Journal of Agrometeorology
ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 25 (3) : 454-457 (September - 2023)
https://doi.org/10.54386/jam.v25i3.2220
https://journal.agrimetassociation.org/index.php/jam

Research paper

Relationship between hydrothermal coefficient (HTC) and productivity of pastures in the arid zone of Northwestern Caspian Sea

L.P. RYBASHLYKOVA[1*], S.N. SIVCEVA[2], and T.F. MAHOVIKOVA[2]

[1]*Federal Scientific Centre of Agroecology, Complex Meliorations and Protective Afforestation of Russian Academy of Sciences, Volgograd, Russia*
[2]*North Caucasian Branch of the Federal Research Centre of Agroecology, Amelioration and Protective Afforestation of Russian Academy of Sciences, Stavropol Krai, Achikulak, Russia*
**Corresponding author: Rybashlykova-l@vfanc.ru*

ABSTRACT

In the arid zone, one of the ways to provide animals with feed is the organization of forested pastures, the productivity of which largely depends on weather conditions. Our study analyzes changes in meteorological conditions and hydrothermal coefficient (HTC) during the growing season April-October from 2018 to 2022 and their impact, on natural and forest-reclaimed pastures of the sandy Bazhigan massif of Northwestern Caspian Sea. Pasture productively was negatively correlated with the temperature and positively correlated with the precipitation. The relationship between hydrothermal coefficient (HTC) and productivity of different types of pastures has been established with coefficient of determination of R^2 of 0.765 under pasture with different density and R^2 of 0.879 under natural pasture. Results showed that the atmospheric humidification is the determining factor of stable pasture productivity in the conditions of climate change in the arid zone of Russia.

Key words: Arid climate, hydrothermal coefficient (HTC), pastures productivity, temperature, precipitation, Bazhigan massif

In recent decades, a significant warming of the climate has been noted in European part Russia (Zolotokrylin *et al*., 2020). The impact of grazing and weather conditions on vegetation in the arid zone are significant factors in changing the structure and dynamic processes. As a result of year-round operation of pasture lands with exceeding the norms of livestock load on the grass, the vegetation cover fails and its degradation occurs (Grebennikov *et al*., 2020). Meteorological data show that average annual temperatures have increased by about 1°C over the past century and are expected to continuously increase by 2-5°C in the future (Zolotokrylin *et al*., 2018; Hidalgo-Galvez *et al.*, 2023). To restore and form the stability of the bio productive structure of pasture lands, different types of protective plantings (backstage, strip, savanna) are effective (Yerusalimsky and Rozhkov 2017; Petrov *et al.,* 2018; Belyaev *et al*., 2021; Manaenkov *et al*., 2023). To increase pasture productivity, in addition to heat supply, optimal moistening of forage lands is required. The main source of moisture in the arid zone is precipitation. An important indicator of soil moisture availability is the hydrothermal coefficient. In this regard, the purpose of the research was to study the influence weather conditions on the productivity of grassland pasture and natural lands of the sandy Bazhigan massif of Northwestern Caspian Sea.

MATERIALS AND METHODS

The objects of research are forest pastures with backstage, strip, savanna plantings and natural forage lands (44.80-44.92°N, 45.16-45.29°E) situated in sandy Bazhigan massif of Northwestern Caspian Sea. This zone is characterized by aridization of the climate, where the average annual precipitation is 340 mm, the maximum amount of precipitation falls in May, June, October. The winter period is characterized by little snow and frequent thaws with increased wind activity. The frost–free period lasts 170 - 190 days. The driest period of the year is the second half of summer. The most unfavorable conditions for vegetation of plants occur from the third decade of May and last until mid-September (Badakhova *et al.,* 2007). The soils at the study sites are desert-steppe type, light

Article info - DOI: https://doi.org/10.54386/jam.v25i3.2220
Received: 10 May 2023; Accepted: 05 August 2023; Published online : 31 August 2023

chestnut sandy and sandy loam. The geobotanical description of vegetation and the assessment of the state of pasture lands were carried out on permanent test areas of 0.25 hectares in size. The stand is formed from old-age stands of elm and robinia (the age of the tree tier is more than 30 years).

The data pertaining to pasture productivity and precipitation and temperature data of 2018 to 2022 period were used. Weather data were obtained from the Neftekumsk weather station. The hydrothermal coefficient (HTC) of humidification was calculated according to the formula of Selyaninov (1928).

$HTC=R \times 10 / \sum t$,

where R is the sum of precipitation in millimeters for a period with temperatures above 10 °C, t is the sum of average daily temperatures in degrees for the same time, 10 is a conditional coefficient. Humid, dry and drought are classified according HTC values as given below.

HTC less than 0.3 - severe drought

HTC between 0.31-0.51 - average drought

HTC between 0.51-0.70 - mild drought

HTC between 0.71-1.0 – dry

HTC more than 1.0 – sufficient moisture

At the test sites, plant density and herbage yield, depending on the type of forest plantations, were determined by the sloping method on plots of 1m² in 5-fold repetition by the envelope method. Statistical data were processed by the method of variance analysis.

RESULTS AND DISCUSSION

Weather conditions

The meteorological conditions during research period (2018-2022) were found to differ seasonally (Table 1). In 2018, the amount of precipitation for April-October was 144.2 mm (57.5% of normal precipitation) which turned out to be very dry. The distribution of precipitation was very uneven with 39.4 mm of precipitation in May-June and 22.8 mm in August-October. The amount of precipitation in 2019 was 163.8 mm (65% of normal). In 2020, only 139.8 mm of precipitation was recorded which was only 44% of normal. In 2021, precipitation amounted to 225.8 mm which was highest among all five-year of study period, due to precipitation in June and September (41.1 and 47 mm). The amount of precipitation for the growing season of 2022 was 176.5 mm, which is 29.7% below normal. This confirms that this territory is characterized by unstable and uneven distribution of precipitation, both by months and by years. (Table 1).

Temperature was also found to vary during the pasture growing season (April to October) and also among the years. In 2018, the monthly temperature varied between 11.7 ^{0}C (in April) to 28.3 ^{0}C (in July). In 2019 temperature was lowest ranging between 11.4 ^{0}C to 26.5 ^{0}C while it was highest in 2022 with temperature ranging between 16.0^{0}C to 31.6^{0}C (Table 1). Based on the data of the dispersion analysis of the average monthly air temperature (April-October period) significant differences were revealed by the years in comparison with the long-term value. The temperature increase

Table 1: Average monthly temperature (℃) and precipitation (mm) during the growing season in different years

Month	Medium - long - term	Average for the growing season of the year				
		2018	2019	2020	2021	2022
		Temperature (^{0}C)				
April	8.8	11.7	11.4	10.1	13.1	16.0
May	16.8	19.8	19.2	18.1	19.5	19.1
June	21.8	24.5	26.5	25.1	24.2	28.2
July	24.8	28.3	25.6	28.1	26.9	26.0
August	23.8	24.2	24.6	24.2	28.3	31.6
September	17.8	20.5	18.3	20.7	17.4	20.3
October	11.2	14.1	13.4	15.2	10.1	16.8
Deviations from the average growing season / +/–	17.8	+2.6	+2.1	+2.4	+2.1	+4.7
LSD_{05} =1.78° C, F_f =5.69 > F_t =2.5						
		Precipitation (mm)				
April	27	13.0	27.6	14.2	25.3	2.9
May	37	9.3	48.3	50.6	38.8	59.2
June	45	30.1	40.5	23.1	41.4	42.0
July	45	69.0	14.1	8.8	18.3	13.8
August	45	20.7	17.3	41.3	13.0	6.6
September	28	0.6	10.2	1.5	47.0	28.0
October	24	1.5	5.8	0.3	42.0	24.0
Deviations from the average growing season / +/–	35.8	-15.2	-12.4	-15.8	-3.5	-10.6

LSD_{05} = 17.4 mm, F_f =1.10 < F_t = 2.5

Table 2: Productivity of forage lands on forested and natural pastures and hydrothermal coefficient (HTC)

Year	Yield (t ha^{-1})		Hydro-thermal coefficient (HTC)
	Forest-reclamation pastures	Natural pasture (control)	
2018	0.94	0.83	0.36
2019	0.87	0.71	0.43
2020	0.49	0.60	0.36
2021	1.26	1.18	0.74
2022	0.48	0.53	0.23
Correlation with temperature	– 0.6	– 0.56	
Correlation with precipitation	0.63	0.71	

over the years ranged from 2.1 to 4.7 **°C** (Table 1). The analysis of the data on the average monthly precipitation during the growing season did not reveal significant differences in the years of research compared with long-term values, however, there is a tendency to decrease their amount to 15.8 mm. An increase in temperature indicators and a decrease in atmospheric moisture affect the growth, development of pasture vegetation and low feed productivity.

Pasture productivity and hydrothermal coefficient (HTC)

The pasture productivity under forest-reclamation pastures and natural pastures are presented in Table 2. It was found that the main factor determining the productivity of the grass stand is the degree of atmospheric moisture. The yield of herbage was lowest in 2022 in spite of getting precipitation (176.5 mm) higher than those 2018 (144.2 mm), 2019 (163.8) and 2020 (139.8). In forest-reclamation pastures the yield varied from 0.48 t ha^{-1} (in 2022) to 1.26 t ha^{-1} (in 2021) and in natural pasture it varied from 0.53 t ha^{-1}to 1.18 t ha^{-1}. The pasture yields were in direct correlation with the amount of precipitation of the growing season (r=0.63) with an inverse dependence on the temperature regime (r=-0.6) forest-reclamation pastures. Under natural pastures the fluctuation in the yield of herbage had direct correlation (r= 0.71) with precipitation and inverse correlation (r= -0.56) with temperature regime (Table 2).

The hydrothermal coefficient (HTC) computed for the growing seasons (April to October) 0f all the five years, ranged between 0.22 (in 2022) to 0.74 (in 2021). As per HTC classification, years 2018, 2019 and 2020 were characterized as average drought years (HTC between 0.31 and 0.50). In 2021, the mild drought or dry conditions was observed with HTC of 0.74, while in severe drought condition of 2022, the HTC was 0.23. Severe drought condition (lowest HTC) during 2022 caused drastic reduction in yield resulting the lowest productivity whereas the highest yield was obtained in 2021, the year having highest HTC.

A polynomial relationship was developed between HTC and pasture yield (Fig.1). The equations developed between for forest reclaimed pasture land is

$$Y = -1.0842x^2 + 2.597x - 0.0666 \qquad R^2 = 0.765$$

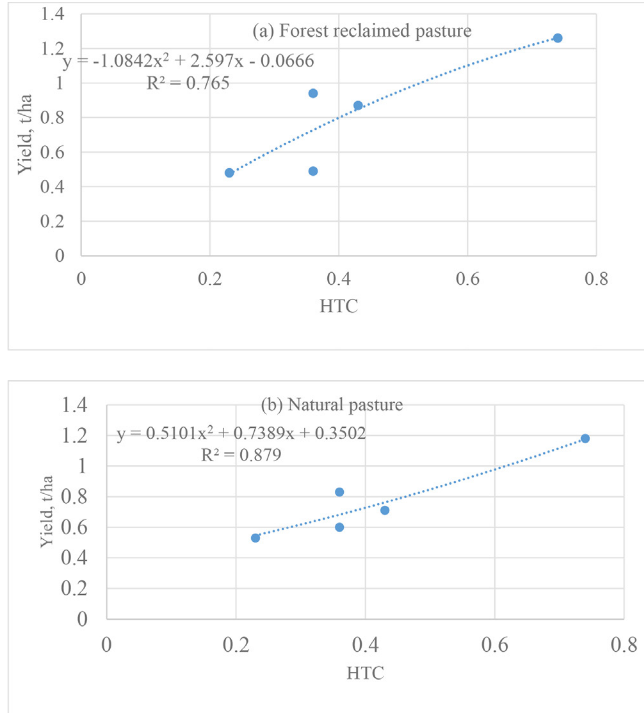

Fig 1: Relation between herbage yield under (a) forest reclaimed pasture, (b) natural pastures and the HTC

Where, Y is pasture yield (t ha^{-1}) and x is HTC

In forest reclaimed pasture land HTC could explain 76.5% of variation in the yield of herbage. Similarly, the equations developed between for forest reclaimed pasture land is

$$Y = 0.5101x^2 + 0.7389x + 0.3502 \qquad R^2 = 0.879$$

In natural pasture the polynomial equation explained 87.9% variation in the yield. Hence, these polynomial equations can be used to predict the level of productivity of various types of pastures using the hydrothermal coefficient (HTC). Evarte-Bundere and Evarts-Bunders (2012) have also related the HTC with distribution of tree species.

CONCLUSION

The analysis of five years (2018-2022) of temperature, precipitation and pasture yield data of the Bazhigan massif of Northwestern Caspian Sea revealed a very close relationship. Pasture yield was positively correlated with precipitation and negatively correlated with temperature. The relationship developed between hydro-thermal coefficient (HTC) and the productivity of different types of pastures explained 78 to 88 % variation in the yield which can be used for yield prediction. Comparing different types of pastures, comparing changes in the productivity of grass with hydrothermal conditions during the study period, it is safe to say that a wet spring, uniform distribution of precipitation during the growing season within the normal limits lead to increased productivity.

ACKNOWLEDGEMENT

This study was funded within the framework of State Tasks No. 122020100309-0 "Theoretical foundations, basic principles and technologies for improving the efficiency of protective afforestation and integrated phytomelioration on degraded, disturbed and low-productive lands of the arid zone of Russia", No. 122020100407-3 "Theoretical foundations and technologies for the sustainable functioning of natural forage lands of arid and subarid regions by means of integrated phytomelioration in conditions of desertification and climate change"

Conflict of interest: The authors declare that there is no conflict of interest related to this article.

Authors contribution: **L.P. Rybashlykova:** systematized and analyzed the data, reviewed literature on the problem under study wrote an article, **S.N. Sivceva:** collected the material, processed and analyzed data, **T.F. Mahovikova**: collected the material, processed and analyzed data.

***Disclaimer*:** The opinions, contents, and views expressed in the research article published in the Journal of Agrometeorology are the authors' own and do not necessarily reflect the position of the organizations they are affiliated with.

***Publisher's Note*:** The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

Badakhova, G.H. and Knutov, A.V. (2007). Stavropol Krai: modern climatic conditions - Stavropol, SUE IC "Regional communication networks". p. 272.

Belyaev, A.I., Kulik, K.N. and Manaenkov, A.S. (2021) Methodological recommendations on phytomeliorative reconstruction of degraded and desolate pastures of the Russian federation with innovative environmentally safe resource-saving technologies. Volgograd: p. 68.

Evarte-Bundere G. and Evarts-Bunders P. (2012). Using of the Hydrothermal coefficient (HTC) for interpretation of distribution of non-native tree species in Latvia on example of cultivated species of genus Tilia. *Acta Biol. Univ. Daugavp*., 12 (2): 135–148.

Grebennikov, V.G., Lapenko, N.G., Shipilov, I.A. and Honina, O.V. (2020) Efficiency of accelerated restoration of low-productive perennial forage lands. *Agric. J.* 1(13): 18–23.

Hidalgo-Galvez, M.D., Matías, L., Cambrollé, J., Gutiérrez E., Pérez-Ramos, I.M. (2023). Impact of climate change on pasture quality in Mediterranean dehesas subjected to different grazing histories. *Plant Soil*. https://doi.org/10.1007/s11104-023-05986-9

Manaenkov, A.S., Rybashlykova, L.P., Sivtseva, S.N. and Makhovikova T.F. (2023). Silvopastoral Transformation of Desert Landsin the Caspian Sea Region. *Arid Ecosyst.,* 13: 1: 11–19. DOI: 10.1134/S2079096123010080

Selyaninov G T. (1928). About the agricultural evaluation of the climate. *TrudyGGO*, 20:177–185. (in Russian)

Yerusalimsky, V.I. and Rozhkov, V.A. (2017). The multifunctional role of protective forest plantations. *Bull. of the V.V. Dokuchaev Soil Inst.,* 88: 121–137.

Zolotokrylin, A.N., Cherenkova, E.A., Titkova, T.B. (2018). Bioclimatic subhumid zone of Russian plains: droughts, desertification, and land degradation. *Arid Ecosyst*. 1: 7–12.

Zolotokrylin, A.N., Cherenkova E.A., Titkova, T.B. (2020). Aridization of drylands in the European part of Russia: secular trends and links to droughts. *Regional Res. Russia.* 2: 207–217.