Republic of Kazakhstan and the Strategic Academic Leadership Program of RUDN University. We appreciate the opportunity to present our study in this journal.

Funding Information

This work was supported by the program BR22883585 “Development of effective technologies for increasing the productive potential and rational use of pastures” for 2024-2026, funded by the Ministry of Agriculture of the Republic of Kazakhstan, and also study was supported by RUDN University Strategic Academic Leadership Program.

Author’s Contributions

Conceptualization: A.B., G.S., B.A. Methodology: A.B., G.S., B.A. Software: B.N., N.M. Validation: M.Z., B.Y.K. Formal analysis: B.N., N.M. Investigation: B.N., N.M. Data curation: A.B., G.S., B.A. Writing-original draft: A.B., G.S., B.A. Writing-review & editing: B.Y.K., M.Z. Visualization: M.Z., B.Y.K. Supervision: M.Z. All co-authors reviewed the final version and approved the manuscript before submission

Ethics

This manuscript presents original, unpublished work. The corresponding author confirms that all co-authors have reviewed and approved the submission, and no ethical concerns are associated with its publication.

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