

THE INFLUENCE OF MORPHOLOGICAL PARAMETERS ON DRY MATTER YIELD IN MIXTURES OF GRASSES AND PERENNIAL LEGUMES IN THE CONTEXT OF CLIMATE CHANGE

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Abstract

The study evaluates the ability of multiple linear regression models to predict dry matter (DM) yield based on morphological indicators (plant height and shoot density) in the second year of vegetation at the Ezăreni farm (Iaşi). Climate change in northeastern Romania necessitates the development of rapid methods for estimating grassland productivity. The results obtained from the forty experimental plots have been processed in Microsoft Excel for two distinct mowings (spring and summer). For the first mowing, under optimal conditions, the model was highly significant ($R^2 = 0.48$), with plant height being the dominant indicator. The second mowing completely nullified these morphological correlations ($R^2 = 0.04$), as the plants entered a physiological stasis adapted to climatic conditions. The classical indicators included in the study lose their predictive utility during periods of water stress, making it necessary to integrate physiological stress indicators into future forecasting models.

Keywords: perennial mixtures, dry matter, morphological parameters, predictive power, height, shoots, yield, stability.

INTRODUCTION

In recent decades, the impact of climate change has become increasingly clear in agriculture. The main observable phenomena, which are becoming more frequent, include: early summer temperatures exceeding 35°C for periods longer than 7–10 days, periods without precipitation, and the uneven distribution of precipitation during the growing season. During the winter, snowfall is scarce, and the soil's water deficit can no longer be

replenished, with this deficit increasing year by year.

Because summers are becoming increasingly dry and heat and water stress set in early, a negative impact on the vegetation's ability to regenerate for the second cut is often seen immediately after the first cut.

In sown pastures, it is recommended to use simple or complex mixtures of perennial grasses and legumes, as growing them together yields a higher

production compared to using pure stands of only legumes or grasses.

In the study conducted by ZILONG et al. (2020), it was found that, in terms of plant morphology in sown pastures during periods of climatic stress, a reduction in root length was accompanied by a reduction in above-ground biomass, but no differences were observed in total root mass.

Plant adaptation to soil and climate conditions is necessary for their proper development, as the study by JING et al., 2026 demonstrated that plants responded better to drought if they were better adapted to growing conditions, regardless of the age of the grassland, so that plant age does not have such a noticeable effect on drought resistance, but the use of plants adapted to soil and climate conditions improves drought resistance and the plants' ability to regenerate.

Legumes can extract water from deeper soil layers due to their

taproot system, while grasses, due to their fibrous root system, make better use of spring precipitation.

However, it has been found that in species with taproots, the ability to move roots toward moister areas is lower, while in species with fibrous roots, they can preferentially distribute root mass to moister areas (FRY et al.; 2018).

Extreme drought events are likely to occur more frequently and last for longer periods, with negative effects on plant development. The root system is the primary part affected (ZHOU et al.; 2018), leading to a decrease in root length in grasses, while in legumes, a decrease in root diameter has been seen (SUN et al., 2024).

The reduction in root system size during dry periods was also associated with an increase in soil nitrogen availability, although soil carbon availability was not directly affected (DE VRIES et al., 2016).

MATERIAL AND METHOD (TNR 11, B)

The research was conducted at the Ezăreni Educational Farm in the village of Miroslava, Iaşi County, a farm belonging to the "Ion Ionescu de la Brad" University of Life Sciences in Iaşi. The geographic coordinates of the site where the experiment was conducted are 47°07'28" north latitude and 27°30'25" east longitude.

The region under study has a temperate continental climate, characterized by hot summers and winters with low temperatures. However, in recent years, changes in temperature and precipitation conditions have been seen, including extreme summer temperatures exceeding 35°C, as well as an uneven distribution of

precipitation throughout the growing season.

The experiment was organized using the split-plot design with three replicates, with the primary aim of observing the yield and structural behavior of simple and complex mixtures of perennial forage grasses and legumes. The factors studied are as follows:

Factor A: 10 simple or complex mixtures of perennial grasses and legumes, as follows: a₁ – *Onobrychis viciifolia* Scop. (100%) (control); a₂ – *Onobrychis viciifolia* Scop. (75%) and *Bromus inermis* Leyss. (25%); a₃ – *Onobrychis viciifolia* Scop. (50%) and *Bromus inermis* Leyss. (50%); a₄ – *Onobrychis viciifolia* Scop. (25%) and *Bromus inermis* Leyss. (75%); a₅ – *Medicago sativa* L. (100%); a₆ – *Medicago sativa* L. (75%) and *Festuca pratensis* (25%); a₇ – *Medicago sativa* L. (50%) and *Festuca pratensis* (50%); a₈ – *Medicago sativa* L. (25%) and *Festuca pratensis* (75%); a₉ – *Medicago sativa* L. (20%), *Lotus corniculatus* L. (15%); *Festuca pratensis* (30%); *Lolium perenne* L. (10%) and *Dactylis glomerata* L. (25%) and a₁₀ – *Onobrychis viciifolia* Scop. (20%), *Lotus corniculatus* L. (15%); *Agropyron pectiniforme* L. (30%); *Bromus inermis* Leyss. (25%) and *Lolium perenne* L. (10%).

Factor B, represented by 4 fertilization levels: b₁—unfertilized (control); b₂ – N₅₀P₅₀K₅₀; b₃ – N₇₅P₇₅K₇₅; b₄ – N₁₀₀P₁₀₀K₁₀₀.

The morphological measurements taken in the field prior to each mowing focused on two indicators:

a) Plant height (X₁; cm): determined by repeated measurements at randomized points within each plot, using a graduated ruler, to establish the average height of each treatment.

b) Number of shoots (X₂; shoots/m²): determined by three repeated counts of shoots per 1 linear meter of each plot, then normalized to square meters.

Biomass harvesting was conducted during the budding and heading stages of the species comprising the mixtures. The specific calendar periods for these phenophase were late May for the first harvest, which coincided with heavy rains in April, and late July for the second harvest, which coincided with one of the driest periods in the study area. A cleanup harvest was conducted in September.

The dry matter content for each plot was determined by collecting green samples in vials, which were dried in an oven at 105°C until there were no longer any differences in weight, in accordance with standard SR ISO 6496/2001.

Statistical analysis using multiple linear regression was performed using Excel by running the Regression function from the Data menu.

The modeling procedure aimed to establish equations for predicting biomass (Y) based on the morphological indicators of height (X₁) and shoots (X₂), with model quality assessed through analysis of

variance (*Fisher's F-test*), the coefficient of determination (R²), and the *Student's t-test* for coefficient significance.

RESULTS AND DISCUSSIONS (TNR 11, B)

Following the entry and processing of experimental data from the second growing season using the Microsoft Excel analysis package, the relationship between grassland biomass—represented by the amount of dry matter per hectare, which served as the dependent variable (Y)— and the morphological factors represented by plant height (X₁) and the number of shoots per square meter (X₂).

KHAVSE, 2025 stated that in agriculture, multiple linear regression helps estimate how different variables collectively influence the results. Using multiple regression, we can more accurately represent certain agricultural phenomena that include two or more independent variables.

A general multiple regression equation (ORLOV, 1996; KHAVSE, 2025) can be written as follows:

$$Y = B_0 + B_1 * X_1 + B_2 * X_2 + \dots + B_n * X_n$$

Y = dependent variable (predicted by a regression model).
 X_i (i=1,2, ...n) = independent variable from total set of p variables.
 B_i (i=1,2, ...n) = coefficient corresponding to x_i.
 B₀ = intercept (or constant)

For a simpler yet direct comparison between the two harvest periods, the summary results on the overall quality of the models and the structural coefficients of the regression equations have been compiled in Table 1 and Table 2

Table 1

Overall statistical indicators of the multiple linear regression models for dry matter yield (Y)

Indicator	Mower I	Mower II
Number of observations (n)	40	40
Average yield (Y; kg/ha)	7056,36	2396,07
Standard deviation (SD)	2273,73	307,65
Multiple correlation coefficient (R)	0,6910	0,2017
Coefficient of determination (R ²)	0,48	0,04
Standard error of the estimate	1687,34	309,36
Calculated F-value (ANOVA)	16,91***	0,78 ^{ns}
Table F value (F _{0,05;2; 37})	3,25	3,25

*** - statistically highly significant at a 0.1% significance level; ns - not statistically significant.

For the first harvest, the analysis of variance (ANOVA) indicates that the model is highly statistically significant; the tabulated *F-test* value is 3.25, and the value obtained from running the program is 16.91.

The coefficient of determination $R^2 = 0.48$, which shows that 48% of the variability in dry matter yield from the first harvest is explained by the combined action of the two morphological factors (X_1 and X_2).

For the second mowing, a sharp decrease in the *F-test* value is observed, dropping to a completely insignificant level of 0.78 ($p=0.4638ns$), with the coefficient of determination being $R^2 = 0.04$, which shows that during the summer (June and July), the number of shoots and plant height account for only 4.00% of the variation in productivity of the studied plots.

Table 2 presents the final indicators that determined this behavior of the temporary grassland.

Table 2

Regression equation coefficients and the significance of the t-test (Student's t-test) for morphological indicators

Mower	Variable	Mean of the variable	Regression coefficient (B)	Standard error of the coefficient	Calculated t-value	Statistical significance
Mower I	Free term (B_0)	-	-1507,5822	1687,344	-0,89	ns
	Height (X_1 ; cm)	91,89	89,923	16,257	5,49	***
	Shoots (X_2 ; Shoots/m ²)	1423,97	0,253	0,589	0,43	Ns
Mower II	Free term (B_0)	-	1524,137	309,361	4,93	***
	Height (X_1 ; cm)	50,46	12,662	12,264	1,03	Ns
	Shoots (X_2 ; Shoots/m ²)	1160,57	0,201	0,167	1,20	Ns

t-critical=2.02 (for $\alpha=0.05$ and $df=37$; ***—statistically significant ($p<0.001$); ns—not statistically significant ($p\geq0.05$))

Based on the coefficients obtained in Table 2, the two multiple linear regression equations were established as follows:

a) Equation for the first harvest:

$$Y = -1507.582 + 89.273 \cdot X_1 + 0.253 \cdot X_2.$$

b) Equation for the second harvest

$$Y = 1524.137 + 12.662 \cdot X_1 + 0.201 \cdot X_2.$$

For the first harvest, it can be observed that plant height is the

dominant indicator, with high statistical significance ($t = 5.49 > t_{critical} = 2.02$; $p < 0.001$).

The coefficient +89.273 indicates that for every additional centimeter in plant height, there is an average increase of 89.3 kg/ha DM. The number of shoots has an insignificant influence ($t=0.43$). This leads to the conclusion that plant height was positively influenced by the abundant rainfall during the spring.

At the second harvest, the situation changes radically, as both indicators become statistically insignificant, and the t -values of 1.03 for height and 1.20 for shoots are both below the critical threshold of 2.02. In this case, the lack of rainfall and high temperatures caused the plants to cease vegetative

growth at this point, resulting in a height of 50.46 cm at this mowing.

But surprisingly, the free term $B_0=1524.137$, with a t -value of 4.93, is highly significant. Thus, from a biological standpoint, the value of B_0 represents a minimum quantity that the mixtures managed to maintain as an adaptive survival mechanism, independent of their size at the time of harvest.

To accurately visualize the predictive capacity of the two mathematical equations in relation to the field data, the distribution of the actual dry matter yield values obtained in the 40 experimental plots was plotted alongside the theoretical values estimated by the regression models (Figure 1 and Figure 2).

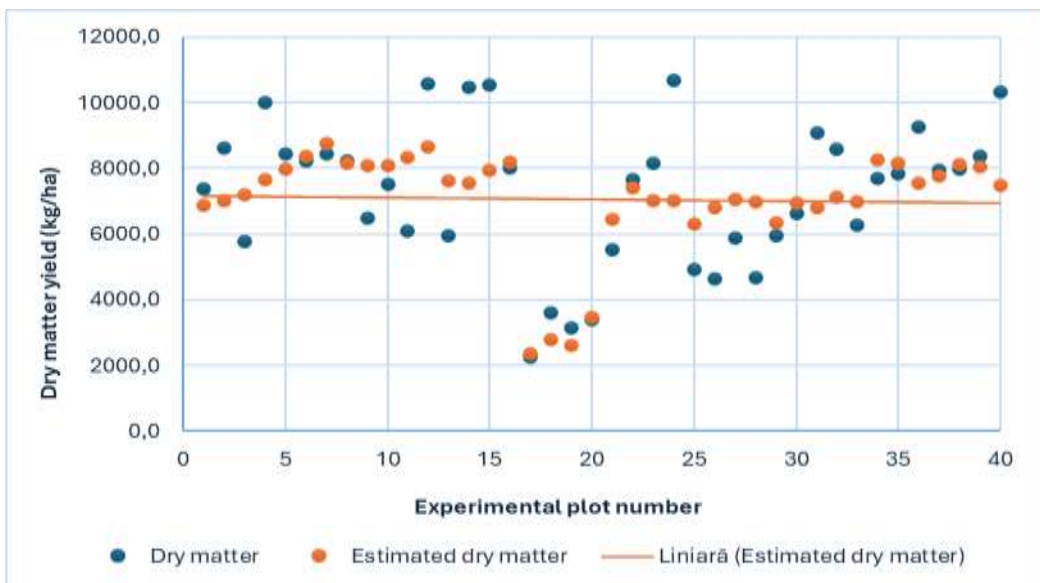


Fig. 1. The relationship between actual and estimated dry matter (DM) yields in the first cut.

Figure 1 confirms an optimal dynamic correlation between the actual data and the theoretical model ($R^2 = 0.48$). The estimated points (orange) closely follow the fluctuations in field production

(blue), a feature particularly visible in the range of plots 17–20, where the model instantly reduces its values in full agreement with the actual collapse in biomass.

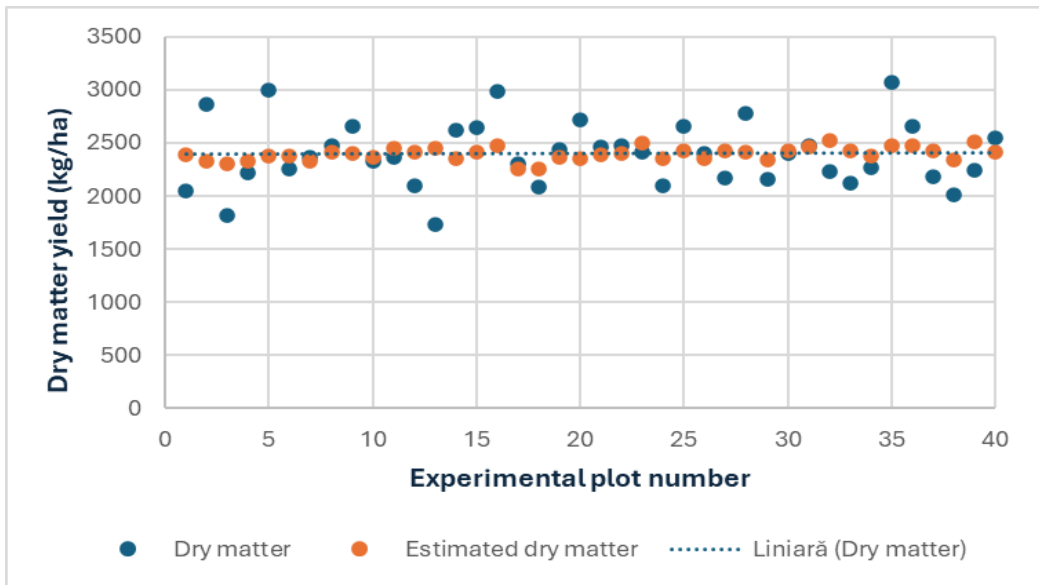


Figure 2 - Relationship between actual and estimated dry matter (DM) yields at the second cut.

In complete contrast, Figure 2 illustrates the model's complete decoupling under the impact of drought ($R^2 = 0.0407$). The estimated values (orange) no longer follow the variations in the field but align rigidly in the form of a

uniform horizontal band around the mean. The trend line (dotted) becomes a rigid plateau, visually demonstrating that the plant phenotype completely loses its predictive capacity under conditions of severe water stress.

CONCLUSIONS

The ability to predict biomass yield through simple measurements depends directly on climatic conditions. In the spring, the model performs with good accuracy ($R^2 = 48\%$), but in the summer it fails completely under the pressure of drought ($R^2 = 4\%$).

At the first cut, plant height is the decisive factor for yield (each centimeter yields an average increase of 89.3 kg/ha DM). In contrast, the number of shoots makes no real contribution to biomass estimation at any of the harvest times.

The statistical significance of the free term at the second mowing shows that, despite the drought, perennial mixtures managed to maintain a critical biomass threshold for survival (~1,524 kg/ha), as an adaptive survival response.

The results demonstrate that traditional estimation methods lose their usefulness during periods of water stress. For grasslands in eastern Romania, it becomes essential to integrate physiological stress indicators into future forecasting models.

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