Bulgarian Journal of Agricultural Science, 26 (No 5) 2020, 919–926

Regression model of the formation of pasture with programmable productivity of the arid lands of the South-East European of Russia

Mikhail Y. Puchkov[1]; Alexander V. Koshkarov[2]; Maksim A. Lysakov[1]; Konstantin V. Isaev[3]; Elena G. Loktionova[4]; Sergey D. Fomin[5, 6]*; Elena S. Vorontsova[6,7] and Vasily M. Strukov[1]

[1]*Astrakhan State University, Educational and Experimental Farm, 414056 Astrakhan, Russian Federation*
[2]*Astrakhan State University, Department of Information Technologies, 414056 Astrakhan, Russian Federation*
[3]*Precaspian Agrarian Federal Scientific Center of the Russian Academy of Sciences, 416251 Astrakhan region, Russian Federation*
[4]*Astrakhan State University, Department of Ecology, Environmental Management, Land Management and Life Safety, 414056 Astrakhan, Russian Federation*
[5]*Volgograd State Agrarian University, 400002 Volgograd, Russian Federation*
[6]*All-Russian Research Institute of Irrigated Agriculture, 400002 Volgograd, Russian Federation*
[7]*Volga Region Research Institute of Manufacture and Processing of Meat-and-Milk Production, 400131 Volgograd, Russian Federation*
**Corresponding author:* fsd_58@mail.ru

Abstract

Puchkov, M.Y., Koshkarov, A.V., Lysakov, M.A., Isaev, K.V., Loktionova, E.G., Fomin, S.D., Vorontsova, E.S. & Strukov, V.M. (2020). Regression model of the formation of pasture with programmable productivity of the arid lands of the South-East European of Russia. *Bulg. J. Agric. Sci., 26 (5)*, 919–926

Recently, due to the changing climatic parameters such as the distribution of atmospheric precipitation and the annual cycle of temperature, there has been a change in the amount of formation of soil moisture reserves. Since the productivity of pasture ecosystems in arid territories is limited by the amount of soil moisture, the modeling of its formation has great practical significance in productivity forecasting. The objective of the study is to create a mathematical model for determining the timing of the formation of pasture agrophytocenoses with programmable productivity, depending on atmospheric processes (air temperature, depth of precipitation and relative air humidity). The main research method is the use of an empirical-statistical approach in modeling a complex atmosphere-plant-soil system. The research resulted in the obtention of regression models, that describe the state of soil moisture reserves and the productivity of pasture ecosystems: we obtained the regression equation for the formation of a soil moisture reserve (0–20 cm), depending on meteorological factors: moisture reserve = 37 – 0.426t, t – air temperature (°C); we obtained equations of formation of soil moisture reserves due to the relative air humidity and the amount of atmospheric precipitation: the moisture reserve = -75 + 1.369f + 0.287R, where f – relative air humidity (%), R – amount of precipitation (mm). It is clear that there is a direct correlation between the formation of soil moisture reserves with the relative air humidity and the amount of precipitation; in the regression equation of the following form we obtained the connection of pasture agrophytocenoses from the moisture reserve in the soil layer of 0–20 cm: the yield of dry matter (t/ha) = 1.9758 + 0.0049w – 0.0069R, where w – moisture reserve in the soil layer 0–20 cm (mm).

Keywords: arid lands; formation of pasture agrophytocenoses; program productivity; regression model

Introduction

Meteorological factors, such as air temperature, relative air humidity and the amount of precipitation, determine the formation of a soil moisture reserve (Kuzmina et al., 2004; Kuzmina, 2007; Voznesenskaya & Beschetnova, 2009; Kuzmina & Treskin, 2014; Kuzmina et al., 2014). In arid ecosystems, the soil moisture reserve is constantly strongly dependent on air temperature (Myalo & Levit, 1996; Nazarenko, 2006). The summer period for arid ecosystems is characterized by extremely high temperature regimes, which leads to constant overheating of the soil. This factor together with the lowest values of the amount of precipitation leads to the dehydration of the soil cover (Neronov, 2002; Ovadykova et al., 2015). In that regard, the productivity of arid ecosystems is minimal (Tuller et al., 1999; Sukopand Or, 2004; Puchkov et al., 2015).

The productivity of arid ecosystems is possible through the creation of pasture agrophytocenoses with specified parameters. To form the guaranteed productive pasture agrophytocenoses of arid ecosystems, it is necessary to take into account the formation of soil moisture reserves and its relation to the productivity of pasture agrophytocenoses (Puchkov et al., 2013, 2014; Assouline et al., 2015; Ovadykova et al., 2015; Sochorec et al., 2015). This interconnection can be measured only through mathematical modeling, which links atmospheric processes with the hydrophysical characteristics of the soil and the productivity of pastures (Or & Wraith, 2002; MacDonald, 2015).

Empirical-statistical modeling, based on a block of experimental data, is a very simple and common method. Regression models obtained with the help of this approach are also useful in predicting the productivity of pasture ecosystems depending on changing atmospheric processes (Puchkov et al., 2015). This allows agricultural experts to program pasture productivity depending on the weather forecast for many months to come, and to rationally plan pasture use taking into account weather forecasts (Steinwand et al., 2006; Shokriet al., 2009; Or et al., 2013; Popova et al., 2015; Bazitov et al., 2016).

The purpose of the study is to create a mathematical model for determining the timing of the formation of pasture agrophytocenoses with programmable productivity, depending on atmospheric processes (air temperature, depth of precipitation, relative air humidity).

Objectives of the study are to study the soil potential of biohorizons, analysis of meteorological indicators (air temperature, amount of precipitation), statistical analysis of the distribution of values of air temperature, the amount of precipitation, the productivity of pasture agrophytocenoses with programmable productivity, to create a mathematical model for determining the timing of the formation of pasture agrophytocenoses with programmable productivity, depending on atmospheric processes (air temperature, depth of precipitation, relative air humidity).

Materials and Methods

The object of research is an anthropogenized landscape complex located on the territory of the North-Western Caspian region, characterized by maximum aridization – the western ilmen-hillock landscape area.

During experimental works we carried out a complex of field and laboratory observations and examinations. Field studies consisted of annual expeditionary geobotanical and field works. Field geobotanical expeditionary studies were conducted with the aim of identifying and laying an ecological profile with a network of stationary sites. Each stationary site had its own ecological zone: 1 – the top of the Baer hillock; 2 – the slope of the Baer hillock; 3 – foot of the Baer hillock.

For each ecological zone, we determined cultivable soil profiles of active root layers from 0–20 cm to 20–45 cm, on which control sections were laid. Horizon 0–20 cm is a layer of soil cultivation according to mini-Till principle. Horizon 20–45 cm is the most root-inhabited layer. We carried out a detailed morphological description of the cultivable active root-inhabited soil layers for each soil section. We determined agrophysical characteristics of soils. These soil profiles were identified as controlling and were observed until the end of the study.

The agrotechnical impact on the soil cover was carried out according to the soil cultivation principle by a mini-Till disc at a depth of 5 cm to 20 cm.

Data on air temperature, amount of atmospheric precipitation, relative air humidity were obtained from the site http://thermograph.ru/.

During calculation of the reserves of productive moisture we took into account the soil moisture content, soil density, thickness of the soil horizon and the moisture content of the stable wilting. It should be noted that for sandy loam soils the moisture content of a stable wilting corresponds to 4% of the weight of absolutely dry soil.

Equation for calculating the reserves of productive moisture:

$$W_{pr} = 0.1dh(W - k),$$

where W_{pr} – productive moisture reserves (mm),

d – soil density (g/cm^3),

h – capacity (thickness) of the soil layer (cm),

W – soil moisture content (in % by weight of absolute dry soil), 0.1 – factor for transferring the height of the water layer to millimeters.

Mathematical processing of the obtained results was carried out in the form of using nonparametric statistics (Box & Whiskers Plot technique) and regression analysis with a significance level of 0.05 (Statistica 6.0 program). Mathematical modeling of the formation of soil moisture and pasture productivity was carried out by the method of empirical-statistical modeling using the statistical analysis of a block of experimental data (Statistica 6.0 program).

Results and Discussions

Soil moisture will remain as a limiting factor during the creation and exploiting pasture agrophytocenoses with programmable productivity in arid ecosystems of the North-Western Caspian region. This indicator depends, first of all, on the amount of precipitation and its distribution by the seasons of the year. Moreover, an important factor is the course of the annual agrometeorological cycle. The magnitude of the limiting factor will also depend on the terrain and the location of the crops.

Characteristics of soil potential of biohorizons of pasture agrophytocenoses

For a clear representation of the formation of a soil moisture reserve, it is necessary to determine the morphological structure of the soil cover of a given territory and its features.

According to the morphological description of the root-inhabited soil layers of 0–20 cm and 20–45 cm, the soil cover of the "Liman" place mark is represented by light brown to brown semi-desert soils and by a subtype from light brown to brown Caspian semi-desert soils. Table 1 presents the agrophysical characteristics of soils.

Soil density of the first environmental zone of the active root-inhabited soil layer of 0–20 cm to 20–45 cm ranges from 1.42 g/cm^3 to 1.48 g/cm^3 (Table 1). At this density value there is a small number of voids corresponding to the porosity data, which is 46% of the soil volume and low moisture capacity. Fluctuations in soil density of the second environmental zone in active root-inhabited soil layers of 0–20 cm to 20–45 is equal to from 1.45 g/cm^3 to 1.47 g/cm^3 and porosity from 46% to 50%. The value of the soil density of the third environmental zone fluctuates in active root-inhabited soil layers of 0–20 cm and 20–45 cm from 1.5 g/cm^3 and up to 1.59 g/cm^3 (Table 1).

In this case, high density values are due to processes in which soil particles coalesce and form a dense monolith, and root systems of vegetation bump into the given horizon. Therefore, plants with a small root system (fibrous) from the group of ephemeras dominate this zone, indicating degradation processes in this zone. However, instead of forming ephemeral vegetation, we managed to form anagrophytocenosis with programmable productivity with a dense vegetation cover, consisting of long-term cultural pasture herbaceous vegetation belonging to the family of cereals due to rational selection of the timing of its formation.

Statistics of distribution of soil moisture reserve, air temperature, amount of precipitation and productivity of pasture arid ecosystems

Table 2 provides data on statistical characteristics of the variation in the amount of precipitation.

From the data given by the analysis with the help of nonparametric statistics, it is evident that during the 6-year observation period over the amount of precipitation, the highest value was reached in May-June and also in September (Table 2).

Statistics analysis of the amount of precipitation by months clearly demonstrates that in May-June the variation of value is larger, which indicates the peaks of precipitation in this period. However, in the period July-August, the amount of precipitation is characterized by a depression, which credibly separates this period due to the low swing and the lower and upper quartiles from the medial value in this period. A different picture emerges in September by contrast with August. The period of September, which is clearly distinguished, is characterized by peak precipitation values, which is proved by the large scale of precipitation values, and by a low median. However, the upper quartile is farthest from the median, so one can say with certainty about peak precipitation values during this period (Table 2).

Table 3 provides data on statistical characteristics of variation of mean values of air temperature.

Table 1. Agrophysical properties of soils at a stationary site

Physical indicators of soils	Size of a soil layer	Environmental zone 1	Environmental zone 2	Environmental zone 3
Bulk density, g/cm^3	0–20 cm	1.42	1.45	1.50
	20–45 cm	1.48	1.47	1.59
Particle density, g/cm^3	0–20 cm	2.56	2.88	2.51
	20–45 cm	2.69	2.63	2.58
Soil porosity,%	0–20 cm	46	50	40
	20–45 cm	46	46	38

Table 2. Basic statistical characteristics of variation in precipitation, mm by month (data block 2011–2016)

Statistical characteristics	January	February	March	April	May	June	July	August	September	October	November	December
Root-mean SD	9.5	13.2	12.7	14.0	55.4	32.0	11.5	6.0	39.6	5.1	7.1	7.8
med	14.5	10.2	21.8	14.8	22.3	20.7	19.3	6.2	14.0	11.0	17.4	18.2
x	14.0	16.4	22.6	17.9	55.5	36.4	20.6	8.5	40.2	11.0	19.0	22.1
Min	0.0	1.6	6.0	0.0	2.0	3.0	2.6	0.5	3.0	1.3	6.9	12.7
Max	26.0	49.4	50.9	45.0	156.2	99.0	43.6	20.1	104.3	22.0	40.0	41.0
D	118.2	324.7	281.1	324.5	4353.6	1525.7	212.8	55.5	2143.6	51.3	125.8	107.4
S	10.9	18.0	16.8	18.0	66.0	36.1	14.6	7.5	46.3	7.2	11.2	10.4
iv	26.0	47.8	44.9	45.0	154.2	95.9	41.0	19.6	101.3	20.7	33.1	28.3
A	-0.1	1.5	0.9	0.6	1.0	1.0	0.5	0.8	1.0	0.3	1.6	1.5
E	-2.4	2.2	0.7	-1.0	-1.2	-0.6	-0.1	-0.7	-1.8	0.2	3.4	2.2
Quartile	18.2	18.8	21.1	33.0	111.8	64.9	16.6	11.6	83.9	9.0	5.7	10.6
Lower quartile 25%	5.3	4.2	7.0	0.0	9.2	5.1	11.0	3.3	10.9	6.0	13.3	15.8
Upper quartile 75%	23.5	23.0	28.1	33.0	121.0	70.0	27.6	14.9	94.8	15.0	19.0	26.4

Note: (*x* – average value; *med* – median value; *Min* (Max) – minimum (maximum) value; *D* – dispersion; *S* – statistical deviation; *iv* – interval of variation; *A* – asymmetry; *E* – excess)

Table 3. Key statistical characteristics of temperature variation by month, °C (data block 2011–2016)

Statistical characteristics	January	February	March	April	May	June	July	August	September	October	November	December
Average SD	1.7	3.4	1.3	1.9	1.2	0.9	0.7	1.3	1.1	1.6	2.5	1.7
med	-2.5	-2.0	4.0	11.5	20.0	24.0	26.5	26.0	18.0	9.5	3.5	-1.5
x	-2.0	-2.8	3.5	12.2	19.8	24.7	26.7	26.0	18.0	10.2	3.2	-1.3
Min	-4.0	-11.0	0.0	9.0	18.0	24.0	26.0	24.0	17.0	8.0	-1.0	-4.0
Max	3.0	2.0	5.0	16.0	21.0	27.0	28.0	28.0	21.0	14.0	7.0	2.0
D	6.8	22.2	3.5	6.2	1.8	1.5	0.7	2.4	2.3	4.6	9.0	4.7
S	2.6	4.7	1.9	2.5	1.3	1.2	0.8	1.5	1.5	2.1	3.0	2.2
iv	7.0	13.0	5.0	7.0	3.0	3.0	2.0	4.0	4.0	6.0	8.0	6.0
A	1.8	-1.1	-1.6	0.5	-0.3	2.0	0.9	-0.0	1.3	1.3	-0.2	0.5
E	3.7	1.2	3.1	-0.1	-2.3	3.7	-0.3	-1.9	1.5	1.9	-1.3	-0.3
Quartile	2.0	6.0	2.0	3.0	2.0	1.0	1.0	2.0	2.0	2.0	4.0	3.0
Lower quartile 25%	-4.0	-5.0	3.0	11.0	19.0	24.0	26.0	25.0	17.0	9.0	1.0	-3.0
Upper quartile 75%	-2.0	1.0	5.0	14.0	21.0	25.0	27.0	27.0	19.0	11.0	5.0	0.0

Note: (*x* – average value; *med* – median value; *Min* (Max) – minimum (maximum) value; *D* – dispersion; *S* – statistical deviation; *iv* – interval of variation; *A* – asymmetry; *E* – excess)

The given analysis data, obtained using non-parametric statistics, shows that the variation of the average atmospheric temperature values by month is characterized by the greatest variation spectrum.

It is evident and significant that in the January-March period the range of temperature values has the lowest mean value. However, in the April-May period the mean value increases and the lower and upper quartiles compress, indicating a steady rise in the atmospheric temperature. And in the June-July period, it is reliably seen that the range of temperature values sharply decreases and the average value increases, indicating a stable predominance of extreme temperatures and narrowing of the atmospheric temperature variation boundaries, and hence the atmospheric drought (Table 3). By contrast, in the September-December period the range of temperature values increases and the average value de-

Table 4. Key statistical characteristics of the moisture reserve variation by month, mm

Statistical characteristics	January	February	March	April	May	June	July	August	September	October	November	December
Average SD	26.5	36.1	50.8	32.8	26.1	3.5	3.5	3.5	10.1	3.5	10.3	9.5
med	52.5	60.1	79.9	34.4	4.0	0.0	0.0	0.0	4.0	0.0	24.5	39.4
x	45.7	63.2	86.7	35.5	20.1	2.7	2.7	2.7	9.4	2.7	22.1	42.8
Min	0.0	10.9	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.1
Max	84.1	130.7	181.0	83.5	85.2	8.1	8.1	8.1	37.2	8.1	45.6	63.1
D	968.5	1719.1	3497.0	1220.3	1028.6	15.4	15.4	15.4	167.2	15.4	191.8	130.1
S	31.1	41.5	59.1	34.9	32.1	4.0	4.0	4.0	12.9	3.9	13.9	11.4
iv	84.1	119.8	166.1	83.5	85.2	8.1	8.1	8.1	37.2	8.1	45.6	37.0
A	-0.4	0.3	0.4	0.1	1.4	0.8	0.8	0.8	1.3	0.8	-0.3	0.3
E	-1.4	-1.4	-1.4	-2.2	0.1	-1.7	-1.7	-1.7	0.4	-1.7	-0.3	-0.7
Quartile	52.6	69.8	99.0	64.4	36.5	8.1	8.1	8.1	16.3	8.1	16.3	15.1
Lower quartile 25%	19.4	30.0	38.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7	35.9
Upper quartile 75%	72.0	99.7	137.8	64.4	36.5	8.1	8.1	8.1	16.3	8.1	30.0	51.0

Note: (*x* – average value; *med* – median value; *Min* (Max) – minimum (maximum) value; *D* – dispersion; *S* – statistical deviation; *iv* – interval of variation; *A* – asymmetry; *E* – excess)

creases. The lower and upper quartiles increase as well by the average value, indicating gradual decrease of temperature and cessation of the atmospheric drought (Table 3).

It is proved that in the December-February period there is an accumulation of moisture, and in the June-July period there is an acute shortage of it. It is clear and reliable that the April-August period is a critical one, because of the atmospheric drought. In September, a decrease of temperature and an accumulation of moisture are observed. So, the autumn period is the most favorable for sowing in terms of humidity (limiting factor), which is proved using non-parametric statistics methods.

The following is the key statistical characteristics of the moisture reserve variation by month (data block 2011–2016) (Table 4).

As it is seen from the given data of non-parametric statistics (Table 4) the greatest accumulation of moisture reserve in the weather-sensitive soil layer, 0–20 cm, is observed in the February-March period. And this is reliably proved by the highest range and the highest average values (Table 4).

The lowest value of moisture reserve in the weather-sensitive soil layer, 0–20 cm, was obtained in the June-August period. This period stands significantly out as characterized by a lack of the range and zero average values of moisture reserves (Table 4). In its turn, during September, November and December period, a moisture reserve is accumulating in the 0–20 cm soil layer, which is proven by significant increase both in the range and the average value, as well as in the upper quartile of the median and in the prevailed maximum values of moisture reserve (Table 4).

Statistical characteristics of yield capacity are characterized in relation to sowing terms of perennial grasses (Table 5).

As it is seen from the above data (Table 5) the yield range of perennial grasses reaches the highest value in autumn sowing. In winter and spring sowing, yield capacity varies within a very narrow range, which indicates the inefficiency of these terms of yield (Table 5). It is reliable that the autumn sowing period is the most effective.

Table 5. Key statistical characteristics of the cropping capacity variation on terms of sowing, ton per hectare (data block 2016)

Statistical characteristics	Autumn	Winter	Spring
Average SD	1.2	0.2	0.2
x	2.5	0.6	0.5
med	2.3	0.6	0.4
Min	0.7	0.0	0.0
Max	5.8	1.2	1.2
D	2.3	0.1	0.1
S	1.5	0.3	0.3
iv	5.1	1.2	1.2
A	0.8	0.3	1.2
E	-0.1	0.1	1.5
Quartile	2.2	0.5	0.3
Lower quartile 25%	1.1	0.4	0.3
Upper quartile 75%	3.3	0.9	0.6

Note: (*x* – average value; *med* – median value; *Min* (Max) – minimum (maximum) value; *D* – dispersion; *S* – statistical deviation; *iv* – interval of variation; *A* – asymmetry; *E* – excess)

Empirical-statistical model of the moisture reserve accumulation in the soil of arid ecosystems pasture agrophytocenoses

As a result of the regression analysis, regression models of the ratio of the moisture reserves accumulation to the atmospheric temperature, relative humidity and the amount of precipitation on the value level of 0.05 were obtained.

The equation of the moisture reserve accumulation in the soil (0–20 cm) depending on meteorological factors:

Moisture reserve = 37 – 0.426*t*,

where *t* – the atmospheric temperature, °C

The equation shows that the moisture reserves accumulation in the soil is of great importance to the atmospheric temperature, which is due to the evaporability of the soil surface.

The diagram of residuals (Figure 1) clearly shows that this model is adequate.

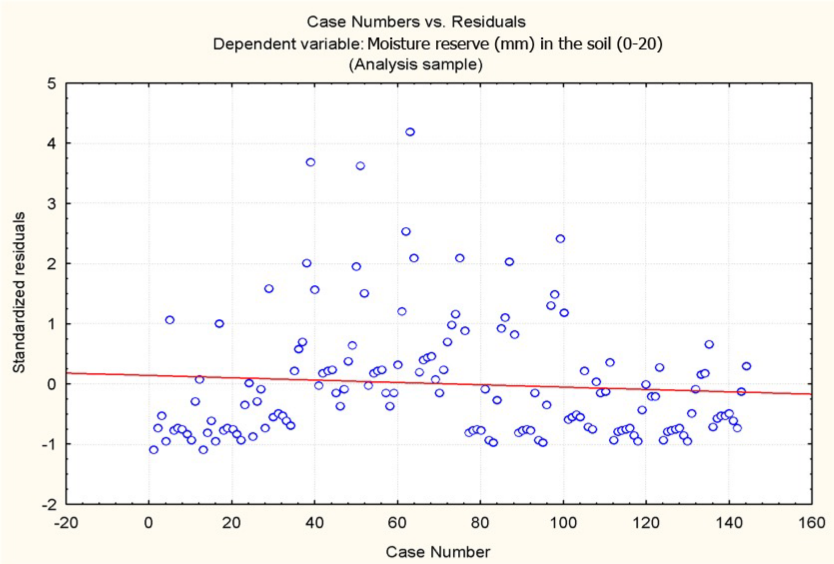

Fig. 1. The diagram of residuals

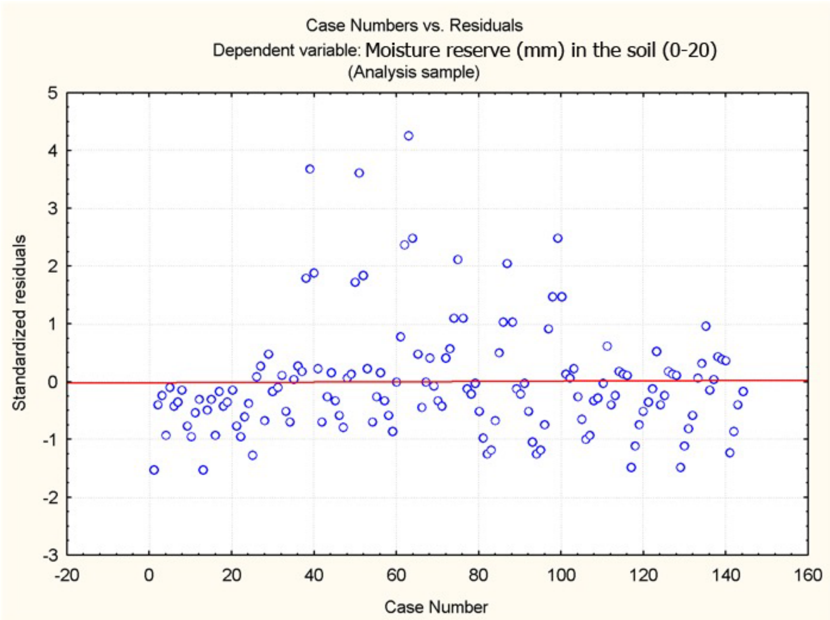

Fig. 2. The diagram of residuals

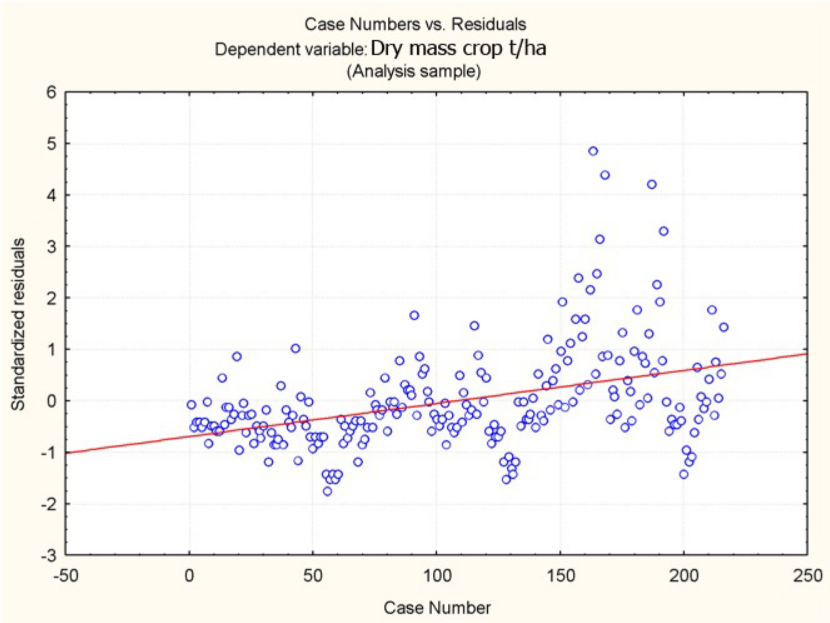

Fig. 3. The diagram of residuals

The equation:

Moisture reserve = -75 + 1.369f + 0.287R,

where f – relative humidity (%) and R – precipitation, mm, clearly shows that there is a direct interrelation of the moisture reserves accumulation in the soil with relative humidity and precipitation.

It can be seen from the diagram of residuals that the model of moisture reserves in the soil is an adequate one (Figure 2).

Empirical-statistical model of pasture agrophytocenosis with programmable productivity of arid ecosystems

We also managed to find dependence of yield capacity of perennial grasses on a moisture reserve in the 0–20 cm soil layer and to express in the regression equation of the following type:

Dry mass crop (t/ha) = 1.9758 + 0.0049w – 0.0069,

where w – moisture reserve in the 0–20 cm soil layer (mm), R – amount of precipitation (mm).

Dry mass yield of pasture agrophytocenosis depends on atmospheric processes, while the dependence is linear, indicating a direct interrelation. The model is able to program the productivity of pasture agrophytocenoses and optimize the timing of the agrophytocenoses formation according to the amount of precipitation and relative humidity.

Verification of the model dry mass crop (t/ha) = 1.9758 + + 0.0049w – 0.0069R on the schedule of residuals confirms that regression model is adequate (Figure 3).

Conclusion

It is clear from the given data of the agrometeorological cycle, the dynamics of the limiting factor behavior (moisture reserve) and dependence on the temperature and precipitation, that the optimal period for creating pastures in arid conditions is the autumn period.

The equation of regression for moisture reserve accumulation in the soil (0–20 cm), depending on meteorological factors, was obtained: moisture reserve = 37 – 0.426t.

The equation for moisture reserve accumulation in the soil due to the relative humidity and precipitation: moisture reserve = -75 + 1.369f + 0.287R.

The dependence of the pasture agrophytocenoses productivity on the moisture reserve in the soil layer of 0–20 cm was obtained in the regression equation of the following type: dry mass yield t/ha = 1.9758 + 0.0049w – 0.0069R.

References

Assouline, S., Russo, D., Silber, A. & Or, D. (2015). Balancing water scarcity and quality for sustainable irrigated agriculture. *Water Resources Research, 51 (5),* 3419-3436.

Bazitov, R., Koteva**, V., Bazitov, V. & Gospodinov, I.** (2016). The water deficiency effect over maize yield cultivated for grain without irrigation in the region of South-Central Bulgaria. *Bulg. J. Agric. Sci.*, *22,* 245-249.

Kuzmina, Zh. V. (2007). Analysis of long-term meteorological trends in the South of Russia and Ukraine (from forest-steppe to deserts). *Aridnye Ekosistemy* (*Arid Ecosystems*), *13 (32),* 47-61 (Ru).

Kuzmina, Zh. V. & Treskin, **S. E.** (2014). Climatic changes in the Lower Volga basin and their impact on ecosystems. *Aridnye Ekosistemy* (*Arid Ecosystems*), *20 (60),* 14-32 (Ru).

Kuzmina, Zh. V., Treskin, S. E. & Karimov, T. Yu. (2014). Current assessment of the status of terrestrial ecosystems of the floodplain and Delta of the Lower Volga in connection with hydraulic engineering and climate change. Land reclamation and water management of the 21st century: problems and prospects of development. In: Materials of international scientific-practical conference of All-Russian Research Institute of Reclaimed Lands, 27-28 August, RU Tver, 31-51 (Ru).

Kuzmina, Zh. V., Treskin, S. E. & Mamutov, N. K. (2004). Impact of climate change and irrigation on the formation of vegetation empirically in dry part of the Aral Sea. *Aridnye ekosistemy* (*Arid ecosystems*), *9 (21),* 1-12 (Ru).

MacDonald, L. (2015). Meteorological instruments for water management. *Applications of Furrow and Micro Irrigation in Arid and Semi-Arid Regions*, 1-9.

Myalo, E. G. & Levit, **O. V.** (1996). The current state and trends in the development of vegetation cover of Black lands. *Aridnye Ekosistemy* (*Arid Ecosystems*), *2 (2-3),* 145-152 (Ru).

Nazarenko, O. G. (2006). To consider the influence of climatic factors on groundwater in the Don-Donetsk basin in the second half of XX century. *Vodnye Resursy* (*Water Resources*), *33 (4),* 504-510 (Ru).

Neronov, V. V. (2002). Dynamics of vegetation and rodent population in the South of Kalmykia in changing environmental conditions. Author's thesis on competition of a scientific degree of candidate of biological sciences, Russian Academy of Science, RU Moscow, 24 (Ru).

Or, D. & Wraith, **J. M.** (2002). Soil water content and water potential relationships. *Soil Physics Companion, 1:* 49-84.

Or, D., Lehmann, P., Shahraeeni, E. & Shokri, N. (2013). Advances in soil evaporation physics. *A review Vadose Zone Journal*, *12* (4).

Ovadykova, Zh. V., Shahmedov I. Sh. & Puchkov, M. Yu. (2015). Fodder-producing areas of the North-Western Caspian. Astrakhan State University, RU Astrakhan, 124 (Ru).

Popova, Z., Ivanova, M., Pereira, L., Alexandrov, V., Kercheva, M., Doneva, K. & Martins, D. (2015). Droughts and climate change in Bulgaria: assessing maize crop risk and irrigation requirements in relation to soil and climate region. *Bulg. J. Agric. Sci.*, *21,* 35-53.

Puchkov, M. Yu., Loktionova, E. G., Puchkova, A. M., Yakovleva, L. V., Andrianov, V. A. & Lysakov, **M. A.** (2015). Use of geosynthetic nonwoven roll material for the restoration of the natural and technogenic systems. *Abstract International Journal of Applied Engineering Research*, *10,* 29083-29089.

Puchkov, M. Yu., Lozitsky, A. Ya., Simankova N. V. & Lysakov, M. A. (2014). Selection of varieties of phytomeliorants to restore degraded pastures of the North-Caspian region. *Modern Problems of Science and Education*, *2,* 615 (Ru).

Puchkov, M. Yu., Simankova N. V. & Lozitsky, A. Ya. (2013). New varieties of perennial grasses for arid zone of the Northern Caspian. *Adaptivnoe kormoproizvodstvo* (*Adaptive Fodder Production*), *1 (13),* 50-53 (Ru).

Shokri, N., Lehmann, P. & Or, D. (2009). Characteristics of evaporation from partially wettable porous media. *Water Resources Research*, *45 (2).*

Sochorec, M., Jandak, J., Raus, J., Kvasnovsky, M., Hejduk, S. & Knot, P. (2015). Influence of different grassland management on water infiltration and soil physical properties. *Bulg. J. Agric. Sci.*, *21,* 573-578.

Steinwand, A. L., Harrington, R. F. & Or, D. (2006). Water balance for Great Basin phreatophytes derived from eddy covariance, soil water, and water table measurements. *Journal of Hydrology*, *329 (3):* 595-605.

Sukop, M. C. & Or, D. (2004). Lattice Boltzmann method for modeling liquid-vapor interface configurations in porous media. *Water Resources Research*, *40 (1).*

Tuller, M., Or, D. & Dudley, L. M. (1999). Adsorption and capillary condensation in porous media: Liquid retention and interfacial configurations in angular pores. *Water Resources Research*, *35 (7),* 1949-1964.

Voznesenskaya, L. M. & Beschetnova, **E. I.** (2009). Agroclimatic resources of the Astrakhan region: monograph. Astrakhan State University, RU Astrakhan, 113 (Ru).

Received: October, 23, 2019; *Accepted:* August, 7, 2020; *Published:* October, 31, 2020