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RESEARCH ARTICLE

Methods for Growing Complete Feed for Livestock on the Forage Lands of West Kazakhstan in the Framework of Sustainable Management

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Abstract: Sustainable management of forage lands is critical for livestock productivity in the arid and semi-arid regions of West Kazakhstan, where pasture degradation and declining forage quality pose increasing challenges to agricultural sustainability. This study aimed to evaluate the effects of different grazing methods on the vegetation condition, productivity, and nutritional quality of pastures in West Kazakhstan. Pasture vegetation was assessed using parameters including projective cover, species composition, grass height, forage yield, digestible protein yield, and metabolizable energy output. Three grazing systems were compared: rotational grazing, continuous grazing, and ungrazed control plots. Results demonstrated that biometric indicators, productivity, and forage quality were significantly influenced by the grazing method applied. Rotational grazing produced the most favorable pasture parameters, with forage yields of 0.60-0.75 t/ha of fodder units, digestible protein yields of 0.11-0.15 t/ha, and metabolizable energy outputs of 1.54-2.03 GJ/ha. A statistically significant dependence of pasture yield on grass height and projective vegetation cover was confirmed ($p < 0.001$). These findings demonstrate that rotational grazing represents the most effective strategy for maintaining forage quality and pasture productivity under the conditions of West Kazakhstan, and provide a practical framework for sustainable forage land management applicable to regions with similar semi-arid pastoral systems.

Keywords: Rotational grazing, Forage quality, Pasture productivity, Metabolizable energy, Digestible protein, Projective cover, Sustainable land management, West Kazakhstan

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Introduction

Finding optimal ways to provide food for the population is a leading objective of the agricultural sector. Among other solutions, this problem can be addressed by ensuring quality provision of livestock farming with complete feed to increase the production of meat, milk, and eggs [1-3].

Kazakhstan holds a prominent place in the global market in terms of food production [4]. One of the country's leading industries is animal husbandry, with a specific share of 42.1% of the gross output of agricultural products [5]. According to the National Statistics Bureau, in January-August 2024, cow milk yield reached 2.4 million t, which is 4.4% higher than in the same period of the prior year. Aside from milk, there is a rise in meat production - 683.5 thousand t (+4.7%) and a minor increase in egg production - 2.9 billion units (+0.8%) [6, 7]. Kazakhstan has started exporting meat to China and agreements have been concluded for the supply of agricultural products to the European Union and world markets [8, 9].

The main task of feed production is to supply high-quality voluminous feeds that contain at least 10.5-11.0 MJ of metabolizable energy and 15-23% of crude protein in dry matter [10, 11]. At present, fodder typically contains 90-92 g of digestible protein per unit compared to the 105-110 g prescribed by zootechnical norms. In this light, providing livestock with a balanced diet according to their nutrient needs. As argued by Vasin et al., the sufficiency and completeness of feed are responsible for 65-70% of the performance of the livestock industry [12]. The full biological potential of animals' growth, development, productivity, longevity, and support of their reproductive processes can only be realized with this kind of diet. Globally, livestock productivity is on average 30-40% lower than their genetic potential due to unbalanced nutrition [13, 14]. The absorption of nitrogen and phosphorus in fattening animals averages at about 37 and 44%, respectively. Other nutrients have even lower absorption rates: 2-7% for Cu and Zn, 10-15% for K, Na, Mg, and Cl, and 57% for Ca [2, 3].

Livestock feeds are produced using fodder lands, which, according to expert estimates, account for 26% of global land area and 70% of agricultural land [15]. To ensure continuous livestock production, Kazakhstan has implemented the Roadmap for the development of the feed industry for 2022-2025. The country aims to double agricultural production by 2028 and increase the area under fodder crops to 3.6 million ha. Kazakhstan's National Statistics Bureau reports that in 2024, the area of land under agricultural crops exceeded 24.1 million ha, of which more than 3.4 million ha were allocated for fodder crops [16], which make up 85-95% of the average daily diet of livestock [17].

Global demand for agricultural products urges farmers to utilize technologies that address the mass degradation of fodder land and the deterioration of its ecological condition and functional capabilities and allow the production of complete feeds with high energy-protein value.

The ecosystems of Kazakhstan's pastures, which play a key role in food production, are facing major problems due to global climate change. Experts report that as a result of irrational land use, Kazakhstan has over 48 million ha of degraded pastures (25.5% of total pasture area) [18-19], which are distinguished by a morescarce vegetation cover, worse quality and functional capacity of the soil, and greater susceptibility to erosion and desertification [20]. For this reason, as part of the strategy to protect pasture ecosystems and ensure their rational use, Kazakhstan has passed the Law "On pastures", which provides for the use of effective grazing technologies [21]. Some pasture management methods, such as rotational grazing, can help restore vegetation cover and the quality of pasture soils while requiring less effort and managerial decisions and potentially improving livestock productivity [20, 22-26]. For example, in the semi-arid grasslands of Kenya, pastures under rotational grazing showed high plant species richness [27]. In a study by Rong et al., the rotation of arid pastures with an 8-year rest period resulted in a stronger vegetation cover and an increase in the content of total nitrogen (110%) and total phosphorus (114%) in the 0-10 cm soil layer [28]. The pastures rested through rotation also offer environmental advantages, including biodiversity preservation [29]. Kazakhstan has few rotational pastures, which makes it topical and relevant to study this issue.

Rotational grazing has been proposed as a cost-effective method to restore vegetation cover, improve forage quality, and mitigate land degradation. Studies in other semi-arid regions report positive effects on species' richness, soil fertility, and biomass productivity. However, little is known about the specific impacts of rotational grazing on forage lands in West Kazakhstan, a key region for the country's livestock industry.

The present study addresses this knowledge gap by evaluating how different grazing methods influence the species composition, vegetation cover, herbage yield, and nutritional quality of pastures in the semi-arid zone of West Kazakhstan.

The findings aim to support sustainable pasture management strategies that can enhance feed availability and livestock productivity.

Thus, our study aims to assess the condition of vegetation on the main forage lands of West Kazakhstan, i.e., its pastures, depending on the most prominent factor livestock grazing.

Materials and Methods

Description of the Study Sites

The production of complete feeds plays an important part in contemporary livestock farming because these feeds positively affect the meat and milk productivity, health, longevity, and reproductive capacity of livestock.

Our driving hypothesis is that the production of various types of complete fodder on forage lands using improved grazing methods will guarantee an increase in the performance of the livestock industry and transform the food and agricultural systems of Kazakhstan.

The hypothesis was tested in studies examining the influence of grazing methods on the parameters of vegetation on pastures in West Kazakhstan conducted in 2022-2024 at the Zhangir Khan West Kazakhstan Agrarian-Technology University on state order from the Ministry of Science and Higher Education of Kazakhstan.

To assess the current condition of vegetation depending on the employed grazing method, a field experiment was conducted on the Miras peasant farm located in the semi-arid zone of West Kazakhstan. The experiment relied on up-to-date methodologies and requirements and relevant GOSTs (Table 1).

Table 1: Design of the field experiment on the influence of grazing methods on the state of vegetation on pastures in the semi-desert zone of West Kazakhstan

Fields and grazing methods	Field management
Intensive grazing (control)	Livestock graze without breaks throughout the spring, summer, and fall, as well as winter in favorable years, i.e., unsystematically, the grazing species - cattle, number - 120 heads.
Rotational grazing - field 1	Livestock graze according to the pasture rotation system (field 1) on a field measuring 560 ha, the grazing species - cattle, number - 120 heads.
Rotational grazing - field 2	Livestock graze according to the pasture rotation system (field 2) on a field measuring 560 ha, the grazing species - cattle, number - 80 heads.

The studied pastures belonged to the type of plain pastures, class "Artemisia lerchiana-Stipa-Festúca valesiáca on light chestnut soils".

Vegetation Studies

The surveys and observations carried out on the experimental pasture fields targeted:

1) The species composition of pasture grasses

2) The yield of pasture vegetation by seasons of the year

3) Changes in the quality of forage mass of pasture phytocenoses: Nutritional and energy-protein value

The transect method (profiles) is an effective indirect method of studying pastures. In the course of monitoring, all routine observations were carried out on transects measuring 100x50 m.

Vegetation cover assessment methods. Particular attention was paid to studying the condition of the vegetation cover of natural pastures (grass species composition, projective coverage, plant height, and yield).

Pasture vegetation was assessed on 10x10 m geobotanical sites. The quantitative ratio of species at the site was characterized using the Drude scale: Soc (socialis) - "highly sociable", the plants grow thickly, interlocking their above-ground parts; Cop.3 (copiosus) - "very abundant", the plants are found in large numbers; Cop.2 - "abundant", the plants are copious; Cop.1 - "rather abundant", the plants are found in considerable numbers; Sp (sparsus) - "sparse-sporadic", the species is abundant, but does not form a continuous cover; Sol (solitarius) - "single plant", the species grows sparsely; Un (unicum) - there are only individual specimens of the species.

The quality of pasture vegetation was evaluated according to relevant methodologies and GOSTs by determining the content of crude nitrogen, crude fat, crude fiber, crude ash, carotene, Ca, P, and K.

Agrochemical analyses of plant and water samples were carried out in an accredited laboratory of Zhangir Khan University.

Data Analysis

The biometric and productive indicators of pastures were processed with one-way ANOVA, which was sufficient to uncover significant differences between the experimental variants.

Changes in average values were visualized using graphs on a Cartesian coordinate system. JASC® software was used for both ANOVA and plotting. The analysis of the experiment involved no other methods because of the use of one-way ANOVA.

Results

Current State of Vegetation Depending on Grazing Methods

Rotational pastures and field rotation are promising techniques in rational pasture management. Studies on the technology of simplified 10-year two-field pasture rotation on Artemisia lerchiana-Stipa pastures in the semi-arid zone of West Kazakhstan have yielded the following results.

The variants of studies conducted in the spring period over 2022-2024 differed by the number of plant species represented in the phytocenoses. A greater variety of species compared to other variants was found in the control variant, intensive grazing pastures. The grasses of the control variant included 20 species in spring. However, the intensive grazing pastures were populated mainly by rarely eaten worthless plants. Fields 1 and 2 under rotational grazing were inhabited by 15 and 16 plant species, respectively.

An important indicator that defines the sustainability of pasture ecosystems is projective coverage, which refers to the relative area of the projection of individual species or their groups, layers, etc. in a phytocoenosis on the soil surface. Projective coverage is a primary indicator of abundance in phytocenology.

In spring, projective coverage on the rotational pastures of fields 1 and 2 reached 76 and 79%, respectively, while the control variant under intensive grazing had a much lower coverage of 39%.

As grass height and species diversity increased in the summer, the projective coverage of pastures began to grow.

The studies show that on average, over the 2022-2024 period, the projective coverage of rotational pastures on fields `1 and 2 in the summer increased compared to spring coverage and reached 80 and 85%, respectively. However, the number of plant species found in the phytocenoses of these two variants dropped to 10. This result is explained by the fact that ephemeral and ephemeroid plants, which make up a large share of grasses in the spring, finish their life cycle by the summer, hence most of them disappear from herbage.

Projective coverage in the intensive grazing pastures of the control variant amounted to 45%, which is 6% higher than that observed in the spring periods of 2022-2024. Similar to rotational pastures, the indicator of plant species diversity for this variant also indicates that a few species have left the herbage, leaving a total of 17 species.

In the fall period, the quantitative and qualitative parameters of vegetation cover on forage lands have also been found to depend on the intensity of their use. Thus, under intensive grazing in the control variant, total projective coverage by grasses was 27%. Decreased load on the pastures of fields 1 and 2 due to rotational grazing resulted in a projective coverage of 68-72% in the same season.

Notably, the number of species growing on the pastures in fall was relatively the same in all experimental variants, ranging between 10 and 12. However, the ratio of different economic-botanical groups differed across the variants depending on grazing intensity. In control pastures under intensive grazing, the share of valuable fodder plants in the total projective coverage was only 4%, whereas decreased load on rotational fields promoted an increase in the share of valuable plants favored by livestock to 47-52% of the herbage.

To summarize, over the three years of research and continuous grazing, we observed the following differences between the two rotational grazing variants from the control in projective coverage: spring coverage was greater by an average of 37% in "Rotational grazing - field 1" and by 40% in "Rotational grazing - field 2"; summer coverage was greater by 35% in "Rotational grazing - field 1" and by 40% in "Rotational grazing - field 2"; fall coverage was higher by 41% in "Rotational grazing - field 1" and by 45% in "Rotational grazing - field 2".

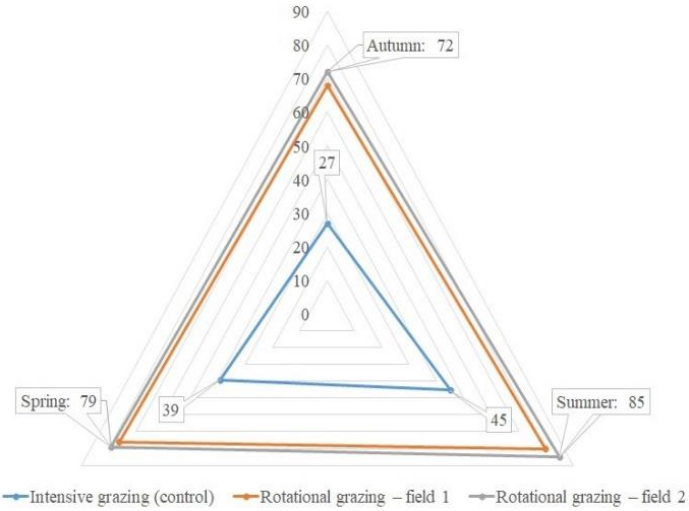

Fig. 1: Projective coverage depending on the grazing method

Fig. 1 illustrates the positive influence of rotational grazing methods on the projective coverage of pastures. Both rotational grazing variants demonstrate statistically significant differences in mean values from the control at a significance level of $p<0.001$.

The height and yield of herbage are important factors describing the condition of pastures.

In the spring period, the control variant, pastures under intensive grazing, had the shortest grass reaching only 19.00 cm. On the rotational field 1, the herbage was 8.2 cm higher. Finally, the highest grasses, measuring 31.40 cm, were observed on field 2 pastures under rotational grazing.

Studies conducted in the summer also demonstrate that decreased load on the pastures of fields 1 and 2 had a positive impact on the height of pasture herbage. Compared to control, the height of grasses on rotational grazing pastures (fields 1 and 2) was 41.86 and 59.30% greater, reaching 30.50 and 34.25 cm, respectively.

The same dependence of plant height on the grazing method was observed in the fall. The shortest herbage measuring 14.20 cm was found on the control pastures under intensive grazing. In contrast, the grasses on field 1 rotational pastures measured 7.20 cm higher. The greatest plant height of 25.70 cm was observed on the rotational pastures of field 2.

The positive influence of grazing methods on grass height is illustrated in Fig. 2. Over the three studied years of continuous grazing, the two rotational grazing variants demonstrated the following differences from the control in terms of plant height: in spring, an average increment of 8.2 cm in "Rotational grazing - field 1" and 12.4 cm in "Rotational grazing - field 2"; in summer, an average increment of 9 cm in "Rotational grazing - field 1" and 12.75 cm in "Rotational grazing - field 2; in fall, an average increment of 7.2 cm in "Rotational grazing - field 1" and 11.5 cm in "Rotational grazing - field 2". The differences in mean values for this season are statistically significant for both rotational grazing options at $p<0.001$.

Finally, the most important quality indicator of pastures, green mass yield, was also found to depend on the intensity of their use. The lowest spring yield of green mass across the experimental variants, which amounted to 0.30 t/ha, was recorded in the control variant with intensive grazing. In turn, the lower load on rotational pastures on fields 1 and 2 resulted in greater yields - 0.28 and 0.38 t/ha, respectively.

The yield of green mass over the summer period in the control variant was 0.35 t/ha. The decrease in load on the pastures of fields 1 and 2 had a positive effect on green mass yield, leading the two variants to outperform the control by 0.25 and 0.40 t/ha, respectively.

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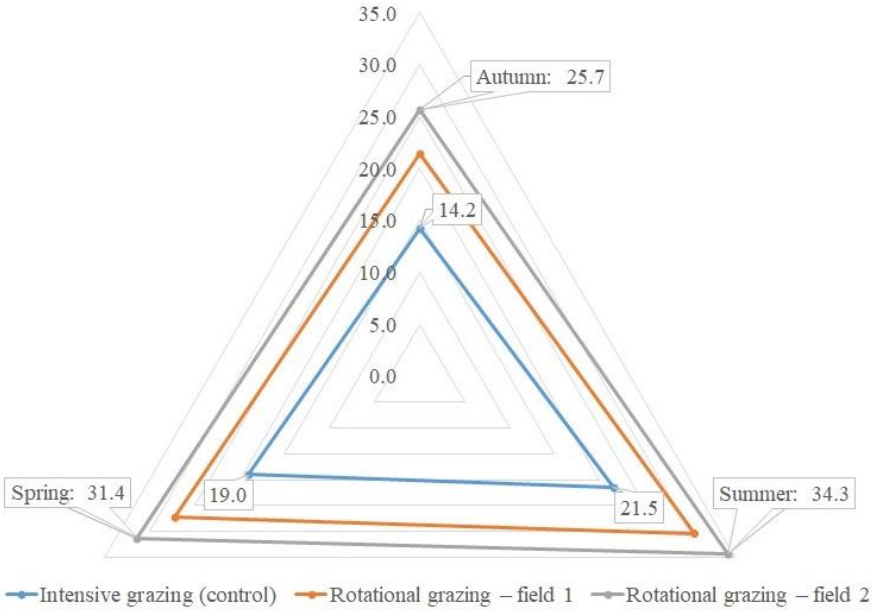

Fig. 2: Grass height depending on the grazing method

Fall yields of green mass also showed a dependence on the grazing method. The yield obtained in the control variant of intensive grazing was quite low at 0.10 t/ha. In contrast, the green mass yields achieved by rotational pastures on fields 1 and 2 averaged 0.30 and 0.37 t/ha, respectively.

The analysis demonstrates the positive impact of grazing methods on the yields of green mass obtained from pastures. Over the three years of study with continuous grazing, the two alternative grazing variants demonstrated the following differences from the control: in spring, the yields were greater by an average of 0.280 t/ha in "Rotational grazing - field 1" and 0.384 t/ha in "Rotational grazing - field 2"; in summer, there was an average increment of 0.250 t/ha in "Rotational grazing - field 1" and 0.400 t/ha in "Rotational grazing - field 2"; in fall, the control variant was outperformed by 0.190 t/ha by "Rotational grazing - field 1" and 0.269 t/ha by "Rotational grazing - field 2". The above differences are statistically significant for both rotational grazing variants at $p<0.001$ (Fig. 3).

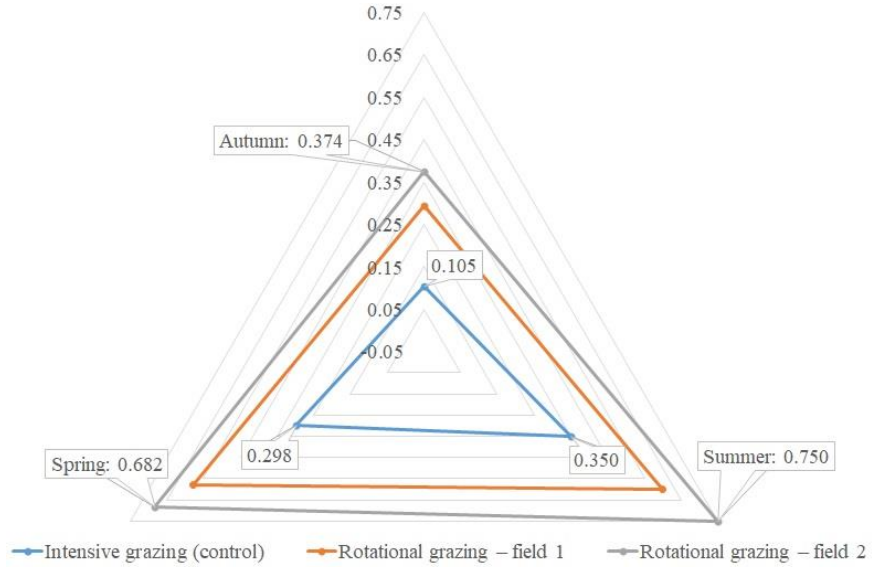

Fig. 3: Pasture yields depending on the grazing method

Pasture management is one of the most influential factors in feed production and nutritional value. Studies suggest that if residue height is too low, the share of plant leaves and the consumption of feed by animals decrease, while the growing season of plants extends [30, 31].

Our results indicate that the fodder and energy-protein value of pasture grass feed is contingent on the grazing method. The 2022-2024 studies found that the yield of grass fodder units in the summer from rotational pastures averaged 0.110.15 t/ha (Table 2).

Table 2: Indicators of fodder and energy-protein value of pastures in the semi-desert zone of West Kazakhstan depending on the grazing method, 2022-2024 averages

	Fodder unit yield, t/ha	Digestible protein yield, t/ha	Metabolizable energy output, GJ/ha
Intensive grazing (control)	0.05	0.003	0.80
Rotational grazing - field 1	0.11	0.01	1.54
Rotational grazing - field 2	0.15	0.02	2.03
T-test	**	**	**

T-test of significance: ** - p<0.001

Under increased load due to intensive grazing, the productivity of the pasture phytocoenosis in terms of fodder unit yield drops to 0.05 t/ha.

In terms of digestible protein yield, the productivity of pasture herbage on rotational fields amounts to 0.01 and 0.02 t/ha, respectively. The content of digestible protein per fodder unit reaches 106-109 g.

The variant of intensive grazing shows a lower output of digestible protein per 1 ha compared to other variants (0.003 t/ha). In this case, the content of digestible protein per fodder unit is only 59 g.

The output of metabolizable energy in the experimental grazing variants falls in the range of 0.80-2.03 GJ/ha. In terms of energy value, rotational grazing on semi-arid pastures proves to be more favorable. Intensive grazing produces 0.74-1.23 GJ/ha, or 48.05-60.59%, less metabolizable energy than the rotational grazing variants.

The statistical analysis demonstrates the positive influence of grazing methods on the yields of fodder units, digestible protein, and metabolizable energy. Over the three years of our research with continuous grazing, in terms of these performance indicators, the "Rotational grazing - field 1" variant outperformed the control variant by 0.058 t/ha. The "Rotational grazing - field 2" variant shows a significant difference from the control at p<0.001.

Therefore, to improve the indicators of vegetation cover, fodder productivity, and energy-protein value of pasture phytocoenoses in the semi-arid zone of West Kazakhstan, it is advisable to use rotational grazing as the best technique for sustainable pasture management.

Field Productivity Depending on the Grazing Methods

Intensive pasture use with unregulated livestock grazing was found to decrease the productivity of vegetation cover [32]. These conclusions are consistent with our results indicating that intensive grazing results in lower herbage yields on pastures in the semi-arid zone of West Kazakhstan [33].

Previous studies further suggest that herbage height kept at 20-30 cm contributes to livestock productivity on the pasture. Intensive grazing, on the other hand, increases livestock productivity in the area but has a negative effect on the parameters of pasture herbage, the individual characteristics of livestock, and the quality of the carcass [34-37].

Research on the influence of grazing methods on the condition of herbage demonstrates that the negative dynamic impact of livestock grazing on grass yields tends to become more noticeable as the load on pastures increases with the intensification of grazing [38-40]. Our studies reveal a decrease in the productivity of pastures from 0.75 to 0.35 t/ha, or by 53.33%, on pastures under intensive grazing (control) compared to rotational grazing.

Our studies also show an association between yields and the height of pasture grasses, which is consistent with prior research. Comasseto et al. established an inverse relationship between pasture yields and grass height, which is both linear and non-linear [41].

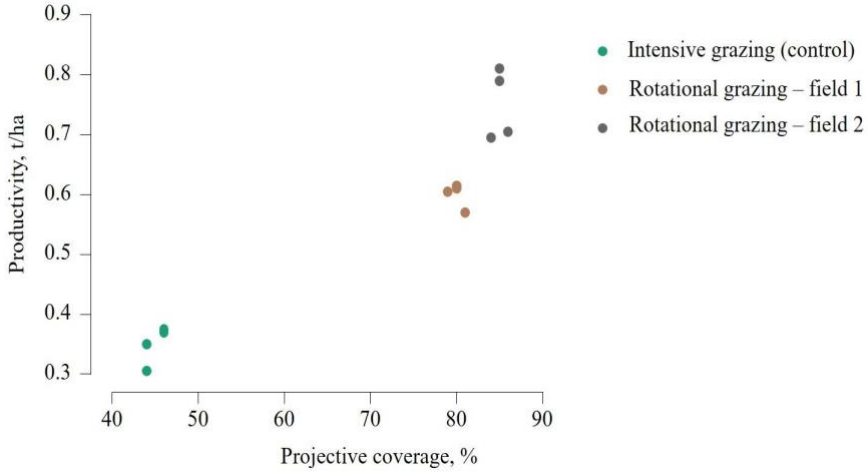

Fig. 4: Dependence of field productivity on projective coverage

The scatter plot in Fig. 4 demonstrates that yields show a positive dependence on the projective coverage of plants. Applying a linear regression model to the data, we obtained an equation Yield = -0.060+0.009* Coverage. The determination coefficient of the resulting model is 89.0%. The model was built using all observations without grouping by grazing methods. In summary, the model is statistically significant at $p<0.001$ and yields from all fields increase by an average of 0.009 t/ha per 1% of projective coverage.

Intensive grazing was found to decrease the projective coverage of vegetation [42-43].

Discussion

The studies established a relationship between the projective coverage of plants and pasture yield. Under intensive grazing, the projective coverage of vegetation in the summer period decreased from 80-85 to 45% compared to the two rotational variants, and the yield of pastures also dropped from 0.60-0.75 to 0.35 t/ha, or by 41.7-53.3%. Similar results were also obtained by other researchers, who conclude that irrational pasture use and its intensity, such as excessive grazing, will accelerate the degradation of pastures and thus reduce the amount of above-ground biomass (pasture yield) and the quality of grasses [44-46].

Studies conducted in an alpine ecosystem in the Hol Municipality in southern Norway [47] in the conditions of high projective coverage of 80-89% report high pasture yields. Because of the fact that in the years of our study, 2022-2024, livestock grazing adhered to the developed pasture rotation system, as a result of projective coverage increasing to 80-85%, the yields of pastures were restored and reached higher levels - 0.65-0.70 t/ha.

The value of pastures lies in their productivity and nutritional quality. Pacheco et al. note that younger pastures have a higher plant height than pastures of the average age, which entails different nutritional values of different plant species [48]. Furthermore, these differences can increase further if pastures are in poor condition, which is supported by our findings [48]. In the studies, the quality of pasture fodder mass was better in the case of rotational pastures. Rotational pastures produced 54.5-66.7% more fodder units and 70.0-85.0% more digestible protein compared to the variant of intensive grazing. Bell et al. note an improvement in the energy value of pasture fodder with regulated grazing, which agrees with the results of our studies [49-51]. When rotational pastures 1 and 2 were used with different numbers of grazing livestock, the output of metabolizable energy was 0.44-1.23 GJ/ha, or 48.1-60.6%, higher compared to the control variant (intensive grazing).

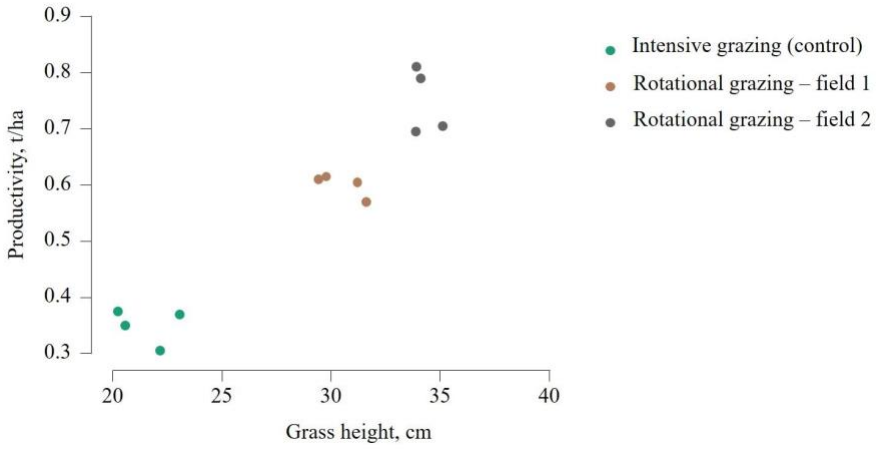

Fig. 5: Dependence of field productivity on grass height

The scatter plot in Fig. 5 shows that yields increase with the height of plants and yield levels show a dependence on the grazing method. Applying a linear regression model to the data, we obtained an equation Yield = -0.281+0.029* Height. The model was built using all observations without grouping by grazing variants. The coefficient of determination for the model is 90%. Overall, the model is statistically significant at $p<0.001$ and yields from all fields increase by an average of 0.029 t/ha per 1 cm of plant height.

Previous studies established the detrimental effect of intensive grazing on projective coverage, yield intensity, and species composition [52, 46]. The research shows that rotational grazing produces better vegetative covers over long periods of time, and this aligns with the study of Nasiyev et al. and Sadyrova et al., who highlighted the humus stock and soil quality retention advantages that are associated with implementing rotational grazing [53-54]. Although the results obtained are positive, more research is needed to ascertain the specific time rotational grazing goes into diminishing returns and the possible effects on farmers. A limitation faced in the study is the subsequent lack of conclusive information. The research focused largely on intensive and rotational grazing, and intensive rotational grazing was not highlighted. Future research should focus on comparative studies involving rotational, intensive, and intensive rotational grazing using similar metrics [55].

Our study shows that rotational grazing in West Kazakhstan was shown to dramatically improve pasture yields and feed quality relative to year-round grazing. In practical terms, the findings suggest that regimented pasture rotation can substantially boost livestock feed availability and nutrition. This aligns with the study of Akhylbekova et al. where local experiments reported that rotational regimes raised herbage height and increased biomass recovery (0.91 vs 0.77 t/ha) compared to unsystematic grazing [56]. These productivity gains directly translate into improved feed security, higher production of energy-protein forage per hectare, and more reliable livestock nutrition, which can stabilize animal weights and yields even in marginal semi-arid areas. At the same time, the richer vegetation under rotational grazing can buffer climate extremes by maintaining ground cover and carbon inputs [56]. Given the notable increase in drought frequency and intensity in Kazakhstan, maintaining dense grass cover through planned grazing is a climate-adaptation strategy that deserves further exploration [57].

However, despite these promising implications, our study has several limitations that caution against overgeneralizing. The trial was limited to three years at a single semi-desert site and did not include additional management factors such as forage supplementation, mechanization, or extreme weather effects. Thus, the responses we observed may differ in other ecological zones or under varying interannual climates. For example, small ruminants exert different grazing patterns than cattle, and recent large-scale analyses found these animals can have disproportionate impacts on steppe vegetation in other parts of Kazakhstan [58]. Future research should therefore test rotational grazing across multiple seasons, livestock species, and pasture types, as well as under drought or winter stress, to gauge its consistency and resilience. These studies could integrate soil moisture, forage quality, and carbon measurements to directly assess climate-related benefits of cover maintenance. Moreover, innovation within rotational schemes should be explored: for instance, alternating crop-fodder rotations or variable rest lengths might further boost productivity or diversify forage, as suggested by adaptive grazing models.

Our results reinforce the need for integrated planning by showing that unsystematic grazing caused many valuable forage species to vanish and weeds to proliferate, whereas rotational grazing maintained higher botanical diversity. Unchecked

intensive use also accelerates invasive shrubs at the expense of grasses, suggesting that rotational schemes should be paired with active management (such as reseeding native grasses) in restoration plans [22]. Future field studies could emulate this approach in West Kazakhstan, measuring not only yield but also ecosystem services like carbon sequestration, water retention, and habitat quality. For instance, integrating remote sensing (e.g., NDVI monitoring) or pasture modeling could help scale up our findings to the landscape level and optimize rest-grazing schedules. Key unanswered questions include whether rotational regimes can lower greenhouse-gas emissions per unit of livestock product or slow erosion rates issues with direct links to climate resilience. Overall, this study's findings have clear practical value for rangeland policy and land use. By demonstrating that rotation can bolster feed production while mitigating degradation, we provide evidence to support pasture management reforms. However, scaling up should be done carefully and systematically.

Conclusion

Based on the results, the research reflects the possibility of applying the practice of rotational grazing in the livestock development program. The rotation-based method of pasture use in the semi-desert zone of West Kazakhstan promoted an increase in the productivity of herbage to 0.58-0.68 t/ha in the spring, 0.60-0.75 t/ha in the summer, and 0.30-0.37 t/ha the in fall grazing seasons while ensuring optimal quality parameters and yields of nutrient mass that is valuable for livestock in terms of its energy-protein content: 0.11-0.15 t/ha of fodder units, 0.1-0.2 t/ha of digestible protein, and 1.54-2.03 GJ/ha of metabolizable energy.

The results are of great significance for policies in animal farming and ensuring food security and for programs for the sustainable management and rational use of pasture ecosystems in Kazakhstan.

The findings are topical and relevant for farmers who raise ruminants and produce meat and milk for food.

Finally, there is no doubt that the recommended techniques will secure a year-round shortage-free supply of complete feeds to provide sustainable ruminant diets and increase livestock productivity.

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Author's Contributions

Beybit Nasiyev: Designed the study and supervised the research; Peizhi Yang performed statistical analysis.

Azhar Latenova, Marat Ongayev, Nurbolat Zhanatalapov, and Askhat Bekkaliyev: Conducted field experiments.

Madiyar Khiyasov and Askhat Okshebayev: Handled sample analysis.

Aidyn Bekkaliyeva and Vladimir Shibaikin: Contributed to data validation.

Zhibek Nokusheva and Tursunay Vassilina: Assisted with the literature review.

Aigerim Khairush: Coordinated manuscript revision. All authors reviewed and approved the final version of the manuscript.

Ethics

This article is composed of original content and does not include any material previously published elsewhere.

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