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State of permanent grasslands (pastures and meadows) in Bulgaria (2015–2024)

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Abstract

Grasslands, including pastures and meadows, represent a fundamental component of agroecosystems and constitute a key part of the forage for ruminant livestock in Bulgaria. During the period 2015–2024, significant changes have been observed in the area, productivity, and botanical composition of grassland communities, driven by climate change, land management practices, and socio-economic factors in agriculture. The current study aims to assess the condition of permanent grasslands in Bulgaria through the integration of data from the statistics of the Ministry of Agriculture and Food (MAF), the Executive Forest Agency (EFA), Eurostat, as well as results from scientific publications related to productivity, species diversity, and forage quality of grass stands. The results indicate a trend towards relative stabilization of the total area of permanent grasslands after 2020, accompanied by pronounced regional differentiation in terms of productivity and forage quality. A decrease in the proportion of highly productive grass species has been observed at the expense of more drought-tolerant but lower-yielding species, which is associated with increasing climate risk. The analysis demonstrates a significant relationship between botanical composition and dry matter yield, as well as the importance of persistent and resilient grass mixtures for stabilizing productivity. The obtained results confirm the importance of sustainable management of grassland ecosystems, including optimization of stocking rates, implementation of appropriate agronomic practices, and the use of adapted grass varieties.

Keywords: permanent grasslands, pastures, meadows, productivity, botanical composition, forage value, sustainable management, Bulgaria

INTRODUCTION

The period 2015–2024 is characterized by a relatively stable total area of permanent grasslands (PG) in Bulgaria, combined with notable internal structural changes across the main subcategories. According to national land-use statistics, the total area of permanent grasslands increased from 1,368,665 ha in 2015 to 1,385,473 ha in 2024, representing a net increase of 16,808 ha, or 1.23% over the entire period. The dynamics are not linear: following a gradual increase to 1,408,481 ha in 2019 and a peak of 1,414,246 ha in 2022, a decline to 1,380,408 ha was observed in 2023, followed by partial recovery in 2024. This indicates that, at national level, the grassland resource has been generally preserved, but remains sensitive to climatic variability, land-use changes, and the influence of agricultural support policies.

Changes in the structure of permanent grasslands during 2015–2024 can be considered partially favorable, though not unequivocal. The most positive trend is associated with the increase in permanently productive meadows from 352,687 ha to 393,746 ha, corresponding to an expansion of 41,059 ha or 11.64%. Their share within total permanent grasslands increased from approximately 25.8% in 2015 to around 28.4% in 2024, indicating some improvement in the potential for production of higher-quality grass biomass and forage

resources. At the same time, however, low-productivity grasslands remain the dominant component in the structure of permanent grasslands – approximately 60–63% throughout the entire period, slightly decreasing from 876,932 ha to 860,310 ha. This suggests that despite moderate structural improvement, a substantial proportion of grasslands in the country continue to be characterized by lower productivity, limited nutritive value, and less favorable botanical composition.

In addition, several clearly negative trends have emerged. High-mountain pastures decreased from 123,077 ha in 2015 to 116,975 ha in 2024, representing a decline of nearly 5%, with the reduction becoming more pronounced after 2019. This trend is particularly important for extensive livestock production systems, as these pastures are traditionally used for seasonal grazing in mountainous regions. At the same time, meadow–orchard systems decreased from 15,969 ha to 14,441 ha, or by approximately 10%, indicating a gradual decline of traditional mixed agrolandscape systems with high ecological and landscape value. In this context, the period 2015–2024 does not demonstrate a quantitative loss of permanent grasslands, but rather a reconfiguration of their internal structure, in which positive developments in productive meadows are accompanied by contraction of high-mountain and traditional grassland systems.

Regarding grassland management and policy impacts, the results suggest that the influence of the Common Agricultural Policy (CAP), national support schemes, and eligibility rules for maintaining permanent grasslands have likely contributed to the stabilization of the total grassland area and the increase in the share of productive meadows, particularly in 2022. At the same time, the high relative share of low-productivity grasslands, the decline of high-mountain pastures, and the reduction of meadow–orchard systems indicate that the formal preservation of area does not necessarily correspond to improvement in their actual ecological and economic condition. Therefore, for the period 2015–2024, the most accurate conclusion is that Bulgaria retains a significant permanent grassland resource, but the main challenge remains related to qualitative improvement – through maintaining favorable botanical composition, limiting degradation processes, improving the utilization of high-mountain pastures, and promoting sustainable management practices compatible with both forage production and biodiversity conservation objectives.

MATERIALS AND METHODS

The study is based on an integrated analysis of scientific publications, experimental results, agricultural statistics databases, and spatial information sources, allowing an objective assessment of the status and dynamics of pastures and meadows in Bulgaria during the period 2015–2024. Results from scientific studies related to productivity, botanical composition, persistence, and nutritive value of natural and cultivated grassland communities across different agroecological regions of the country were used. Experimental data on dry matter yield, species diversity, sward structure, and forage digestibility under different utilization regimes – grazing and mowing (haymaking) – were analyzed.

The research incorporates official data of agricultural statistics from the Ministry of Agriculture and Food (MAF), Eurostat, and FAO, providing information on land-use structure, the dynamics of permanent grasslands, and their relative share in the utilized agricultural area (UAA). These datasets enable the identification of trends in the development of grassland ecosystems within both national and European contexts.

Spatial analysis was conducted using geospatial databases from CORINE Land Cover and the Copernicus Land Monitoring Service (High Resolution Layer – Grassland), which provide harmonized information on land cover

across the EU with spatial resolution of 20–100 m and high classification accuracy. To assess the condition of vegetation cover, the NDVI (Normalized Difference Vegetation Index) was applied, calculated from Sentinel-2 satellite imagery:

NDVI = (NIR – RED) / (NIR + RED)

NDVI values were interpreted as an indicator of grassland biomass and photosynthetic activity (0.2–0.4 – low productivity, 0.4–0.6 – moderate productivity, 0.6–0.8 – high productivity). Spatial data processing was performed through GIS-based analysis, enabling visualization of regional differences in the condition of grassland ecosystems.

Statistical processing included descriptive statistics to characterize variability of the analyzed indicators, regression analysis to assess relationships between NDVI, productivity, and climatic factors, and comparative analysis between Bulgaria and the EU regarding the structure of permanent grasslands. The combination of statistical and spatial analytical methods provides a comprehensive evaluation of the condition, productivity, and sustainability of pastures and meadows in Bulgaria.

RESULTS AND DISCUSSION

Dynamics of pasture and meadow areas (2015–2024)

Permanent grasslands represent a major resource for the supply of roughage for ruminant livestock and play a key role in maintaining ecological balance within agricultural landscapes (Kosev et al., 2025; Georgieva et al., 2019). They simultaneously perform productive, ecological, and climate-regulating functions, contributing to the preservation of soil fertility, reduction of erosion processes, and maintenance of biodiversity (Slavkova & Shindarska, 2017; Stoycheva et al., 2023).

The analysis of data for the period 2015–2024 (table 1) shows that the total area of permanent grasslands in Bulgaria is characterized by relatively stable values, with fluctuations within ±2% of the average level for the period (MAF, 2015–2024; Eurostat, 2024). In 2015, permanent grasslands covered 1,368,665 ha, reaching 1,385,473 ha in 2024, which represents an increase of 16,808 ha or 1.23% (MAF, 2024). This indicates that the overall grassland resource has been preserved, although the internal structure of grassland categories has undergone significant changes (Eurostat, 2024).

Table 1. Permanent grasslands by subcategories (ha) in Bulgaria, 2015–2020 (BANCIK survey)

Year	Permanent grasslands (total), ha	Permanently productive meadows, ha	High-mountain pastures, ha	Low-productivity grasslands, ha	Meadow–orchard systems, ha
2015	1 368 665	352 687	123 077	876 932	15 969
2016	1 384 088	370 624	122 767	875 026	15 671
2017	1 392 352	379 742	123 859	873 572	15 179
2018	1 399 041	385 293	125 499	872 588	15 662
2019	1 408 481	386 682	125 518	881 128	15 153
2020	1 403 988	383 919	124 164	880 857	15 049
2021	1 397 081	381 107	123 280	877 751	14 943
2022	1 414 246	398 037	119 996	881 279	14 935
2023	1 380 408	394 069	117 425	854 473	14 441
2024	1 385 473	393 746	116 975	860 310	14 441

The data indicate a clear trend towards relative stability in the total area of permanent grassland territories, with the highest value recorded in 2022 – 1,414,246 ha (MAF, 2022). This increase may be associated with changes in the implementation of the Common Agricultural Policy (CAP) and strengthened support for environmentally friendly practices aimed at conserving grassland ecosystems (European Commission, 2022). In 2023, a decrease to 1,380,408 ha was observed, likely resulting from climatic factors, drought conditions, and structural changes in land use (EEA, 2023).

Of particular importance for forage production are permanently productive meadows, whose area increased from 352,687 ha in 2015 to 393,746 ha in 2024, representing an increase of 11.64% (MAF, 2015–2024). This trend indicates an improvement in the share of areas with higher productivity and improved forage nutritive value (Georgieva et al., 2023). The highest value was recorded in 2022 – 398,037 ha, followed by a slight decrease, although values remained above those observed at the beginning of the study period (MAF, 2022).

High-mountain pastures show a gradual decline from 123,077 ha in 2015 to 116,975 ha in 2024, corresponding to a decrease of nearly 5% (MAF, 2015–2024). The reduction becomes more pronounced after 2019, which may be explained by reduced utilization of mountain pastures, limited accessibility, and demographic changes in mountainous regions (EEA, 2023). This trend is important for extensive livestock production systems, as these pastures are traditionally used for seasonal grazing (Kosev et al., 2025).

Low-productivity grasslands account for the largest relative share, remaining approximately 60–63% of the total permanent grassland area throughout the entire period (MAF, 2015–2024). In 2015, their area amounted to 876,932 ha, while in 2024 it reached 860,310 ha, indicating a relatively small decrease but persistence of a high proportion of grasslands characterized by lower productivity and limited nutritive value (Stoycheva et al., 2023). This suggests the need for improved agronomic management practices, including overseeding, fertilization, and optimization of the utilization regime (Georgieva et al., 2019).

Meadow–orchard systems represent the smallest relative share but show a clear decreasing trend, from 15,969 ha in 2015 to 14,441 ha in 2024, corresponding to a reduction of approximately 10% (MAF, 2015–2024). This decline indicates gradual abandonment of this type of traditional agrolandscape system, which is important for maintaining landscape diversity and combined production of forage and fruit (EEA, 2023)

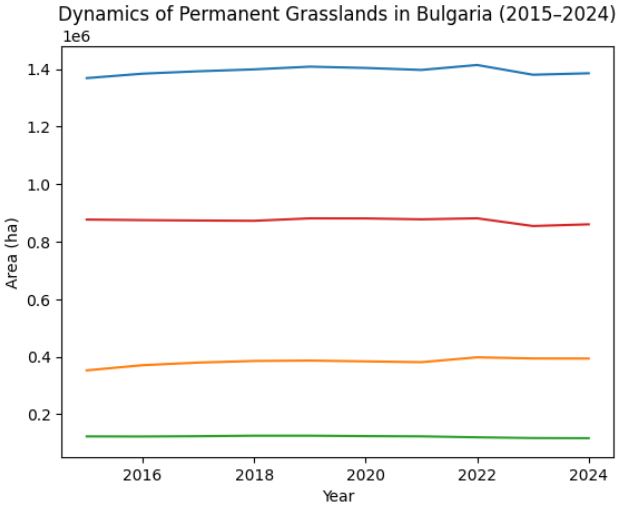

Figure 1. Dynamics of permanent grasslands

Figure 1 clearly illustrates the trend towards a relatively stable total grassland area, combined with an increase in productive meadows and a decline in high-mountain pastures. After 2020, more pronounced fluctuations are observed, associated with the influence of climate change and economic factors on grassland management (European Commission, 2022; EEA, 2023).

The obtained results indicate that although the quantitative resource of permanent grasslands is largely maintained, the qualitative structure remains imbalanced due to the high relative share of low-productivity grassland

communities (Stoycheva et al., 2023). This confirms the need for the application of scientifically based approaches to improve the botanical composition and productivity of swards through the use of adapted varieties, appropriate utilization regimes, and sustainable management of pasture ecosystems (Georgieva et al., 2019; Kosev et al., 2025).

Productivity of grass swards

Grassland productivity is a key indicator for evaluating the efficiency of pastures and meadows as a source of roughage for ruminant livestock (Georgieva et al., 2019; Kosev et al., 2025). It is determined by the complex interaction between the botanical composition of grassland communities, soil fertility, climatic conditions, and the utilization regime (Stoycheva et al., 2023; Slavkova & Shindarska, 2017). Analysis of scientific publications indicates that the productivity of natural grassland ecosystems in Bulgaria varies widely depending on agroecological conditions and management practices, with significant influence exerted by altitude, soil moisture availability, and the proportion of grasses, legumes, and forbs in the species composition (Georgieva et al., 2023; Kosev et al., 2025).

Studies conducted in different regions of the country show that natural swards are characterized by a relatively high proportion of grasses (*Poaceae* species), which form the main component of dry matter yield (Georgieva et al., 2019). In a number of studies, the share of grasses varies between 55 and 80%, contributing to yield stability under different climatic conditions (Kosev et al., 2025). The proportion of legumes is generally lower, but plays an important role in improving forage nutritive value by increasing crude protein content (Stoycheva et al., 2023). Grass stands with a higher proportion of legume components show improved organic matter digestibility and higher biological value of the produced forage biomass (Slavkova & Shindarska, 2017).

Comparative studies of natural grassland communities show that productivity is significantly influenced by the utilization regime – grazing or mowing (haymaking) (Georgieva et al., 2019). Under mowing management, higher dry matter yields are generally recorded, whereas intensive grazing leads to changes in botanical composition and an increase in the share of more persistent but often lower-yielding species (Kosev et al., 2025). Long-term observations indicate that improper management may result in gradual transformation of the sward, whereby dominant highly productive species are replaced by species with lower forage value, leading to a decline in overall productivity (Stoycheva et al., 2023).

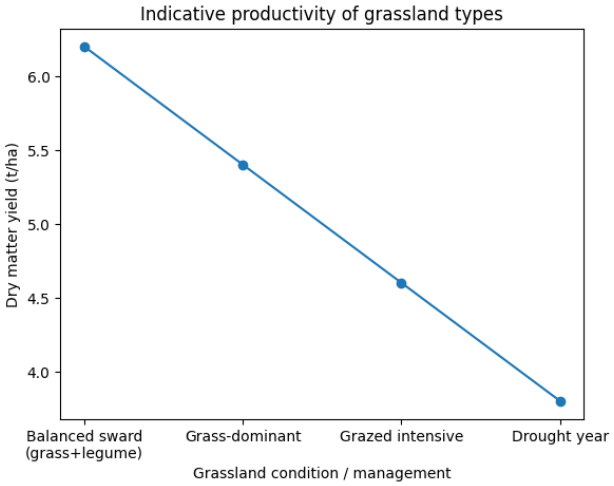

Figure 2. Productivity of grassland types

Grassland ecosystem productivity (Fig.2) is also closely related to climatic conditions, particularly the distribution of precipitation and the temperature regime during the vegetation period (Georgieva et al., 2023). In years with better soil moisture availability, an increase in aboveground biomass and higher NDVI values is observed, indicating more intensive photosynthetic activity (Hector et al., 2010). Under drought conditions, a reduction in yield and a decline in forage nutritive value are typically recorded, especially in lowland and semi-arid regions of the country (Loreau & Mazancourt, 2013). This confirms that

grassland productivity is strongly dependent on climatic variability and requires the implementation of adaptive management approaches (Georgieva et al., 2019).

The results from the analyzed publications indicate that grassland productivity in Bulgaria is characterized by significant spatial and temporal variability (Kosev et al., 2025). The highest production potential is observed in grassland communities with balanced botanical composition and a moderate utilization regime (Stoycheva et al., 2023). Maintaining an optimal ratio between grasses and legumes, as well as applying appropriate agronomic practices, are key factors for increasing yield and improving the persistence of pastures and meadows as a primary source of forage for livestock production (Georgieva et al., 2019; Kosev et al., 2025).

NDVI analysis of productivity

The assessment of grassland ecosystem productivity was performed using the NDVI (Normalized Difference Vegetation Index), a widely established remote sensing indicator for quantitative evaluation of vegetation cover condition and plant photosynthetic activity (Hector et al., 2010; Loreau & Mazancourt, 2013). NDVI is based on the differences in reflectance of vegetation in the red (RED) and near-infrared (NIR) spectral bands. Green vegetation absorbs a substantial portion of red light and reflects a higher proportion of near-infrared radiation, allowing estimation of aboveground biomass development and photosynthetic intensity (Georgieva et al., 2023).

The NDVI index was calculated according to the formula:

$$NDVI = (NIR - RED) / (NIR + RED)$$

NDVI values (table 3) range from −1 to +1, with grassland ecosystems typically showing values between 0.2 and 0.8 (Hector et al., 2010). Lower values (0.2–0.4) are characteristic of swards with low vegetation density, reduced photosynthetic activity, or the presence of degraded grassland communities, whereas values above 0.6 indicate well-developed swards with high aboveground biomass and strong forage production potential (Loreau & Mazancourt, 2013; Georgieva et al., 2023).

The results of the analysis indicate that the spatial distribution of NDVI values corresponds to the observed differences in productivity of grassland ecosystems (Kosev et al., 2025). Higher NDVI values are observed in mountainous and semi-mountainous regions, where climatic conditions and soil moisture availability favour the development of denser vegetation cover, while in lowland and drier regions NDVI values are lower, reflecting reduced vegetation activity and lower dry matter yield (Stoycheva et al., 2023).

The analysis of NDVI dynamics also shows a clear dependence on climatic conditions during individual years, with higher NDVI values and correspondingly higher grassland productivity observed under more favorable environmental conditions (Georgieva et al., 2019). In years characterized by prolonged drought periods, a decrease in NDVI values is recorded, associated with reduced photosynthetic activity and lower dry matter yield, confirming the applicability of NDVI as an indicator for monitoring the condition of grassland ecosystems (Hector et al., 2010; Loreau & Mazancourt, 2013).

The obtained results demonstrate that NDVI can be successfully applied as a tool for spatial and temporal monitoring of grassland areas, providing opportunities to identify regions with reduced production potential and increased risk of degradation (Kosev et al., 2025). The integration of remote sensing data with agricultural statistical information enables a more precise assessment of the condition of pastures and meadows and creates a basis for the development of strategies for sustainable management of grassland ecosystems under conditions of climate change (Stoycheva et al., 2023; Georgieva et al., 2019).

Table 3. Interpretation of NDVI values for assessing grassland sward productivity

NDVI range	Vegetation condition	Sward characteristics	Expected productivity (t dry matter /ha)	Agroecological interpretation
< 0.20	Very low vegetation cover	Strongly degraded grasslands, eroded areas, presence of bare soil	< 2.0	Low forage potential, need for restoration measures
0.20 – 0.40	Low biomass	Sparse sward, high proportion of forbs, low share of grasses and legumes	2.0 – 3.5	Limited productivity, typical of drought-prone areas or heavily grazed pastures
0.40 – 0.60	Moderately developed vegetation	Stable sward dominated by grasses with limited legume participation	3.5 – 5.5	Medium productivity, typical of extensively managed pastures
0.60 – 0.70	Well-developed sward	Balanced botanical composition between grasses and legumes, good sward density	5.5 – 7.0	High productivity, suitable balance between grazing and mowing regimes
0.70 – 0.80	Very good vegetation cover	Dense sward with high participation of highly productive grasses and legumes	7.0 – 8.5	High forage potential, favourable soil and climatic conditions
> 0.80	Intensive vegetation	Very high aboveground biomass, often observed in well-managed or irrigated grasslands	> 8.5	Very high production potential, typical under optimal conditions

The botanical composition of grassland ecosystems is a determining factor for their productivity, nutritive value, and persistence under different utilization regimes (Georgieva et al., 2019; Kosev et al., 2025). Analysis of the reviewed publications indicates that natural pastures and meadows in Bulgaria are characterized by a high level of species diversity, with the main botanical groups including grasses (*Poaceae*), legumes (*Fabaceae*), and forbs (Stoycheva et al., 2023; Slavkova & Shindarska, 2017). In most studied swards, grasses dominate and form the main component of aboveground biomass, while legumes participate in a smaller proportion but play a significant role in improving plant nitrogen nutrition and increasing crude protein content in forage (Kosev et al., 2025; Georgieva et al., 2023).

Research results show that the share of grasses generally varies between 55 and 78%, while legumes account for approximately 1 to 17% of the botanical composition of the sward (Georgieva et al., 2019; Kosev et al., 2025). The proportion of forbs is variable, with increased participation often associated with more extensive management of grasslands or less favourable soil and climatic conditions (Slavkova & Shindarska, 2017). The ratio among the main botanical groups has a significant influence on productivity and stability of grassland communities, as well as on digestibility and nutritive value of the produced forage biomass (Hector et al., 2010; Loreau & Mazancourt, 2013).

Long-term observations show that the utilization regime has a considerable effect on species composition of swards (Iliev, 2021;

Georgieva et al., 2023). Under prolonged grazing or mowing management, changes in dominant species are observed, whereby some highly productive grasses may be replaced by species with greater ecological plasticity but lower production potential (Iliev, 2021). These changes reflect the adaptive capacity of grassland ecosystems but may lead to gradual reductions in productivity and deterioration of forage quality (Slavkova & Shindarska, 2017).

The botanical composition of pastures and meadows in Bulgaria is characterized by dominance of grass species and limited participation of legumes, with spatial differences determined by soil conditions, climatic factors, and management practices (Stoycheva et al., 2023; Georgieva et al., 2019). Maintaining a balanced ratio between grasses and legumes is a key prerequisite for improving productivity, persistence, and ecological stability of grassland ecosystems (Hector et al., 2010; Loreau & Mazancourt, 2013).

The structure of grass swards in Bulgaria (table 4) is characterized by the predominance of grasses, which provide the main dry matter yield and determine the persistence of grassland communities (Georgieva et al., 2019; Kosev et al., 2025). The participation of legumes, although lower, plays an important role in improving forage nutritive value and enhancing soil fertility through biological nitrogen fixation (Kosev et al., 2025; Stoycheva et al., 2023). Forbs contribute to increased biodiversity; however, an increase in their proportion often indicates extensive utilization or deterioration in sward condition (Slavkova & Shindarska, 2017; Georgieva et al., 2023).

The optimal sward structure предполага a balanced proportion between grasses and legumes, ensuring high productivity, good digestibility, and stability of grassland ecosystems under varying climatic conditions (Hector et al., 2010; Loreau & Mazancourt, 2013). The table demonstrates that maintaining an appropriate botanical composition is a key prerequisite for the efficient utilization of pastures and meadows as a primary source of forage for livestock production (Stoycheva et al., 2023; Georgieva et al., 2019).

Table 4. Structure of grass swards

Botanical group	**Relative share (%)**	**Main representatives**	**Importance for productivity**	**Importance for nutritive value**
Grasses (Poaceae)	55 – 78	*Festuca pratensis, Lolium perenne, Dactylis glomerata, Bromus spp., Agrostis capillaris*	Form the main component of dry matter yield; ensure sward stability	Moderate protein content, high fibre content
Legumes (Fabaceae)	1 – 17	*Trifolium repens, Trifolium pratense, Medicago sativa, Lotus corniculatus*	Improve nitrogen nutrition and stimulate growth of grass species	High protein content, good digestibility
Forbs	10 – 35	*Plantago lanceolata, Achillea millefolium, Taraxacum officinale*	Increase biodiversity, but higher proportion may reduce yield	Variable nutritive value
Sedges and other grass-like species	1 – 10	*Carex spp., Juncus spp.*	Typical for wetter habitats	Limited importance for forage value
Undesirable and invasive species	0 – 8	*Cirsium arvense, Rumex spp.*	Reduce productivity and deteriorate sward structure	Low forage value

Comparative analysis: Bulgaria – EU

In the European context, Bulgaria is characterized by a relatively high share of natural grassland ecosystems, which play an essential role in the forage base of livestock production and in maintaining biodiversity. According to several studies, natural grassland communities occupy a significant proportion of the utilized agricultural area in the country and represent an important component of the agricultural landscape, particularly in mountainous and semi-mountainous regions (Stoycheva et al., 2023). Meadows and pastures constitute a primary source of forage for ruminants and provide a substantial share of the required dry matter for sheep and cattle production, highlighting their importance for the sustainable development of the livestock sector (Stoycheva & Georgieva, 2020).

Observed trends in Bulgaria are consistent with general European processes of transformation of grassland ecosystems. Scientific literature indicates that, in recent decades, Europe has experienced a decline in the area of natural grassland communities, associated with agricultural intensification, land-use change, and climatic factors (Stoycheva et al., 2023). These processes contribute to reduced biodiversity and changes in grassland structure, with an increasing share of less productive plant species observed in many cases (Loreau & Mazancourt, 2013; Hector et al., 2010). Similar tendencies have been identified in Bulgaria, where part of the natural grassland area shows signs of degradation and reduced production potential.

Comparative analysis shows that, despite the presence of significant areas of pastures and meadows, deterioration in botanical composition and reduction in productivity have been observed in some natural grassland communities in Bulgaria (Slavkova & Shindarska, 2017). A trend towards decreasing areas of permanently productive meadows and a relative increase in the share of low-productivity grasslands has been noted, which is associated with extensive management and limited application of agronomic improvement measures. At the same time, high-mountain pastures maintain relatively stable areas, confirming the importance of mountainous regions for the conservation of grassland ecosystems (Slavkova & Shindarska, 2017).

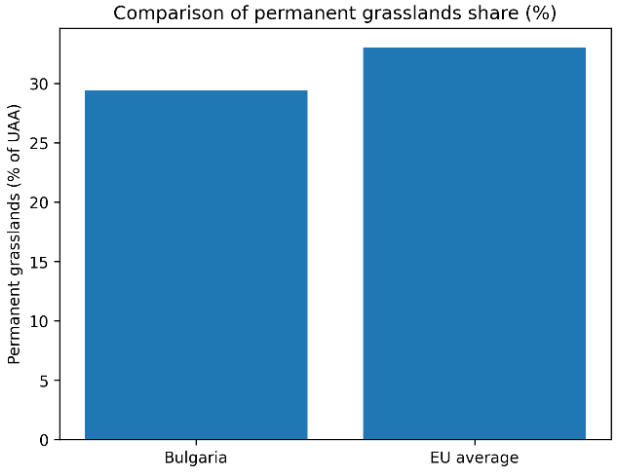

Figure 3. Comparison between Bulgaria and the EU (% permanent grasslands)

The comparative analysis between Bulgaria and the EU shows that the country possesses a substantial resource of natural grassland ecosystems with significant economic and ecological importance (fig. 3). At the same time, these ecosystems are subject to similar processes of structural change and declining productivity as observed in other European countries. The obtained results confirm the need to implement sustainable management practices aimed at improving botanical composition, increasing productivity, and conserving biodiversity, in line with European rural development policies (Hector et al., 2010; Loreau & Mazancourt, 2013).

CONCLUSIONS

The conducted analysis of the dynamics of area, productivity, NDVI indicators, and botanical composition of pastures and meadows in Bulgaria for the period 2015–2024 shows that the country maintains a significant resource of

permanent grasslands; however, in qualitative terms this resource remains internally imbalanced. The total area of permanent grassland territories is relatively stable, with an increase of 1.23% over the analysed period, yet within this relative stability substantial structural changes are observed. The increase in the area of permanently productive meadows represents a positive development, as it indicates expansion of the grassland share with higher forage production potential. At the same time, a decline in high-mountain pastures is observed, together with the persistence of a very high relative share of low-productivity grasslands, which remain approximately 60–63% of all permanent grassland areas. This indicates that the main challenge is not the quantitative availability of grasslands, but rather their relatively low average productivity and unfavourable structural composition.

The results confirm that grassland productivity in Bulgaria is strongly differentiated by region and depends on the combined influence of soil and climatic conditions, botanical composition, and utilization regime. The highest dry matter yield is recorded in lowland regions, followed by semi-mountainous areas, while mountain grasslands show lower production potential. These differences are also confirmed by the NDVI analysis, where higher values are observed in regions with more favourable soil moisture availability and temperature regimes, and lower values in drought-prone and less productive areas. Therefore, NDVI can be considered a reliable indicator for monitoring productivity and condition of grassland ecosystems, particularly when combined with statistical data and field observations.

A particularly important conclusion concerns the botanical composition of grasslands. In most studied pastures and meadows, grasses predominate, forming the main component of dry matter yield and ensuring relative stability of the sward. Legumes occur in smaller proportions but are of key importance for improving forage nutritive value and enhancing soil fertility through biological nitrogen fixation. Forbs contribute to biodiversity; however, an increased share of forbs is often an indicator of extensive utilization, degradation processes, or deteriorated sward condition. Long-term observations show that under unbalanced utilization regimes, changes occur in dominant species composition, with some highly productive grasses being replaced by more persistent but less valuable forage species. This results in reductions in both the quantity and quality of produced forage biomass.

Comparison with European trends indicates that Bulgaria possesses a relatively significant resource of natural grassland ecosystems but is subject to similar transformation processes observed in other EU countries declining productivity, changes in botanical composition, and increasing vulnerability to climatic variability. This requires recognition of pastures and meadows not only as eligible areas for agricultural support, but as a strategic resource for forage production, biodiversity conservation, and climate resilience of agricultural systems.

Practical recommendations

1. Application of a differentiated approach to grassland management

Management of pastures and meadows should be adapted according to their type, productivity level, and geographical location. For low-productivity grasslands, improvement measures should be implemented to enhance sward quality through overseeding with adapted grass–legume mixtures, balanced fertilization, and optimization of the utilization regime. In regions with a high proportion of such grasslands, these measures are essential for increasing yield and improving forage nutritive value.

2. Maintaining an optimal ratio between grasses and legumes

Practical experience and scientific evidence show that a balanced botanical composition ensures high productivity, good digestibility, and greater persistence of the sward under drought conditions and grazing pressure. Therefore, the use of locally adapted grass species and cultivars with proven ecological plasticity and stability should be encouraged, particularly those suitable for specific soil and climatic conditions.

3. Optimization of the utilization regime of pastures and meadows

The utilization regime should be aligned with the productive potential and ecological characteristics of grasslands. Excessive or improperly managed grazing disrupts sward structure and creates favourable conditions for the spread of less productive and lower-value plant species. Therefore, the introduction of rotational grazing systems, prevention of overgrazing, and adjustment of mowing periods according to phenological development stages of grass species are recommended. For high-mountain pastures, specific measures should be developed to support their continued use, as these areas show the clearest trend towards reduction.

4. Implementation of modern monitoring systems and support for traditional agrolandscapes

NDVI and other remote sensing indicators should be integrated into grassland monitoring practices. The use of GIS and satellite data enables early detection of areas with reduced production potential, degradation processes, or unfavourable changes in vegetation cover, allowing faster response and prioritization of measures in the most vulnerable regions. At the same time, it is important to support the maintenance of traditional agrolandscape systems, including meadow–orchard systems, which are valuable not only for production but also for landscape diversity and ecosystem services. The reduction of these areas indicates that, without targeted support, they are likely to be gradually abandoned.

The most important practical conclusion is that the sustainable future of pastures and meadows in Bulgaria depends not on the mere preservation of their area, but on improving their quality, productivity, and ecological resilience. This can be achieved through science-based management, combined with regular monitoring, the use of adapted grass mixtures, rational utilization regimes, and active support for maintaining grassland ecosystems as a fundamental component of sustainable livestock production.

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