IOP Conference Series: Earth and Environmental Science

Yearly dynamics in the elemental composition of the floodplain meadow phytocenoses herbage

Yearly dynamics in the elemental composition of the floodplain meadow phytocenoses herbage

L F Shepeleva[1], A N Cherepinskaya[2], E S Rabtsevich[1], L G Kolesnichenko[1]

[1]Research Institute of Biology and Biophysics, Tomsk State University, Tomsk, Lenin Ave. 36, 634050, Russia
[2]Surgut State University, Surgut, Lenin Ave.1, 628412, Russia

E-mail: shepelevalf@mail.ru

Abstract. The results of the analysis of the chemical elements composition in the herbage samples taken in meadow phytocenoses in the floodplain of the Bolshoy Yugan river (tributary of the Ob river in the Khanty-Mansi Autonomous Okrug - Ugra) are presented in connection with the flooding dynamics, weather conditions, and herbage composition. The study employed the method of mass spectrometry with inductively coupled plasma. It is shown that the height and duration of floods play a decisive role in the formation of the elemental composition of meadow herbage and the quantitative content of chemical elements.
Keywords: elemental composition, dynamics, flooding, meadows, Western Siberia.

Introduction

Studying species diversity, and the overall ecology of floodplain meadows of taiga rivers is of great theoretical interest. Floodplains are landscapes with a high life density and accumulators of geochemical energy of living matter. [1, 2].

The vegetation cover in the territory of the Khanty-Mansi Autonomous Okrug (KhMAO) has not been studied enough, especially the issues of its natural dynamics and changes associated with anthropogenic influences, which is of primary importance in solving problems of environmental management. The study of meadow vegetation in the Khanty-Mansi Autonomous Okrug was carried out mainly in the 1940-60s [3, 4] before the beginning of intensive industrial development of the territory for oil and gas production. Contemporary information about the dynamics of meadows is fragmentary, refers mainly to the Ob floodplain [5, 6, 7].

The aim of the work was to estimate the level of accumulation of chemical elements by herbage of meadow phytocenoses in the Bolshoy Yugan floodplain in dynamics. The objectives of the study included the analysis of the ratio of the following elements (K, Ca, P, Mg, Mn, Al, Fe, Na, Si) depending on the position in the relief, the flooding duration, weather conditions and herbage composition.

Materials and methods

The site under study is located in the estuary part of the Bolshoy Yugan river valley near the village of Yugan, Surgut district of the Khanty-Mansi Autonomous Okrug. The floodplain in this site is about 7-8 km wide and mostly occupied by meadows. Near the village of Yugan in the near-terrace floodplain there are lakes and sedge meadows, dumping objects, the central and near-riverbed parts are occupied mainly by meadows and shrubs.

The investigations were carried out in 2015-2016. In 2015 the flooding in the Bolshoy Yugan river was high and long-lasting, the floodplain was completely covered with flood waters. Ridges were in water for 2.5 months (from the beginning of May to the first decade of July), the release of low levels from water was in August-September. In 2016, the flood was close in height but short in duration. The high and medium-sized ridges in the floodplain were flooded for a period of about 5-10 days in May before the beginning of the vegetation period.

The samples were taken in 6 phytocenoses [8]:

Sampling area (SA) 1– mixed-herb sedge meadow developed on medium-high ridge situated near a river channel, used for haymaking. In 2015 herbage mainly consisted of (60%) *Carex acuta* L., there were also hygrophilous species *Persicaria amphibia* S.F. Gray, *Stachys palustris* L., *Naumburgia thyrsiflora* Reichenb. In 2016 they were replaced by mesophytes *Poa pratensis* L., *Rhinanthus serotinus* Oborny, *Porentilla anserina* L., the proportion of herbs increased in general.

SA 2 – flooded sedge phytocenosis is developed by the lake situated near a terrace. Apart from hydrophilic *Carex aquatilis* Wahlenb. (50%) and *C. acuta* (45%), in 2015 *Filipendula ulmaria* Maxim. (1-2%) was registered, and in 2016 – *Juncus filiformis* L. and *Comarum palustre* L.

SA 3 – canary grass meadow is developed in a flat riverbed hollow. The dominating species is *Phalaroides arundinacea Rausch* (61%). In 2015, there was a little amount (2-4%) of *Thalictrum flavum* L., *Lysimachia vulgaris* L., *Equisetum arvense* L., *Vicia cracca* L., *S. palustris*. In 2016 because of phytomass growth and the presence of *P. arundinacea* the number of herbage species decreased.

SA 4 – mixed-herb quackgrass meadow developed in a high terrace of the Bolshoy Yugan river near a village. The dominating species is *Elytrigia repens* Nevski (50%), abundant herbage species (7-10%): *Artemisia vulgaris* L., *Taraxacum officinale* L., *Leontodon autumnalis* L. In 2016 there was an increase in the species constituting phytocenosis (e.g. *Epilobium adenocaulon* Hausskn., *Achillea millefolium* L., *Rumex acetosella* L. appeared).

SA 5 – water-sedge phytocenosis is developed in annually flooded hollow. In 2015 *C. aquatilis* (95%) dominated, in 2016 the main dominating species was *Carex acuta* L. (45%). There were groups of *Eleocharis palustris* Roem. et. Schult., *P. amphibia*, *Juncus filiformis.*

SA 6 – sedge-horsetail phytocenosis is developed on the bottom of a deep near-channel hollow. *Equisetum fluviatile* L. (28%) and *E. arvense* (45%) dominate. There are groups (5-12%) of *C. aquatilis* and *Eleocharis palustris*.

In each SA every year grass was cut from 10 plots with an area of 0.25 m^2 each. After drying and weighing it, an average sample of about 100 g was made, which was crushed and homogenized.

Geochemical studies were done by specialists of the Tomsk Regional Center for Collective Use of Scientific Equipment of Tomsk State University. The elemental composition of the herbage was established by inductively coupled plasma mass spectrometry (ICP-MS), which combines the use of an inductively coupled plasma as an ion source with a quadrupole mass spectrometer acting as a mass analyzer and a discrete-diode detector used for registration of individual ions and their flows [9].

Using an analytical balance, a weighed portion of a ground sample weighing 0.10 g was taken, placed in a fluoroplastic cylinder, 1.0 ml of concentrated nitric acid was poured in, then it was covered with a protective laboratory film and placed in a thermoblock heated to 115 ° C, where it was held for one hour until the sample was completely dissolved. The dissolved sample was transferred to a measuring polypropylene tube, rinsing from the cylinder walls three times, and brought up to 10 ml with deionized water. It was hermetically sealed with a protective laboratory film and mixed. Mass spectral determination of the content of elements in the analyzed samples was performed using Agilent 7500cx, AgilentTechnologies, Japan. The analysis was replicated three times. Statistical processing of the results was performed using software packages "Statistica 6.0" and "Excel".

Results and discussion

In herbage samples taken in all phytocenoses the highest content of potassium (K) was found, an order of magnitude higher than the concentration of other elements. Based on the reference data on the content of macronutrients in feed in Siberia [10], the following K concentration distribution is characteristic of hay in floodplain meadow lands of the KhMAO: for tall grass meadows (SA 3 and 4) - 6590 mg / kg; for sedge meadows (SA 2, 5 and 6) - 6630 mg / kg; for grassland-sedge communities (SA 1) - 7330 mg / kg.

The data we got in 2015-2016 point up the increase in potassium concentration in phytomass compared to literature (Figure 1). The direct dependence of the quantity of K on the position of communities in the relief and on the duration of flooding is traced. Indicative are multi-year values. In 2015, sedge-horsetail phytocenosis (SA 6) had the highest content (31868 ppm). The smallest amount of K is established in the herbage of not flooded mixed-herb quackgrass meadow (9350.8 ppm). Moreover, this indicator is as close as possible to the average value in contrast to the rest of the SAs. A similar situation was observed in 2016 for SA 1, when the content of K was approximately equal to the average. Such a contrast in the distribution of values confirms the relationship between the concentration of potassium in the composition of plants and the mode of flooding.

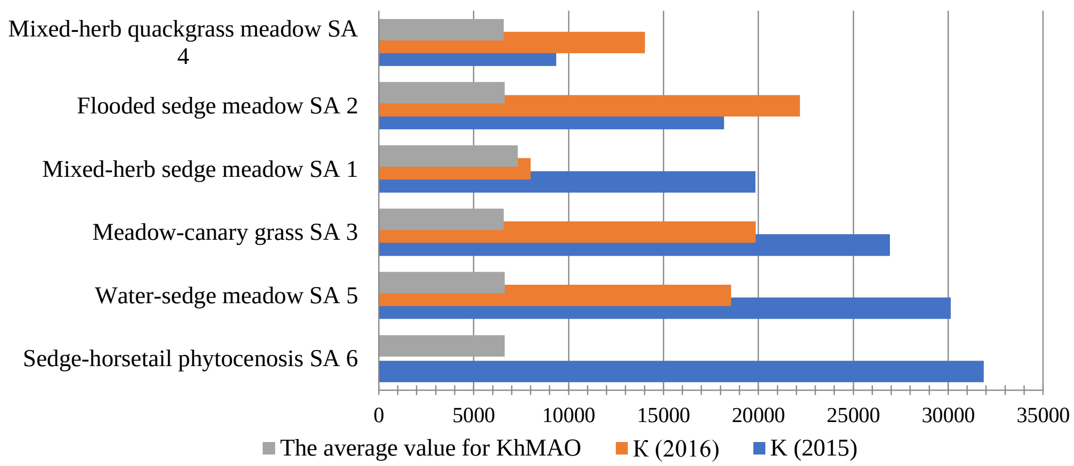

Figure 1. Concentration of potassium (ppm) in the herbage of the phytocenoses in the Bolshoy Yugan floodplain

In 2015, water-sedge meadow (30,142.5 ppm) and canary grass (26,926.4 ppm) phytocenoses were also characterized by a high K concentration in herbage. Out of them, the first one was flooded for a long time, and the second one was free from water in July. However, in 2016, with a general decrease in the K concentration in the floodplain herbage (except for SA 2 phytocenosis), an increase in K concentrations was observed in the herbage of the mixed-herb quackgrass meadow (SA 4). Apparently, weather conditions and features of dominant species also influence the K concentration in plants. Thus, in 2016 in Western Siberia, all the months of the vegetation period were characterized by high air temperatures and precipitation shortage (less than 80%) [11].

In 2016, one of the communities with high concentration of potassium was the sedge meadow (SA 2). This phytocenosis, unlike other sedge communities, is affected by flooding for a long time, respectively, the herbage development occurs later. Here, a high potassium concentration could be associated with a phenological state, since in the early stages of development, plants absorb and accumulate 3-5 times more K than adult individuals. This is related to an intensive increase in phytomass, during which potassium is actively involved in the processes of metabolism and cell division.

In 2015, ferrum (Fe) ranked second by quantity in the above-ground mass, the highest content of which was found in SA 6 (Figure 2). Then flooded sedge (SA 2) and water-sedge meadow meadows (SA 5) come. Flooded, but developed on the ridges, the canary grass and mixed-herb sedge phytocenoses contained less Fe than sedge ones, and the lowest concentration of ferrum was established in the herbage of the terraced mixed-herb quackgrass phytocenosis (Table 1). In 2016, with a decrease in the length of flooding, ferrum concentration in the plants of all meadow phytocenoses decreased. The total range of Fe concentration in the studied range of communities was from 5,869.4 ppm in the herbal stand of the phytocenosis SA 2 to 8.2 ppm in the herbs and couch grass phytocenosis (Table 1).

In the waters of the Khanty-Mansi Autonomous Okrug, Fe and Mn are contained in high concentrations, which is related to the wide distribution of wetlands [12]. Therefore, the amount of Fe in the meadow herbage reflects the duration of flooding the site. It is known [13] that at high concentrations of mobile iron in the soil plants can absorb it in amounts up to 3,550 mg / kg, however, the accumulation of Fe over 1,000 mg / kg is 3-6 times more than its content in healthy parts of the plant. Therefore, at the concentrations established, we can speak about the pollution of the herbage of the floodplain sedge meadows in the Bolshoy Yugan in the years of long flooding.

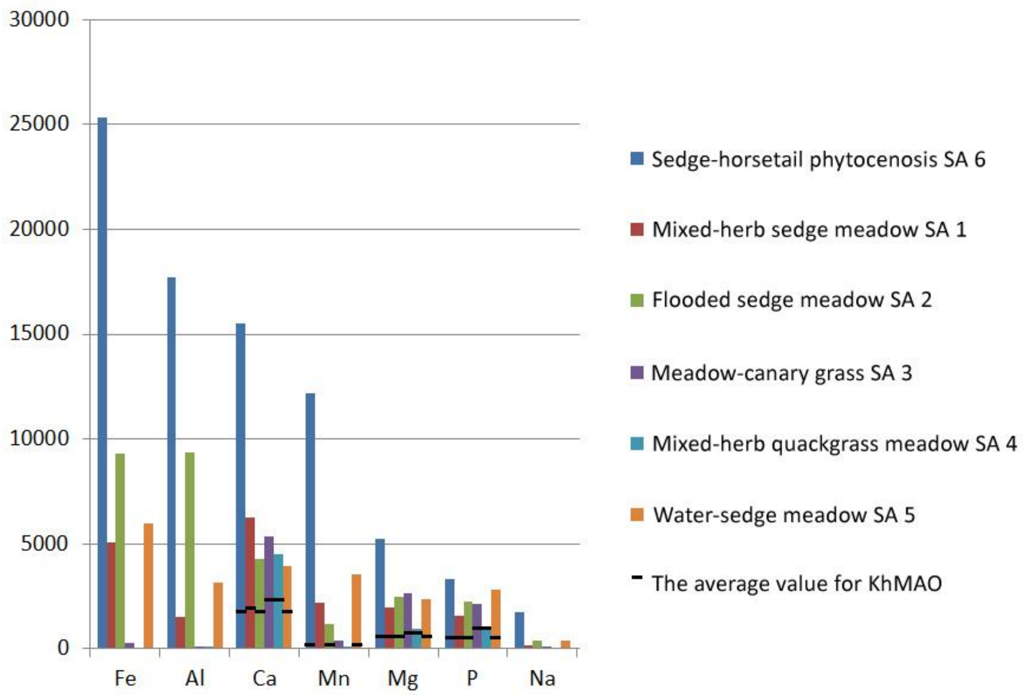

Figure 2. Element concentration (ppm) in meadow herbage in the Bolshoy Yugan floodplain in 2015

Table 1. Ferrum concentration in herbage in 2015-2016.

Indicators	Ferrum concentration in herbage, ppm					
	SA 6	SA 2	SA 5	SA 1	SA 3	SA 4
Fe (2015)	25,306.44	9,291.13	5,962.40	5,075.19	272.71	27.38
Fe (2016)	no data	5,869.36	61.74	29.28	32.46	8.17
Mean (KhMAO)	Hay from floodplain sedge meadows 54.0-330.0			mixed-herb sedge meadows 54.0-135.0	canary grass meadows 63.0-282.0	mixed-herb gramineous meadows 60.0-156.0

The distribution of Al in the herbage in 2015 was characterized by the same regularities as Fe distribution (Figure 2). The range of Al concentrations was from 17,710.0 ppm in sedge-horsetail phytocenosis (SA 6) to 83.1 ppm in the mixed-herb quackgrass one (SA 4). The amount of Al in sedge grass stands was an order of magnitude higher than in gramineous herbage (from 9,380 ppm in SA 2 to 1,534 ppm in SA 1). The ratio Fe / Al in floodplain herbage varied from 1 to 2, in contrast to them, the Al concentration exceeded the Fe content by about 3 times in the mixed-herb quackgrass phytocenosis. In 2016 (Figure 3), the Al content in most floodplain grass stands decreased by an order of magnitude, remaining high only in flooded SA 2. In the mixed-herb quackgrass phytocenosis (SA 4), the decrease in the aluminum content was insignificant.

Ca in the herbage of all phytocenoses was contained in large quantities, in 2015 the range of indicators was 3948-15490 ppm. The maximum content, as in the previous cases, was found in sedge-horsetail herbage (Figure 2). The second position in terms of Ca concentration (6256.2 and 5351.2 ppm) was occupied by phytocenoses, developed on the floodplain ridges (SA 1, 3). The Ca content in the herbage of the mixed-herb quackgrass (SA 4) and the near-terrace sedge (SA 2) communities was characterized by average values (more than 4,300 ppm), the smallest amount of Ca was in SA 5 in the herbage of the water-sedge meadow community (about 4,000 ppm).

In 2016, the content of Ca in the aboveground phytomass of the meadows developed on the floodplain ridges (SA 1, 3, 5) decreased, in contrast to the long-term flooded plant communities (SA 2). An increase in Ca content also occurred in SA 4. At the same time, the mixed-herb quackgrass meadow in this indicator (6,629.6 ppm) was in the lead among other communities. This indicator in 2016 turned out to be the highest among the values of the other considered elements (Figure 3).

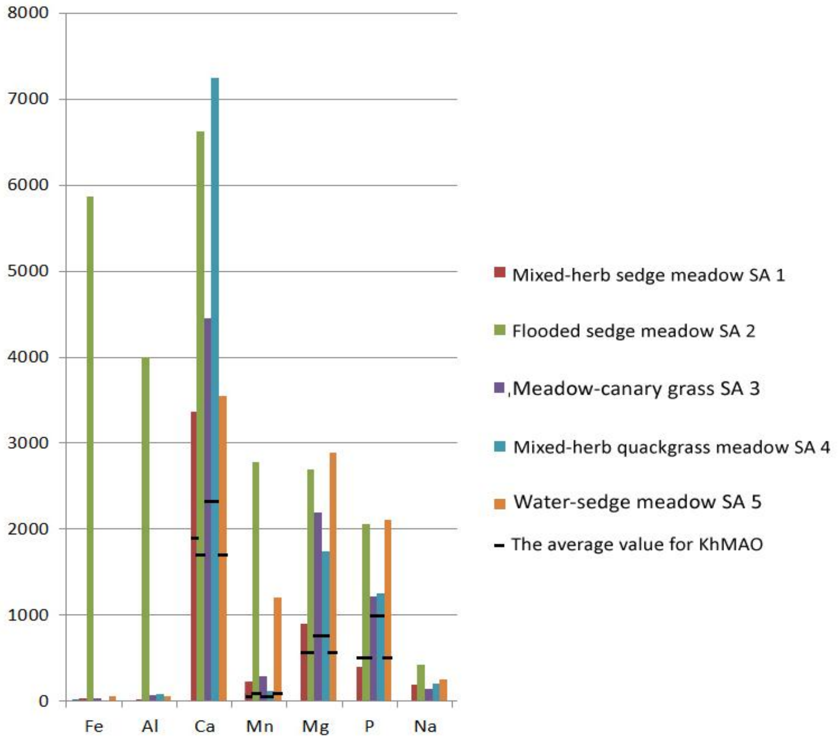

Figure 3. Element concentration (ppm) in meadow herbage in the Bolshoy Yugan floodplain in 2016

The distribution range of the Mn content in herbage in 2015 varied from 91.7 ppm in the mixed-herb quackgrass herbage to 12,198.0 ppm - in the sedge-horsetail one. Sedge phytocenoses were rich in Mn, especially in the water-sedge (3,558.9 ppm) and mixed-herb sedge one (2,219.3 ppm). In 2016, the concentration of Mn decreased in all floodplain SAs (except for SA 2, where the content increased by 2 times), which confirms the information [12] on intensive accumulation of Mn with high water saturation of the soil. The most significant decrease (10 times) in the concentration of Mn in the above-ground mass was in SA 1. In the herbage of mixed-herb quackgrass phytocenosis, the content of Mn increased slightly.

Mg content in the above-ground mass of meadow communities in the Bolshoy Yugan floodplain in 2015 ranged from 5,242.9 ppm in sedge-horsetail to 942.9 ppm in the mixed-herb quackgrass phytocenoses. For other floodplain phytocenoses, the typical amount was 1,958.5-2,653.8 ppm. In 2016, there was a slight increase in the Mg content in the herbage of the phytocenoses of depressions (SA 2, 5) and a decrease in the amount of this element in the herbage of the meadows on ridges (SA 1, 3). A significant increase in the Mg content (approximately 2 times) was in the mixed-herb quackgrass herbage (Figure 3), which could be associated with an increase in the share of motley grass [14, 15], as well as an increase in the temperature and biological activity of the soil in the conditions of the warm vegetative season.

The range of P content in the studied herbage in 2015 (Figure 2) was from 3,314.5 ppm (sedge-horsetail community) to 952.9 ppm (mixed-herb quackgrass community). In 2016, a decrease in the amount of P was observed in all floodplain phytocenoses, a more significant - on the ridges (Figure 3). So, in the mixed-herb quackgrass community in SA 1, the content of P has decreased by 3 times. In the terrace phytocenosis (SA 4), the amount of P increased by about 1.3 times.

The highest Na content in 2015 was also in the herbage of sedge-horsetail community (1,756.9 ppm), the smallest amount - in the herbage of mixed-herb quackgrass meadows (55.6 ppm), and in 2016 - in the phytomass of the canary grass phytocenosis (143.03 ppm). In the herbage of sedge communities developed in depressions, in 2015-2016 the Na content was 2-3 times higher than in the phytocenoses developed on ridges (Figure 2, 3).

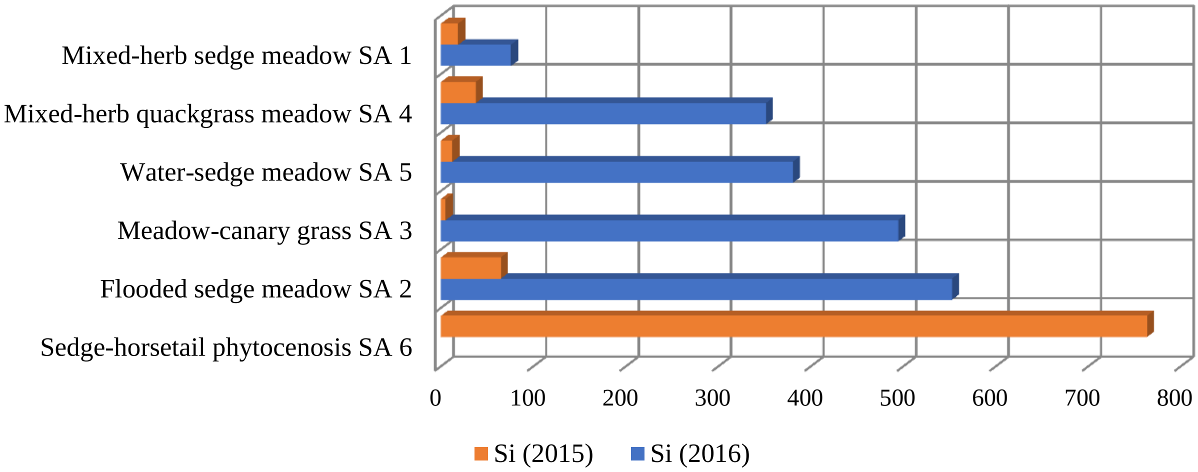

Figure 4. Concentration (ppm) of Si in meadow herbage in the Bolshoy Yugan floodplain in 2015-2016

The distribution of Si (Figure 4). The maximum silicon content in 2015 (763.4 ppm) is noted in the above-ground mass of sedge-horsetail (SA 6) and flooded sedge (SA 2) communities. The minimum amount of Si (5.1 ppm) was accounted for by the canary grass phytocenosis (SA 3). In the dynamics from 2015 to 2016, Si had a widespread increase in values. At the same time on some SAs its content increased by 4-5 times.

The earlier development of the herbage in 2016 and its composition might have influenced the plant accumulation of Si (it is known that ripe sedges and cereals contain a lot of silicon). The significant difference in Si concentrations in different years can also be explained by the influence of the 2015 water regime on the soil macronutrient composition in 2016, which is undoubtedly reflected in the amount of Si in the composition of herbage.

Conclusion

Flooding in the Bolshoy Yugan floodplain is the most important factor determining the quantitative content and elemental composition of meadow plants. During the years of high and long floods, nutrients are accumulated in the phytomass of the meadows.

At the same time, sedges dominate in the meadows and high (to toxic) concentrations of Fe, Al, Mn are observed in the herbage of communities developed in hollows and medium-height ridges, which is caused by the hydrochemical features of the Khanty-Mansi Autonomous Okrug water bodies.

With a brief inundation, the content of most elements under study (K, Ca, P, Fe, Al, Mn, Mg, Na) in the herbage decreases, and Si concentration increases. Especially significant nutrient depletion is observed in meadow phytocenoses developed on floodplain ridges.

Non-flooded mixed-herb gramineous communities of terraces accumulate primarily K, Ca, P, Mg, but the values themselves are not high. The growth of nutrients in the herbage of these meadows occurs in the warm weather conditions of the vegetation period.

Acknowledgements

The work is published in the framework of the government order of the Ministry of Education and Science of the Russian Federation, project № 5.4004.2017/4.6, RFBR project № 18-00-01493.

References

[1] Dobrovolsky G V 1968 *Soils of River Floodplains of the Center of the Russian Plain* (Moscow: Publishing House of Moscow State University) p 298

[2] Viers J, Barroux G, Pinelli M, Seyler P, Oliva P, Dupre B and Resende Boaventura G 2005 The influence of the Amazonian floodplain ecosystems on the trace element dynamics of the Amazon River mainstem (Brazil) *Science of the Total Environment* **339** 219– 32

[3] Dydina R A 1961 Ob-Irtysh meadows within the Khanty-Mansiysk district *Proc. the Research Institute of Agriculture of the Far North, Norilsk* **10** 159-250

[4] Shvergunova L V 2004 Natural forage lands of the Ob and the Irtysh *Atlas of the Khanty-Mansiysk Autonomous Okrug - Ugra* **2** 85

[5] Shepeleva L F and Volegova E A 2013 Meadow communities of the latitudinal segment of the floodplain of the Middle Ob: classification and structure *Study and preservation of floodplain meadows: materials of the Intern. Ow.* (Kaluga: Publishing house “Noosphere”) 64-73

[6] Kushanova A U 2016 Features of use of forage lands in the territory of the Nizhnevartovsk district of the KhMAO-UGRA *International research journal* **11-2**(53) 81-5

[7] Tyurin V N 2017 The results of long-term observations of the productivity dynamics of grass communities of the coastal shoals (Surgut section of the Ob river) *Proc. of the Samara Scientific Center of the Russian Academy of Sciences* **19** (2-3) 570-7

[8] Cherepinskaya A N and Shepeleva L F 2017 Fluctuations of floodplain meadows of the Bolshoy Yugan River *Bulletin of the KrasGAU* **12** 170-8

[9] MUK 4.1.1483-03 2003 *Determination of the content of chemical elements in diagnosable biosubstrates, preparations and biologically active additives by mass spectrometry with inductively coupled argon plasma* (Moscow) p 22

[10] Feed of Siberia - composition and nutritional value: Method. Recommendations 1988 *Agricultural Sciences. Sib. detachment. SibNIPTIZh* (Novosibirsk) p 680

[11] Bulygina O N, Korshunova N N and Arzhanova N M 2016 Weather in the Russian Federation in 2016 *Federal Service for Hydrometeorological Monitoring of the Environment* [Electronic resource]. - Access mode: http://meteo.ru/pogoda-i-klimat/93-klimaticheskie-usloviya/697-pogoda-na-territorii-rossijskoj-federatsii-v-2016-godu

[12] Moskovchenko D V 2007 Ecological and geochemical state of water bodies on the territory of the Surgutsky reserve *Bulletin of Ecology, forest science and landscape science* (Tyumen: Publishing house IPOS SB RAS) **7** 163-71
[13] Kabata-Pendias A and Pendias X 1998 *Trace elements in soils and plants* (Moscow: Mir) p 439
[14] Grzegorczyk S, Alberski J and Olszewska M 2012 Accumulation of potassium, calcium and magnesium by selected species of grassland legumes and herbs // *J. Elem. s.* 69-78.
[15] Cevheri C, Küçük Ç, Avci M, Atamov V 2013 Element content, botanical composition and nutritional characteristics of natural forage of Şanlıurfa, Turkey *Journal of Food, Agriculture & Environment* **11**(3-4) 790-4