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Influence of Cattle Grazing Methods on Changes in Vegetation Cover and Productivity of Pasture Lands in the Semi-Desert Zone of Western Kazakhstan

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ABSTRACT

Monitoring pasture vegetation indicators is critical as decreased productivity could jeopardize the stability of pasture lands. This study aimed to evaluate the status of vegetation cover across pastures utilized in diverse manners within the semi-desert zone of Western Kazakhstan. Specifically, the impacts of rotational, seasonal, and intensive grazing on the functionality, diversity, and productive potential of pasture vegetation were investigated. Systematic vegetation observations, including species diversity examination, projective coverage estimation, height measurements, and yield determination, were conducted in transects established across pastures with varying grazing methods at the Miras farm in Western Kazakhstan. The findings reveal that unregulated intensive grazing significantly altered vegetation indicators, suggesting potential degradation processes. Intensive grazing proved particularly detrimental, resulting in decreased species richness, projective coverage, height, and a lower productive vegetative mass. In contrast, rotational and seasonal grazing methods appeared more effective in Western Kazakhstan. Pastures where regulated grazing was practiced exhibited higher species richness and biometric and production indicators compared to those with unsystematic grazing. Understanding the alterations in biometric and productive vegetation indicators relative to grazing practices is crucial for quality assessment of pastures and determining appropriate pasture management. The absence of adequate and efficient grazing could trigger irreversible deterioration in pasture vegetation conditions. Therefore, to safeguard the biological resources and biodiversity of the region's pastures, it is strongly advocated to employ regulated grazing and entirely eliminate excessive intensive grazing. This approach will help maintain a healthy balance in the pasture ecosystem and promote sustainable farming practices.

1. INTRODUCTION

Cattle grazing is globally recognized as a primary contributor to the degradation of pasture lands, homogenization of spatial landscapes, functional alteration of pasture lands, and loss of species diversity [1].

The escalating demand for environmentally friendly food has amplified livestock numbers and expanded agricultural activities, even in challenging environmental conditions such as the semi-desert zone of Western Kazakhstan [2]. Thus, understanding the impact of animal husbandry on grassland vegetation quality becomes imperative for making informed management decisions [3].

Pasture lands, often found in plant biomes including meadows, shrubs, savannas, and deserts, are expansive natural vegetation areas supporting animal husbandry [4]. These regions are typically characterized by arid climates, low rainfall, and marked seasonal temperature fluctuations. The quality of these pasture lands is closely tied to animal productivity, rendering the maintenance of their sustainable forage resources without quality degradation as a critical concern [5].

Managing the productivity and rational use of pastures necessitates an optimal grazing system. This includes parameters such as grazing methods, timing of grazing initiation and termination, livestock numbers and density, as well as the frequency and duration of individual grazing periods [6-8]. However, the impact of grazing methods on pasture quality remains a controversial topic. Some studies advocate the benefits of rotational grazing (RG) for sustaining pasture productivity and land condition [9], while others, such as the work by McDonald et al. [10], suggest that strategic rest in comparison to continuous livestock grazing could enhance vegetation condition and biodiversity, and maximize feed production per unit area.

Overgrazing, as Atamov et al. [11] noted, could lead to the transformation of the primary steppe into the secondary steppe, eventually causing the semi-desert to change into a desert vegetation zone, a particularly relevant issue for Western Kazakhstan [12]. Overgrazing is a significant concern as it stresses valuable pasture species, reduces the feed, energy, and protein value of pasture lands, and long-term productivity loss and vegetation cover reduction can cause community social losses due to malnutrition and poverty [11-

13]. Additionally, overgrazing over extended periods alters the composition of dominant species [13, 14], the distribution of forage and poisonous species on pastures [15, 16], and negatively impacts vegetation productivity [17], greenhouse gas balance, and biodiversity [18-20]. In most countries, including Kazakhstan, due to climatic conditions and traditional systems of free (excessive) grazing, strong destruction of vegetation is observed [21-23].

In research conducted in Extremadura, Spain, keeping animals at rates exceeding 1 astronomical unit (a.u.)/ha-1 showed signs of reduced productivity and pasture quality [24]. Schuman et al. [25] found that intensive grazing (IG) led to a decrease in the maximum yield of aboveground live phytomass, with plots becoming dominated by weeds. Grazing alters the reproduction, productivity, and composition of plant species [26], as well as the quantity and composition of root secretions, rhizosphere activity, and litter decomposition [27].

Notably, long-term exclusion of cattle grazing also negatively impacts grasslands, leading to an increase and spread of poisonous species and shrubs in the herbage [28]. Therefore, defining an effective grazing method is crucial for sustainable pasture management and efficient land use [29]. The economic benefits of cattle grazing are primarily linked to a reduction in feed costs, making it essential to have a promising pasture management system for an almost continuous supply of high-quality pasture feed [30].

In the semi-desert zone of Western Kazakhstan, cattle grazing is a leading anthropogenic influence on the vegetation cover of pasture lands. Our study centers on effective grazing technologies that prevent the degradation of new territories. The research question involves evaluating the conditions and changes in the main parameters of vegetation cover, specifically the projective cover, height, and yield of pasture grass under the influence of grazing. Upon obtaining data from the chemical analysis of pasture grass quality, the productivity and energy, and protein value of pastures were assessed, depending on their usage methods.

This study aimed to: 1) Assess the impact of various cattle grazing methods on the vegetation cover and productivity of Western Kazakhstan's semi-desert pasture lands, 2) Ascertain the methods that foster greater species diversity and vegetative cover, and 3) Inform pasture management recommendations to promote productive and sustainable pasture use.

2. MATERIALS AND METHODS

2.1 Description of the study plots

The study was conducted in 2018-2022 at the Zhangir Khan West Kazakhstan Agrarian and Technical University (ZKATU, Republic of Kazakhstan) on the initiative of the Ministry of Agriculture on the pastures of the Miras farm in the semi-desert zone of Western Kazakhstan. Agrochemical analyses of soil samples were carried out in the accredited laboratory of the ZKATU.

Currently, in the Republic of Kazakhstan, out of 188.9 million ha of pastures, 26.6 million ha have reached the state of extreme degradation (run-down) and as a result of pasture degradation, the loss of feed equals 4.3 million tons of fodder units [12, 31, 32].

In the Western Kazakhstan region, the area of pasture lands is 10.2 million ha, while more than 65% of pastures are located in the semi-desert zone of the region, where farms specializing in the production of meat by raising cattle are mainly concentrated. The farm we have chosen is typical of a semi-desert zone with vegetation mainly consisting of Artemisia Lerchiana, where the productivity of pasture land strongly depends on management techniques, in particular on the methods of grazing livestock.

The terrain of the farm is flat. The Miras farm is located on the Caspian lowland. The climate is continental, winters are frosty, and summers are moderately hot. Average temperatures in January reach 12-14℃ and in July 24-25℃. The average annual precipitation is 250-300mm. The Aralsor lake is located next to the farm. The soils are light chestnut and sandy.

Experimental work was carried out according to the scheme indicated in Table 1.

Table 1. Design of the field experiment on the study of methods of grazing farm animals on pastures of the semi-desert zone of western Kazakhstan

Grazing Method Variants	Pasture Area, Type, and Number of Livestock
No grazing (NG) (control)	NG
RG	560 ha, cattle in the amount of 80 heads
Seasonal grazing (SG)	560 ha, cattle in the amount of 80 heads
IG	560 ha, cattle in the amount of 80 heads

Experiment variants: RG, SG, and IG were studied on the territories of pasture lands of the Miras farm. The pasture plots were located next to each other within the same pasture land.

In the RG variant, pastures are used by the rotation method, i.e., in the 1st year the pasture is used only in spring, in the 2nd year in summer, in the 3rd year in autumn, then in the 4th year the pasture rests.

In the SG variant, pastures are used for grazing cattle only in a certain season without rest.

In the IG variant, pastures are used in all seasons of the year without rest.

The control variant implies that the untouched plot is located outside the farm territories. This plot is selected in a semi-desert zone as a reference for comparing pastures.

2.2 Study of the vegetation cover of pastures

To study the plant community on pasture transects measuring 100×50m were established, where all regime observations were carried out: the study of species composition, projective coverage, height, and yield of pasture grass.

The quantitative ratio of species in pastures was characterized using the Drude scale: Soc (socialis): “abundant”, plants grow everywhere, connecting with their aboveground parts; Cop. 3 (copiosus): “copious”, plants are found in very large numbers; Cop. 2: “a lot”, plants are found in large numbers; Cop. 1: “many”, plants are found in considerable numbers; Sp (sparsus): “sparse”, the species is abundant, but does not form a continuous cover; Sol (solitarius): “single”, the species grows scattered; Un (unicum): the species occur in single instances [33].

The indicator projective coverage is the ratio of the area of the projection of vegetation cover to the area on which they are projected, expressed as a percentage. The projective coating was evaluated visually [34].

The height of the plants was measured before grazing using a measuring ruler. The end of the ruler was placed on the surface of the soil. The sample size was 10 plants selected in different places along the diagonal of the accounting area. In this case, the stem is measured from the soil surface to the tip. The final indicator of accounting is the average height of plants on the plot [34].

Yield accounting was carried out by the cutting method. On pastures during cattle grazing, crop accounting was carried out when the pasture ripeness of the herbage was reached. To do this, along the diagonal of the plot, the grass was mowed with a hand sickle (Prompribor LLC, Yekaterinburg, Russia) on four accounting platforms of 2.5m^2 each, the height of the cut reaching 4 to 5cm. The mowed mass was weighed and an average sample of 1kg was taken. The sample was dried under a canopy to a humidity of 17 to 18% to determine the yield of air-dry matter [34].

To assess the quality of pasture vegetation, the content of crude nitrogen, crude fat, crude fiber, crude ash, carotene, Ca, P, and K. The content of crude nitrogen in vegetation was determined based on the Kjeldahl titrimetric method using the Kjeldahl installation (Labreaktiv LLP, Ust-Kamenogorsk, Kazakhstan) [35].

The content of crude fat was determined by extraction of crude fat with diethyl ether using a Vilitek ASV-6M Soxhlet apparatus (VILYTEK LLC, Moscow, Russia) [35].

The content of crude fiber was determined according to Genneberg and Shtoman using a Vilitek ASV-6M Soxhlet apparatus (VILYTEK LLC, Moscow, Russia).

The content of raw ash was determined by dry ashing-burning of a sample of air-dry feed in a PM-8 muffle furnace (Stankopark LLP, Almaty, Kazakhstan) at a temperature of 500-525℃ [35].

The content of carotene in the plant sample was determined by extraction with petroleum ether using a PE-5400VI spectrophotometer (Ekroskhim, St. Petersburg, Russia) [35].

The Ca content was determined based on the trilonometric method using an atomic absorption spectrophotometer (Iskroline LLP, St. Petersburg, Russia). The P content was determined based on the photometric method using a PE-5400VI spectrophotometer (Ekroskhim, St. Petersburg, Russia). The K content was determined based on the flame photometric method using a Jenway PFP 7 flame photometer (Jenway, UK) [35].

Based on the obtained quality indicators, the fodder and energy-protein value of pasture vegetation was calculated depending on the grazing methods using the methodological recommendation [35].

2.3 Data analysis

The productivity indicators of the plant community were statistically processed by single-factor analysis of variance [34]. The intergroup variance for three variants of the experiment (NG, SG, RG) was compared with statistical significance at the p-level<0.01 using the SAS OnDemand for Academics software. The chart of indicators of pasture lands by grazing variants was built using the MS Excel tabular editor.

3. RESULTS

3.1 Species composition and diversity

The dynamics of the overall projective coverage of economic and botanical groups of plants on pastures depend on the ways they are used. In our studies, the most qualitative composition of pastures was noted in the pastures of RG. Thus, in this area of pasture, with total projective coverage of 85%, the most valuable cereal plants, such as Agropyron desertorum, Stipa capillata, Festuca valesiaca, Leymus ramosus, Koeleria cristata, and Kochia prostrata account for 55% of the phytomass. In this area, wormwood occupies 12%, and mixed grasses with weeds occupy 16%. In the pasture phytocenosis, the specific weight of weeds and poisonous plants was 2%.

In the area of SG, where pastures were used annually only in the summer season with rest in the spring and autumn seasons, with 75% of the total projective coverage, cereals account for 44% of the total phytocenosis. In this area, wormwood occupies 13%, and the specific gravity of various types of grass was 14%. In the composition of various types of grass, 4% is used by weeds and poisonous plants.

As the study data show, the worst qualitative composition of phytocenosis by economic and botanical groups of pasture plants is formed during the unsystematic grazing of farm animals. Thus, in an IG area, where pastures were used annually without rest in all seasons, i.e., haphazardly, the total projective coverage of pastures does not exceed 45%. As part of the phytocenosis, the specific weight of the most valuable forage plants is maximally reduced. The share of cereals in the total phytocenosis was at the level of 9%. As a result of trampling by cattle, an increase in the proportion of wormwood Artemisia lerchiana and Artemisia austriaca in the vegetation cover was noted to be 15%.

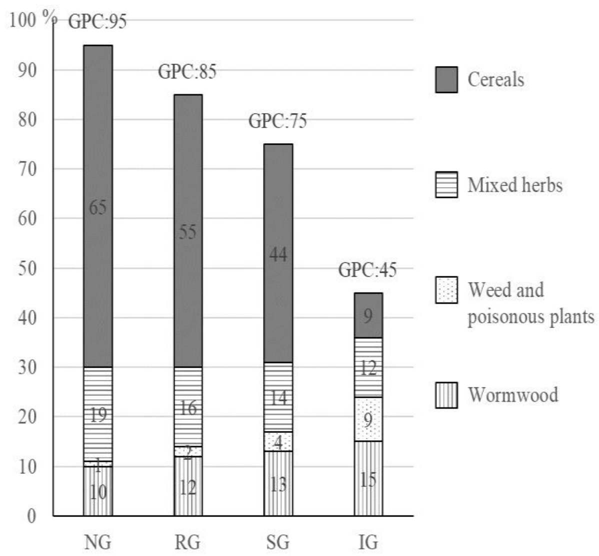

Figure 1. Dynamics of the total projective cover of herbage and the projective cover of economic and botanical groups of pasture plants depending on grazing methods for 2018-2021, %. No grazing: NG, Rotational grazing: RG, Seasonal grazing: SG, Intensive grazing: IG

In comparison with other pasture areas, the specific gravity of various types of grass was minimal, at the level of 12%. It should be noted that haphazard grazing has affected the qualitative composition of the grass. In this grazing variant, weeds and poisonous plants Tanacetum achilleifolium, Lipidium perfoliatum, Anabasis aphylla, Datura, Xanthium strumarium, Alhagi pseudalhagi, and Euphorbia occupied up to 9% of the total grass.

In studies on the reference plot with untouched vegetation and soil cover, located in a semi-desert zone outside the territories of the farm, the total projective coverage was 95%. At this control plot, the share of valuable species in the feed ratio was 65%, and the specific weight of the wormwood group was minimal, at the level of 10%. In the rest plot, the proportion of various types of grass was also maximal and reached up to 19% of the total vegetation of the reference plot. Weeds and poisonous plants in the composition of various types of grass occupied only 1% of the pasture cenosis (Figure 1).

3.2 Influence of cattle grazing methods on indicators of vegetation cover

Quantitative and qualitative indicators of pasture phytocenoses also depended on the way pastures were used. At the same time, the projective coverage of pastures, depending on the method of their use, ranged from 50 to 90% (Table 2).

Table 2. Indicators of vegetation cover of pastures in the semi-desert zone of Western Kazakhstan, depending on grazing methods, the average for 2018-2022

Grazing Method Variants	Projective Coverage, %	Number of Species	Height of the Herbage, cm
NG (control)	95	22	60
RG	90	16	44
SG	80	15	35
IG	50	12	27

The largest projective coverage was determined in the control area (95%), and the RG pastures (90%). The smallest projective cover (50%) was observed on pastures with unsystematic farm animal grazing. On seasonally used pastures, the projective coverage was at the level of 80%. The present study showed that the vegetation cover decreased with an increase in the intensity of grazing from 95 to 50%.

In studies based on the results of botanical analysis, the largest number of plant species (22) was established in the control area with SG. The height of the herbage at the control was 60cm.

On pastures, the number of pasture plant species depended on the way they were used. At the same time, the largest number of species (15-16) were identified on pastures of SG and RG. The height of pasture grass with SG and RG variants was 35-44cm.

In studies, the herbage with the lowest growth of 27cm was recorded on pastures with unsystematic grazing. As a result of excessive load on pastures of unsystematic grazing, the species diversity of pasture plants decreases to 12, and degraded areas are formed, which is especially evident in the summer.

3.3 Nutritional quality and pasture productivity

According to research data, the productivity of pasture grass depends on the methods of farm animal grazing. In the 2018-2022 studies, when using SG and RG, the yield of the dry mass of pasture grass was 0.68-0.87 t/ha.

While at the control plot, the yield of the dry mass of pasture grass was 1.29 t/ha, with an increase in the load due to unsystematic grazing, the productivity of pasture cenosis decreased to the level of 0.40 t/ha of dry mass (Figure 2, block A).

The yield indicator (A) of Figure 2 shows the change in average values depending on the experiment variants. There is a tendency to decrease values from the maximum control values to the minimum values in the IG variant. All indicators for the experiment variants are stable. The intra-group deviation of the indicator values is slight. The smallest variation of the trait is observed for the SG experiment. Comparing the intergroup variance for three variants of the experiment (NG, SG, RG) using a one-factor analysis of variance, it turns out that the average values of the trait for the variants of the experiment differ with statistical significance at the p-level<0.01. Consequently, the yield indicator depends on the intensity of pasture use.

According to the indicators of the collection of feed units, digestible protein, the productivity of pasture grass was high at the control plot, i.e., in the absence of grazing, reaching 0.28 and 0.032 t/ha, and when using pastures according to the methods of SG and RG, respectively, with 0.13-0.18 and 0.013-0.019 t/ha.

The yield of feed units and digestible protein from 1 ha was lower compared to the above-mentioned variants of SG on the variant of unsystematic grazing (0.06 and 0.003 t/ha).

In block B of Figure 2, the indicator of the yield of feed units shows a tendency to decrease values from the maximum control values to the minimum values in the IG variant. Visually, one can note the difference between the average values and the experiment variant. The size of the blocks in the diagram shows the variation. All indicators for the experiment variants have an average variation. The intra-group deviation of the indicator values is average and the same is true for all variants of the experiment. Comparing the intergroup variance for three variants of the experiment (NG, SG, RG) using a one-factor analysis of variance, we determined that the average values of the trait for the variants of the experiment differed with statistical significance at the p-level<0.01. Consequently, the yield of feed units depends on the intensity of pasture use.

Collection of digestible protein (Figure 2, block C). Visually, one can note the difference between the average values and the experiment variant. The size of the blocks in the diagram shows a slight variation. All indicators for the experiment variants have the same variation. Using a one-factor analysis of variance, we determined that the average values of the trait for the variants of the experiment differed with statistical significance at the p-level<0.01.

The output of the exchange energy in the experimental variants was at the level of 0.90-3.51 GJ/ha. The highest output of exchange energy was observed at the control plot, equaling 3.51 GJ/ha. In terms of energy value, the use of SG and RG pastures on chestnut sandy soils of the semi-desert zone has an advantageous position. On these pastures, the collection of exchange energy exceeds the variants for intensive use of pastures by 0.86-1.52 GJ/ha. With haphazard use of pastures, the collection of exchange energy was at a level of 0.90 GJ/ha.

The indicator of the output of the exchange energy (Figure 2, block D) is stable for the IG variant of the experiment and has the smallest variation. The indicator of the average value "Output of exchange energy" decreases depending on the intensity of grazing. The average values of the indicator vary from the maximum values (in the control variant) to the minimum values in the IG variant. Differences in the average values of the trait in the experiment variants differ with statistical significance at the p-level<0.01. Consequently, the indicator of the output of exchange energy depends on the intensity of pasture use.

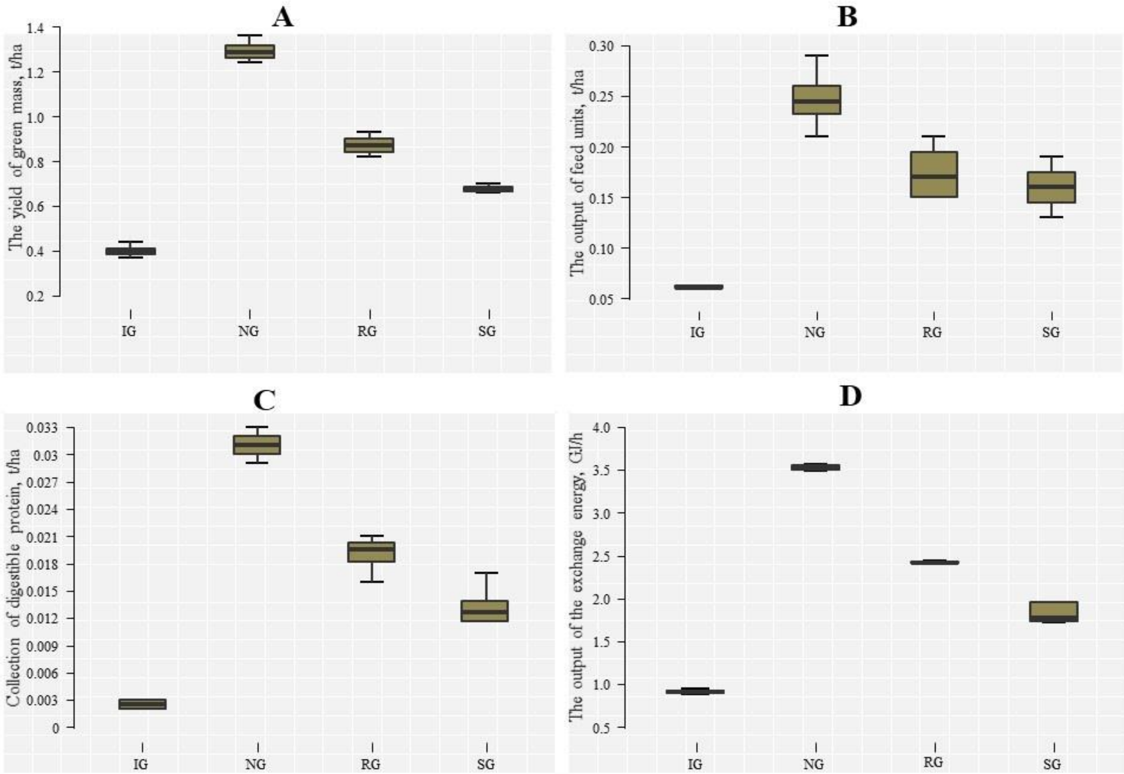

Figure 2. Indicators of productivity, energy, and protein value of pastures, depending on the methods of their use
A: the yield of green mass, t/ha; B: the output of feed units, t/ha; C: collection of digestible protein, t/ha; D: the output of the exchange energy, GJ/h; NG: no grazing (control); RG: rotational grazing; SG: seasonal grazing; IG: intensive grazing

The conducted one-factor analysis of variance showed the statistical significance of differences in the average values of the indicator depending on the methods of pasture use. The most severe use case is IG (unsystematic grazing).

Thus, for all three indicators: A-Yield of green mass, t/ha (0.40); B-Yield of feed units, t/ha (0.06); C-Collection of digestible protein, t/ha (0.003), the values for unsystematic grazing are the minimum of all four variants of the experiment (IG, NG, RG, SG). The difference in the average values of the indicators of the IG unsystematic grazing option compared to the control NG value is maximal: A-Yield of green mass, t/ha (0.89); B-Yield of feed units, t/ha (0.19); C-Collection of digestible protein, t/ha (0.029). The most optimal in terms of values of indicators is the use of pastures in the RG variant: A-Yield of green mass, t/ha (0.87); B-Yield of feed units, t/ha (0.18); C-Collection of digestible protein, t/ha (0.019).

4. DISCUSSION

4.1 Impact of lean grazing practices on study areas

Our study confirmed the researchers' assumption that moderate RG of livestock can be used as a useful management method to maintain species diversity and productivity of pasture lands [36]. Moreover, a low or moderate grazing level can increase production compared to SG [37]. In our studies, the most optimal species diversity, biometric indicators (projective coverage and height), and productivity of pasture vegetation were established on the variants of RG and SG, where grazing is carried out in a moderate mode.

Pasture rest significantly improves phytocenosis biodiversity [38, 39]. The best biometric and productive indicators of vegetation were observed in studies on the reference plot with untouched vegetation.

In our study, the use of SG and RG methods for the livestock as a result of careful treatment and protection of pasture areas contributed to an increase in overall productivity and by increasing the most valuable species in the feed ratio in the total grassland, improving the quality and energy and protein value of pasture feed.

The combined effects of vegetation loss and pasture degradation affect primary production and, ultimately, animal productivity [40].

4.2 Influence of IG on territory degradation

The obtained results also confirm previous reports that the vegetation cover on pastures strongly depends on the intensity of grazing [41-43]. An increase in livestock grazing, as a rule, leads to an increase in plant mortality and, ultimately, to a decrease in species richness, especially in conditions of lack of water and nutrients [44-46]. In the case of IG, we have established the worst vegetation indicators, where the projective cover equals 50%, the number of species is 12, with a grass stand height of 27cm. A significant decrease ($P<0.05$) in grass height with an increase in degradation intensity corresponds to the data of Haider et al. [39] and Li et al. [45].

As noted by Hickman and Hartnett [40], overgrazing also reduces pasture productivity. In the studies, the lowest indicators of productivity and energy-protein value were found precisely on pastures of IG.

Other studies show that although overgrazing can lead to pasture degradation [47], moderate grazing can promote plant growth and increase species diversity [40]. This is confirmed by the data of studies conducted in the semi-desert zone of Western Kazakhstan.

As the practice of pasture management shows, intensive grazing is increasingly used in Kazakhstan and is associated with an increase in the number of livestock due to an increase in demand for livestock products, as well as a shortage of pasture land [48].

4.3 Influence of grazing methods on the composition of herbage and ecological consequences for the study areas

The data obtained on the species composition of grass stands are consistent with the conclusions of scientists that overgrazing contributes to the rapid penetration of less desirable invasive species, mainly species of shrubby plants [49-51]. As a result of IG, an increase in the specific weight in the herbage of invasive species of shrub plants such as Artemisia lerchiana and Artemisia austriaca was noted.

Muller et al. [52] noted that many acceptable and productive species, which are indicators of undisturbed pastures, have been greatly reduced as a result of long-term grazing, and many grazing-resistant species, which are indicators of disturbance, have spread over transformed pastures. Patra et al. [53] determined that the IG of livestock led to changes in the composition and structure of plant communities of pastures compared with light grazing of livestock.

Our studies have established clear signs of the spread of weed and poisonous plants Tanacetum achilleifolium, Lipidium perfoliatum, Anabasis aphylla, Datura, Xanthium strumarium, Alhagi pseudalhagi, and Euphorbia. In this case, according to Chadaeva et al. [54], pastures need urgent restoration.

Therefore, this study contributes to the understanding of the ecological impact of cattle grazing on the vegetation characteristics of pasture lands of the semi-desert zone of Western Kazakhstan, which have important theoretical and practical significance on a national scale.

Further unsystematic use of pasture resources poses a threat to the well-being of animal husbandry and destabilizes the habitat of the population and leads to environmental consequences due to the disappearance of valuable species of pasture plants and the increase in degradation and desertification of pasture lands.

Since the focus of this study was on grazing practices, we did not consider additional factors (technological factors: the use of different types of equipment, the influence of weather conditions, etc.) that other studies may take into account when interpreting the results.

5. CONCLUSIONS

Based on the results of the conducted study, we achieved the goal of assessing the conditions of the vegetation cover of pastures in the semi-desert zone of Western Kazakhstan, depending on the methods of their use.

In addition, valuable theoretical data on the effects of various methods of cattle grazing on biometric and productive indicators of vegetation of pasture ecosystems of the semi-desert zone have been obtained.

In practical terms, the use of the study results by introducing and implementing SG and RG methods in pasture management strategies will help relieve stress from some species and increase the productivity and feed value of pastures, as well as prevent degradation processes in pasture ecosystems.

However, the pastures of the semi-desert zone of Western Kazakhstan are not productive enough and they need proper protection, management, and rehabilitation using ecological and adaptive approaches.

In conclusion, such studies have the prospect of continuing in the area of interest, and the results can be used in countries with similar natural and climatic conditions and pasture ecosystem management strategies. Further research could be directed toward effective planning and management in arid and semi-arid grasslands.

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