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Short communication

Variability in hydrothermal coefficient (HTC) and productivity of pasture ecosystems in Tersko-Kuma lowland, Russia

L. P. RYBASHLYKOVA

Federal Scientific Centre of Agroecology, Complex Meliorations and Protective Afforestation of Russian Academy of Sciences, Volgograd, Russia
*Corresponding author: *Rybashlykova-l@vfanc.ru*

The territory of Russia is subject to changes in climatic conditions associated with an increase in ambient temperature, a decrease in precipitation and an increase in the extreme weather events (Chernokulsky *et al.,* 2022; Popova *et al.,* 2022). It is quite reasonable that the agricultural production is closely associated with the changes in climatic factors, especially in the arid zones of the southern regions of Russia (Ksenofontov and Polzikov, 2020). The abnormal climatic conditions characterized by an increase in temperature and a decrease in precipitation during crop growing season have a negative impact on crop yields (Vasiliev *et al.,* 2013; Zakharyan *et al.,* 2023; Pavlova *et al.,* 2023). The change in climatic conditions of the Tersko-Kuma lowland towards aridization during the growing season of crops affected a decrease in their productivity, including pasture lands, which was one of the reasons for the desertification of territories. Meteorological observations over the last century show that in the future the average annual temperatures will constantly increase by 2-5°C. (Zolotokrylin *et al.,* 2020; Hidalgo-Galvez *et al.,* 2023). An analysis of the average annual increase in air temperature compared to the long-term climatic norm showed an increase in extremely arid and arid zones by 1.7 and 1.5 °C with a decrease in precipitation by 10 and 6%, respectively. (Voloshenkova *et al.,* 2023). A change in these indicators towards climate aridization and uncontrolled grazing of animals on pasture lands leads to a violation of the dynamics of natural phytocenoses, a decrease in forage productivity by 0.05-0.10 t/ha and a change in species diversity due to the loss of valuable species of cereals and legumes from the herbage and a decrease in the dynamics of their growth and development. (Manaenkov *et al.,* 2023; Rybashlykova *et al.,* 2023).

The purpose of this research is to study the dynamics of changes in climatic conditions in the Tersko–Kuma lowland with an assessment of the productivity of pasture lands using climatic data of 31-year period from April to October 1994 – 2024. The soil cover of the study area is represented by light chestnut soils of medium and light loamy granulometric composition with a bonus of 19-29 points. Data on agro-climatic conditions in the Tersko-Kuma lowland for the years 1994 – 2024 were obtained from the electronic resources: climat.sniish.ru/index. index.hhp and scientific publication materials (Badakhova and Knutov, 2007). The sharply continental climate inherent in this area is characterized by an average annual precipitation of 387-400 mm, HTC – 0.63 – 0.72, the sum of temperatures above 10 °C – 3720 – 3750 °C, high temperatures were set in August to 41.1 °C, and a decrease in air temperature was observed to -14.1 °C in January. The average long-term air temperature in the study area is 16.4°C, 152 sunny and clear days, 19 days with snowfall, 72 days with precipitation, 123 cloudy days.

The hydrothermal coefficient (HTC) was calculated using the formula (Rybashlykova *et al.,* 2023).

$$HTC = R \times 10 / \Delta t$$

Where R is the sum of precipitation in millimeters over a period with temperatures above 10 °C, t is the sum of average daily temperatures in degrees over the same time, and 10 is a conditional coefficient. In HTC classification: HTC less than 0.3 - severe drought; 0.3-0.50 - average drought; 0.51-0.70 - moderate drought; 0.71-0.90 - aridity; 0.91-1.10 - unstable moisture, > 1.1 – sufficient moisture.

The assessment of the productivity of pasture lands and the analysis of the geobotanical composition of vegetation were carried out on stationary test sites measuring 10 x 10 m. The determination of the yield of herbage by economically valuable groups was carried out by mowing on plots of $1m^2$ in 5-fold repetition. In the pastures of the Tersko-Kuma lowland, the vegetation cover is mainly

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Table 1: Dynamics of productivity of pasture phytocenoses and hydrothermal coefficient (HTC) during 2018 – 2024

Years	Productivity of the herbage (t ha^{-1})			Hydrothermal coefficient (HTC)		
	Wormwood-cereals	Ephemeral-cereal	Herbs-cereals	Summer	Autumn	Growing season
2018	0.83	0.80	0.75	0.32	0.39	0.36
2019	0.71	0.68	0.63	0.70	0.25	0.43
2020	0.60	0.54	0.52	0.49	0.28	0.36
2021	1.18	0.92	0.90	1.15	0.45	0.74
2022	0.53	0.40	0.37	0.25	0.25	0.25
2023	0.52	0.45	0.50	0.56	0.39	0.46
2024	0.72	0.53	0.61	0.44	0.26	0.33

Table 2: Correlation coefficient between pasture productivity and HTC

Community	Growing season periods		
	Summer	Autumn	Growing season
Wormwood-cereals	0.75	0.63	0.80
Ephemeral-cereal	0.66	0.63	0.72
Herbs-cereals	0.75	0.67	0.77

represented by cereal, wormwood-cereal and mixed-grass-cereal communities. The groups consisted of different vegetation as given below;

i. Wormwood-cereals: *Agropyron fragile (Roth) P. Candargy*, *Cynodon dactylon (L.) Pers*., *Stipa capillata L. -Artemisia austriaca (Jacq.);*

ii. Ephemeral-cereal: *Cynodon dactylon (L.) Pers*., Stipa capillata L.- Poa bulbosa L., Alyssum turkestanicum Regel & Schmalh);

iii. Herbs-cereals: *Stipa capillata L., Poa bulbosa L.- Phlomis pungens Willd. Falcaria vulgaris Bernh.*

To identify the impact of climate variability on pasture productivity in the Tersko-Kuma lowland, the hydrothermal coefficient (HTC) was calculated for summer season, autumn season and for whole growing period (April to October) for the years 1994 – 2024. Fig. 1 depicts the variability and changes in the HTC in different years. During spring-summer season, HTC values are high indicating availability of sufficient moisture while, in autumn season generally dry condition persisted (Fig. 1).

Climatic changes during the growing season can affect the species structure of the herbage, which affects its yield. During dry periods, the volume of phytomass decreases by 2 times in all types of pasture lands. During the driest growing season (June-August), with minimal precipitation (< 30 mm) and high temperature (25.0-28.0 °C), yields decrease by 61.7% in all types of pastures. A comparison of changes in the productivity of grassland from different pasture communities with hydrothermal conditions during the study period showed that during a wet spring, with a uniform distribution of precipitation during the growing season within the normal range, there is an increase in productivity of grassland. The highest yield of herbage was formed in 2021 in the wormwood-cereal community and amounted to 1.18 t ha^{-1}, while in the ephemeral-cereal and mixed-grass-cereal communities it was less (Table 1).

The correlation worked out between the amount of

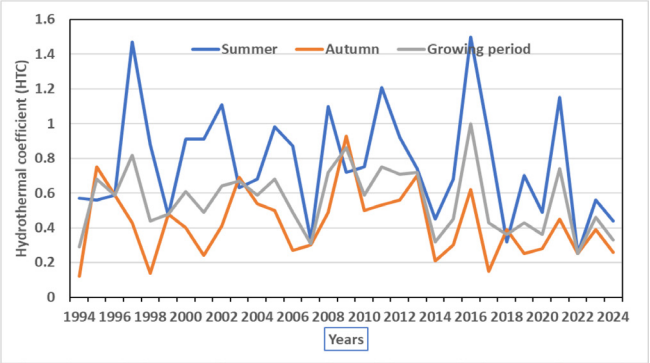

Fig. 1: The hydrothermal coefficient (HTC) during 1994 – 2024 in Tersko-Kuma lowland

precipitation during the growing season and crop yield was amounting to r = 0.73 for wormwood-cereal communities, r = 0.67 for ephemeral cereals and r = 0.66 for mixed grasses. Similar calculations have established a high correlation between the HTC index and the productivity of wormwood–cereal and grass-grass pasture communities during the growing season r = 0.80 and r = 0.77, respectively, while the most intense response to the prevailing agro-climatic conditions was noted in the spring and summer period (r = 0.75). The productivity of the herbage of ephemeral cereal communities correlates less intensively with the HTC index for the growing season (r = 0.66 and r = 0.63, respectively), however, the relationship with the HTC value for the growing season is quite high and amounts to r = 0.72 (Table 2).

Thus, it can be summarized that in the extremely arid zone of the Tersko-Kuma lowland, there was large variability in rainfall and temperature in different years resulting in variation in HTC during different years Precipitation and HTC were positively correlated with the pasture productivity. Similar results were reported by Rybashlykova *et al.,* (2023)

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