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

*Abstract.* Degradation of pastures caused by anthropogenic and climatic factors leads to desertification, loss of soil fertility, reduces productivity of the pasture grass and 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. Because of 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*

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 assumes, that good pasture management and improved of degraded pastures to play a fundamental role in mitigating greenhouse gas emissions, especially with regard to carbon storage and absorption (Conant *et al.* 2011, O'Mara 2012, Nordborg and Röös 2016).

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 commandment for the rational use of pastures is the compliance with principle matching to their natural capacity and number of animals grazing on them. Long-term scientific researches conducted by the scientists from different countries in the second half of XX century show that without prejudice to 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 (Baytkanov 2007, Gayevskaya and Krasnopolin 2006, Shamsutdinov 2012, Nasiyev et al. 2015, Nasiyev 2016).

One of the important levers for restoration and conservation of pasture biodiversity is grazing factor management and ecological optimization of the pasture load, which will also increase the pasture productivity, environmental sustainability and economic efficiency. According to Khaziakhmetov (2002), it is important to determine the load standards for pasture ecosystems.

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 (Kosolapov 2009). Researches of scientists from 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 global importance, as they are derived from three international environmental conventions, namely: halting the spread of deserts (Convention to Combat Desertification), conserving biodiversity due to habitat restoration and expansion (Convention on Biological Diversity) and carbon absorption (Convention on Climate Change).

MATERIALS AND METHODS

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

*1 zone* – Dry-steppe zone, coordinates of the reference area and grazing land: reference site *49001****′****N; 018027****′****103****″****E*. Moderate grazing land 5*0057****′****N; 050046****′****390****″****E*. Weak grazing land 50057***′****N*; *050048****′****049″E*. Intensive grazing land *50059****′****N; 050047****′****223****″****E.*

*2 zone* – Dry steppe zone, coordinates of the reference area and glazing land: reference site *50021****′****N; 051000****′****073E.* Moderate grazing land *50019****′****N; 050058****′****091****″****E.* Weak grazing land *50019****′****N; 050057****′****064****″****E.* Intensive grazing land *50020****′****N; 050053****′****225****″****E.*

*3 zone* – Coordinates of the reference area and grazing land in semi-desert: reference site *49005****′****N; 049008****′****101****″****E*. Moderate grazing land *49008****′****N; 048042****′****751****″****E*. Weak grazing land *49009****′****N; 048042****′****452****″****E*. Intensive grazing land *49008****′****N; 048041****′****017****″****E.*

*Soil sampling*. In order to determine the grazing influence 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 (K1), chestnut (K2) and light chestnut (K3) types of soil in the layer of 0-10 cm, 10-20 cm and 20-30 cm. In addition, to identify changes in soil parameters by comparison in each zone, soil samples were taken from the reference sites (grazing free) in the layer of 0-10 cm, 10-20 cm and 20-30 cm. Sampling procedure is 4-fold frequency.

*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 Kachinskii;

soil moisture - by 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 Dolgovoy and Bakhtin, structural coefficient;

the humus content, by Tyurin’s method in modification by the Central Institute for Agrochemical Surveys (TsINAO) (GOST (State Standard) 26213-91);

the salt composition of water extracts, according to GOST 264237-85;

the adsorption capacity and the contents of exchange-able cations, by the Pfeffer method;

the available phosphorus (Р2О5) content, according to Machigin’s method in modification by the TsINAO (GOST 26205-91).

The soil salinity factor was determined by the accepted method (Reference book 1981).

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 100x50 m in size were established, where the species composition of grasslands, projective coverage and yield were determined.

*Grazing technology options*. In the course of the studies, considerable attention was paid to the influence of alienation for annual growth of the surface mass during the grazing on zonally typical pastures. Pastures with 3 grazing technologies are studied: 1. Intensive grazing - alienation of 100% of annual growth of pasture plants (control); 2. moderate pasture - alienation of 65-75% of annual growth of pasture plants; 3. weak grazing - alienation of 30-40% of annual growth of pasture plants.

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), using the program Statistica 6.0. Statistical graphs and non-parametric analysis of 2 independent samples using Mann-Whitney U-test were conducted.

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 solution of the issues on rational use of pasture ecosystems. The content and reserves of humus depended on the technology of farm animals grazing. In this regard, more dynamic changes in humus content occurred in the pastures of arid climate 3 in semi-desert zones with light chestnut soils. 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 the reference. The content of humus on pastures with weak grazing 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. At humus content 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). According to our hypotheses, the strong change in 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).

On dark chestnut and chestnut soils of pastures 1 and 2 zones with the method of weak and moderate grazing, the content of humus in comparison with reference site soils has decreased not essentially from 0.11 to 0.22 %, and decrease in humus stock in the layer of soil 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, Grishina 1986). In the light chestnut soils when intensive grazing is used, the content (from 0.35-0.42%) and the stock of humus (from 10.88-12.35%) decreases, as well as in chestnut and dark chestnut soils. At that, the soil is degraded to the 1st degree by the index of humus reserve.

Statistical analysis data confirm the dependence of humus content from 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 on light chestnut soils in semi-desert zones 3.

*Movable phosphorus and sodium exchange content*. In chestnut soil types one of the limiting elements of soil fertility is the content of phosphorus (Rusanov 1995). 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 zones 3 in Western Kazakhstan (Table 1). In zone of dark chestnut soils the decrease in mobile phosphorus content compared to the control (reference) site was from 0.23 to 0.59 mg/100 g of soil. On chestnut soils of pastures in zones 2, the change of mobile phosphorus content from the control level is 0.43-0.69 mg/100 g of soil. In zone 3, the content of mobile phosphorus in light chestnut soils decreased from 0.10 to 0.41 mg/100g of soil in comparison with control site.

The conducted U-test showed the influence of grazing technology factor on the response of the effective factor of mobile phosphorus content. In *p-value* column of the table the importance of the effective factor (F) response from technologies by soil zones take the value of p <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.

On dark chestnut soils of zone 1 the difference in median value of mobile phosphorus at technology of weak grazing, in comparison with technology of grazing absence makes – 0.24 mg/100g, at technology of moderate grazing the difference makes – 0.41 mg/100g, and at intensive grazing – 0.61 mg/100g.

For the chestnut soils of zone 2, the difference of mobile phosphorus content in median value from the technology of grazing absence, at weak grazing technology was – 0.45 mg/100g, at technology of moderate grazing – 0.61 mg/100g, and at intensive grazing technology – 0.69 mg/100g

For light chestnut soils of zone 3, the response to grazing technology was accordingly: weak grazing - 0.1 mg/100g; intensive grazing -0.41 mg/100g. According to 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/100g).

Thus, it was established that the content of mobile phosphorus increases with the increase in the intensity of grazing on all types of soils except for the technology of moderate grazing in zone 3 of light chestnut soils.

The analysis of the normal distribution has shown that within the compared factors the sampling does not correspond to the normal distribution. There are only few values in the sampling and this is the reason why the distribution is not normal.

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.* 2016). On 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 0.32 cmol(equiv.)/kg. (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 15.10-15.65 cmol(equiv.)/kg the content of sodium exchange rate was 1.41-1.65 cmol(equiv.)/kg or 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.

On dark chestnut soils the content of sodium exchange depending on the grazing technology was at the level of 0.36-0.61 cmol(equiv.)/kg or 1.71-2.77% of the sum of exchange bases. In terms of sodium exchange content, the dark chestn cmol(equiv.)/kg ut soils of pastures in zone 1 are non-saline soils.

The conducted U-test showed the influence of grazing technology factor on the response of the effective factor of sodium exchange content. In *p-value* column of the table the importance of the effective factor response from technologies by soil zones take the value of p<05. Consequently, all 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 value of sodium exchange at the weak grazing technology in comparison with grazing-free technology is 0.09 cmol(equiv.)/kg, at technology of moderate grazing the difference will be 0.29 cmol(equiv.)/kg, and at intensive grazing - 0.33 cmol(equiv.)/kg.

For chestnut soils, there is a difference in the median value from the grazing-free technology, for weak grazing technology - 0.09 cmol(equiv.)/kg, moderate grazing - 0.29 cmol(equiv.)/kg, and for intensive grazing technology - 0.33 cmol(equiv.)/kg.

For light chestnut soils of zone 3, the response to grazing technology was respectively: weak grazing - 0.10 cmol(equiv.)/kg; moderate grazing - 0.19 cmol(equiv.)/kg; and intensive grazing - 0.34 cmol(equiv.)/kg.

Conducted tests have confirmed the available statistical regularity of increasing the sodium exchange rate, as the grazing intensity for all soil types increases.

*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 Debano 1991, Tesla 2006).

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 structure under the influence of weak and moderate grazing on pasturelands, 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 structural coefficient of 1.80-2.48. On chestnut soils at application of weak grazing mode the structure of soil was at the level of 65.57 % with structural coefficient of 2.73, at moderate grazing the structure of soil was at the level of 65.57 % and coefficient of 1.92. At the use 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.

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, take the value of p <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 on 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 will makes 12.95% and intensive grazing 16.89%.

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 the technology in this sampling does not cause a significant response from 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%.

Based on received results it is possible to conclude on presence of statistical regularity of decrease in the content of agronomically valuable structural aggregates in process of increase in intensity of grazing for all types of soil except for weak grazing technology in zone 2 of chestnut soils.

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

It should be noted that the content of agronomically valuable structural aggregates and 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 here the soil had less negative impact, stayed at rest under some pressure for a longer period of time and such hydrodynamic conditions appeared in this layer at 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, only indirectly affects the plants, the soil density has 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 necessarily accompany the complete soil profile characterics (Revut 1972).

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 of intensive grazing is degraded to the 3rd 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 conditions close to anaerobic in the root layer and 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 Debano 1991, Sun and Liddle 1993).

On 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 organization of pasture by 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. At 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 at 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 2 zone of arid steppes of chestnut soils at application of 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 1st level at intensive grazing.

Varying of physical conditions is one of the factors in 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. Level of degradation is 3. In this regard, our study is highly relevant.

CONCLUSIONS

Chestnut soil types of pastures in Western Kazakhstan under the influence of grazing animals were 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 of pastures under 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 technologies against the background of arid climate in semi-desert zone 3of light chestnut soils. Decrease in humus reserves by 27.78% is noted, which corresponds to the 2nd level of degradation. This is accompanied by the decrease in the content of humus in the layer of 0-30 cm by 0.47% and increase in the content of sodium exchange 26.92%. When the load on pastures increases, the soil compacts by 13.11% or up to 3 level of degradation, the content of agronomically valuable structural aggregates decreases by 21.97%, while the structural coefficient decreases until the assessment “satisfactory”. 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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Table 1. Content of mobile phosphorus in chestnut soil types on pastures in Western Kazakhstan depending on the grazing technology, in the soil layer of 0-30 cm.

|  |  |  |  |
| --- | --- | --- | --- |
| Grazing technology | 1 zoneDark chestnut soils (К1) | 2 zoneChestnut soils(К2) | 3 zoneLight chestnut soils (К3) |
| Mobile phosphorus content, mg/100g  | Differ from reference,mg/100g  | Mobile phosphorus content, mg/100g  | Differ from reference,mg/100g  | Mobile phosphorus content, mg/100g  | Differ from reference,mg/100g  |
| No grazing | 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 |

Table 2. Sodium exchange content in chestnut soil types on pastures of Western Kazakhstan depending on grazing technology, soil layer 0-30 cm

|  |  |  |  |
| --- | --- | --- | --- |
| Grazing technology | 1 zoneDark chestnut soils (К1) | 2 zoneChestnut soils(К2) | 3 zoneLight chestnut soils (К3) |
| Exchange sodium content, cmol (equiv.)/kg | Differ from reference, cmol (equiv.)/kg | Exchange sodium content, cmol (equiv.)/kg | Differ from reference, cmol (equiv.)/kg |  Exchange sodium content, cmol (equiv.)/kg | Differ from reference, cmol (equiv.)/kg |
| No grazing | 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 |

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

|  |  |  |  |
| --- | --- | --- | --- |
| Grazing technology | 1 zoneDark chestnut soils (К1) | 2 zoneChestnut soils(К2) | 3 zoneLight chestnut soils (К3) |
| 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 | 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 |

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