Asian Journal of Water, Environment and Pollution, Vol. 17, No. 1 (2020), pp. 19–26.
DOI 10.3233/AJW200002

Choice of Melioration Facies Regimes Using Catenary-facies Models of Watersheds of the Forest-steppe Zone of the Republic of Bashkortostan

Aigul Khazipova*, Ayrat Chafizov, Aleksander Komissarov, Radik Mustafin and Ruslan Zubairov
Federal State Budgetary Educational Establishment of Higher Education, Bashkir State Agrarian University
Ufa, Russian Federation
✉ hazipova.aigul@rambler.ru

Received August 30, 2019; revised and accepted September 6, 2019

Abstract: Unfavourable environmental state of the reclaimed land requires to revise common methods of determining reclamation modes. Reclamation regimes should be chosen as part of complex facilities, depending on different physical, geographical and climatic conditions where the reclaimed land is located. This can be done by building catenary-facies models of watersheds. In our research we applied computer-based simulation methods of the functioning of the watershed facies catenas. The methods to be applied are based on the calculation of the moisture transfer processes by solving the differential equation of two-dimensional moisture movement in the soils and subsoils of the zones of aeration and complete saturation. The paper presents a catenary-facies model, its operation under natural conditions taking into account hydrotechnical ameliorations.

The model allows to make forecast calculations of water regimes and of the watersheds facies productivity. We have developed a method of justification of environmental reclamation regimes by simulation of watershed facies catenas. Watershed facies have been classified according to their hydrothermal coefficient and the humidity ratio within watersheds of the forest-steppe zone of the Republic of Bashkortostan. There was revealed the integral dependence of relative crop capacity on soil washability of facies catenas. As a part of the study, there were found environmentally friendly meliorative regimes available for the conditions of the forest-steppe zone. The use of these regimes contributes to the minimum soil washability and the maximum crop capacity.

Key words: Watersheds, catenary-facies models, geomorphological scheme, physiographic regions, natural and climatic parameters, reclamation regimes, environmentally friendly irrigation and drainage norms, agricultural crop capacity.

Introduction

The day to day agriculture more adversely affects natural environment. Annual deterioration of the land ecological state in the Republic of Bashkortostan is associated with its degradation. According to scientists AV. Komissarova, H. M., Safina, A. R. Chafizova, Gabasova I. M., etc., the most common environmental problems in the Republic are loss of forests, soil destruction processes, grass stands degression and arable land degradation (Komissarov and Komissarov, 2015; Gabbasova et al., 2016; Khafizov and Kamaletdinova, 2017; Safin and Yaparov, 2018). Unfavourable ecological state of natural resources is also mentioned

*Corresponding Author

in the studies of foreign scientists (Tyagi et al., 2009; Abdullayev, 2010; Chandio et al., 2016; Merten et al., 2016; Singh, 2017; Thomas et al., 2018) .

Irrigation and drainage are the most effective means to ensure agricultural production stability in many countries. Melioration measures today are aimed at obtaining high yields of agricultural crops. However, these measures worsen general land ecological state. Heavy irrigation leads to hydrowashing of nutrients from irrigated land which are removed with surface and underground runoff. Drainage in its turn usually leads to soil salinization.

Among other problems, soil swamping and salinization have a direct and indirect impact on the growth and productivity of crops cultivated in semi-arid and arid regions of India (Singh, 2017). These problems result from the expansion of irrigation farming. We did a review of the aspects of soil swamping and salinization problems and their impact on the irrigation farming stability. Studies are grouped according to the mechanism of soil swamping and land salinization, the plants reaction to soil swamping and salinization, and the effect of soil swamping and salinization on plant productivity (Singh, 2017).

The problem of soil swamping has also been observed in Pakistan in the area along the Rohri channel of the Jaipur region. Such scientists as Chandio et al. (2016) studied the issues of the surrounding soil swamping elimination. They also considered in their works the effectiveness of various measures such as modeling of horizontal and vertical drainage systems in order to create favourable conditions for the development of crop roots. It is shown that the most effective way to maintain the underground water table at the optimum depth is a combined drainage system (i.e. vertical and horizontal drainage).

The considered works show the need to determine such ecological melioration regimes that do not cause soil swamping, salinization and reduction of soil fertility (Ermakov, 2017).

Problems of fertile land loss and watershed erosion fall within the field of current investigation. Specifically, the focus was laid on the soil particles wash-off in the basins of the Iowa and Yazu rivers during the period from 2006 to 2008. The impact of rain and flood waters on soil erosion was studied in detail. It was proved that good decisions contribute to prevent such negative processes (Merten et al., 2016).

Soil erosion in the mountain river basin in India was assessed using the universal equations of soil loss and the sediment delivery coefficient to determine the annual nutrient loss (Thomas et al., 2018). As mechanical erosion of soils and landslides occur typically on the slopes, to preserve fertile soil, a comprehensive approach is needed (Rakhimov et al., 2018).

Attaching significance to the works on the study of soil fertility decline, it has to be noted that they should be considered taking into account the climatic and landscape watersheds features (Mustafin et al., 2018). Soil and vegetation within watersheds area interact with such factors as soil moisture, relative humidity and air temperature, and this interaction is of a constant, continuous and dynamic character (Trautz et al., 2017).

When exploring the functioning of watersheds as runoff-producing areas, it is necessary to form a fairly large single source of initial data. The data should include geomorphological schemes, meteorological, soil-geological and reclamation conditions, and biological characteristics of cultivated crops (Woodhouse et al., 2018).

To understand the environmental sustainability of the region in the future keeping records of climatic and moisture features of the area is of a particular importance, especially when applying irrigation and drainage. Global climate change, for example, results in recurrent dry or hyperhumid years with consecutive drought. Warming in the West of the United States is due to the anthropogenic climate change (Hoekema and Sridhar, 2011).

Based on the calculated Palmer drought indices, a comparative analysis of the impact of drought on the mountainous and low-land areas of the Free State province of the South Africa was carried out. Drought assessment with allowance made to high-altitude location of the territories proves the need to justify the use of irrigation and drainage systems, taking into account the relative position of watershed particular parts (hills, slopes and lowlands) (Mbiriri et al., 2018).

Modern approaches to improve the land ecological state are aimed at carrying out reclamation activities as part of the complex arrangement of territories. Complex arrangement of territories is aimed at increasing land productivity, and at the same time preserves their ecological stability. Watersheds are large genetically homogeneous landscape complexes and are identified as an object in complex arrangement of territories (Golovanov et al., 2006; Aidarov et al., 2007).

Differential equation of moisture transfer in the aeration zone was developed to model lateral moisture movement in the soil from the watershed to the watercourse, and vertical water exchange in watersheds (Koi et al., 2019).

Today there are works on complex arrangement of watersheds of the western part of the Republic of Bashkortostan, where reclamation watersheds regimes are determined taking into account their averaged natural and climatic parameters (Khafizov, 2010; Khafizov et al., 2019).

However, the study of physiographic and climatic conditions of the forest-steppe zone of the Republic of Bashkortostan revealed the differences in landforms, geological conditions, soils, vegetation and climatic conditions. The differences were revealed not only within watersheds, but also within their facies. Thus, it was proved that natural, climatic and physiographic diversity of watershed facies should be taken into account when determining their ecological melioration regimes (Hazipova and Khafizov, 2016).

Having analyzed the issue, we came to a conclusion that scientific works aimed at improving the ecological state of the reclaimed lands are relevant today not only for the Republic of Bashkortostan and the Russian Federation as a whole, but also for foreign countries. Currently, there are still unsettled questions on the determining of ecological melioration regimes within the watershed facies with regard to their natural and climatic parameters.

Methods

The definition of ecological melioration regimes is based on the idea of complex arrangement of large genetically homogeneous areas, i.e. watersheds. The parameters of melioration regimes are determined by the method of the computer simulation of the watersheds catenas facies functioning according to the "Catena" program. The program contains the computational solution of two-dimensional equation of moisture transfer in the aeration zone and in the zone of the complete catenas saturation (Golovanov and Sukharev, 2005). Determination of the ecological reclamation regimes modelling is possible when applying geo-systematic and catenary approaches, which are based on geomorphological mapping of watershed catenas facies. Such a schematization allows to present a watershed area as a catenary-facies model consisting of the watershed itself, catenas facies and facies (Table 1).

Watershed is a integrated geosystem, united on the principle of hydro-chemical fluxes unity. It performs the main function of run-off producing. According to the boundaries of physiographic regions, watershed areas are divided into the catena facies. Catena is a series or chain of regularly changing natural complexes (facies which are morphological parts of the landscape). Catenas changing is carried out from the watershed down the slope to the nearest watercourse. A watershed and a watercourse in their turn are connected by lateral unidirectional flows of matter and energy.

Within catenas facies there are three sectors belonging to different relief layers: eluvial facies (a hill) located on watershed surfaces and pitching slightly; transit facies (a slope) occupying an intermediate position between eluvial and superaqual facies, when located on watershed, they are divided into trans-eluvial and trans-accumulative facies; and superaqual facies (a lowland) which is the lowest watershed part adjacent to subaqueous facies (water course) (Glazovskaya, 2002).

The catenary-facies model contains watershed boundaries, belonging to each watershed, catenas facies and facies to a specific physiographic region with specific climatic conditions. In the model, climatic conditions are determined by the hydrothermal coefficient (according to G. T. Selyaninova) and by moisture ratio (according to N.N. Ivanov). The same parameters were used to make the classification of watershed facies in accordance with natural and climatic conditions (Khafizov et al., 2019).

Meteorological data (precipitation, temperature and humidity), geomorphological schemes, soil-geological and meliorative conditions are necessary to make a model.

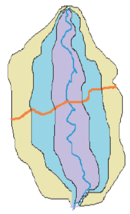
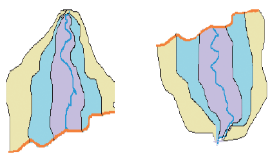
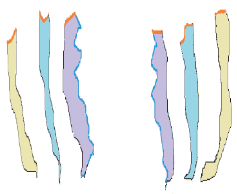
Geomorphological graphs are constructed in accordance with the found morphometric parameters of watersheds, catenas facies and facies. They are schematized width and height of the catenas facies, morpho isograph point and the routine contours form factor outline (Figure 1).

The "Catena" program used for the calculation of reclamation modes allows to simulate the functioning of a developed catenary-facies model in natural conditions and with regard to hydrotechnical amelioration (Figure 2).

The functioning of a watershed catenary-facies model in natural conditions is considered taking into account natural moisture of facies: precipitation, evaporation, transpiration by plants and infiltration, inflow and outflow of groundwater in facies. As for the model in which hydrotechnical amelioration is taken into account, besides natural moisture for its functioning, moisture from irrigation sprinkler is taken into account. The removal of moisture excesses is due to the drainage systems.

According to the existing system of irrigation farming, perennial herbs and vegetables are worth being

Table 1: Catenary-facies watershed model

Model structure		*Making the model*			*Natural and climatic conditions taken into account for the model*	
		Border establishment	*Entitling*	*Constructing of geomorphological graphs in accordance with:*	*Physiographic regions*	*Natural and climatic parameters*
Watershed		Along with the watershed line of the main river on the topographic map	For the main river	Watershed area river length	From one to six regions	HTC from 0.85 to 1.3. Humidity factor (HF) from 0.5 to 0.8
Facies catenas		In accordance to the borders of the physiographic regions within watersheds	According to the physiographic region they belong to	According to schematized width and height, to the morpho isograph point, to the routine contours form factor	Of one region	HTC from 0.85-1.00; 1.00-1.15 up to 1.15-1.30. HF from 0.5-0.6; 0.6-0.7 to 0.7-0.8
Facies		According to the area slope and location towards the river within the catena facies	According to the mutual altitude location	According to schematized facies height and width	Of a part of one region	HTC = 0.85-1.00; HTC = 1.00-1.15; HTC = 1.15-1.30. HF = 0.5-0.6; HF = 0.6-0.7; HF=0.7-0.8

Note: HTC – Hydrothermic coefficient, HF – Humidity factor cultivated effectively on reclaimed lands. In our model this approach is implemented by using facies as crops such as potatoes and perennial grasses.

Based on the developed generalized watershed catenary-facies model, we have designed watershed models for the rivers of the forest-steppe zone of the Republic of Bashkortostan. Their verification has been carried out by comparing calculated and experimental values of the groundwater table: in natural conditions on a water-balance station plot, and in the conditions of irrigation - on a plot of Dmitrievsky irrigation system. The maximum differences between the calculated and experimental values of the groundwater table did not exceed 7%, which confirmed that the watershed catenary-facies models have been constructed properly (Komissarov et al., 2013).

Environmental reclamation regimes have been identified by matching their parameters. According to the "Katena" program and using the trial method, the most optimal values of the antecedant soil water and irrigation rate have been determined, which will provide a minimum soil washability, taking into account the maximum possible yield. They can be estimated by the reclamation component η (according to Aidarov (2007)):

$$\eta = \frac{(c+g)_M}{(c+g)_{Mn}} \cdot \frac{y_{Mn}}{y_M} \quad (1)$$

where $(c + g)_M$ is the flow of the surface runoff and the value of non-reclaimed lands washability, mm; $(c + g)_{Mn}$ is the same but for the reclaimed lands, mm; and Y_M, Y_{Mn} is the plants yield capacity on non-reclaimed and reclaimed lands. Reclamation regimes are considered to be ecological if the reclamation component η is as close to one as possible.

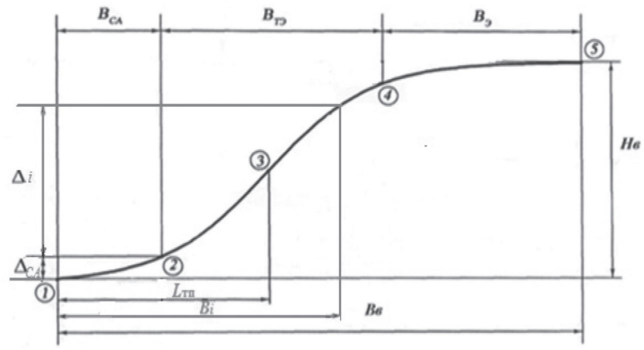


Figure 1: Geomorphological schematization of the watershed catenas facies. Morphometric parameters: B_{sa}, B_{te}, B_e – width of superaqual, trans-eluvial and eluvial facies respectively, $H_В$, $B_В$ - schematized height and width of the catenas facies; $L_{ТП}$ – catenas width inside morpho isograph; 1 – the beginning of the catena (river bank), 2 – transition from superaqual facies to trans-eluvial, 3 – slope break point, 4 – transition from trans-eluvial to eluvial facies, 5 - end of the catenas facies (watershed).

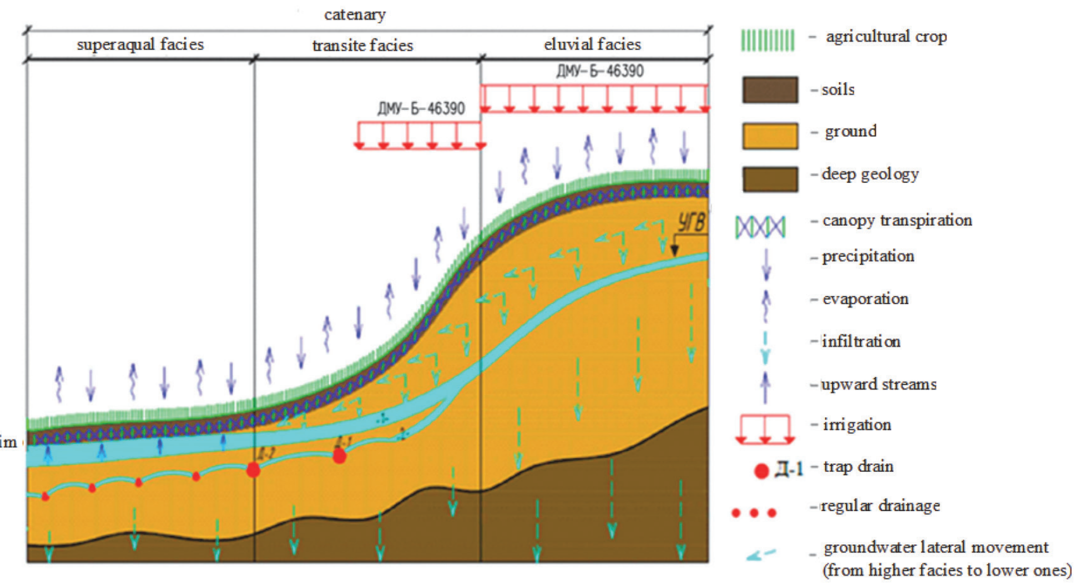


Figure 2: Functioning of the catenary-facies mode.

Research Results

We calculated long-term average annual parameters of water regime and watersheds facies yield of the forest-steppe zone of the Republic of Bashkortostan for the period from 1973 to 2013.

Table 2: Recommended irrigation norms, mm

HF	*Eluvial facies*				*Transit facies*			
	HTC			*Average according to the HTC*	*HTC*			*Average according to the HTC*
	0.85-1.00	*1.00-1.15*	*1.15-1.30*		*0.85-1.00*	*1.00-1.15*	*1.15-1.30*	
0.5-0.6	61	81	48	63	52	55	0	36
0.6-0.7	-	30	38	34	0	0	0	0
0.7-0.8	83	83	-	83	-	0	0	0
Average according to the HF	72	65	43	60	26	18	0	12

Note: HTC – Hydrothermic coefficient, HF – Humidity factor

Table 3: Relative crop yield capacity calculated according to the methods of determination of ecological meliorative regimes, in proportion

HF	*Eluvial facies*				*Transit facies*				*Superaqual facies*			
	HTC			*Average according to the HTC*	*HTC*			*Average according to the HTC*	*HTC*			*Average according to the HTC*
	0.85-1.00	1.00-1.15	1.15-1.30		0.85-1.00	1.00-1.15	1.15-1.30		0.85-1.00	1.00-1.15	1.15-1.30	
0.5-0.6	0.78	0.75	0.77	0.77	0.69	0.67	0.67	0.68	0.64	0.63	0.60	0.62
0.6-0.7	-	0.73	0.78	0.75	0.73	0.72	0.69	0.71	0.57	0.64	0.63	0.61
0.7-0.8	0.7	0.80	-	0.75	-	0.70	-	0.70	-	0.62	-	0.62
Average according to the HF	0.74	0.76	0.77	0.76	0.71	0.62	0.68	0.70	0.61	0.63	0.62	0.62

Note: HTC – Hydrothermic coefficient, HF – Humidity factor

Ecological reclamation watersheds facies regimes have been developed on the basis of the calculations. To increase the watersheds' productivity, irrigation of all eluvial facies with an average irrigation rate of 60 mm is recommended. Irrigation of superaqual facies is not required. The irrigation of transit facies is recommended with the hydrothermal coefficient being from 0.85 to 1.15 and the moisture coefficient from 0.5 to 0.6. The irrigation norms should be up to 55 mm (Table 2). For superaqual facies drainage is required, i.e. a special device for systematic drainage should be used with the average norm of 1.75 m. To protect superaqual facies from groundwater inflow coming from upland facies a trap drain device is required.

Crop yield capacity for the watersheds facies of the forest-steppe zone of the Republic of Bashkortostan calculated using the developed method are given in Table 3.

The results of determining the environmental reclamation regimes are given in the form of integral dependence of relative yield capacity on the soil washability of the catenas facies (Figure 3).

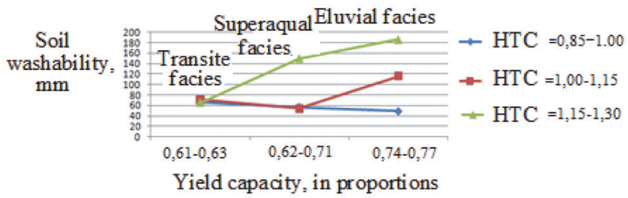


Figure 3: Integral dependence of relative yield capacity on the soil washability of the catenas facies.

According to the dependence, it is evident that soil washability in superaqual facies, which guarantees environmental sustainability, doesn't depend on the hydrothermal coefficient and is within 60-80 mm. At the same time, the maximum possible relative yield capacity ranges from 0.61 to 0.63.

Soil washability of the transit facies increases amounting to 140-160 mm when the hydrothermal coefficient is 1.15-1.30. For other values of the hydrothermal coefficient it is within 40-60 mm with relative yield capacity being 0.62-0.71.

The soil washability value of eluvial facies with the maximum possible yield capacity of 0.74-0.76 depends on the hydrothermal coefficient: at 0.85-1.00 HTC it is within 40-60 mm, at 1.00-1.15 HTC –100-120 mm, when the HTC is 1.15-1. 30 the possible yield capacity makes 180-200 mm.

Discussion of the Results

On the basis of the calculated parameters of the facies water regimes got by the constructing catenary-facies models and made both for natural conditions and after hydrotechnical amelioration, we have determined the following environmental reclamation regimes:

- Irrigation of watersheds eluvial facies which is recommended with an average irrigation norm of 60 mm. Drainage of eluvial facies is not required. When applying hydrotechnical amelioration, relative eluvial facies productivity will increase 1.5 times.
- On transit watersheds facies of the forest-steppe zone irrigation is recommended with irrigation norms up to 55 mm but only for groups in which the hydrothermal coefficient is 0.85–1.15. The groundwater table is rising, but drainage is not yet required. The relative yield capacity of transit facies after hydrotechnical ameliorations will increase 1.3 times.
- On superaqual facies drainage with the norm up to 1.75 m is recommended. Irrigation is not required. With that, relative superaqual facies productivity increases 3.2 times.

Significant differences in irrigation norms for facies and for their individual parts, divided according to different parameters such as natural and climatic indicators, show the relevance of determining the irrigation norm depending on the natural and climatic facies indicators. The same conclusion is confirmed by the works of scientists from Egypt, Israel and other countries located in desert and semi-desert zones. Environmentally sound reclamation regimes can be obtained only by drip irrigation (Golovanov and Abdel-Azim, 2009; Megersa and Abdulahi, 2015).

Conclusions

1. In our research we have developed a method of determining environmental reclamation regimes on the basis of catenary-facies watersheds models of the forest-steppe zone. The models have been designed by constructing a geomorphological graph and computer simulations of 18 watersheds catenas facies of the forest-steppe zone of the Republic of Bashkortostan.
2. As a part of the study, there were found environmentally friendly melioration regimes available for the conditions of the forest-steppe zone. The use of these regimes contributes the minimum soil washability and the maximum crop capacity:
   - Irrigation of eluvial facies is recommended with an average irrigation rate of 60 mm, of transit facies – 12 mm. Irrigation of superqual facies is not required.
   - Drainage is recommended for all superaqual facies with an average norm of 0.75-1.25 m. Transit and eluvial facies drainage is not required.

References

Abdullayev, I. (2010). Aral Sea Crisis: Large Scale Irrigation and Its Impact on Drinking Water Quality and Human Health. *Asian J. Water Environ. Pollut*., **7(1):** 63-69.

Aidarov, I.P. (2007). Complex arrangement of lands. Moscow. Moscow State University of Environmental Engineering.

Chandio, A.S., Mirjat, M.S. and T.S. Lee (2013). Simulation of Horizontal and Vertical Drainage Systems to Combat Waterlogging Problems along the Rohri Canal in Khairpur District, Pakistan. *J. Irrig. Drain Eng.*, **139(9):** 710-717.

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.

Gabbasova, I.M., Suleymanov, R.R., Kabirov, I.K., Komissarov, M.A., Fruhauf, M., Libelt, P., Garipov, T.T., Sidorova, L.V. and F.H. Khaziev (2016). Change of eroded soils in time depending on their agricultural use in the southern Urals. *Soil Sci*, **10:** 1277-1283.

Glazovskaya, M.A. (2002). Geochemical bases of typology and methods of research of natural landscapes. Smolensk. Ojkumena Publishing House.

Golovanov A.I. and M.M. Abdel-Azim (2009). Evaluation the Irrigation Rate in Drip Irrigation and Identify Standards Irrigation in Terms of Egypt. The First International Conference "Economics and Management of Water in Arab World and Africa". Assiut University, Egypt.

Golovanov, A.I. and Yu.I. Sukharev (2005). Mathematical model of moisture transfer in landscape catenas. Proceedings of the International Scientific and Practical Conference. Moscow. Moscow State University of Environmental Engineering.

Golovanov, A.I. and Yu.I. Sukharev (2006). Complex arrangement of territories – further stage of land reclamation. *Melioration and Water Management*, **2:** 25-31.

Khazipova, A.F. and A.R. Chafizov (2016). Assessment of ecological status of catenas of forest-steppe zone of Western Bashkortostan and ways to improve environmental sustainability. *In:* Agricultural science in the innovative development of agricultural complex. Proceedings of the International Scientific and Practical Conference within the 26th International Special Exhibition. "Agrokompleks–2016". Ufa. Bashkir State Agrarian University.

Hoekema, D.J. and V. Sridhar (2011). Relating climatic attributes and water resources allocation: A study using surface water supply and soil moisture indices in the Snake River basin, Idaho. *Water Resour. Res.*, **47(7)**: W07536.

Chafizov, A.R. (2010). Ecological problems and complex arrangement of the Western Bashkortostan watersheds. *Agrarian Bulletin of the Urals*, **3(69):** 86-88.

Chafizov, A.R. and L.A. Kamaletdinova (2017). Economic and technogenic characteristics of the Western Bashkortostan watersheds and measures to improve their environmental sustainability on the example of steppe watersheds. *Problems of the Regional Ecology*, **2:** 79-85.

Chafizov, A., Khazipova, A., Kutliyarov, D., Mustafin, R., Kamaletdinova, L., Nedoseko, I., Galeev, E., Kutliyarov, A and R. Zubairov (2019). Justification of Reclamative Watershed Regimes of the Forest-steppe Zone of the Western Part of the Republic of Bashkortostan with Regard to Their Provision with Heat and Moisture. *Asian J. Water Environ. Pollut*., **16(2):** 101-108.

Koi, K., Sukharev, Yu.I., Piven, E.A. and V.A. Shuravilin (2019). Justification of potato cultivation technologies depending on fertilizers and varietal characteristics in the Moscow region. *Agrochemical Bulletin*, **1:** 37-40.

Komissarov, A.V. and M.A. Komissarov (2015). Effect of long-term irrigation on the properties of leached chernozem in the Southern Urals. *Agriculture*, **2:** 5-9.

Komissarov, A.V., Chafizov, A.R. and A.F. Khazipova (2013). Verification of the computer model of the watersheds catenas functioning based on the results of field experiments. *Environ. Eng.*, **1:** 16-21.

Mbiriri, M., Mukwada, G. and D. Manatsa (2018). Influence of altitude on the spatiotemporal variations of meteorological droughts in mountain regions of the free state Province, South Africa (1960–2013). *Adv. Meteorol*., **18**.

Megersa, G. and J. Abdulahi (2015). Irrigation system in Israel: A review. *Int. J. Water Res. Environ. Eng.*, **7(3):** 29-37.

Merten, G.H., Welch, H.L. and M.D. Tomer (2016). Effects of hydrology, watershed size, and agricultural practices on sediment fields in two river basins in Iowa and Mississippi. *J. Soil Water Conserv.*, **71(3):** 267-278.

Mustafin, R., Ryzhkov, I., Sultanova, R., Khabirov, I., Khasanova, L., Zagitova, L., Asylbaev, I., Kutliyarov, D., Zubairov R. and A. Rajanova (2018). Assessment of Slope Stability in Coastal Water Protection Zones. *J. Eng. Appl. Sci.*, **13:** 8331-8337.

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. *J. Eng. Appl. Sci.*, **13:** 6505-6511.

Safin, H.M. and G.H. Yaparov (2018). Optimization of economic use of the reclaimed lands of the Republic of Bashkortostan. Ufa: The Press World.

Singh, A. (2017). Waterlogging and Salinity Management for Sustainable Irrigated Agriculture. I: Overview, Implication, and Plant Response. *J. Irrig. Drain Eng.*, **143(9):** 04017036.

Thomas, J., Joseph, S. and K.P. Thrivikramji (2018). Assessment of soil erosion in a monsoon-dominated mountain river basin in India using RUSLE-SDR and AHP. *Hydrolog. Sci. J.*, **63(4):** 542-560.

Trautz, A.C., Illangasekare, T.H., Rodriguez-Iturbe, I., Heck, K. and R. Helmig (2017). Development of an experimental approach to study coupled soil-plant-atmosphere processes using plant analogs. *Water Resour. Res.*, **53(4):** 3319-3340.

Tyagi, S.K., Datta, P.S., Sharma, R.K. and S. Kulshreshtha (2009). Nitrate and Fluoride Contamination in Ground Water under Intensive Agricultural Landuse. *Asian J. Water Environ. Pollut*., **6(2):** 81-86.

Woodhouse, C.A. and G.T. Pederson (2018). Investigating runoff efficiency in upper Colorado river streamflow over past centuries. *Water Resour. Res.*, **54(1):** 286-300.