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INFLUENCE OF GRAZING TECHNOLOGIES ON THE INDICES OF CHESTNUT SOILS IN WESTERN KAZAKHSTAN

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Abstract. Degradation of pastures caused by anthropogenic and climatic factors leads to desertification, loss of soil fertility, reduces productivity of the pasture grass and it is a prerequisite for socio-economic problems. Pastures of Western Kazakhstan cover more than 70% of the lands under economic use and are the main fodder source for the farm animals. In the late years, degradation of pastures in Western Kazakhstan takes place due to intensive animal grazing. The aim of research is to study the impact of technology for grazing the farm animals on the pastures soil cover to prevent the processes of degradation and desertification, as well as the rational use of pasture ecosystems. Through these studies, experimental data were obtained on the current state of the pastures soil cover in Western Kazakhstan with different types of chestnut soils depending on the grazing technology. An excess intensive grazing of the farm animals has negative influence on physical and chemical factors of the chestnut soil types.

Keywords: chestnut soils, indices, degradation, grazing, technologies

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INTRODUCTION

Global population growth (the world's population will be about 9.2 billion in 2050), global climate change and its adverse effects on agriculture, depletion of natural resources having essential importance for the global agriculture development, food safety and new ethical requirements for producers, are all future challenges related to the sustainable management of natural resources and investment in food production and agriculture (Scollan *et al.* 2002).

The grasslands, which are a major part of the global ecosystem, occupy 37% of the Earth's land area, contribute significantly to food security by providing most of the energy and proteins needed by ruminant animals to produce meat and dairy products. It is assumed that good pasture management and improvement of degraded pastures play a fundamental role in mitigating greenhouse gas emissions, especially with regard to carbon storage and absorption (Conant *et al.* 2011, O'Mara 2012, Nasiyev *et al.* 2015, Nordborg and Rööös 2016, Nasiyev and Bekkaliyev 2019).

Numerous scientific researches and developments of agricultural and biological research institutions show that in order to maintain the ability of pastures to continuously renew and reproduce the necessary level of feed resources, they must be used within the ecological imperative. The first ecological condition for the rational use of pastures is the compliance with the principle matching to their natural capacity and number of animals grazing on them. Long-term scientific studies conducted by the scientists from different countries in the second half of the 20th century show that without harming the subsequent productivity of pastures it is possible to withdraw from 25 to 75% of the above-ground vegetation mass in different natural zones. In arid conditions of Russia and Central Asia, it is possible to withdraw 60–75% of annual growth of plants (Weber and Horst 2011, Shamsutdinov 2012, Nasiyev *et al.* 2015, Nasiyev 2016). One of the important conditions for restoration and conservation of pasture biodiversity is grazing management and ecological optimization of the pasture load, which will also increase the pasture productivity, environmental sustainability and economic efficiency (Costas *et al.* 2015, Loris *et al.* 2019).

Among the agrotechnical methods for increasing the pasture productivity the paramount importance is provision of recovery period to medium and highly degraded pasture areas from livestock grazing. Recovery of even a year period, will give the pastures an opportunity to significantly restore the thinned out grass cover (Loris *et al.* 2019). Researches of scientists from the USA and China established decrease in productivity and condition of vegetation at heavy grazed pastures (Manley 1997, Holechek 1999, Gasanov 2006). To improve this condition and rational use, the priority task is to monitor the current state of soils and vegetation cover of grazing lands.

Application of the results of these studies will contribute to the achievement of three results of not only national but also of global importance, as they are derived from three international environmental conventions, namely: halting the spread of deserts (Convention to Combat Desertification), maintaining biodiversity due to habitat restoration and expansion (Convention on Biological Diversity) and carbon sequestration (Convention on Climate Change).

MATERIALS AND METHODS

Study area

The studies were conducted in 3 edaphic-climatic zones of Western Kazakhstan (Fig. 1).

Zone 1 – dry-steppe zone, coordinates of the reference area and grazing land: reference site 49°01'N; 018°27'103"E. Moderate grazing land 50°57'N; 050°46'390"E. Weak grazing land 50°57'N; 050°48'049"E. Intensive grazing land 50°59'N; 050°47'223"E.

Zone 2 – dry-steppe zone, coordinates of the reference area and grazing land: reference site 50°21'N; 051°00'073"E. Moderate grazing land 50°19'N; 050°58'091"E. Weak grazing land 50°19'N; 050°57'064"E. Intensive grazing land 50°20'N; 050°53'225"E.

Zone 3 – coordinates of the reference area and grazing land in semi-desert: reference site 49°05'N; 049°08'101"E. Moderate grazing land 49°08'N; 048°42'751"E. Weak grazing land 49°09'N; 048°42'452"E. Intensive grazing land 49°08'N; 048°41'017"E.

Soil sampling

In order to determine the influence of grazing on the indices, soil samples were taken from 3 farms with pastures of moderate, weak and intensive grazing, located in 3 zones of Western Kazakhstan with dark chestnut (Haplic Kastanozems), chestnut (Luvic Kastanozems) and light chestnut (Calcic Kastanozems) types of soil from the layer of 0–10 cm, 10–20 cm and 20–30 cm, respectively. In addition, to identify changes in soil parameters by comparison in each zone, soil samples were taken from the reference sites (no grazing, control) from the layer of 0–10 cm, 10–20 cm and 20–30 cm. Sampling procedure is 4-fold frequency.



Fig. 1. Location of the study sites

Physical and chemical soil analyses

Soil cover research was carried out on pasture by sampling and determination of physicochemical parameters in agrochemical laboratories. Soil samples were analyzed according to generally accepted methods: Soil density – according to the Kachinskii method. The essence of the method is the use of sample-cylinders developed by Kachinsky to determine density. In field conditions, samples were taken from soil horizon by a sample-cylinder with the capacity of about 500 cm³. At the same time, soil samples were collected into the sample bottle to determine humidity. During laboratory-chamber period soil was dried at 105°C to constant weight. Knowing the mass of sample bottle with dried soil and the mass of empty one, the mass of air-dry soil was found. Then, by dividing the dry soil mass by its volume (ring volume), soil density was obtained (Gabdulov *et al.* 2015).

Soil moisture was estimated by the weight method; assessment of the structural condition of chestnut soil types of pastures was carried out according to the main factors of aggregation analysis: content of agronomically valuable separation at dry sifting, evaluated according to the criteria proposed by Dolgov and Bakhtin, as well as the structural coefficient. The results of aggregate analysis were used to calculate a structural factor, which means ratio of the number of aggregates from 0.25 to 10 mm (in %) to the total content of aggregates less than 0.25 and more than 10 mm (in %). The larger structural factor, the better soil structure. The scale developed by Dolgov and Bakhtin is used to assess the structural state of soils (Gabdulov *et al.* 2015).

The humus content was measured by Tyurin's method in modification by the Central Institute for Agrochemical Surveys (TsINAO) (GOST (State Standard) 26213-91). The method is based on the oxidation of soil organic matter with chromic acid to carbon dioxide formation. The amount of oxygen consumed for organic carbon oxidation was determined by the difference between the amount of chromic acid used for oxidation and the amount remaining unspent after oxidation. $K_2Cr_2O_7$ solution in the sulfuric acid which was previously diluted with water in the ratio was applied as an oxidizer. The supply of humus in individual genetic horizons or soil profile in general makes it possible to judge the potential fertility and energy reserves caused by organic matter. In addition to the percentage of the component to be determined and the capacity of the layer for which the reserves were calculated, soil horizon density data was needed. Density was determined simultaneously with taking soil samples. Reserves of humus and nitrogen in the soil layer are calculated in t/ha according to the following formula: $Q = m \cdot h \cdot d_v$, where Q means reserves of humus or nitrogen (t/ha) for soil layer h ; m – content of the determined component, %; h – soil layer capacity (cm); d_v – soil layer density, g/cm³ (Mamontov *et al.* 2012).

The mobile phosphorus (P_2O_5) content was measured according to Machigin's method in modification by the TsINAO (GOST 26205-91). The method is based on extraction of mobile phosphorus compounds from soil with the ammonium carbonate solution with the concentration of 10 g/dm³ at soil/solution ratio of 1:20 and subsequent determination of phosphorus in the form of blue phosphorus-molybdenum complex on a photoelectric colorimeter and potassium on a flame photometer (Mamontov *et al.* 2012).

The contents of exchangeable sodium was estimated using the GOST (State Standard) 26950-86. The essence of method is the extraction of exchanged and soluble sodium with ammonium acetic acid solution with the concentration of 1 mole/dm³ at the ratio of soil sample weight and solution volume 1:20 and further determination of sodium in extract on a flame photometer. At the same time, soluble sodium in water extract was determined and exchange was calculated on the basis of the difference (Mamontov *et al.* 2012).

The soil salinity factor was determined by the accepted method (Reference Book 1981), whereas the soil cover degradation factor was determined on the basis of physical criteria of the land assessment (Order 2017).

Studying the vegetation cover of pastures

In order to study the vegetation of pastures in the studied areas, the transects of 100×50 m in size were established, where the species composition of grasslands, projective coverage and yield were determined.

Grazing technology options

The research has focused heavily on the impact of grazing farm animals on the annual growth in plant mass of area typical pastures. Pastures with 3 grazing technologies are studied: weak grazing – alienation of 30–40% of annual growth of pasture plants; moderate grazing – alienation of 65–75% of annual growth of pasture plants; intensive grazing – alienation of 100% of annual growth of pasture plants. The reference sites (no grazing) serve as a control sample. Pasturing of the phytocenoses was carried out within all terms of use: spring, summer and autumn.

Statistical analyses

Statistical processing of the study results was carried out by the method of dispersion analysis (Dospekhov 1985) and non-parametric Mann–Whitney U-test, using the program Statistica 6.0. Statistically, the box plot graphs were constructed for each soil species separately, then these graphs were combined into one figure.

RESULTS AND DISCUSSION

Agrochemical factors of pastures: Dynamics of decrease in the humus content

Study of the content and reserves of humus on pastures in Western Kazakhstan is a necessary condition for the assessment of their fertility, as well as for finding the solution to the problem of rational use of pasture ecosystems. The content and reserves of humus depended on the degree of load of farm animals on the soil of pastures. At the same time, more dynamic changes in humus content have been detected on light chestnut soils of the pastures of the third semi-desert zone with arid climate with the use of intensive grazing technology. On the pasture of moderate grazing the humus content in the layer of 0–30 cm

decreased by 0.15% in comparison with the reference site (Fig. 2). The stock of humus is 44.16 t/ha, which is 7.19% less than in the reference site. The content of humus on pastures with weak grazing and light chestnut soils is 1.25%, while the stock of humus is 46.50 t/ha. In semi-desert zone 3, the lowest humus content is established on pastures with intensive grazing. With the humus content at the level of 0.83%, the stock of humus in the layer of 0–30 cm is 34.36 t/ha. Compared to the reference site, the decrease in the stock of humus is at the level of 27.78%. As the grazing has a significant impact on the number of ecosystem services (e.g., nutrients retention, water storage, pollution abatement), its reduction may lead to decrease in soil fertility and, consequently, the land degradation (Rounsevell *et al.* 1999, Nasiyev and Bekkaliyev 2019). According to our hypotheses, the strong change in the humus content and reserves in pastures of semi-desert zone 3 is the result of the effects from excessive loads by agricultural animals on arid climate background (Nasiyev *et al.* 2015).

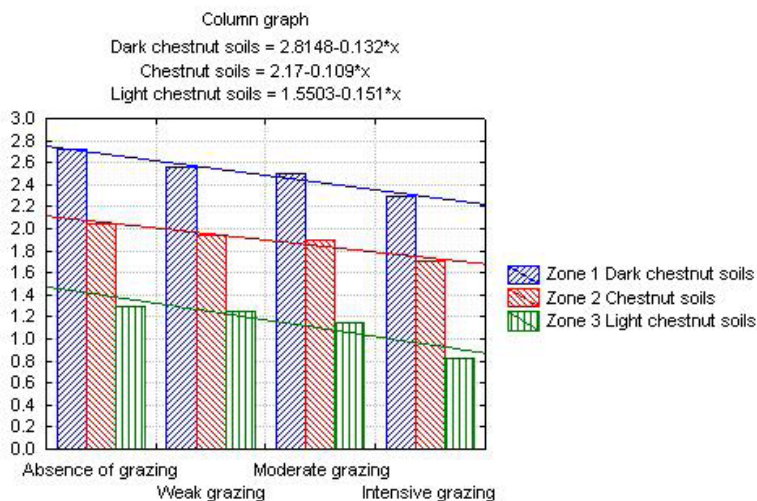


Fig. 2. Humus content of chestnut soil types in pastures of Western Kazakhstan depending on grazing technology

On dark chestnut and chestnut soils of pastures 1 and 2 zones with weak and moderate grazing, the content of humus in comparison with reference sites (no grazing, control) has decreased not significantly from 0.11 to 0.22%, and decrease in humus stock in the layer of 0–30 cm is at level of 4.59–6.67%. With a certain degree of conventionality, it is possible to assume that the humus in soils of these zones has been preserved under the influence of pasture use, accompanied by a decrease in the inflow of living and dead plant material into the soil. It should be taken into account that there is no oxidation of soil organic matter on pastures, i.e. there is no phenomenon leading to dehumification

of arable land due to its annual plowing; neither the humus is spent here on the formation of plant biomass, which changes its species composition and productivity under the influence of failure (Tesla 2006). In the light chestnut soils, when intensive grazing is used, the content (from 0.35 to 0.42%) and the stock of humus (from 10.88 to 12.35%) decreases. The same can be observed in case of chestnut and dark chestnut soils. Therefore, the soil is degraded to the first degree by the index of humus reserve.

Statistical analysis data confirm the dependence of humus content upon the intensity of pasture use. The intensity of humus content change is determined by the type of soil and has a negative tendency. This trend is described by the linear regression equation. The largest decrease in the percentage of humus content at the increase of grazing intensity is noted in case of light chestnut soils in semi-desert zone 3.

Mobile phosphorus and sodium exchange content

In chestnut soil types, one of the limiting elements of soil fertility is the content of phosphorus (Futa *et al.* 2016, Nasiyev and Bekkaliyev 2019). In this regard, the mobile phosphorus content in chestnut soils is of great importance for agricultural use. As research data show, the farm animals grazing modes insignificantly change the content of mobile phosphorus in the chestnut soil types of zone 3 in Western Kazakhstan (Table 1). In the zone of dark chestnut soils, the decrease in the content of mobile phosphorus in the technologies of weak, moderate and intensive grazing compared to the area of no grazing (control) was 0.23–0.59 mg/100g⁻¹. In case of chestnut soils of pastures in zone 2, the change of mobile phosphorus content from the control level is 0.43–0.69 mg/100 g⁻¹. In the third zone in the light chestnut soils of pastures, the content of mobile phosphorus in the technologies of weak, moderate and intensive grazing decreased in comparison with the area of no grazing (control) by 0.10–0.41 mg/100g⁻¹.

The conducted U-test showed the influence of grazing technology factor on the response of the effective factor of mobile phosphorus content. Statistical U-test showed the materiality of the influence of grazing technologies, across all soil categories, on the content of mobile phosphorus content. Influence materiality is tested at p-level significance level < 0.05. An exception is the technology of moderate grazing for zone 3. On the basis of this factor, it can be concluded that all technologies for zones 1, 2, 3 have a significant impact on the content of mobile phosphorus. The quantitative concept of this influence is determined by the difference between the median of corresponding technology and technology of grazing absence.

In case of dark chestnut soils of zone 1, the difference in median value of mobile phosphorus in case of technology of weak grazing, in comparison with technology of grazing absence, was 0.24 mg/100 g⁻¹, in case of the technology

of moderate grazing, the difference was 0.41 mg/100 g⁻¹, and at intensive grazing – 0.61 mg/100 g⁻¹. For the chestnut soils of zone 2, the difference of mobile phosphorus content in median value from the technology of grazing absence, in case of weak grazing technology was 0.45 mg/100 g⁻¹, in case of technology of moderate grazing – 0.61 mg/100 g⁻¹, and in case of intensive grazing technology – 0.69 mg/100 g⁻¹. For light chestnut soils of zone 3, the response to grazing technology was accordingly: 0.1 mg/100 g⁻¹ (weak grazing) and 0.41 mg/100 g⁻¹ (intensive grazing). According to the significance level of *p*, the moderate grazing technology in this sampling does not cause a significant response for quantitative factor of mobile phosphorus content (*F*, mg/100 g⁻¹). Thus, it has been determined that the content of mobile phosphorus increases as grazing intensity decreases across all soil types.

Table 1. Content of mobile phosphorus in chestnut soil types on pastures in Western Kazakhstan depending on the grazing technology (soil layer of 0–30 cm)

Grazing technology	Zone 1 Dark chestnut soils		Zone 2 Chestnut soils		Zone 3 Light chestnut soils	
	Mobile phosphorus content, mg/100 g ⁻¹	Differ from control, mg/100 g ⁻¹	Mobile phosphorus content, mg/100 g ⁻¹	Differ from control, mg/100 g ⁻¹	Mobile phosphorus content, mg/100 g ⁻¹	Differ from control, mg/100 g ⁻¹
No grazing (control)	2.00±0.047	-	1.54±0.023	-	1.05±0.008	-
Weak grazing	1.77±0.016	-0.23	1.11±0.015	-0.43	0.95±0.009	-0.10
Moderate grazing	1.60±0.018	-0.40	0.94±0.009	-0.60	0.87±0.093	-0.18
Intensive grazing	1.41±0.030	-0.59	0.85±0.007	-0.69	0.64±0.004	-0.41

Deterioration of physical and chemical properties in turn leads to an increase in the content of sodium exchange in soil, which is an indicator of salinity and increase in the process of alkalinization of soils (Nasiyev *et al.* 2015). In case of chestnut soils of pastures in zone 2, the content of sodium exchange, depending on the grazing technology, has increased in comparison with control (reference) value from 0.08 to 0.32cmol/kg⁻¹(Table 2). In pasture soils, the content of sodium exchange rate ranges from 4.98 to 5.92% of the sum of exchange bases, which corresponds to the degree of weak salinity. In light chestnut soils of zone 3,with the sum of exchange bases at the level of 15.10–15.65 c_{mol}/kg⁻¹,the content of sodium exchange rate was 1.41–1.65 c_{mol}/kg⁻¹or 9.33–10.54% of the cation exchange capacity. The pasture soils of weak and moderate grazing in terms of sodium exchange rate belong to weak saline soils, and for intensive grazing – to medium saline soils. In case of dark chestnut soils, the content of sodium exchange depending on the grazing technology was

at the level of 0.36–0.61 $c_{\text{mol}}/\text{kg}^{-1}$ or 1.71–2.77% of the sum of exchange bases. In terms of sodium exchange content, the dark chestnut soils of pastures in zone 1 are non-saline soils.

Table 2. Sodium exchange content in chestnut soil types on pastures of Western Kazakhstan depending on the grazing technology (soil layer of 0–30 cm)

Grazing technology	Zone 1 Dark chestnut soils		Zone 2 Chestnut soils		Zone 3 Light chestnut soils	
	Exchange sodium content, $c_{\text{mol}}/\text{kg}^{-1}$	Differ from control, $c_{\text{mol}}/\text{kg}^{-1}$	Exchange sodium content, $c_{\text{mol}}/\text{kg}^{-1}$	Differ from control, $c_{\text{mol}}/\text{kg}^{-1}$	Exchange sodium content, $c_{\text{mol}}/\text{kg}^{-1}$	Differ from control, $c_{\text{mol}}/\text{kg}^{-1}$
No grazing (control)	0.29±0.011	-	0.92±0.014	-	1.30±0.010	-
Weak grazing	0.36±0.005	+0.07	1.00±0.015	+0.08	1.41±0.004	+0.11
Moderate grazing	0.57±0.007	+0.28	1.20±0.013	+0.28	1.50±0.015	+0.20
Intensive grazing	0.61±0.015	+0.32	1.24±0.012	+0.32	1.65±0.015	+0.35

The U-test analysis showed that all grazing technologies for zones 1, 2, 3 have a significant impact on the content of sodium exchange. Technology in this sampling causes a significant response to the quantitative factor of sodium exchange content. The quantitative concept of this influence is determined by the difference between the median of corresponding technology and technology of grazing absence.

According to the grazing technology for dark chestnut soils of zone 1, the difference in the median level of sodium exchange in case of the weak grazing technology, in comparison with grazing-free technology, is 0.09 $c_{\text{mol}}/\text{kg}^{-1}$, in case of technology of moderate grazing, the difference is 0.29 $c_{\text{mol}}/\text{kg}^{-1}$, and in case of intensive grazing – 0.33 $c_{\text{mol}}/\text{kg}^{-1}$.

For chestnut soils, there is a difference in the median sodium level from the grazing-free technology, for weak grazing technology – 0.09 $c_{\text{mol}}/\text{kg}^{-1}$, for moderate grazing – 0.29 $c_{\text{mol}}/\text{kg}^{-1}$, and for intensive grazing technology – 0.33 $c_{\text{mol}}/\text{kg}^{-1}$.

For light chestnut soils of zone 3, the response to grazing technology was respectively: weak grazing – 0.10 $c_{\text{mol}}/\text{kg}^{-1}$, moderate grazing – 0.19 $c_{\text{mol}}/\text{kg}^{-1}$; and intensive grazing – 0.34 $c_{\text{mol}}/\text{kg}^{-1}$.

From the above written points, we have identified a pattern of increasing the deviation of median sodium level from the baseline level, depending on the intensity of use. We can conclude that the intensity of pasture use increases sodium content in all 3 soil types.

Agrophysical factors

The soil density and its structure are the most important factors of the soil fertility. They do not provide plants with any of the nutrients they need for their activity, but they can influence their growth and development. Therefore, the knowledge of the physical characteristics of soils and ability to regulate them are necessary for enhanced soil fertility (Ferrero 1991, Severson and Debanò 1991, Mohammad *et al.* 2005, Tesla 2006, Nasiyev and Bekkaliyev 2019). Assessment of the density and structural condition of the chestnut soils in Western Kazakhstan under the main indicators, depending on the grazing technology for the farm animals on pastures, showed their sensitivity to trampling. However, the physical properties of pastures in comparison with virgin lands changes insignificantly when decreasing the load of weak and moderate grazing, that can be explained first of all by the processes of grass restoration on pastures, and therefore, by the properties of the soil solid phase and stability of soil structure. Thus, for weak and moderate grass pasturing the deterioration of physical and chemical properties of pasture ecosystems occurs less dynamically than for intensive grazing (Sun and Liddle 1993, Tesla 2006). The analysis of dynamics of the structural and aggregate composition of dark chestnut, chestnut and light chestnut soils indicates a certain deterioration of soil structure under the influence of long-term pasture use and a distinctive tendency to recovery noted during the period of observations. In spite of some loss in the structure under the influence of weak and moderate grazing on pasture lands, as a result of vegetation restoration, the factors of agronomically valuable aggregates and structural coefficient were good (Table 3). In dark chestnut soils with weak and moderate grazing, the soil structure made up 63.83–71.20% with the structural coefficient of 1.80–2.48. In chestnut soils at application of weak grazing mode, the structure of soil was at the level of 65.57% with the structural coefficient of 2.73, at moderate grazing the structure of soil was at the level of 65.57% and the coefficient of 1.92. In case of moderate grazing, the structure of light-chestnut soils (67.50%) in comparison with the structure of the reference site soil (75.03%) decreased by 7.53%. Soil structural coefficient of this pasture area is 2.10. At moderate grazing the structural coefficient at pastures of light chestnut soils was 1.88, at that the soil structure was 64.41%, which is 10.62% less than the reference level. In all edaphic-climatic zones on pastures of weak and moderate grazing the state of soil structure is “good”.

Intensive grazing can change the soil structure (Cui *et al.* 2005). In all types of chestnut soils, the soil structure decreases to 53.06–60.57% with a structural coefficient of 1.22–1.50, the soil structure factors and structural coefficient correspond to “satisfactory” assessment.

Table 3. Content of agronomically valuable structural aggregates and the structural coefficient of chestnut soil types of pastures in Western Kazakhstan depending on the grazing technology (soil layer of 0–30 cm)

Grazing technology	Zone 1		Zone 2		Zone 3	
	Dark chestnut soils		Chestnut soils		Light chestnut soils	
	Content of agronomically valuable structural aggregates, %	Structure coefficient	Content of agronomically valuable structural aggregates, %	Structure coefficient	Content of agronomically valuable structural aggregates, %	Structure coefficient
No grazing (control)	77.10±1.30	3.41	76.00±1.09	3.19	75.03±0.43	3.15
Weak grazing	71.20±0.21	2.48	71.89±1.05	2.73	67.50±0.72	2.10
Moderate grazing	63.83 ±0.24	1.80	65.57 ±0.42	1.92	64.91 ±1.10	1.88
Intensive grazing	60.57 ±0.89	1.59	54.82 ±0.50	1.22	53.06 ±1.31	1.24

The conducted U-test showed the influence of grazing technology factor on the response of the effective factor of agronomically valuable structural aggregates. In p -value column of the table, the importance of the effective factor response for agronomically valuable structural aggregates depending on the technologies applied to soil zones, takes the value of $p < 0.05$. The exception is the technology of weak grazing for zone 2. On the basis of this indicator, it is possible to conclude that all technologies in zones 1, 2, 3 exercise a significant influence on the content of agronomically valuable structural aggregates. Quantitative concept of this influence is determined through the difference between the median on corresponding technology and technology of grazing absence.

For dark chestnut soils of zone 1, the difference in median value of structural aggregates at technology of weak grazing in comparison with grazing-free technology makes 5.6%, at moderate grazing technology the difference is 12.95% and intensive grazing – 16.89%. From the analysis of the table it can be seen that the intensity of use of pastures (grass), soils of zone 1, negatively affects the structural aggregates.

For chestnut soils of zone 2, the difference in median value from the technology of grazing absence, at the moderate grazing technology, is 10.46%, and intensive grazing technology is 21.2%. Weak grazing technology in this sampling does not cause a significant response from the quantitative indicator of the content of agronomically valuable structural aggregates.

For light chestnut soils of zone 3, the response to grazing technology was respectively: weak grazing – 7.53%; moderate grazing – 10.13%; intensive grazing – 21.97%. On the basis of Table 3, we can draw conclusions that graz-

ing intensity in pastures negatively affects the content of agronomically valuable structural aggregates of soil. As grazing intensity increases, the content of agronomically valuable structural aggregates decreases.

What is interesting is the study of dependence of soil structure upon various factors of the soil fertility (Rounsevell *et al.* 1999, Cui *et al.* 2005). The statistical analysis has shown a high degree of linear dependence of structural aggregates content upon humus reserves. In all types of chestnut soil, there is a high positive linear correlation of dependence of agronomically valuable structural aggregates upon the humus stock. Thus, the highest dependence of the structural aggregates content upon humus stocks with the change of technologies was shown by chestnut soils (Fig. 3).

It should be noted that the content of agronomically valuable structural aggregates and the structural coefficient are growing in direction from the pastures of intensive grazing to the reference sites. This can be explained by the following: the root system of pasture plants plays a major role in division of the soil into macrostructures (Tesla 2006). And it is quite understandable, given the strong root system of plants typical for these areas. In addition, it should be noted that the structural coefficient in virgin lands and areas of weak and moderate grazing in all subtypes of chestnut soils is high. Probably, it can be explained by the fact that in this case the soil had a less negative impact, it stayed at rest under some pressure for a longer period of time and such hydrodynamic conditions appeared in this layer under which more humus substances were formed perfectly impregnating the aggregates (Tesla 2006).

Thus, according to the content of agronomically valuable soil aggregates during dry sieving and with structural coefficient, the studied chestnut soil types under the pastures of weak and moderate grazing in the root layer are evaluated as “good”. The soil condition of intensive grazing areas under highly beaten associations is “satisfactory”.

Another fundamental property of the soil is its density. In contrast to the soil structure, which is a known regulator of the physical conditions in the soil (and affects the plants indirectly), the soil density has a direct influence on their life processes (Xie and Wittig 2004). Without knowledge of soil density, it is not possible to apply the quantitative analysis of the soils. Therefore, the soil density data for soil layers and horizons are necessary to create the complete soil profile characteristics (Nasiyev and Bekkaliyev 2019).

Excessive grazing can lead to soil degradation and loss of fertile topsoil, especially where rainfall is low and evaporation is high (Xie and Wittig 2004). This is confirmed by research data. In semi-arid zone 3 of the arid climate, the soil exposed to intensive grazing is degraded to the third level in terms of density, and the soil density in 0–30 cm layer is at the level of 1.38 g/cm³, or the level of compaction of light chestnut soil under the influence of grazing is 13.11% (Fig. 4). Such a high compaction of the soil leads to the creation of

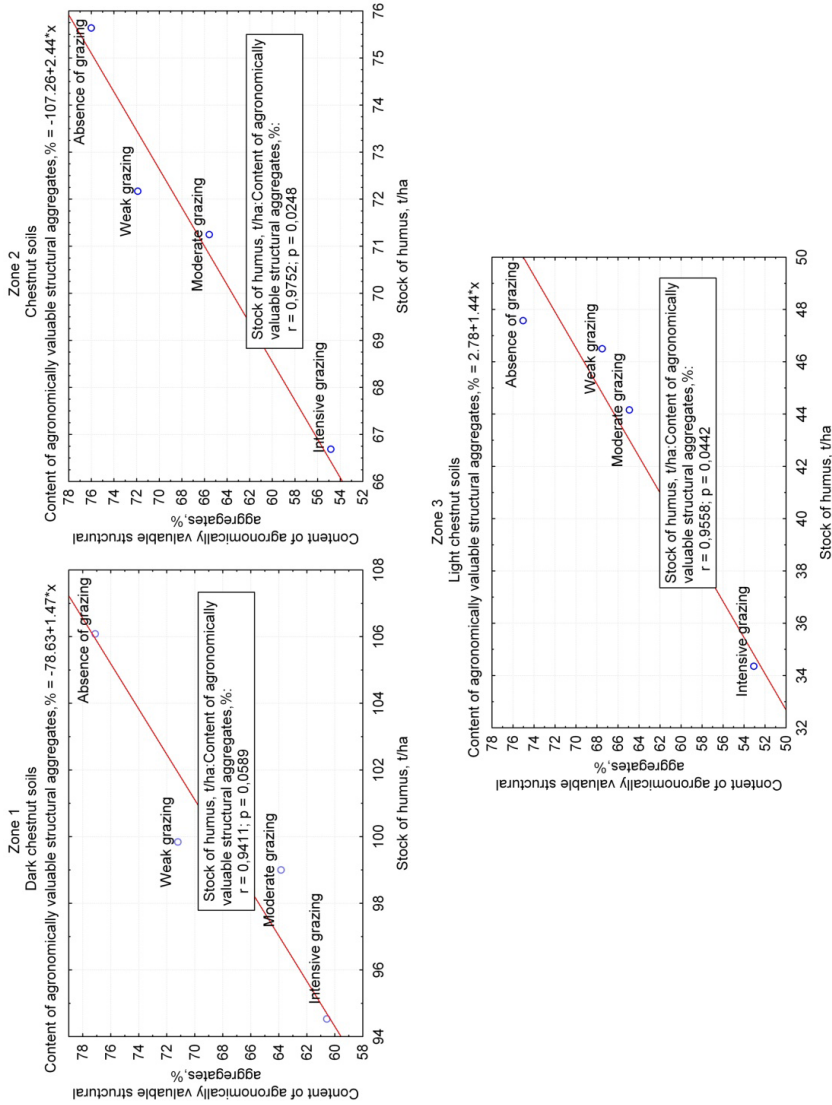


Fig. 3. Dependence of agronomically valuable structural aggregates content from the humus stock in chestnut soil of pastures in West Kazakhstan, according to grazing technologies with the soil layer of 0–30 cm.

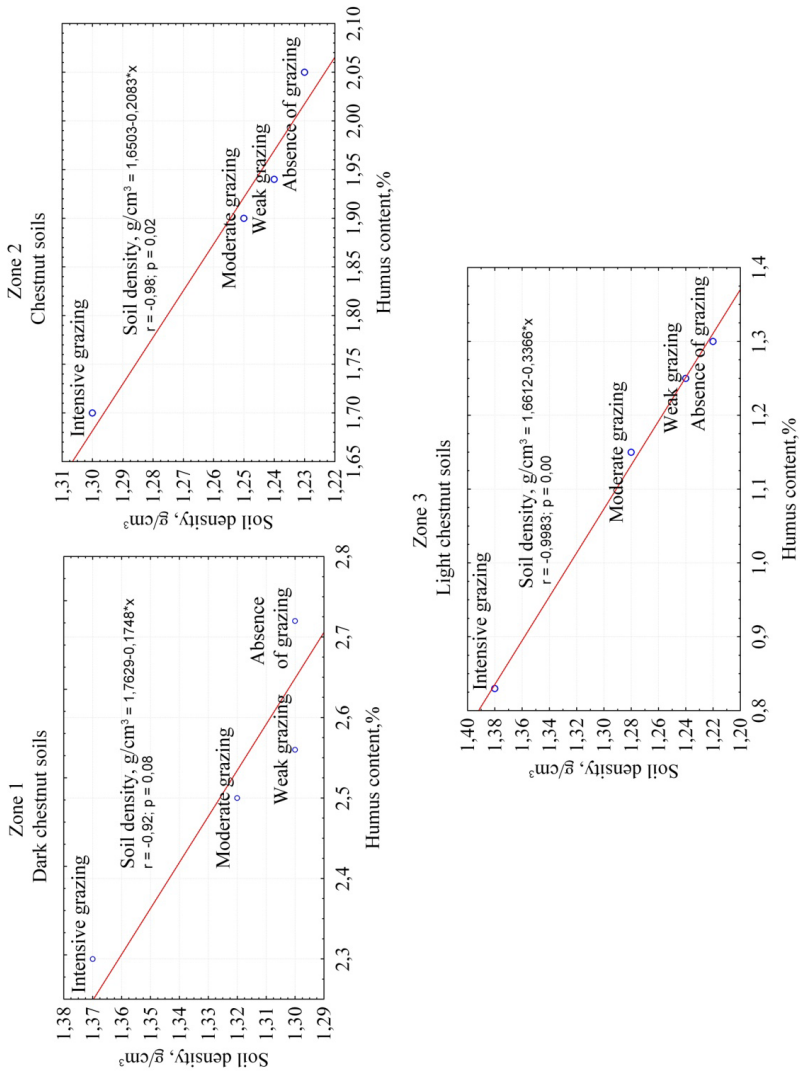


Fig. 4. Density of chestnut soil types in pastures of Western Kazakhstan depending on grazing technologies with the soil layer of 0–30 cm.

conditions close to anaerobic in the root layer and to changes in the structure of soil horizons (Trimble and Mendel 1995, Tesla 2006). The destructive effects of high grazing intensity on physical properties, especially soil density, have been reported by many researchers (Ferrero 1991, Severson and Debanò 1991, Sun and Liddle 1993).

In light chestnut soils of zone 3, the soil density of the reference site in the horizon of 0–30 cm is at the level of 1.22 g/cm³. In the management of pasture by the technology of weak grazing, the change of density in a layer of soil of 0–30 cm is insignificant up to 1.24 g/cm³ or compaction to 0.02 g/cm³. In case of moderate grazing, there is also a small compaction of the soil from 1.22 to 1.28 g/cm³ or by 4.91%.

The studies also revealed the compaction of chestnut and dark chestnut soils in zones 1 and 2 under the increased load on pastures. Thus, in 1 dry-steppe zone of dark chestnut soils exposed to intensive grazing the soil is compacted by 5.38% in comparison with the density of the reference site (from 1.30 to 1.37 g/cm³). In zone 2 of arid steppes of chestnut soils exposed to intensive technology of grazing the density of soil increases from 1.23 g/cm³ (standard) to 1.30 g/cm³ or by 5.69%. Soil of the mentioned zones is degraded to the first level in case of intensive grazing.

Varying of physical conditions is one of the factors in terms of conservation and maintenance of biodiversity, which is the most important environmental component of any ecosystem, including soil. Assessment of the parameters of linear regression allowed to make conclusions that light chestnut soils have the greatest tendency in compaction under the influence of grazing. Increase of the index at technology change is 0.052 g/cm³. It is the third level of degradation. In this regard, our study is highly relevant.

CONCLUSIONS

To sum up, chestnut soil types of pastures in Western Kazakhstan under the influence of grazing animals has been changed. Increased load on pastures by means of intensive grazing has a negative impact on the physical and chemical parameters of chestnut soil types. Soil exposed to excessive pasture degrades, and negative physical and chemical processes intensifying the process of salinization occur in the soil cover.

Processes of soil degradation are especially evident under intensive grazing against the background of arid climate in semi-desert zone 3 of light chestnut soils. Decrease in humus reserves by 27.78% is noted, which corresponds to the second level of degradation. When the load on pastures increases, the soil compacts by 13.11% or up to the third level of degradation, the content of agronomically valuable structural aggregates decreases by 21.97%, while the structural coeffi-

cient decreases to the “satisfactory” level. Processes of land cover degradation as a result of intensive grazing contributed to the reduction of vegetation cover of valuable pastures by 35% and reduction of grassland productivity by 72.10%.

Thus, it is important to take into account both climatic and soil conditions of the zone when making decisions on pasture management to address sustainability and biodiversity conservation, reduce greenhouse gas emissions and the mitigate climate change consequences. At the same time, it is rational to use the moderate grazing technology, with alienation of 65–75% of annual growth of pasture plants.

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