Proposals to reduce the impact of climatic anomalies on the productivity of hayfields in arid conditions

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Abstract. The aim of the research was to assess the productivity of natural and phytomeliorated hayfields depending on the hydrothermal coefficient in the arid climate of the Don basin. An increase in the biomass of a phytomeliorated meadow from the beginning of the growing season and after mowing in the first and second years of use after phytoreconstruction is shown. A potential harvest of phytomeliorated hayfields has been established, which can be obtained with sufficient moisture and heat, depending on the biological properties of the cultivated species. The maximum possible yield of dry biomass of hayfields corresponds to 12.7 t/ha. The dependence of the yield of phytomeliorated and natural haymaking on the hydrothermal coefficient is presented. In 2023 (the second year of the meadow's use), a significant decrease in the dependence of the yield of phytomeliorated hayfields on weather conditions was revealed (r = 0.011) compared with natural hayfields (r = 0.392).

1 Introduction

The feed industry plays a leading role in global agriculture, ensuring the efficiency and sustainability of all agriculture, maintaining the balance of industries and linking crop and livestock production, agriculture and ecology.

The yield of long-term uncovered grasses for hay on average in Russia in 2022 was 2.4 t/ha in farms of all categories, 2.2 t/ha in farms. The hayfields of the southern regions are characterized by the highest yield: farms of the Southern (2.9 t/ha), small enterprises of the North Caucasus (3.3 t/ha) and farms of the population of the North Caucasus (4.7 t/ha) Federal Districts, Figure 1.

Agroforestry landscape improvement leads to an increase in the sustainability of the agricultural sector in general and farms in particular. This supports long-term environmental stability (contributes to mitigating the effects of climate change) and reduces dependence on inorganic fertilizers, herbicides and pesticides [1-8].

Phytomeliorative reconstruction of forage lands with perennial forage grasses and legumes is promising.When drying, stirring and raking, cereals break down a little and retain their valuable economic properties. Legume-cereal grass mixtures are able to maintain high

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yields for many years, give green mass throughout the growing season and restore it after alienation (haymaking or grazing), accumulate organic substances in the soil and distribute them in various soil horizons, create a root filter intercepting subsurface water, which protects the soil from salinization. The overall rate of development and longevity of phytomeliorants is not the same and affects the speed, power and energy of regrowth of otava after mowing and bleaching [9-12].

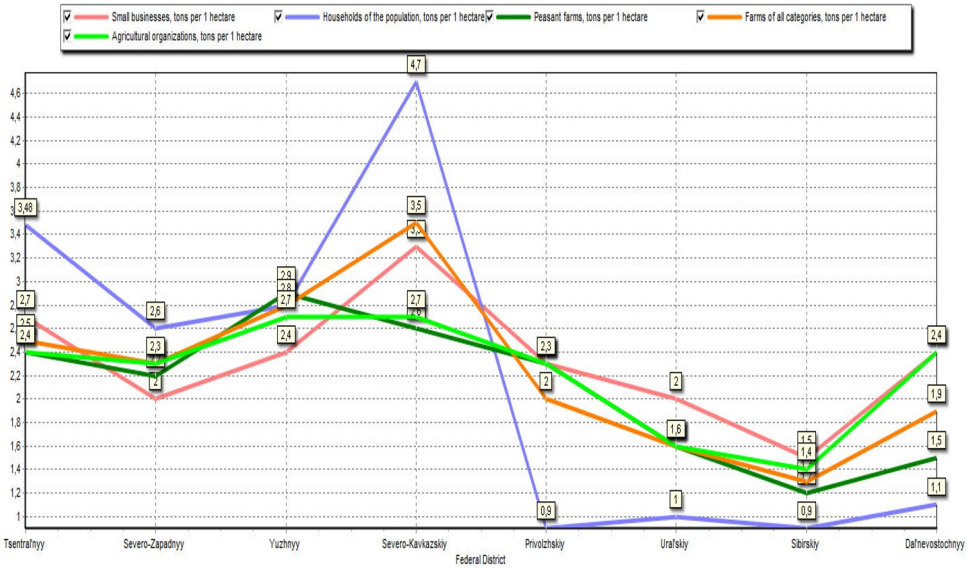

Fig. 1. Yield (t/ha) of perennial grasses sown this year, including the sowing of autumn last year for hay in Russia in 2022.

2 Materials and methods

The aim of the research was to assess the productivity of natural and phytomeliorated hayfields depending on the hydrothermal coefficient in the arid climate of the Don basin.

Phytomeliorative reconstruction of hayfields was carried out in 2021 according to the following scheme: As the main tillage, anti-erosion flat-cut plowing was carried out to a depth of 35-40 cm. Before sowing herbs, the soil was treated with tooth harrows. Sowing was carried out by a sowing complex. Rolling was carried out in 1-2 approaches, depending on the soil moisture. Phytomeliorants: a multicomponent mixture of species of the cereal family.

The data on air temperature and the amount of precipitation during the vegetation period of plants (March-September) are taken from an Internet resource rp5.ru.

A potential crop (or the maximum possible yield of an absolutely dry mass) is a crop that can be obtained with sufficient moisture and heat. It depends on the arrival of photosynthetically active radiation (PAR), agrotechnical background, biological properties of the species. The determination of the potential yield (PY) can be calculated by the formula:

$$PY = \frac{Q_{par} \times K_{par} \times 10^4}{C},$$

where PY is the maximum possible yield of absolutely dry weight, c/ha;

Qpar – arrival of headlights during the growing season of the crop, kJ/cm2;

Kpar – the coefficient of use of headlights by sowing, %;

C – caloric content of 1 kg of dry biomass, kJ;

10^4 is the conversion factor to absolute values.

Statistical data processing was carried out using the STATGRAPHICS+5.0 program (correlation coefficient, coefficient of determination, regression equation).

3 Results and discussion

The research area belongs to the dry-steppe zone of the white-field-chamomile-grass subzone with a well-pronounced mosaic and the fifth halophytic type of vegetation. The area is located within the boundaries of the Russian Platform in the bend of the Don River on the territory of the East Don formation-tier ridge. The surface of the ridge (gently undulating plain) has a slope in the south direction, where the marks of absolute heights of 140-250 m prevail. In some places there are deep ravines and washouts.

Due to the fact that the riverbed continuously migrates, alluvial sediments are characterized by heterogeneity of mechanical composition (sandy are transformed into loamy, loamy - into sandy). The fertility of floodplain soils annually depends on the characteristics of the spring flood. The formation of floodplain processes affects the species diversity and productivity of vegetation, contributes to the increase of groundwater, affects soil-microbiological processes, salt regime, and, as a result, affects the choice of the direction of agricultural use of the territory.

The climate of the region is arid. June and August were particularly dry in 2022 (HTC=0.04), Figure 2.

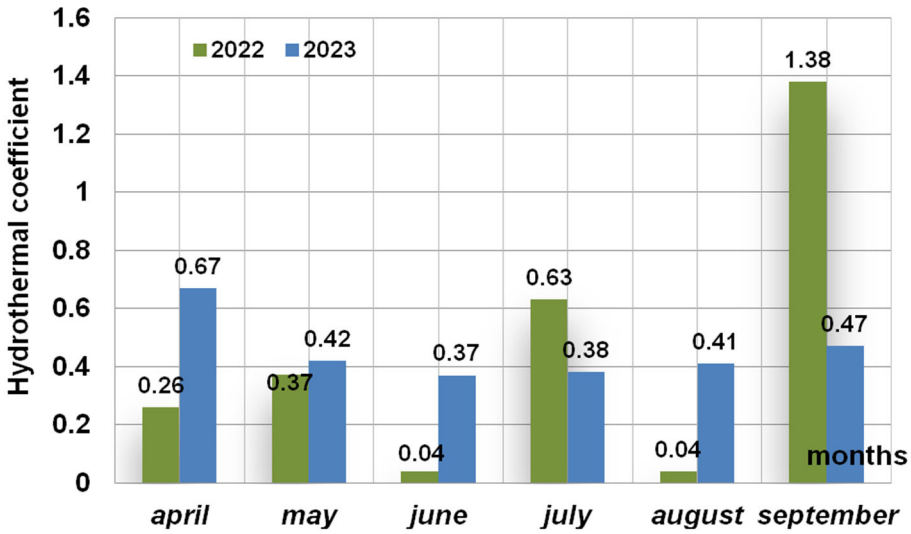

Fig. 2. Hydrothermal coefficient of the research region during the growing seasons of 2022 and 2023.

September was a good humidification period in 2022 for plants (HTC = 1.38). The annual precipitation from October 2021 to September 2022 was 417.2 m, most of which fell during the cold period (233 mm). The average air temperature from April to September 2022 ranged from 12.9°C to 26.9°C. The maximum air temperatures in the summer of 2022 were: in June – 37.4°C (22.06), in July – 38.8°C (20.07), in August – 39.9°C (08).

The amount of precipitation from April to May 2023, when the plants were in the phase of rapid growth, and they needed sufficient moisture for growth and development, was 35.0 and 29.6 mm, respectively. During the cold period, 143 mm of precipitation fell, during the

warm period – 163.9 mm. The average air temperature in the warm period of 2023 ranged from 11.7°C to 37.1°C.

The increase in biomass of phytomeliorants during the growing season of 2022 and 2023 is shown in Figure 3. In 2022, the yield of phytomeliorants for mowing reached 271 g/m^2, in 2023 – 291 g/m^2.

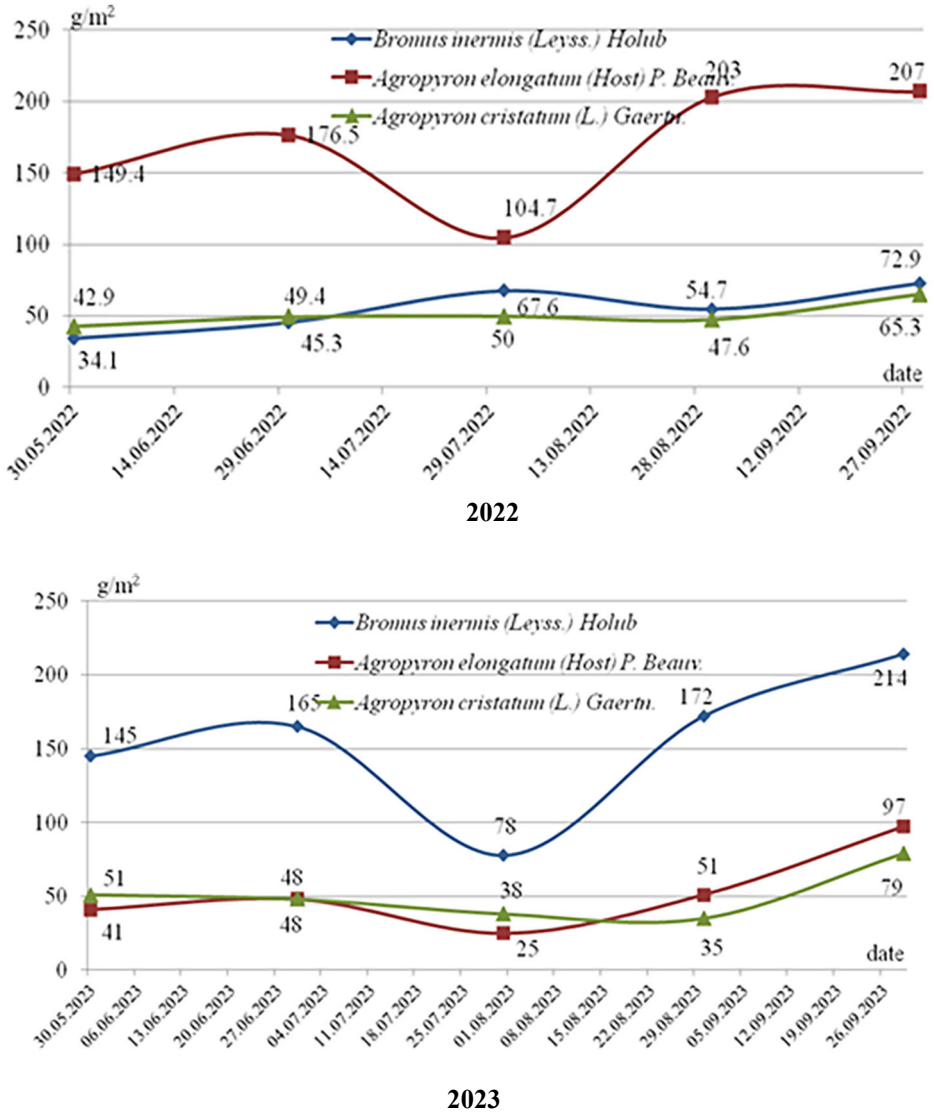

Fig. 3. Increasing the biomass of phytomeliorated hay from the beginning of the growing season and after mowing in the first and second years of use after phytoreconstruction.

The dependence of the yield of phytomeliorated and natural haymaking on the hydrothermal coefficient is presented in Table 1. In 2023 (the second year of the meadow's use), a significant decrease in the dependence of the yield of phytomeliorated hayfields on weather conditions was revealed (r = 0.011) compared with natural hayfields (r = 0.392).

Table 1. Correlation dependence of the yield of phytomeliorated and natural haymaking on the hydrothermal coefficient.

Indicator	Yield of natural hayfields, g/m² (x1)		Yield of phytomeliorants, g/m² (x2)	
	2022	2023	2022	2023
Coefficient of determination	16.162	15.396	35.497	0.013
Correlation coefficient	0.402	0.392	0.595	0.011
Regression equation	y = -0.113998 + 0.0159512·x1	y = 51.4669 + 250.149x1	y = -0.13615 + 0.00151428·x2	y = 0.320385 + 0.000161462x2

The yield of biomass of phytomeliorants (under identical weather conditions) reaches a maximum for 3-6 years of life and during the growing season with two-axis use ≥ 10 t/ha of dry weight can be expected.

In arid conditions of the Volgograd region during the growing season with a temperature above 10 °C The total PAR is 166.63 kJ/cm2, or 16.663 billion kJ/ha. The maximum possible yield of dry biomass of hayfields with PAR = 166.63 kJ/cm2, its use by 2% (average percentage of PAR use) and the caloric content of phytomeliorants 26200 kJ/kg corresponds to 12.7 t/ha (127.19 c/ha) of dry biomass:

$$PY = \frac{166.63 \times 2 \times 10^4}{26200} = 127.19$$

However, usually as a result of intensive use of the phytomeliorated meadow, the yield from the 6th year of life is slightly reduced. After 8-10 years, there is a need to repair crops.

The time of mowing significantly affects the speed and power of regrowth of the grassy tier, changes in species diversity and the structure of meadow associations. Haymaking reduces the population size of the dominant species during the periods of their budding or release into the tube, no later than the flowering of ephemera. Haymaking during flowering of the dominant species of the *Poáceae* and *Fabáceae* family does not allow the formation of seeds and self-seeding and inhibits such species *as Festuca pratensis* Huds., *Stipa capillata* L., *Stipa lessingiana* Trin. & Rupr., *Stipa ucrainica* P.A. Smirn., which fall out of the cenosis. The species that are capable of vegetative reproduction last longer than others: *Elytrigia repens* (L.) Nevski и *Bromopsis inermis* (Leyss.) Holub. However, when the soil is blackened and compacted, they also fall out of the herbage. The grassroots grass Poa pratensis L. is the most resistant to unfavorable conditions.

The change of herbage under the influence of haymaking (or haymaking deformation of cenosis) is noted both on natural and seeded phytocenoses. Haymaking affects the species composition of communities, the abundance and power of development of certain species or biological groups in the herbage. During haymaking, natural vegetation competing with grasses is destroyed, new groupings appear (especially with artificially sown haymaking), the conditions for the development and growth of grasses change, and, consequently, the productivity of communities.

Haymaking does not have a direct effect on the turf and soil. According to some data, in the first few years after the cessation of haymaking, the terrestrial biomass of the grass tier increases sharply, but then decreases. Long-term two-axis use of haymaking can lead to gradual depletion of the soil with nutrients (due to alienation with biomass), reduced productivity and will require fertilization.

The dependence of changes in the biomass of meadow grasses on the temperature and humidity regime (expressed by the hydrothermal coefficient) is confirmed by our research. In the event of a particularly dry period, this dependence can be smoothed out by agrotechnological solutions. Since the time of the first mowing has a great influence on the

hay harvest of the second mowing, in order to obtain a large harvest of the second mowing, we recommend early first mowing in the period from full earing to full flowering inclusive, when meadow plants have the highest amount of protein content, their best digestibility and the greatest feed value. It is necessary to start haymaking at the end of the earing of cereals and the formation of flower heads in legumes, focusing on the development and composition of dominant species in the herbage, and taking into account weather conditions. Two mowing at an early first mowing gives a lot more hay than one later. With early first mowing and timely second mowing, hay is obtained richer in leaves, that is, with a high content of feed units in the feed. Such methods of using seeded meadow stands can increase their biodiversity and productivity.

Compliance with the regulations for the use of floodplain meadows is the most important condition for preserving its environmental sustainability. Productive longevity and agromeliorative condition of hayfields is maintained by constant maintenance, which prevents the development of degradation processes. Operational care and the conditions determining its necessity include the following measures:

- When compacting the soil to 1.3-1.4 t/m^3, it is necessary in the period from September to October, after moistening the soil with precipitation, to carry out loosening of the turf and underdark layer by slitting;
- With an increased density of Pooideae grasses (number of shoots > 2500 pcs./m^2), after harvesting grasses for hay on soil moistened with precipitation, disking and loosening is necessary to destroy the sod within 20-30%;
- If large foci of non-edible and poisonous species are detected, it is necessary to carry out timely harvesting or early mowing of grasses (before the middle of June) to prevent the seeding of annual weed species, as well as the complete transfer of the meadow to the haymaking regime;
- With a decrease in the density of the herbage to 60% of the initial indicators as a result of long-term intensive use (> 8 years), it is necessary to sow forage grasses (30% of the initial norm) in the period from November to December after disking in two tracks.

Variable hay-pasture use has a good effect on increasing the yield of meadows. At the same time, it is necessary to exclude early spring grazing and subsequent haymaking, as this can significantly reduce yields. Grazing of animals is organized according to the rule of changing areas of early and late grazing and alternating with haymaking over the years, taking into account the environmentally safe load, depending on the productivity of the meadow. For example, with a yield of 4 t/ha, cattle are grazed for 100-110 days with a load rate per 1 ha: dairy cows – 2-3 heads, fattening bulls – 4-5 heads, sheep – 8-15 heads. With a yield of 1.5-2.0 t/ha, cattle are grazed for 40-50 pasture days with a load rate per 1 ha: dairy cows – 1.0-1.5 heads, fattening bulls – 2-3 heads, sheep – 5-6 heads.

4 Conclusion

A necessary condition for the stability of phytomeliorated forage lands is the determination of their potential maximum yield and longevity in compliance with the rules of use in the recommended modes. In 2022, the yield of phytomeliorants for mowing reached 2.7 t/ha, in 2023 – 2.9 t/ha. The total yield of phytomeliorated hayfields was 3.4 t/ha in 2022, and 3.6 t/ha in 2023. The maximum possible yield of dry biomass of hayfields corresponds to 12.7 t/ha. In 2023 (the second year of the meadow's use), a significant decrease in the dependence of the yield of phytomeliorated hayfields on weather conditions was revealed ($r = 0.011$) compared with natural hayfields ($r = 0.392$).

The work was carried out within the framework of State Task No. 122020100450-9 "Development of a new methodology for optimal management of biological resources in agricultural landscapes of the arid zone of the Russian Federation using system-dynamic modeling of soil-hydrological processes, a comprehensive assessment of the impact of climatic changes and anthropogenic loads on agrobiological potential and forest conditions" and 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".

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