Asian Journal of Water, Environment and Pollution, Vol. 17, No. 1 (2020), pp. 83–90.
DOI 10.3233/AJW200009

Long-term Irrigation Effect on Soil and Vegetation Cover of Floodplain Estuaries in the Southern Urals

Alexander Komissarov*, Mikhail Komissarov[1], Khalil Safin, Marat Ishbulatov and Yuri Kovshov[2]

Bashkir State Agrarian University, Ufa, Russia
[1]Ufa Institute of Biology, Ufa, Russia
[2]Ufa Melioration and Water Supply Systems Operation Management, Ufa, Russia
✉ komissarov1al1@rambler.ru

Received October 21, 2019; revised and accepted November 13, 2019

Abstract. The given paper presents the results of long-term (1986-2012) monitoring of the hydrological regime of spring flood, soil, vegetation and productivity of estuaries of the high Sakmar-Tanalyk plain in the steppe zone of the Trans-Urals of the Republic of Bashkortostan. It is found that large water storage reservoirs built in 1986-2012 on the Tanalyk River and its feeders have reduced the amount, frequency and duration of flooding due to high flow and rainfall. It showed lower productivity of natural hayfields from 2.87 to 1.96 t/h as well as the reduction of valuable moisture-loving grasses (wheat grass, slough grass) in the botanical composition of grass from 61 to 32%. It is revealed that the decisive role in replenishing soil moisture reserves of floodplain estuaries takes place during flooding by flood waters. A single spring flooding is found to provide one cut of natural grasses. Long-term flood irrigation (about 30 years) led to 15 cm silt deposit, enriched the upper layers of meadow-Chernozem saline soils (*Luvic chernozems sodic*) with organic matter and nutrients, and improved the structural and aggregate composition. The salinity quality changed from chloride-sulfate to sulfate-sodic. The salinity level altered from medium to weak.

Key words: Estuaries, flooding duration, salination, soil properties, steppe Trans-Urals, Luvic chernozems sodic.

Introduction

The southern Urals is in a zone of unstable natural moisture. According to the Russian Met centre, drought probability in this region is 42% (Khomyakov et al., 2005). With global warming, climate aridization and water shortage (Zalibekov, 2011; Kouzmina and Treshkin, 2014; Sobol et al., 2015; Nikanorova et al., 2016; Nasiri et al., 2018), as well as deficiency of regular water sources for irrigation and lack of manpower make flood irrigation the only possible means to supply the soil with moisture and create a sustainable food supply (Halldorf, 1994; Paz-Kagana et al., 2017). Thus, in Kalmykia, taking into account the main agroecosystem characteristics and the peculiarities of the technological process to optimize its functioning, it is possible to achieve the planned level of productivity in estuaries with heavy soils at 4-4.5 t/ha of hay (Dedova et al., 2017).

In recent times they return to traditional meadow irrigation in Europe. Regular artificial meadow flooding in the floodplain of the Keich River in Germany increased the amount of legume grasses by three times compared to non-irrigated meadows. Flooding irrigation enhanced the response of meadow grasses for seed and vegetative reproduction (Muller et al., 2016). Studies conducted in the Bolshoy Yugan floodplain (a feeder of the Ob River in the Khanty-Mansiysk Autonomous

*Corresponding Author

district) have shown that high and prolonged floods result in nutrients accumulation in the meadow phytomass. With short-term flooding, most of the studied elements (K, Ca, P, Fe, Al, Mn, Mg, Na) in the grass stand decreases while the Si concentration increases. Particularly high nutrient depletion is observed in meadow phytocenoses developed in non-flooded areas of the floodplain (Ermakov et al., 2017; Shepeleva et al., 2019). The growth of many plant species depends on specific conditions with more or less regular flooding. Changes in their growing conditions lead to significant reductions in these species (Joyce and Wade 1998; Gattringer et al., 2018).

Great potential of flood irrigation is not fully used. Flooding schedule disturbance as well as casual use of flood waters lead to mire formation and salination of productive agricultural lands, grass degeneration, worse ecological condition of estuaries, lower agrocenoses productivity and fodder quality (Tarasenko and Tuktarov, 2013; Khamaletdinov et al., 2018).

Long-term sprinkling (Komissarov and Gabbasova, 2017) or flood irrigation can bring in a number of changes in the biogeocenosis, as the water factor is a driving force in the landscape change. Under the influence of flooding, the upper soil horizons are washed away and there is a sediment accumulation (Rakhimov et al., 2018). Hydromorphic and semi-hydromorphic soils and moisture-loving plant communities develop. In the flooding areas and surrounding them there is an active groundwater replenishment and dam development (Novikova et al., 2015; Novikova and Volkova, 2016). Zalibekov et al. (2017) claim that higher climate aridity and soil water-salt balance changes lead to the change of plant communities: meadow plants alter to meadow-steppe ones while semi-desert grasses are replaced with desert ones.

To date, Russia has about one million hectares of land suitable for flood irrigation. More than 95% of these are used as hayfields and pastures (Safin et al., 2010). In the Republic of Bashkortostan, flood irrigation is used in the Khaibulinsky district on 2400 hectares in the floodplain of the Tanalyk river (the right feeder of the Ural river. It’s 225 km long, the flood basin is 4160 km^2, the channel density is 0.24 km/km^2, the annual runoff is 2.0 l/s km^2. The river width varies from 2 to 35 m, depth is within 0.5-2.0 m, the flow rate is 0.1-0.2 m/s. Snow is the main source of water supply (Bashkortostan: Brief encyclopedia, 1996). Estuaries are used as hayfields. About 100 thousand hectares in the steppe zone of Bashkortostan, including 40 thousand hectares in the Trans-Urals can be used for flood irrigation (Zhigulev et al., 2010).

The goals and objectives of the research: to analyze the impact of water storage reservoir construction on the hydrological regime of the Tanalyk river and the estuary grass yield; to study the effect of long-term flood irrigation on properties (including salt regime) of meadow black saline soils (*Luvic chernozems sodic*) and botanical composition of natural grass; to examine the influence of the flooding duration (duration of flood water standing) on the properties and dynamics of soil moisture, as well as on the productivity of natural hayfields.

Research Target and Methods

The research target is estuary biogeocenosis, namely the soil and vegetation of an artificial estuary, having been functioning in the “Mambetovsky” farm of the Khaibullinsky district of the Republic of Bashkortostan (Russia) since 1970. The climate of the region is characterized as continental, arid. The average annual precipitation is 300-350 mm, the average annual temperature is from +1.2 to +1.8 °C, the annual evaporation rate is 340-420 mm. The share of solid precipitation per year is 22-27%, the mixed one amount 9%. The moisture index Selianinov hydrothermal coefficient (HTC) being 0.6-0.9 characterizes the studied area as arid and extremely arid.

The soil of the floodplain estuary is meadow solonetzic, heavy clayed, medium deep, medium humic chernozem.

The estuary (51°51′29″ N 58°26′17″ E) was studied from 1986 to 2012. The research included a set of works: collection and analysis of the main calculated hydrological characteristics of the “Mambetovo” hydropost, as well as retrospective monitoring of the estuary soil and vegetation. The water flow from the estuary during floods occurs in stages. First the water runs off the areas that are higher in relief. In this regard, to conduct a more detailed assessment, four key areas were selected, different in flooding duration: 10, 20, 30 and 40 days.

Soil monitoring included the analysis of changes in morphological, agrochemical and water-physical properties for almost 30-year cycle of flooding. For this purpose in 1986 and 2011 there were indicated sample points on these sites (places of digging coincided). Soil samples were taken from the main genetic horizons. Soil samples were tested to determine moisture, humus and nutrient content. Water-physical and agrochemical properties of soil were determined by conventional methods (Peverill et al., 1999). In 1986 there were put benchmarks to find the rate of wash in and out.

Vegetation cover monitoring at key plots included analysis of changes in the botanical composition, hay yield and nutrient content as well as the grass density. Phenological observations and geobotanical description were carried out according to Hopp (1974). The yield of grasses was analyzed by mowing and weighing the green mass of the registration plots. The yield of the air-dry mass is examined by trial sheaves weighing 1 kg. The botanical composition of the grass stand is analyzed on plant samples weighing 1 kg. Legume, grass and herbs are taken and weighed separately. The nutritional value of hay is assessed by the method of the all-Russian Fodder Research Institute (Grigoriev, 1985).

The total water consumption of plants is found by the method of water balance according to the calculation formula:

$$E = W_i - W_f + P - Q \quad (1)$$

where E is total water consumption of plants, mm; W_i – initial soil moisture reserves, mm; W_f –final soil moisture reserves, mm; P – precipitation, mm; and Q – infiltration beyond the calculated soil layer, mm.

Statistical data processing is done by the variance analysis method (Dospekhov, 1985) using Microsoft Excel 2003 and AGROS 2.11.

Research Results

In Europe and North America, a large amount of floodplain land has been degraded as a result of human actions related to river flow management (Tockner and Stanford, 2002). Over the past 30 years large water storage reservoirs have been built in the Trans-Ural steppe zone of the Republic of Bashkortostan: Tanalyk of 14.2 million m^3, Makan – 9.3 million m^3, Akyar – 5.3 million m^3 and Buzavlyk – 19.1 million m^3. Built reservoirs regulate the flow of spring flood in the region. Thus, at 50% of the flow probability in the spring flood, these reservoirs accumulate 2/3 of its volume, and at 85% of the flow probability they accumulate the entire flow. The annual replenishment of these reservoirs has led to a significant decrease in the volume of river flow in the lower course of the Tanalyk River. Thus, the volume of spring flood at the Tanalyk River gauging station (Mambetovo village) decreased from 181 (1985-1996) to 124 million m^3 (1997-2015) (Figure 1). A serious problem arose due to the regulation of the river flow. It resulted in a sharp decrease in the flooding frequency and duration in the floodplain hayfields.

The yield of natural grass stand in estuaries of Khaibullinsky district farms decreased. If during the period from 1985 to 1996 (before the construction of reservoirs) it averaged 2.87 t/ha, during the period from 1997 to 2015 it decreased to 1.96 t/ha (Figure 1). Similar results are obtained for the estuaries of the Mamai system, located in the semi-desert zone of the Caspian lowland in the West Kazakhstan region of the Republic of Kazakhstan (Nasiev and Eleshev, 2014). It is worth noting that in the conditions of the steppe zone of the Trans-Urals it is economically expedient to produce fodder (hay of natural grasses) using 25% of flow probability. It is 55-60 mm for deep water and

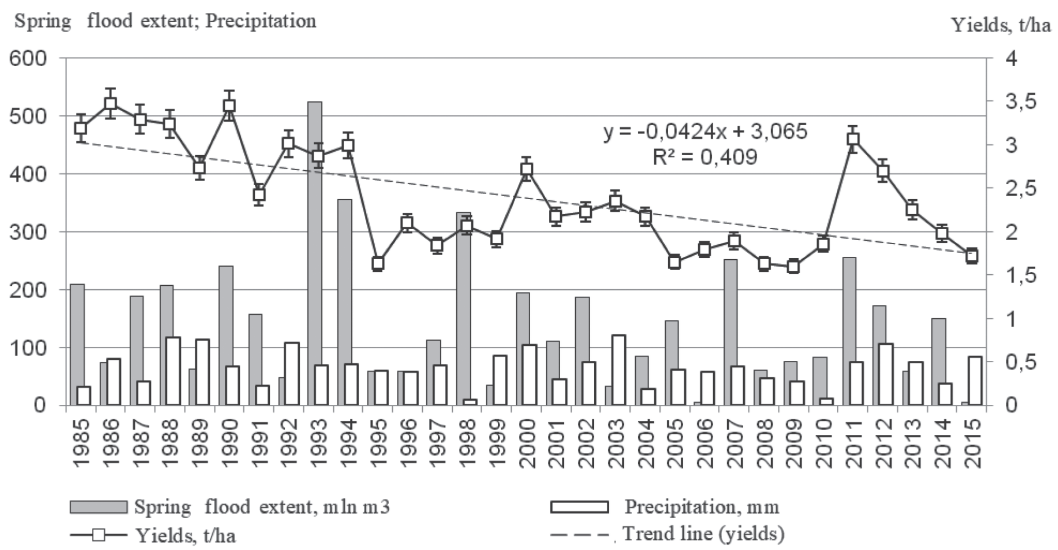

Figure 1: Spring flood extent on the Tanalyk river, precipitation (May-June) and natural grass stand yields in the estuaries of the Khaibullinsky district of the Bashkortostan Republic.

floodplain estuaries, and 78-85 mm for shallow slope estuaries (Komissarov and Mosienko, 1991).

Precipitation during the growing season has a significant impact on the yield of estuary natural grass. A regression analysis of the relationship between the hay yield of estuaries (y, t/ha) and the volume of spring flood (W, million m^3) and the amount of precipitation (P, mm) in May-June for the period from 1985 to 2015 provided a regression equation (y = 1.499 + 0.003 W + 0.008 P; r = 0.87). It allows predicting the hay yield.

One of the factors to develop green mass of natural grasses is productive moisture in the soil. Observations proved that estuary spring flooding maintains soil moisture within the optimal limits (from the lowest moisture content (FC) to the discontinuous capillary moisture (DCM)) in the layer of 0-50 cm until mid June (Figure 2). Throughout the growing season soil moisture in the layer of 50-100 cm did not significantly change and was 88-111% FC. It is due to the capillary feeding from the upper water and groundwater. Natural wheat-slough grass stand in estuaries uses moisture from the top layer (0-50 cm). This is related to biological features of the root system structure. Moisture content of this layer is enough to form a green mass for one mowing. Then there is moisture shortage and no possibility to get a second mowing.

As is known, the water regime in the floodplain estuary soils is caused by sediment and melts water infiltration, water redistribution in the soil column, top water development and drainage, the presence of temporary and permanent confining layer, capillary flow of soil-ground water, etc. When developing the flood irrigation regime for natural grass, it is necessary to know its total water consumption that is the main article of the water balance. The value of total water consumption for the studied period (1985-2012) varied from 218 to 280 mm at the site of 10-day flooding, 245 to 326 mm at the site of 20-day flooding, from 259 to 327 mm at the site of 30-day flooding, and from 300 to 311 mm at the site of 40-day flooding. The use of the irrigation norm included in evapotranspiration increased with longer flooding while groundwater participation decreased. Precipitation accounted 25-30% of total water consumption, the soil moisture reserves use was negligible (Figure 3).

Spring aftergrowing of natural grass and its further phenological development is due to the average daily air temperatures and the estuary flooding. Meadow grass germinated in April 19-30 (at the average daily temperature of the air 8.6-13.6 °C), tillering took place in April 30 - May 13. Grass on the plots of long-term flooding (20, 30 and 40 days) usually germinated while being in the water. Thus, the tillering of devil's grass (*Elytrigia repens*) and Bechman's grass (*Beckmannia eruciformis*) on the plots of 30 and 40 day flooding occured when there was 5-15 cm of water on the soil. During this period, Beckman's grass formed specific water leaves, being well-developed, elongated water bodies (Mamin and Savelyeva, 1986). Afterwards, different types of grasses cycled their basic biotic season at different time. Plants under longer flooding passed it earlier. This is due to the fact that the water, having a

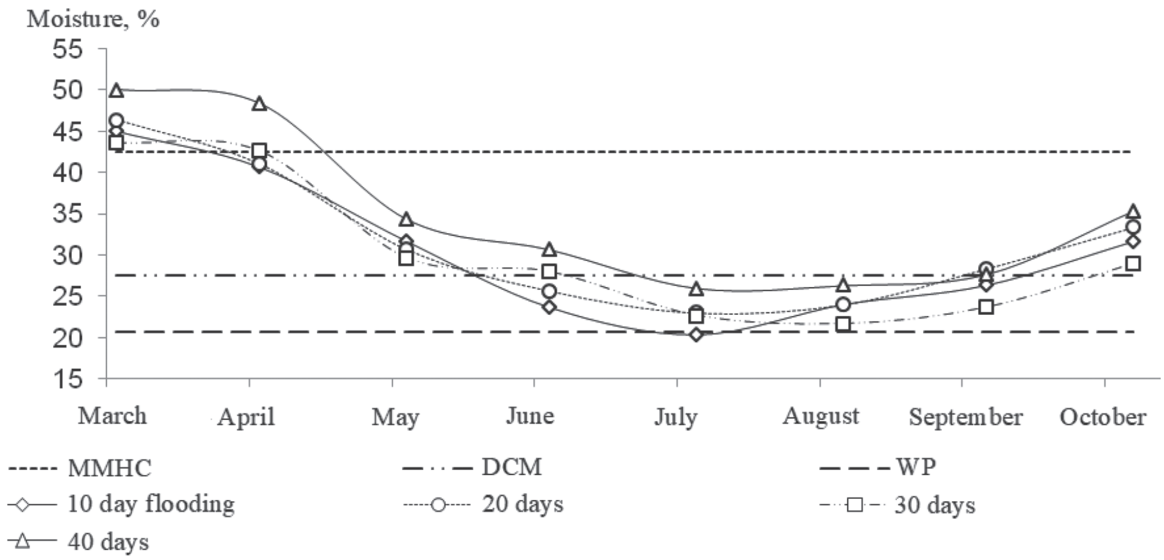

Figure 2: Soil moisture dynamics under natural grass stand in the estuary at different flooding duration. The layer of 0-50 sm. Average for 1986-2012. MMHC – Minimum moisture-holding capacity; DCM – Discontinuous capillary moisture; WP – Wilting percentage.

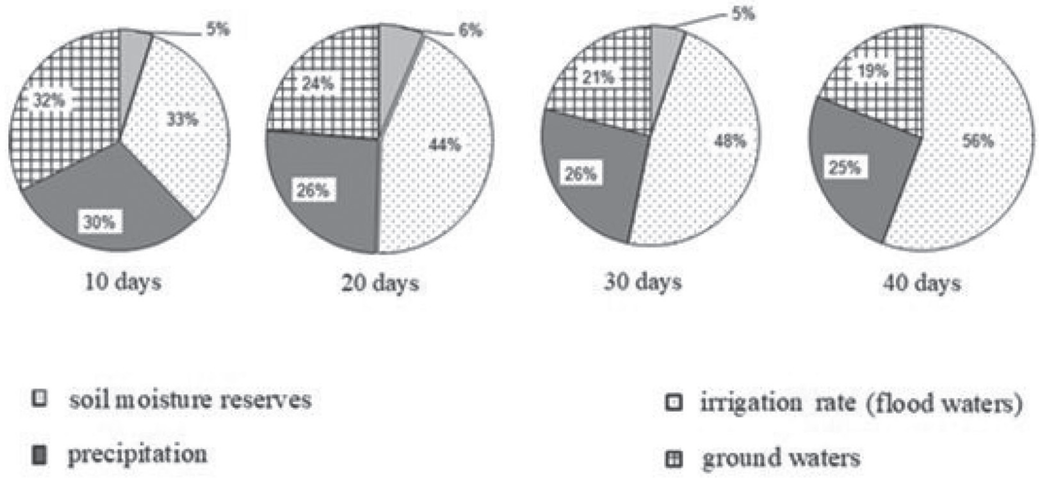

Figure 3. The water balance structure of natural grass stand at different flooding duration, average for 1986-2012,%.

large heat capacity, provided a more favourable thermal regime and prevented the soil cooling at sharp air temperature drop. By the mowing time the predominant estuary grasses were in the following phases: devil's grass – heading-initial blooming, Bechman's grass and smooth brome (*Bromusinermis*) – heading, crested wheat grass-shaped (*Agropyron cristatus*) – blooming, meadow foxtail (*Alopecurus pratensis*), sheap fescue (*Festuca valesiaca*) – seed formation, bird vetch (*Vicia cracca*) – budding.

The flooding duration has a high impact on the density, height and botanical composition of natural grass stand (Duong et al., 2019). The yield of grasses increased with increasing duration of flooding. Thus, on average for the period 1986-1988 enlarged flooding from 10 to 40 days resulted in bigger height of plants by 18-33 cm and increased yield from 3.0 to 3.5. There were 2.0-2.9 t/ha of hay in 2010-2012. The time of flooding influenced on the botanical composition. Enlarged period from 10 to 40 days provided the number of grasses almost two times (Table 1). At the same time, coach grass became dominant and its share increased more than four times. Longer flooding up to 40 days depleted the botanical composition of the stand and developed devils and Beckman's grass plant aggregation. The greatest diversity in the grass composition was on plots flooded 20 and 30 days.

For more than 30 years of estuary flooding there was decreases in the share of devils grass almost two times, a complete depletion of Beckman's grass and more perennial wild growing grasses. This indicates the steppe formation beginning of the Tanalyk river estuary due to disturbed estuary meadow spring flooding. These negative changes in the botanical composition of the

Table 1: Varieties composition of the estuary natural grass stand,%.

Variety	*Flooding duration, days*			
	0-10	*10-20*	*20-30*	*30-40*
1. Coach grass	16/-	38/18	46/28.5	73/45
2. Awnless brome	1,8/-	1,8/-	2,6/-	-/-
3. Crested wheat grass	-/15	1,6/-	-/-	-/-
4. Sheap fescue	22,1/-	6,7/-	3,2/-	-/-
5. Bechman's grass	-/-	-/-	0,9/0,5	13,4/4
6. Meadow foxtail	-/-	3,3/-	10,0/-	0,9/-
7. Meadow grass	-/-	0,2/-	1,0/15	-/-

Note: Before the sign (/) there are the results of 1986-88, after the sign – 2010-12.

grass stand eventually affected the hay quality. Hay quality is known to improve with higher proportion of cereal grasses. The fodder value depends on protein content and decreased amount of fibre (French, 2017). The most common trend in longer flooding from 10 to 40 days was an increase in the content of crude protein in dry matter (DM) by 0.78% with fibre being 29.9-33.4%. DM of different grass associations (10-20 days of flooding) was characterized by a higher content of fat compared to devil's and Beckman's grass composition (30-40 days of flooding).

Thus, fat content in DM on the plot flooded 10 days was 3.59-4.08% while on the plot flooded 40 days it was 1.86-3.73%. The most highly-nutrient hay was on the plot of 40 day flooding: exchange energy of 1 kg of DM was 9.05 mJ. The biochemical analysis of hay harvested in 2010-2012 demonstrated worsened nutrient value of fodder in terms of crude protein content compared to the hay of 1986-1988: from 16.6 to 8.5%. At the same time, the decrease in the content of available energy and feed units was insignificant. Thus, the exchange energy in 1 kg of DM dropped in average from 8.96 d to 8.88 mJ. The available energy of fodder units reduced from 0.65 d to 0.64 c.u.

Longer flooding from 10 to 30-40 days increased the productivity of natural grass from 1620 to 1830-1920 fodder units per 1 ha. Flooding during 30-40 and 10-20 days did not significantly affect the yield of fodder units. Thus, the best productivity of natural grass is received with 40-day flooding.

Alluvial soils in meadows are formed under the influence of surface waters of spring and summer floods. These waters in river valleys, depending on the flooding duration, flow rate and frequency of flooding, determine the spatial distribution of suspended sediments, the variability of their granulometric composition, as well as the thickness of the layers, the content of organic matter and the diversity of alluvial material in different parts of the floodplain. These factors have a significant impact on the structure of the soil profile (Czyz et al., 2013).

With flood irrigation, the effect on the soil properties is longer and stronger than with regular irrigation (Aidarov, 1985). As the result of more than 30-year cycle of spring flooding of the central floodplain part of the Tanalyk river there were significant changes in the soil properties. The soil strength in humus accumulative soils improved, the number of organo-mineral films on the faces of structural separates in illuvial soils increased, the boiling line decreased by 10-20 cm, the carbonate waste became more softened, with a greater number of scattered spots and powdery inclusions (Komissarov and Komissarov, 2014). According to the morphological properties of the soil and bench mark measurements, the strength of the humus accumulative horizon became greater by 15±2 sm (from 55 to 70). In our opinion, this is due to the silt inflow with melted water. Balkov (1978) claim that the average concentration of suspended material in the Tanalyk river by Mambetovo village in April-May was 229 g/m^3 while the average annual value of the spring flood was 40 mm. With 3270 km^2 of the flood basin by Mambetovo village there are about 30 thousand cubic metres (36 thousand m^3) in the average spring flooding. If 70% of this solid flow (about 30% runs down the course) is redistributed on the estuary (about 500 ha), flooded in the average water year, then the annual silt deposit will be about 0.5 cm. Thus, the given calculation confirms the previously proposed hypothesis on the increased strength of the humus horizon.

In the granulometric composition of the soil there was a weighting of the upper horizons and lighting of the horizons in the bottom source rock. As the result of flooding by flood waters of the Tanalyk River, floodplain soils were enriched with organic matter (humus) and nutrients down to the Northern horizon. In the humus-accumulative horizon, the content of labile and total phosphorus, hydrolyzed nitrogen, exchange calcium and humus reserves increased from 486 to 714 t/ha. The horizon A structure reaction changed from neutral to slightly alkaline (Komissarov and Komissarov, 2013).

Irrigation water dissolves simple salts as well as decomposes aluminosilicates, complex inorganic and organic compounds. During irrigation, the weathering processes of aluminosilicates are faster, the energy of electrolytic cleavage is higher than the alkaline and fine-grained soil. Long-term flooding alters the concentration of soil solution and soluble salts that leads to changes in the composition of molecular cations (Kistanov, 1970; Karimov et al., 2019). The amount of sodium absorption in the saline soil horizon in 1986 reached 22% of the amount of absorbed bases, i.e. the soil was strongly saline. By 2010, this indicator had decreased by about 9% of the amount of absorbed bases, i.e. the soil was slightly saline. The type of salinity changed from strong chloride-sulphate to medium sulphate-sodic (Komissarov and Komissarov, 2013).

Conclusion

Changes in the water balance associated with the regulation of flow on the Tanalyk River have a great impact on the ecological condition of floodplain terraces located in the lower reaches of these reservoirs. There is the steppe formation, reduced productivity of the grass stand, the change of the botanical composition and worsened fodder quality.

In the floodplain estuaries of the Bashkortostan Trans-Urals during the formation of the first mowing, the moisture reserves in the upper half-metre layer of the soil vary in the full moisture capacity to the moisture content of the capillaries. After mowing, the humidity of the upper soil layers (0-50 cm) is in the range from the humidity of the capillary rupture to the humidity of wilting and the natural herbage of the estuary experiences an acute shortage of moisture. A single spring flooding is found to provide one cut of natural grasses. With longer estuary flooding from 10 to 40 days, the yield increased from 2.5 to 3.2 t/ha of hay, the share of grasses in the botanical composition of the herbage changed from 40 to 88%. At the same time, the value of the dry residue of water-soluble salts in the root layer of the soil (0-50 cm) decreased from 0.17 to 0.14%, and the degree of salinity from medium to weak.

Retrospective monitoring (1986-2012) of meadow-Chernozem saline soils showed that flood irrigation contributed to the deposition of fertile silt at 15 cm and an increase in the strength of the humus horizon from 55 to 70 cm. The content of humus in the root layer of soil increased from 7.8 to 8.1%, mobile phosphorus from 2.1 to 2.6, and alkaline-hydrolyzed nitrogen from 106 to 161 mg/100 g. Lack of flood waters in estuaries due to the regulation of flow by reservoirs resulted in a decrease in yield from 2.87 to 1.96 t/ha of hay, as well as a reduction in the share of moisture-loving valuable grasses (wheat grass, Beckman's grass) in the botanical composition of the grass from 61 to 32%.

References

Aidarov, I.P. (1985). Regulation of water-salt and nutrient regime of irrigated soils. Agropromizdat Publ., Moscow.

Balkov, V.A. (1978). Water resources of Bashkiria. Bashknigoizdat Publ., Ufa.

Bashkortostan: Bried encyclopedia (1996). Scientific Publication Bashkir encyclopedia, Ufa.

Czyz, H., Malinowski, R., Kitczak, T. and A. Przybyszewski (2013). Chemical characteristics of soils and vegetation cover of grasslands in the Warta Estuary valley. *Rocznik Ochrona Srodowiska*, **15(1):** 694-713.

Dedova, E.B., Borodychev, V.V. and M.A. Sazanov (2017). Modeling agroameliorative landscapes of estuary irrigation systems in the Republic of Kalmykia. *Russian Agricultural Sciences*, **43:** 88-92.

Dospekhov, B.A. (1985). Methodology of field experience. Agropromizdat Publ., Moscow.

Duong, A., Greet, J., Walsh, C.J. and M.J. Sammonds (2019). Managed flooding can augment the benefits of natural flooding for native wetland vegetation. *Restoration Ecology*, **27(1):** 38-45.

Ermakov, V.V., Gulyaeva, U.A., Tyutikov, S.F., Kuz'mina, T.G. and V.A. Safonov (2017). Biogeochemistry of calcium and strontium in the landscapes of eastern Transbaikalia. *Geochemistry International*, **55(12):** 1105-1117.

French, K.E. (2017). Species composition determines forage quality and medicinal value of high diversity grasslands in lowland England. *Agriculture, Ecosystems and Environment*, **241:** 193-204.

Gattringer, J.P., Ludewig, K., Harvolk-Schöning, S., Donath, T.W. and A. Otte (2018). Interaction between depth and duration matters: Flooding tolerance of 12 floodplain meadow species. *Plant Ecology*, **219(8):** 973-984.

Grigoriev, N.G. (1985). Analyzing the content of metabolic energy and digested protein in cattle fodder and diets and rationing the need for them (recommendations). Rosselkhozizdat Publ., Moscow.

Halldorf, S. (1994). Runoff water as a soil forming factor in arid zones. Thesis, Swedish University of Agricultural Sciences, Upsala.

Hopp, R.J. (1974). Plant phenology observation networks. *In:* Phenology and Seasonality Modeling. H. Lieth (ed.), Springer, Dordrecht.

Joyce, C.B. and P.M. Wade (1998). Wet grasslands: A European perspective. *In:* European Wet Grasslands: Biodiversity, Management and Restoration. C.B. Joyce and P.M. Wade (eds). Wiley, Chichester.

Karimov, B.K., Matthies, M., Talskikh, V., Plotsen, M.A. and E.B. Karimov (2019). Salinization of river waters and suitability of electric conductivity value for saving freshwater from salts in Aral Sea Basin. *Asian Journal of Water, Environment and Pollution*, **16(3):** 109-114.

Khamaletdinov, R.R., Gabitov, I.I., Mudarisov, S.G., Khasanov, E.R., Martynov, V.M., Negovora, A.V., Stupin, V.A., Gallyamov, F.N., Farkhutdinov, I.M. and D.Y. Shirokov (2018). Improvement in engineering design of machines for biological crop treatment with microbial products. *Journal of Engineering and Applied Sciences*, **13:** 6500-6504.

Khomyakov, P.M., Kuznetsov, V.I., Alferov, A.M. and A.A Belyakov (2005). The impact of global climate change on the functioning of the main sectors of the economy and the health of the population of Russia. Lenand Publ., Moscow.

Kistanov, N.S. (1970). Salination, desalination and salinization during flood irrigation. Papers of the Volga scientific research Institute of hydraulic engineering and land reclamation, Saratov, **3(3):** 9-11.

Komissarov, A.V. and M.A. Komissarov (2013). Changes in soil properties during flood irrigation in the steppe Trans-Urals of the Republic of Bashkortostan. *Fertility*, **6:** 47-50.

Komissarov, A.V. and M.A. Komissarov (2014). Influence of duration of estuary flooding on some soil properties and productivity of natural hayfields of the steppe Trans-Urals. *Bulletin of Krasnoyarsk State Agrarian University*, **4:** 102-108.

Komissarov, A.V. and N.A. Mosienko (1991). Slope runoff in the steppe zone of the Trans-Urals in Bashkiria. *Meteorology and Hydrology*, **2:** 92-96.

Komissarov, M.A. and I.M. Gabbasova (2017). Erosion of agrochernozems under sprinkler irrigation and rainfall simulation in the southern forest-steppe of Bashkir Cis-Ural region. *Eurasian Soil Science*, **50(2):** 253-261.

Kouzmina, J.V. and S.E. Treshkin (2014). Climate changes in the basin of the Lower Volga and their influence on the ecosystem. *Arid Ecosystems*, **4(3):** 142-157.

Mamin, V.F. and L.F. Savelyeva (1986). Estuaries are storerooms of forages. Volgograd.

Muller, I.B., Buhk, C., Alt, M. and M.H. Entling (2016). Plant functional shifts in Central European grassland under traditional flood irrigation. *Applied Vegetation Science*, **19:** 122-131.

Nasiev, B.N. and R. Eleshev (2014). Modern state of the soils of flood irrigation systems in the semidesert zone. *Eurasian Soil Science*, **47(6):** 613-620.

Nasiri, P., Yazdani, S. and R. Moghaddasi (2018). The effects of agricultural water pricing policies on the sustainability of the water resources: A case of irrigation network in Qazvin Plain. *Asian Journal of Water, Environment and Pollution*, **15(4):** 1-14.

Nikanorova, A.D., Milanova, E.V., Dronin, N.M. and N.O. Telnova (2016). Estimation of water deficit under climate change and irrigation conditions in the Fergana Valley of Central Asia. *Arid Ecosystems*, **6(4):** 260-267.

Novikova, N.M. and N.A. Volkova (2016). Structure of the Flora of the Coasts in the Area of Influence of the Reservoirs on the South of the European Part of Russia. *Arid Ecosystems*, **6(4):** 268-276.

Novikova, N.M., Volkova, N.A. and O.G. Nazarenko (2015). The methodology for studying and assessing the impact of reservoirs on natural shore complexes. *Arid Ecosystems*, **5(4):** 268-276.

Paz-Kagana, T., Ohana-Levia, N., Shachaka, M., Zaadyb, E. and A. Karnielia (2017). Ecosystem effects of integrating human-made runoff-harvesting systems into natural dryland watersheds. *Journal of Arid Environments*, **147:** 133-143.

Peverill, K.I., Sparrow, L.A. and D.J. Reuter (1999). Soil analysis: An interpretation manual. CSIRO, Melbourne.

Rakhimov, Z., Mudarisov, S., Gabitov, I., Rakhimov, I., Rakhimov, R., Farkhutdinov, I., Tanylbaev, M., Valiullin, I., Yamaletdinov, M. and R. Aminov (2018). Mathematical description of the mechanical erosion process in sloping fields. *Journal of Engineering and Applied Sciences*, **13:** 6505-6511.

Safin, H.M., Zhigulev, M.A. and A.V. Komissarov (2010). Prospects of flood irrigation development in Bashkortostan. *Achievements of Science and Technology in Agriculture*, **5:** 50-52.

Shepeleva, L.F., Cherepinskaya, A.N., Rabtsevich, E.S. and L.G. Kolesnichenko (2019). Yearly dynamics in the elemental composition of the floodplain meadow phytocenoses herbage. IOP Conference Series: *Earth and Environmental Science*, **232(1):** 012022.

Sobol, N.V., Gabbasova, I.M. and M.A. Komissarov (2015). Impact of climate changes on erosion processes in Republic of Bashkortostan. *Arid Ecosystems*, **5(4):** 216-221.

Tarasenko, P.V. and R.B. Tuktarov (2013). Modern ecological and meliorative state of engineering systems of flood irrigation of semi-desert zone of the Saratov trans-Volga region. *Current Issues of Science and Education*, **1:** 421.

Tockner, K. and J.A. Stanford (2002). Riverine flood plains: Present state and future trends. *Environmental Conservation*, **29:** 308-330.

Zalibekov, Z.G. (2011). The arid regions of the world and their dynamics in conditions of modern climatic warming. *Arid Ecosystems*, **1(1):** 1-7.

Zalibekov, Z.G., Mamaev, S.A., Biarslanov, A.B., Asgerova, D.B., Galimova, U.M. and M.S. Sultankhamedov (2017). Regional distribution patterns of soils in delta ecosystems and their potential use on different continents. *Arid Ecosystems*, **7(2):** 73-79.

Zhigulev, M.A., Komissarov, A.V. and H.M. Safin (2010). State and prospects of flood irrigation development in the Republic of Bashkortostan. *Melioration and Water Management*, **6:** 9-11.