Romanian Journal of Grassland and Forage Crops

The Romanian Society for Grassland
RJGFC No. 32/2025
https://sropaj.ro

Romanian Journal
of Grasslands and Forage Crops

Cluj Napoca 2025

Printed In Cluj Napoca By Academic Press Printers
ISSN 2068 - 3065 (Print)
For Submission Instructions, Subscription And All Other Information Visit: http://www.sropaj.ro

Publisher Romanian Journal of Grasslands and Forage Crops is Published by Academicpress Printers - University of Agriculture Science and Veterinary Medicine Cluj-Napoca, Mănăştur St., No. 3, 400372, Cluj-Napoca, România. Tel: 004/0264-596384, Fax: 004/0264-593792, e-mail: eap@usamvcluj.ro

Typing: - Adrian-Ilie NAZARE

Cover: - Bogdan Ioan GRIGORAȘ

Contents

Book presentation

"SWISS PASTORAL DIARY" by PhD, Engineer Teodor Marușca

The book "Swiss Pastoral Diary", written by the eminent specialist, scientist, Dr. Teodor Marușca, is part of a series of specialized works with a high technical and scientific degree, in a field of exceptional importance not only for the pastoral system in Romania, but also for the environment, biodiversity and the entire national economy.

"Swiss Pastoral Diary" is a book that impresses with its sincerity, naturalness and rare attention to the details of mountain life. Written in the form of a diary, the volume presents the author's experiences in a peaceful Swiss landscape, where the rhythm of nature intertwines with the inner rhythm of man.

The book thus becomes a space of introspection, in which Teodor Marușca notes observations, emotions and reflections that arise from the closeness to nature and the assumed isolation of pastoral life.

One of the strengths of the volume is the way in which the author manages to transform the everyday into a source of contemplation: the routine of caring for animals, the changes of the seasons, the discreet sounds of the mountain and the encounters with the local people acquire a poetic value, without being artificial. Marușca's prose maintains a clean simplicity, but behind it one feels a mature sensitivity, doubled by a diffuse nostalgia.

The Swiss landscape is not only a descriptive setting, but a secondary character that influences the author's state of mind: the alpine tranquility, pastoral order and rural aesthetics give the diary a calm and restorative atmosphere.

Teodor Marușca delicately captures the deep connection between man and place, between interior and exterior, between routine and meaning. In its pages, the reader finds a mental refuge, a micro-world in which it is not haste that defines existence, but presence.

The tone is warm, sometimes meditative, sometimes rigorously descriptive, as if the author were trying to capture on paper not only images, but also experiences that the mountains awaken in him.

The journal perfectly captures the idea that true knowledge occurs in silence, in observation and in close proximity to nature. "Swiss Pastoral Journal" is a book about rediscovery, peace and harmony.

Teodor Marușca offers an authentic perspective on a simple but meaningful world, transforming the pastoral experience into a meditation on life.

I recommend it to those looking for a calm, reflective and deeply connected reading to nature.

President of the Romanian Grassland Society in Romania

PhD, Prof. Costel Samuil

"Ion Ionescu de la Brad"Iasi University of Life Sciences

HIGH NATURE VALUE (HNV) GRASSLANDS IN THE APUSENI MOUNTAINS: A SYNTHESIS OF BIODIVERSITY, TRADITIONAL LAND USE AND CURRENT PRESSURES WITHIN A CULTURAL MOUNTAIN LANDSCAPE

Ioan ROTAR[1] and Ioana GHEȚE[*1],

[1]Faculty of Agriculture, Department of Plant Crops. University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Manăștur street, 3-5, 400372,Romania
**corresponding author: ioana.ghete@usamvcluj.ro*

Abstract

High Nature Value (HNV) grasslands in the Apuseni Mountains represent some of Romania's most valuable agro-pastoral ecosystems, maintained through traditional land-use practices and characterized by high biodiversity. This paper provides a comprehensive synthesis of the distribution, floristic characteristics, ecological dynamics and current pressures affecting HNV grasslands in the Apuseni, integrating results from long-term research conducted in the region. The main grassland types, indicator species and functional groups are described, with particular emphasis on sensitive habitats associated with species such as Arnica montana, Gentiana lutea and other oligotrophic forbs. The analysis highlights the impact of agricultural abandonment, localized intensification, climate change and tourism-related pressures on ecosystem structure and functioning. Results show that extensive management (annual mowing, moderate grazing, reduced organic fertilization) is the only strategy compatible with maintaining the ecological and conservation value of HNV grasslands. Mineral fertilization and abandonment lead to declining diversity, accelerated succession and the loss of sensitive species. The study underscores the importance of an integrated landscape-scale approach that includes support for traditional management, active interventions in abandoned areas and conservation of species-specific habitats for Arnica montana. HNV grasslands in the Apuseni Mountains remain key systems for biodiversity, cultural identity and the socio-economic sustainability of mountain communities.

Keywords: *HNV grasslands; biodiversity; traditional management; abandonment; mountain landscapes; Apuseni Mountains; socio-ecological systems.*

INTRODUCTION

High Nature Value (HNV) grasslands represent one of the most valuable types of agro-pastoral ecosystems in Europe, characterized by high biodiversity, traditional low-input land use and strong integration into the rural culture of mountain regions (Lomba et al., 2014; Herzon et al., 2020). At the European scale, these systems are recognized as major providers of essential ecosystem services—from maintaining floristic and faunistic diversity to regulating ecological processes and supporting cultural landscapes (Bengtsson et al., 2019).

Romania is among the countries with the largest extent of HNV grasslands in the European Union, totaling approximately two million hectares, most of them located in the Carpathian region, where agro-pastoral traditions have persisted uninterrupted for centuries (PNDR, 2019; PNS 2023). Within this context, the Apuseni Mountains constitute a major nucleus of HNV grasslands due to the geographical, climatic and socio-cultural conditions that have favored the development of mosaic landscapes in which forests, grasslands, hay meadows and small agricultural parcels coexist.

The unique character of Apuseni grasslands derives from the long-term interaction between human activities and the mountain environment: low-intensity manual or mechanized mowing, moderate organic fertilization, balanced grazing and intergenerational transmission of traditional practices. These elements have contributed to the maintenance of species-rich plant communities dominated by associations such as *Festuca rubra–Agrostis capillaris* or *Trisetum flavescens*, as well as to the conservation of representative and sensitive species including *Arnica montana*, *Campanula serrata* and *Gentiana lutea* (Michler et al., 2005; Păcurar et al., 2023).

The Apuseni Mountains do not constitute a homogeneous unit, but rather a complex ensemble of intramontane depressions, karst plateaus, forested ridges and traditional hay meadow and grazing areas, resulting in high variability among HNV grassland types. Within the massif, both oligotrophic and mesotrophic or eutrophic grasslands occur, differentiated by altitude, lithological substrate, grazing pressure and land-use history. Part of this mosaic is included today in protected areas (e.g., Apuseni Natural Park), yet HNV grasslands extend far beyond these boundaries, covering a considerable territory.

In recent decades, socio-economic transformations affecting mountain regions—including the decline in the number of active households, rural depopulation, localized intensification of land use and, conversely, agricultural abandonment—have triggered rapid changes in the dynamics of HNV grasslands. These shifts threaten the stability of traditional agro-pastoral systems and accelerate succession toward closed habitats, leading to the loss of oligotrophic species and degradation of the ecological and cultural values of the landscape.

The aim of this paper is to provide an updated synthesis on HNV grasslands in the Apuseni Mountains, drawing on scientific literature and studies conducted in the region over the past two decades. The paper examines the structure and distribution of habitats, the floristic and ecological characteristics of HNV grasslands, current pressures acting upon them, their socio-economic functions, and the main directions for sustainable management within a mountain cultural landscape undergoing significant transformation.

THE NATURAL FRAMEWORK OF THE APUSENI MOUNTAINS

The Apuseni Mountains represent a complex unit of the Western Carpathians, characterized by high geomorphological, climatic and biogeographical diversity. From a physical–geographical perspective, the Apuseni stand out through their moderate altitudes, predominantly fragmented relief and a cultural mountain landscape shaped by centuries of interaction between agro-pastoral activities and the natural environment (Păcurar, 2005). This interdependence has generated a mosaic of habitats in which natural and semi-natural grasslands occupy significant surfaces, integrated among forests, traditional agricultural plots and scattered rural settlements.

Geology and landforms

The geology of the Apuseni Mountains is complex, with alternating calcareous formations, conglomerates, crystalline schists and volcanic rocks, which explains the diversity of lithological substrates and, implicitly, the variety of HNV grassland types. Extensive karstic areas, especially in the Central Apuseni, have generated plateaus characterized by shallow soils and oligotrophic edaphic conditions, favorable for the development of plant associations such as *Festuca rubra–Agrostis capillaris*, or for *Nardus stricta* grasslands at higher elevations (Păcurar & Rotar, 2014). In transitional areas between plateaus and broad valleys, mesotrophic grasslands occur, traditionally used as hay meadows.

Climate

The climate of the Apuseni Mountains is temperate-continental with mountain influences, including oceanic effects and considerable spatial variability. Annual precipitation ranges from about 800 mm in lower areas to over 1,200 mm at higher elevations, conditions that support communities with moderate productivity and high floristic diversity. Interannual climatic variability, documented in recent studies on oligotrophic grasslands, shows that fluctuations in temperature and precipitation regimes directly influence species composition—particularly sensitive species such as *Arnica montana*—and may even affect the co-dominance between the species shaping the vegetation structure, such as *Festuca rubra–Agrostis capillaris* (Păcurar et al., 2014).

Soils and edaphic conditions

Grassland soils in the Apuseni are predominantly cambisols, rendzinas and acidic brown soils, with naturally low to moderate fertility, which confers a high potential for maintaining oligotrophic plant communities. Rendzinas on calcareous substrates favor the occurrence of species characteristic of xeromezophilous habitats, while acidic brown soils support the development of oligotrophic grasslands with high specific diversity. This edaphic diversity is a key factor explaining the mosaic of HNV grassland types throughout the massif.

Traditional socio-economic structure

The Apuseni region possesses a distinct demographic and economic structure, characterized by scattered settlements, small household farms, seasonal livestock mobility and an economy historically based on animal husbandry and forest resource use (Plăiaș, 1994; Auch et al., 2001). Grasslands have played a central role in this system, providing the primary fodder resource for cattle and sheep (Rotar et al., 2016), as well as an important source of medicinal plants, particularly *Arnica montana* (Păcurar, 2005; Michler et al., 2005; Rotar et al., 2010).

This traditional socio-economic structure has contributed to the maintenance of low-input management favorable to biodiversity. However, recent transformations—including depopulation, the decline in the number of active farmers and changes in land-use systems—now threaten the stability of these habitats.

HNV grasslands as a central element of the cultural mountain landscape

The Apuseni Mountains are considered a representative example of Romania's cultural mountain landscape. HNV grasslands form a key component of this system, being distributed across intramontane depressions, intermediate ridges and calcareous plateaus. Habitat diversity reflects the interaction between traditional practices (annual mowing, moderate grazing, organic fertilization) and natural conditions, which explains the persistence of species-rich communities with indicator species of low fertilization and high conservation value.

A well-documented example of grassland structure and dynamics is found within the Apuseni Natural Park, where the Management Plan (2023) provides a detailed picture of land-use patterns. Here, both natural and secondary grasslands form one of the most extensive open-habitat nuclei in the Western Carpathians, while recent assessments (Moș & Brînzan, 2024) highlight an accelerated process of abandonment in certain areas. This local example illustrates a broader trend affecting the entire massif—the rapid transformation of the traditional landscape under the pressure of socio-economic changes.

CHARACTERISTICS OF HNV GRASSLANDS IN THE APUSENI MOUNTAINS

High Nature Value (HNV) grasslands in the Apuseni Mountains reflect remarkable floristic, ecological and functional diversity, shaped both by the varied natural conditions of the massif and by traditional land-management practices. Their distribution is closely linked to the region's agro-pastoral heritage, where extensive mowing and grazing systems have shaped open mountain landscapes for centuries.

Grassland types and floristic particularities

The plant communities characteristic of HNV grasslands in the Apuseni belong mainly to mesotrophic and oligotrophic associations, developing on soils with low to moderate fertility and traditionally managed through annual mowing or moderate grazing. Among the most frequent grassland types are:

- mesotrophic hay meadows dominated by *Trisetum flavescens*,
- oligotrophic *Festuca rubra–Agrostis capillaris* grasslands, widespread throughout the Central Apuseni,

- oligotrophic *Nardus stricta* grasslands characteristic of higher elevations or acidic soils,
- habitats associated with sensitive species such as *Arnica montana*, *Gymnadenia conopsea*, *Campanula serrata*, which indicate reduced fertilization levels and stable traditional use.

Studies conducted in the Apuseni (Gârda et al., 2010; Păcurar et al., 2008) confirm that these meadow types exhibit complex floristic structures, hosting numerous rare species and indicators of low fertilization such as *Briza media*, *Carex pallescens*, *Carlina acaulis*, *Polygala vulgaris*, *Gentiana lutea*, and others. The highest diversity is found in extensively managed grasslands, where traditional interventions maintain habitat openness and prevent succession towards shrublands or young forests.

Biodiversity and characteristic species

HNV grasslands in the Apuseni are renowned for their high concentration of oligotrophic species and for the balanced representation of the three main functional groups: grasses, legumes and forbs. This diversity results from low-input management, which limits the competitiveness of nitrophilous species and allows the coexistence of floristic groups adapted to moderate fertility conditions.

Representative species of high ecological and conservation value include:

- *Arnica montana* – an umbrella species for oligotrophic habitats, extremely sensitive to intensification and eutrophication (Michler et al., 2005; Vârban et al., 2011; Păcurar et al., 2023);
- *Gentiana lutea*, *Plantago media*, *Gymnadenia conopsea*, indicators of extensive management (Păcurar et al., 2025);
- legumes such as *Trifolium pratense*, *T. repens*, and *Medicago lupulina*, occurring in balanced proportions in well-managed grasslands.

In areas where traditional management persists, plant communities reach high alpha-diversity values, and the ratio between Poaceae : Fabaceae : forbs remains within the ranges considered optimal for HNV systems. Conversely, under intensification or abandonment, community structure shifts rapidly, with declines in sensitive species and increases in competitive or nitrophilous ones.

Recent studies on other sensitive species from HNV grasslands in Romania, such as *Adonis vernalis* in native extracarpathian habitats (Păcurar et al., 2025), highlight the potential of density-based quantitative approaches for evaluating population status—approaches that may also be relevant for mountain species such as *Arnica montana*.

Effects of fertilization and land use on diversity

Long-term research in the Apuseni Mountains, including experimental studies documented in the habilitation thesis, demonstrates how fertilization inputs and agricultural practices influence the floristic composition and functioning of HNV grasslands.

Moderate organic fertilization

Organic fertilization (e.g., 10 t/ha of farmyard manure) maintains or even increases floristic diversity, supporting both moderate-competitive grasses and perennial legumes and a variety of forbs. In certain experiments, the Shannon index increased when moderate manure application was combined with mulching (Rotar et al., 2005; Păcurar et al., 2018).

Intensive mineral fertilization

High mineral inputs lead to:

- rapid declines in species richness,
- increased dominance of nitrophilous grasses (e.g., *Dactylis glomerata*, *Festuca pratensis*),
- reduction of low-fertility indicator species,
- homogenization of the vegetation structure (Rotar et al., 2013).

These effects are incompatible with maintaining HNV character.

Absence of fertilization and minimal management

The unfertilized variant (control) favors the persistence of oligotrophic communities with a high number of indicator species. However, in areas with reduced mowing/grazing pressure, lack of intervention leads to biomass accumulation and triggers succession towards closed habitats (Păcurar & Rotar, 2011).

Agricultural abandonment

Studies indicate that abandonment leads to:

- increases in Cyperaceae and Juncaceae species,
- gradual disappearance of sensitive species (*Arnica*, *Carex pallescens*, oligotrophic forbs),
- changes in the vertical structure of vegetation,
- encroachment by shrubs (*Rubus*, *Juniperus*) and pioneer trees (Păcurar et al., 2015).

These transformations rapidly reduce the conservation value of habitats.

PRESSURES ON HNV GRASSLANDS IN THE APUSENI MOUNTAINS

High Nature Value (HNV) grasslands in the Apuseni Mountains are currently subjected to multiple ecological, socio-economic and territorial pressures. The accelerated transformations of recent decades reflect profound changes in traditional agro-pastoral systems, with direct implications for biodiversity, ecosystem functioning and the stability of the cultural mountain landscape.

The most significant pressures identified in the scientific literature and in studies carried out in the Apuseni region include agricultural abandonment, localized intensification of land use, climate change and various territorial and tourism-related pressures.

Agricultural abandonment — the dominant pressure in the Apuseni Mountains

Grassland abandonment represents the strongest and most widespread pressure on HNV grasslands in the Apuseni, with deep ecological and landscape-level consequences (Păcurar et al., 2015).

Across the massif, the decline in the number of active households, depopulation of mountain villages, reduced livestock numbers and land fragmentation have led to diminished traditional use of grasslands. Abandonment results in biomass accumulation, reduced interspecific competition and rapid onset of secondary succession.

Long-term experiments conducted in the Apuseni show that abandonment drives the transition of oligotrophic grasslands toward early shrub stages (genera *Rubus*, *Crataegus*, *Juniperus*) and subsequently toward natural forest regeneration (Păcurar, habilitation thesis). At the same time, indicator species of open habitats—such as *Arnica montana*, *Thymus pulegioides*, *Festuca rubra*, *Potentilla erecta*, *Carlina acaulis*, *Scorzonera rosea*, among others—gradually decline in frequency or disappear completely (Gârda et al., 2009; Păcurar et al., 2015).

Floristic and ecological analyses in the Apuseni have also identified indicator species for abandonment stages, such as *Silene nutans*, *Plantago media* and various Cyperaceae and Juncaceae species, which establish preferentially in unmown or ungrazed vegetation (Păcurar, 2005; Rotar et al., 2013).

Abandonment affects not only floristic composition but also ecosystem functioning, leading to:

- decreased alpha- and beta-diversity,
- loss of ecosystem services (forage, medicinal plants),
- reduced habitat connectivity,
- degradation of the traditional cultural landscape,
- increased fire risk due to the accumulation of dry biomass.

Land-use intensification

In contrast to abandonment, some accessible areas of the Apuseni have undergone agricultural intensification. Although these zones are limited in extent, their impact on HNV grasslands is substantial.

The main forms of intensification include:

- repeated mineral fertilization (NPK),
- overseeding with competitive species such as *Dactylis glomerata*,
- use of heavy agricultural machinery,
- increased grazing pressure in restricted areas.

Results from experiments conducted in the Apuseni (Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2014) consistently demonstrate that intensification leads to:

- reduction of floristic diversity through exclusion of sensitive species,
- increased dominance of nitrophilous grasses,
- decreased proportion of perennial legumes,
- altered Poaceae–Fabaceae–forb ratios,

- homogenization of the vegetation cover and loss of conservation value.

Ecologically, intensification produces a predictable type of grassland dominated by a few robust species with high short-term pastoral value but low long-term conservation value.

Climate change — interannual variations with significant ecological impact

Climate exerts a direct influence on the dynamics of HNV grasslands. Studies conducted in the Apuseni Mountains (Păcurar et al., 2014; Sângeorzan et al., 2018) show that interannual variability in precipitation and temperature significantly affects biomass production, floristic composition and species distribution.

Observed effects include:

- reduced productivity in dry years, especially on shallow soils,
- increased dominance of xerophilous species during periods of low precipitation,
- large fluctuations in the abundance of sensitive species such as *Arnica montana*,
- decreased resilience of grasslands in areas already affected by abandonment.

Climate change amplifies the effects of other pressures—particularly abandonment—by accelerating succession toward closed habitats.

Territorial and tourism pressures, and landscape fragmentation

The Apuseni Mountains are among the most visited mountain regions in Romania, and tourism pressure together with infrastructure development has increased significantly in recent decades.

Moș & Brînzan (2024) highlight several risks:

- expansion of tourist facilities into sensitive areas,
- habitat fragmentation caused by roads and utility networks,
- intensified motorized traffic in mountain zones,
- aggressive tourism affecting fragile habitats (e.g., *Arnica montana* sites),
- degradation of the cultural landscape through replacement of managed grasslands with unused or afforested land.

Landscape fragmentation and loss of ecological connectivity reduce the long-term capacity of HNV grasslands to persist, especially in areas dependent on continuous traditional human intervention.

THE SOCIO-ECONOMIC ROLE OF HNV GRASSLANDS IN THE APUSENI MOUNTAINS

High Nature Value (HNV) grasslands in the Apuseni Mountains hold significant socio-economic importance and are deeply embedded in the way of life of mountain communities. For centuries, they have formed the foundation of traditional agro-pastoral systems, providing forage resources, agricultural products, medicinal plants, as well as cultural identity and landscape stability.

Although recent socio-economic transformations have altered the rhythm of their use, the functions fulfilled by these grasslands remain essential both for local communities and for maintaining the characteristic landscape of the Apuseni region.

Pastoral importance and the forage base of mountain communities

In the Apuseni, semi-natural grasslands constitute the central element of traditional livestock-raising systems. Households have historically depended on mesotrophic hay meadows and secondary pastures to provide fodder for cattle and sheep, and this model still persists in many mountain villages (Păcurar, 2005).

Extensive management, characterized by:

- annual mowing,
- moderate grazing,
- reduced organic fertilization,

has endowed these grasslands with moderate productivity but high forage quality, well suited to the needs of local pastoral systems.

Studies on digestibility, chemical composition and the nutritional value of traditional hay from the Apuseni (Dale et al., 2012; Dale et al., 2013) show that extensively managed grasslands provide balanced fodder rich in high-quality fiber, carotenoids and functional compounds important for animal nutrition. These characteristics confirm the high pastoral value of HNV grasslands despite their moderate productivity compared with intensified systems.

In many mountain villages—including Gârda de Sus, Horea, Poiana Vadului and Vidra—grasslands remain essential for sustaining livestock production, even though the number of active households is declining.

Medicinal plant resources and local economic value

HNV grasslands in the Apuseni are among the most important natural sources of medicinal plants in Romania. The most emblematic species is *Arnica montana*, which has high economic value and a long tradition of use.

Studies carried out in the Apuseni (Michler et al., 2005; Păcurar et al., 2023) show that:

- *Arnica montana* is strictly dependent on oligotrophic grasslands,
- it is highly sensitive to mineral fertilization and intensification,
- it is severely affected by abandonment and the encroachment of woody vegetation,
- it represents a significant economic resource for households in areas such as Gârda–Ghețari, Horea and Albac.

The collection, drying and commercialization of *Arnica montana* inflorescences represent a traditional activity with important economic relevance for many families in a mountain context where alternative income sources are limited. In addition, Apuseni grasslands provide several other medicinal resources (e.g., *Colchicum autumnale*, *Viola tricolor*, *Euphrasia roskoviana*), contributing to the diversified socio-economic value of the region.

Cultural and identity-related role of HNV grasslands

HNV grasslands are not only functional ecosystems but also identity-forming elements of the traditional mountain landscape. In the Apuseni, they are deeply integrated into local lifestyles, village organization and the agricultural calendar, contributing to:

- preservation of traditions related to mowing, haymaking and seasonal livestock movements,
- maintenance of seasonal farm structures (hay barns, mountain shelters),
- perpetuation of traditional architecture in pastoral-cultural landscapes,
- transmission of local knowledge across generations (Păcurar, 2005).

The resulting landscape—characterized by a harmonious alternation of forests, grasslands, hay meadows and scattered settlements—is perceived as a defining feature of the Apuseni Mountains and represents one of the region's major tourist attractions.

Fragmentation, abandonment and agricultural intensification affect not only the ecological structure of grasslands but also the cultural heritage of local communities. In the long term, the loss of the mountain cultural landscape may diminish both local identity and the tourist appeal of the region.

Ecosystem services and broader economic value

HNV grasslands provide numerous ecosystem services, including:

- **provisioning services** (fodder, medicinal plants, water),
- **regulating services** (carbon sequestration, erosion control, microclimate regulation),
- **cultural services** (landscape value, recreation, traditional practices),
- **supporting services** (nutrient cycling, soil and biodiversity maintenance).

The stability of these services depends on maintaining traditional low-input management. Abandonment, intensification and climate change reduce the ability of HNV grasslands to deliver these benefits to communities and ecosystems.

MANAGEMENT AND CONSERVATION

Management of HNV grasslands in the Apuseni Mountains is essential for maintaining biodiversity, ecosystem stability and the socio-economic functions of the cultural mountain landscape. These systems are extremely sensitive to changes in land use, and research conducted in the region shows that both intensification and abandonment lead to rapid and often irreversible transformations (Păcurar & Rotar, 2011; Rotar et al., 2013).

The results of long-term studies in the Apuseni allow the development of clear scenarios for adaptive management based on low-input agriculture, preservation of local traditions and conservation of indicator species characteristic of high natural value.

Extensive (low-input) management — the foundation of HNV maintenance

High Nature Value grasslands are, by definition, ecosystems created and maintained through extensive management. In the Apuseni Mountains, this model is characterized by:

- annual or biennial mowing,
- moderate grazing,
- occasional organic fertilization,
- avoidance of mineral inputs.

Experiments carried out in the Apuseni over more than 20 years confirm that low-input management:

- maintains the highest levels of floristic diversity,
- promotes indicator species of oligotrophic conditions,
- supports the presence of conservation-interest species (e.g., *Arnica montana* and rare forbs),
- ensures a functional balance among grasses, legumes and forbs,
- provides stability in the face of climatic variability.

Extensively managed hay meadows have also demonstrated high resilience during dry years due to their complex vegetation structure and well-developed root systems.

Moderate organic fertilization — a tool compatible with HNV conservation

Experimental results from the Apuseni indicate that moderate organic fertilization (10 t/ha of farmyard manure), applied periodically, is compatible with the maintenance of HNV characteristics.

Benefits of moderate organic fertilization include:

- moderate increases in productivity,
- maintenance of diversity (with increases in Shannon index in some treatments),
- support for Fabaceae and mesotrophic species,
- limitation of nitrophilous grass expansion.

The combination of organic fertilization and mulching, tested in long-term experiments, has resulted in a more balanced vegetation structure, enhanced diversity of perennial species and reduced interannual fluctuations in floristic composition.

However, excessive or overly frequent organic fertilization remains incompatible with HNV status.

Mineral fertilization — intensification effects and loss of HNV value

Mineral fertilizers (NPK), even when applied at moderate doses, lead to:

- reductions in species diversity,
- increased dominance of competitive grasses (*Agrostis capillaris*, *Dactylis glomerata*, *Festuca pratensis*),
- decreases in legumes and oligotrophic species,
- profound alteration of the functional structure of vegetation.

The effects are rapid and predictable: grasslands shift to a different successional trajectory, becoming productive systems but losing their conservation value.

These findings confirm the broader European literature and underline that mineral fertilization is not compatible with the maintenance of HNV grasslands.

Managing abandonment — the need for active intervention

Abandonment is the most frequent issue in the Apuseni and requires an intervention plan adapted to the stage of succession. Observations and floristic analyses show that the first signs of abandonment include:

- accumulation of plant litter (felt),
- decline of oligotrophic species,
- increases in Juncaceae and Cyperaceae species,
- appearance of *Rubus*, *Juniperus*, *Crataegus*,
- reduced abundance of indicator species (*Arnica montana*, *Gymnadenia conopsea*, *Plantago media*, etc.).

Recommended actions for abandoned areas include:

1. Reintroduction of periodic mowing

Ideally annually or biennially, to reduce biomass accumulation.

2. Controlled extensive grazing

With low stocking rates and well-defined grazing periods to prevent overgrazing.

3. Removal of shrubs and pioneer trees

Through mechanical or manual interventions in sensitive zones.

4. Gradual ecological restoration

Especially in oligotrophic grasslands where sensitive species have drastically declined.

Studies show that if intervention occurs in the early years of abandonment, grasslands can significantly recover their structure and functionality.

Protecting species-specific habitats for *Arnica montana*

Arnica montana is a key indicator species of HNV grasslands in the Apuseni. Management of its habitats requires:

- avoiding mineral fertilization,
- avoiding excessive manure application,
- late mowing (after seed maturation),
- moderate grazing pressure,
- protection from woody vegetation encroachment,
- periodic monitoring of populations.

Arnica habitats are among the most sensitive to intensification and abandonment. Any change in traditional management results in direct effects on plant density and vitality.

Integrated landscape-level management

Conservation of HNV grasslands cannot be achieved solely at the plot or farm level. The Apuseni region requires an integrated landscape approach because:

- pressures are unevenly distributed (abandonment in remote areas, intensification in accessible ones),
- habitat connectivity is essential,
- tourism development may conflict with conservation goals,
- socio-economic dynamics directly influence land use.

Effective management should include:

- landscape-scale conservation plans,

- financial support for low-input practices (agri-environment measures, HNV payments),
- involvement of local communities in decision-making,
- integration of scientific research into land-use regulations.

The model proposed by Moș & Brînzan (2024) confirms that the cultural mountain landscape can be maintained only through continuity of traditional use, diversification of income sources and adoption of management adapted to new socio-economic conditions.

CONCLUSIONS

High Nature Value grasslands in the Apuseni Mountains represent an ecological and cultural system of major importance, characterized by high floristic diversity, traditional low-input use and deep integration into the identity of mountain communities. The bibliographic analysis and the results of long-term research carried out in the region confirm that the functioning of these systems depends on the maintenance of traditional agro-pastoral practices, particularly annual mowing, moderate grazing and limited organic fertilization.

The variability of grassland types—from mesotrophic hay meadows to oligotrophic *Nardus stricta* communities and those associated with sensitive species such as *Arnica montana*—reflects the complex interaction between natural conditions and traditional management. The high biodiversity, pastoral value and socio-economic role of HNV grasslands are closely tied to this interdependence.

Current pressures—agricultural abandonment, localized intensification, climate change and landscape fragmentation—strongly affect the stability of these ecosystems. Abandonment, in particular, leads to rapid succession towards closed habitats, with the loss of indicator species and conservation value. Intensification produces opposite but equally problematic effects by homogenizing the vegetation cover and reducing floristic diversity. These processes highlight the vulnerability of HNV grasslands and the need for adapted conservation measures.

Research conducted in the Apuseni Mountains shows that low-input management, based on moderate organic fertilization, controlled grazing and periodic mowing, is the most effective strategy for maintaining grassland biodiversity and ecological functioning. Active interventions in abandoned areas, including shrub removal and the reintroduction of mowing, are essential for restoring sensitive habitats, while the protection of species-specific habitats for *Arnica montana* requires targeted measures and continuous monitoring.

In the context of socio-economic and climatic changes, conservation of HNV grasslands in the Apuseni cannot be ensured solely at the plot level; instead, it requires an integrated landscape-scale approach that includes adequate financial support, involvement of local communities, coherent territorial planning and the integration of scientific research into management decisions.

This study underscores the necessity of preserving and revitalizing traditional agro-pastoral systems as the foundation for maintaining biodiversity, cultural values and the ecosystem functions of HNV grasslands in the Apuseni Mountains. Their conservation represents not only an ecological responsibility but also a social and economic one, with direct implications for the future of mountain communities and the cultural landscape characteristic of this region.

REFERENCES

1. Auch E., F. Păcurar, A. Goia, 2001, Economic and Technological Aspects of the Agricultural Systems in Ţara moţilor (Gheţar, Gârda de Sus), în Buletinul USAMV, Seria Agricultura, vol. 55-56: 215
2. Balázsi, Á., Pacurar, F., Mihu-Pintilie, A., & Konold, W. (2018). How do public institutions on nature conservation and agriculture contribute to the conservation of species-rich hay meadows? *International Journal of Conservation Science*, *9*, 549–564.
3. Balázsi, Á., Păcurar, F., Rotar, I., & Vidican, R. (2016). Alternative management for oligotrophic grassland conservation in the Apuseni Mountains. In *Proceedings*, 678–680.
4. Bengtsson, J., Bullock, J. M., Egoh, B., Everson, C., Everson, T., O'Connor, T., ... & Lindborg, R. (2019). Grasslands — more important for ecosystem services than you might think. Ecosphere, 10(2), e02582.
5. Brinkmann, K., Pacurar, F., & Reif, A. (2009). Secondary succession and fluctuations in meadows of the Apuseni Mountains (Transylvania, Romania) under different fertilisation regimes. *Transylvanian Review of Systematical and Ecological Research*, *7*, 41–58.
6. Corcoz, L., Păcurar, F., Pop-Moldovan, V., Vaida, I., Stoian, V., & Vidican, R. (2021). Mycorrhizal patterns in the roots of dominant *Festuca rubra* in a high-natural-value grassland. *Plants*, *11*, 112.
7. Dale, L. M., Thewis, A., Boudry, C., Rotar, I., Păcurar, F. S., Abbas, O., Dardenne, P., Baeten, V., Pfister, J., & Fernández Pierna, J. A. (2013). Discrimination of grassland species and their classification in botanical families by laboratory scale NIR hyperspectral imaging: Preliminary results. *Talanta*, *116*, 149–154.
8. Dale, L., Fernandez, J. A., Vermeulen, P., Lecler, B., Bogdan, A. D., Pacurar, F., Rotar, I., Thewis, A., & Baeten, V. (2012). Research on crude protein and digestibility of *Arnica montana* L. using conventional NIR spectrometry and hyperspectral imaging NIR. *Journal of Food, Agriculture & Environment*, *10*(1).

9. Dale, L., Thewis, A., Rotar, I., Boudry, C., Păcurar, F. S., Lecler, B., Agneessens, R., Dardenne, P., & Baeten, V. (2013). Fertilization effects on the chemical composition and in vitro organic matter digestibility of semi-natural meadows as predicted by NIR spectrometry. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41*, 58–64.
10. Gaga, I., Pacurar, F., Vaida, I., Plesa, A., & Rotar, I. (2022). Responses of diversity and productivity to organo-mineral fertilizer inputs in a high-natural-value grassland, Transylvanian Plain, Romania. *Plants, 11*, 1975.
11. Gârda, N. T., Păcurar, F., Rotar, I., & Bogdan, A. (2010). The floristic and stational characterisation of the grassland subtype *Agrostis capillaris + Trisetum flavescens* from Apuseni Mountains, Romania. *Research Journal of Agricultural Science, 42*, 454–457.
12. Gârda, N., Rotar, I., Păcurar, F., & Vidican, R. (2009). The role of pastoral landscape in defining the mountainous space in Apuseni Mountains. *Lucrări Științifice vol. 52. Seria Agronomie*.
13. Ghețe, I., Rotar, I., Pleșa, A., Ghețe, A., Șerban, C., & Stoian, V. (2025). Effect of mineral fertilization on vegetation of HNV pastures in the Apuseni Mountains (Romania). *Plants, 14*, 3564.
14. Gliga, A., Rotar, I., Vidican, R., Păcurar, F., & Balazsi, A. (2013). Evolution of semi-natural grasslands in Europe (bibliographical paper). *Romanian Journal of Grasslands and Forage Crops, 16*, 17–22.
15. Herzon, I., Aakkula, J., & others. (2020). The role of High Nature Value (HNV) farmland in the EU's biodiversity and rural development policies. Journal of Environmental Management, 261, 110214.
16. Lomba, A., Guerra, C., Alonso, J., Honrado, J. P., Jongman, R. H. G., & McCracken, D. (2014). Mapping and monitoring High Nature Value farmlands: Challenges in European landscapes. Journal of Environmental Management, 143, 140–150.
17. Mălinas, A., Rotar, I., Vidican, R., Iuga, V., Păcurar, F., Mălinas, C., & Moldovan, C. (2020). Designing a sustainable temporary grassland system by monitoring nitrogen use efficiency. *Agronomy, 10*, 149.
18. Mălinaș, A., Rotar, I., Vidican, R., Păcurar, F., & Balazsi, A. (2013). Phosphorus in grassland systems. *Romanian Journal of Grasslands and Forage Crops, 16*, 23–29.
19. Marușca, T., Păcurar, F. S., Scrob, N., Vaida, I., Nicola, N., Taulescu, E., Dragoș, M., & Lukács, Z. (2021). Contributions to the assessment of grasslands productivity of the Apuseni Natural Park (ROSCI 0002). *Romanian Journal of Grasslands and Forage Crops, 24*, 23.
20. Marușca, T., Păcurar, F. S., Taulescu, E., Vaida, I., Nicola, N., Scrob, N., & Dragoș, M. M. (2022). Indicative species for the agrochemical properties of mountain grasslands soil from the

Apuseni Natural Park (ROSCI 0002). *Romanian Journal of Grasslands and Forage Crops, 25*, 31.

21. Michler, B., Käthe, W., Schmitt, S., Rotar, I., & Pacurar, F. (2005). Conservation of Eastern European medicinal plants: *Arnica montana* in Romania. In *Proceedings of the XXXXVIII Scientific Symposium – Agriculture and Environment*, Iași.
22. Michler, B., Rotar, I., Pacurar, F., & Goia, A. (2006). Biodiversity and conservation of medicinal plants: A case study in the Apuseni Mountains in Romania. *Bulletin of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca: Agriculture, 62*, 86–87.
23. Michler, B., Rotar, I., Păcurar, F., & Stoie, A. (2005). *Arnica montana*, an endangered species and a traditional medicinal plant: The biodiversity and productivity of its typical grasslands habitats. In *Grassland Science in Europe* (Vol. 10, pp. 336–339).
24. Morea, A., Rotar, I., & Păcurar, F. (2008). Drying possibilities of *Arnica montana* flower heads using local resources. *Hop and Medicinal Plants, 16*(1–2), 210–212.
25. Morea, A., Rotar, I., Vidican, R., & Păcurar, F. (2013). The influence of different types of management upon the floristic structure of grassland systems, with special attention on *Arnica montana* L. *Bulletin UASVM Agriculture, 70*(1).
26. Morea, A., Rotar, I., Vidican, R., Păcurar, F., & Stoian, V. (2008). Changes in vegetation in a *Festuca rubra* meadow in Apuseni Mountains due to organic fertilization. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 36*, 120–124.
27. Moș, A., & Brînzan, C. (2024). Dinamica utilizării pajiștilor și tendințe de abandon în Parcul Natural Apuseni. Romanian Journal of Grasslands and Forage Crops, 30, (în curs de publicare / sau paginile când le știi).
28. Păcurar, F. (2005). *Cercetări privind dezvoltarea durabilă a satului Ghețari, comuna Gârda, prin îmbunătățirea pajiștilor naturale și a unor culturi agricole* (Teză de doctorat). USAMV Cluj-Napoca.
29. Păcurar, F. S., Rotar, I., & Vaida, I. (2019). The effects of wild boar disturbances on the agronomical value of semi-natural grasslands. *Romanian Journal of Grasslands and Forage Crops, 20*, 27.
30. Păcurar, F. S., Rotar, I., Michler, B., & Vidican, R. (2008). Traditional management of *Arnica montana* grasslands. In *Grassland Science in Europe* (Vol. 13, pp. 297–300).
31. Păcurar, F., & Rotar, I. (2006). The evolution of biodiversity in a *Festuca rubra* meadow following some specific technological inputs to sustainable agriculture. *Bulletin UASVM Agriculture, 62*, 124–127.
32. Păcurar, F., & Rotar, I. (2011). The effect of low-input upon semi-natural grasslands of Apuseni Mountains. *Lucrări Științifice – Seria Agronomie, 54*(2).

33. Păcurar, F., & Rotar, I. (2014). *Metode de studiu și interpretare a vegetației pajiștilor*. AcademicPres.
34. Păcurar, F., Balázsi, Á., Rotar, I., Vaida, I., Reif, A., Vidican, R., Rușdea, E., Stoian, V., & Sângeorzan, D. (2018). Technologies used for maintaining oligotrophic grasslands and their biodiversity in a mountain landscape. *Romanian Biotechnological Letters, 23*(10).
35. Păcurar, F., Morea, A., & Gârda, N. (2008). Productivity and biodiversity evolution of *Festuca rubra* grasslands during a seven-year period. *Bulletin UASVM Agriculture, 65*, 5.
36. Păcurar, F., Reif, A., & Rusdea, E. (2023). Conservation of oligotrophic grassland of high nature value (HNV) through sustainable use of *Arnica montana* in the Apuseni Mountains, Romania. In *Medicinal Agroecology*. Taylor & Francis.
37. Păcurar, F., Rotar, I., Balázsi, Á., & Vidican, R. (2014). Influence of long-term organic and mineral fertilization on *Festuca rubra* L. grassland. In *The Future of European Grasslands* (EGF Proceedings), 294.
38. Păcurar, F., Rotar, I., Bogdan, A. D., Vidican, R. M., & Dale, L. (2012). The influence of mineral and organic long-term fertilization upon the floristic composition of *Festuca rubra* L.–*Agrostis capillaris* L. grassland in Apuseni Mountains, Romania. *Journal of Food, Agriculture & Environment, 10*(1).
39. Păcurar, F., Rotar, I., Gârda, N., & Morea, A. (2009). The management of oligotrophic grasslands and the approach of new improvement methods. *Transylvanian Review of Systematical and Ecological Research, 7*, 59.
40. Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New directions in the study of oligotrophic grasslands in the mountain area. *Lucrări Științifice – Seria Agronomie* (Iași).
41. Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New possibilities for sustainable use of oligotrophic grasslands in Apuseni Mountains. *Bulletin UASVM Agriculture, 66*.
42. Păcurar, F., Rotar, I., Vaida, I., Vidican, R., & Mălinaș, A. (2017). Indicator species of fertilization intensity in mountain grasslands. In *Grassland Resources for Extensive Farming Systems in Marginal Lands* (EGF Proceedings, Vol. 22, pp. 378–381).
43. Păcurar, F., Rotar, I., Vidican, R., & Gârda, N. (2007). Organic fertilization and biodiversity of *Festuca rubra* grasslands. In *Permanent and Temporary Grassland: Plant, Environment and Economy* (EGF Proceedings, Vol. 12, pp. 363–366).
44. Păcurar, F., Rotar, I., Vidican, R., Vaida, I., Pleșa, A., Stoian, V., Tomoș, L., & Ghețe, A. (2025). Density-based assessment of *Adonis vernalis* abundance in native habitats. *Scientific Papers Series A. Agronomy, 68*(1).
45. Păcurar, F., Rotar, I., Pleșa, A., Balázsi, Á., & Vidican, R. (2015). Study of the floristic composition of certain secondary grasslands in different successional stages as a result of abandonment. *Bulletin of*

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, 72, doi:10.15835/buasvmcn-agr:11165.

46. Plăias I., 1994, Agricultura montană - Societate,Ed. Libris Cluj-Napoca
47. PNDR. (2019). Programul Național de Dezvoltare Rurală 2014–2020 – versiune actualizată. Ministerul Agriculturii și Dezvoltării Rurale, București.
48. Planul Național Strategic 2023-2027 al României (2023). Ministerul Agriculturii și Dezvoltării Rurale, București.
49. Reif, A., Auch, E., Bühler, J., Brinkmann, K., Goia, A. I., Pacurar, F., & Rusdea, E. (2005). Landschaft und Landnutzung im Apuseni-Gebirge Rumäniens. *Carinthia II, 195,* 161–201.
50. Reif, A., Brinkmann, K., Goia, A., Hoernstein, H., Jaeckle, S., Mohr, B., Păcurar, F., Rotar, I., Rusdea, E., & Schmidt, U. (2008). Differences of development patterns in Central and Eastern European mountain regions: History of land uses and landscapes in the Southern Black Forest (Germany) and the Central Apuseni Mountains (Romania). *Bulletin UASVM Agriculture, 65*.
51. Reif, A., Rusdea, E., Păcurar, F., Rotar, I., Brinkmann, K., Auch, E., Goia, A., Bühler, J., & Aronsson, M. (2008). A traditional cultural landscape in transformation. *Mountain Research and Development, 28*, 18–22.
52. Rotar, I., Huygens, D., Vidican, R., Carlier, L., Pacurar, F., & Mălinaș, A. (2013). The effect of low-input grassland management on *Arnica montana* L. species in Apuseni Mountains, Romania. *ProEnvironment/ProMediu, 6,* 13.
53. Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2014). Effects of low-input treatments on *Agrostis capillaris L.–Festuca rubra* L. grasslands. In *The Future of European Grasslands* (EGF Proceedings, 17th Meeting, Ghent).
54. Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2013). The influence of limestone upon the vegetation of *Festuca rubra–Agrostis capillaris* semi-natural grassland type in the mountain regions and on dry matter yield. *Romanian Journal of Grasslands and Forage Crops, 15,* 31–36.
55. Rotar, I., Păcurar, F., Stoie, A., Gârda, N., & Dale, L.-M. (2010). The evolution of *Arnica montana* L. grasslands depending on the performed management (Apuseni Mountains, Romania). *Scientific Papers Series Agronomy, 53,* 221–226.
56. Rotar, I., Pacurar, F., Vidican, R., & Morea, A. (2010). The organic-mineral fertilization of a *Festuca rubra* L. grassland in Apuseni Mountains. *Romanian Journal of Grasslands and Forage Crops, 2,* 55–60.
57. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2003). Effects of manure/sawdust fertilisation on *Festuca rubra* type meadows at Ghețari (Apuseni Mountains). In *Optimal Forage Systems for*

Animal Production and the Environment (EGF Proceedings, Vol. 8, pp. 192–194).
58. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2005). Impact of the agricultural use on the biodiversity of a *Festuca rubra* meadow. In *XX International Grassland Conference: Offered Papers* (p. 616). https://doi.org/10.3920/978-90-8686-552-9_520
59. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2005). The influence of organic and organo-mineral fertilization on biodiversity of the *Festuca rubra* meadows in Apuseni Mountains. *Lucrări Științifice – Seria Agronomie, 48,* 355–359.
60. Rotar, I., Toth, G., Vaida, I., Mălinaș, A., Stoian, V., & Deac, V. (2016). Ecological and agronomical value of *Festuca rupicola*–*Bromus erectus* grasslands. *Romanian Journal of Grasslands and Forage Crops, 19,* 81–87.
61. Rotar, I., Vaida, I., & Păcurar, F. (2020). Species with indicative values for the management of mountain grasslands. *Romanian Agricultural Research, 37,* 2067–5720.
62. Rotar, I., Vidican, R., Ciure, A., Păcurar, F., Gliga, A., & Balázsi, A. (2014). The behavior of the mixture formed by *Trifolium pratense, Medicago sativa, Lolium perenne, Festulolium, Phleum pratense* and *Dactylis glomerata* under the influence of mineral fertilization. *Romanian Journal of Grasslands and Forage Crops, 9,* 87.
63. Rotar, I., Vidican, R., Păcurar, F., Mălinaș, A., & Vaida, I. (2016). A forage mixture with red clover in the fourth experimental year. *Bulletin UASVM Agriculture, 73*(2).
64. Rușdea, E., Reif, A., Höchtl, F., Păcurar, F., Rotar, I., Stoie, A., Dahlström, A., Svensson, R., & Aronsson, M. (2011). Grassland vegetation and management—On the interface between science and education. *Bulletin UASVM Agriculture, 68*(1).
65. Samuil, C., Nazare, A.-I., Sîrbu, C., Grigoraș, B., & Vîntu, V. (2025). The impact of fertilizer gradient on high nature value mountain grassland. *Plants, 14,* 3397.
66. Sângeorzan, D. D., Păcurar, F., Reif, A., Weinacker, H., Rușdea, E., Vaida, I., & Rotar, I. (2024). Detection and quantification of *Arnica montana* inflorescences in grassland ecosystems using convolutional neural networks and drone-based remote sensing. *Remote Sensing, 16,* 2012.
67. Sângeorzan, D. D., Rotar, I., Vidican, R., & Păcurar, F. (2018). Romania's diet footprints: Minimum arable land and ecological footprint of consumption (1961–2013). *Romanian Journal of Grasslands and Forage Crops, 20,* 65–74.
68. Sângeorzan, D., Rotar, I., Păcurar, F., Vaida, I., Šuteu, A., & Deac, V. (2018). The definition of oligotrophic grasslands. *Romanian Journal of Grasslands and Forage Crops, 20,* 17.
69. Sima, N., & Păcurar, F. (2002). Quality of forage obtained from a mountain pasture as influenced by harvesting phenophase and management. In *Multi-function Grasslands: Quality Forages,*

Animal Products and Landscapes (EGF Proceedings, Vol. 7, pp. 160–161).
70. Stoian, V., Vidican, R., Crișan, I., Puia, C., Șandor, M., Stoian, V. A., Păcurar, F., & Vaida, I. (2019). Sensitive approach and future perspectives in microscopic patterns of mycorrhizal roots. *Scientific Reports, 9,* 10233.
71. Stoian, V., Vidican, R., Rotar, I., Păcurar, F., & Morea, A. (2014). The development of mycorrhizal fungi in the roots of *Festuca rubra* under the influence of fertilization and maintenance of a constant climate. *Romanian Journal of Grasslands and Forage Crops, 10,* 85.
72. Stoian, V., Vidican, R., Rotar, I., Păcurar, F., & Niște, M. (2014). Analysis of disturbing impact of management on the stability of mycorrhizal colonization in mountain meadow ecosystems. *Romanian Journal of Grasslands and Forage Crops, 9,* 11.
73. Vaida, I., Păcurar, F., Rotar, I., Tomoș, L., & Stoian, V. (2021). Changes in diversity due to long-term management in a high nature value grassland. *Plants, 10,* 739.
74. Vaida, I., Rotar, I., & Păcurar, F. (2017). The cumulative effect of manure on a *Festuca rubra* grassland for 15 years. *Bulletin UASVM Agriculture, 74*(2).
75. Vaida, I., Rotar, I., Păcurar, F., Vidican, R., Pleșa, A., Mălinaș, A., & Stoian, V. (2016). Impact of the abandonment of semi-natural grasslands from Apuseni Mountains. *Bulletin UASVM Agriculture, 73*(2).
76. Vârban, D., Păcurar, F., Vârban, R., & Odagiu, A. (2011). Research concerning the study of germination in *Arnica montana* L. species. *ProEnvironment/ProMediu, 4,* 8.

GRASSLANDS DOMINATED BY *FESTUCA RUBRA*: ECOLOGY, FUNCTIONING, AND MANAGEMENT

Ioan ROTAR[1] and Ioana GHEȚE[*1]

[1]*Faculty of Agriculture, Department of Plant Crops. University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Manăștur street, 3-5, 400372,Romania*
**corresponding author: ioana.gheţe@usamvcluj.ro*

Abstract

Grasslands dominated by Festuca rubra represent a defining component of mountain landscapes in Romania and across Europe, owing to their characteristic combination of structural stability, floristic diversity, and sensitivity to management changes. This paper provides an integrated bibliographic synthesis on the ecology of Festuca rubra, the functioning of grasslands in which it becomes dominant, and the ways these ecosystems respond to different fertilization regimes and management practices. The analysis of Romanian and European literature highlights the ecological versatility of the species, capable of thriving on low- to moderately fertile soils, under humid mountain conditions, and within traditional mowing and grazing systems. Festuca rubra grasslands maintain a favorable balance between productivity and biodiversity when managed extensively or moderately. However, long-term studies show that intensive mineral fertilization leads to vegetation simplification by promoting nitrophilous species, while the absence of management triggers successional processes that gradually diminish the semi-natural character of the habitat. Belowground interactions—particularly associations with arbuscular mycorrhizal fungi—enhance the resilience of these grasslands and are influenced by soil fertility and land-use practices. Integrating research from Romania, especially from the Apuseni Mountains, with European findings underscores the ecological, agronomic, and cultural value of Festuca rubra-dominated grasslands and highlights the need for sustainable management supported by appropriate agricultural policies.

Keywords: *Festuca rubra; mountain grasslands; biodiversity; fertilization; sustainable management; semi-natural grasslands; succession; agro-ecological conservation.*

INTRODUCTION

Permanent mountain grasslands in Europe represent some of the most valuable agro-pastoral ecosystems, owing to their high biodiversity and the ecosystem services they provide, including forage production, soil protection, carbon storage, and the maintenance of traditional cultural landscapes. In Romania, particularly in the Carpathians, semi-natural grasslands form a central component of the rural landscape, shaped by long-term extensive use, low external inputs, and traditional mowing and grazing practices (Reif et al., 2005; Reif et al., 2008; Rușdea et al., 2011).Within this context, grasslands dominated by *Festuca rubra* hold a distinct position. They occur frequently in humid mountain and hilly areas on low- to moderately fertile soils and are often classified as High Nature Value (HNV) grasslands when managed extensively (Păcurar et al., 2018; Vaida et al., 2021). *Festuca rubra* is characterized by high ecological plasticity and the capacity to dominate oligotrophic or moderately fertilized grasslands in the Apuseni Mountains and in other European regions (Brinkmann et al., 2009; Gliga et al., 2013). Long-term research conducted in the Apuseni Mountains—particularly in the Ghețari and Gârda de Sus areas—has identified these grasslands as model systems for studying the relationship between biodiversity, fertilization, and management (Auch et al., 2001; Păcurar, 2005; Reif et al., 2005). Findings show that *Festuca rubra* grasslands respond sensitively to input intensity and type, with clear shifts in floristic composition and productivity (Păcurar et al., 2008; Păcurar et al., 2012; Rotar et al., 2003, 2005a, 2005b, 2010). Additional long-term studies conducted over 7–15 years confirm the existence of a productivity–diversity trade-off under moderate use, whereas high fertilization accelerates the decline of oligotrophic species (Păcurar et al., 2008; Vaida et al., 2016, 2017; Păcurar et al., 2014; Rotar et al., 2014; Gaga et al., 2022; Samuil et al., 2025; Ghețe et al., 2025). Beyond agronomic aspects, numerous studies have investigated belowground ecological processes, highlighting the importance of mycorrhizal associations and edaphic indicators in the stability of *Festuca rubra* grasslands (Corcoz et al., 2021; Stoian et al., 2014a, 2014b, 2019; Marușca et al., 2021, 2022). At the European scale, similar grasslands are recognized as elements of traditional cultural landscapes, tightly linked to extensive use and local identity (Reif et al., 2008; Balázsi et al., 2016, 2018). Recent transformations—whether intensification or abandonment—raise important questions regarding the ecological future and resilience of these systems (Morea et al., 2013; Vaida et al., 2016; Moș & Brînzan, 2024; Sângeorzan et al., 2018b). European and national agricultural policies, including the Romanian RDP 2014–2020 and the National Strategic Plan 2023–2027, incorporate measures targeted at HNV grasslands and extensive systems, reflecting the recognition of their ecological and socio-economic value (PNDR, 2019; PNS, 2023; Sângeorzan et al., 2018a; Rotar et al., 2020). In the Apuseni Mountains, interdisciplinary studies have demonstrated strong connections between *Festuca rubra* grasslands, pastoral landscape structure, and traditional management practices (Gârda et al., 2009, 2010; Rotar et al., 2005a; Păcurar et al., 2015). In this context, the aim of the present paper is to synthesize scientific knowledge regarding *Festuca rubra*-dominated grasslands, with emphasis on species ecology, community functioning, management responses, and implications for the conservation of mountain ecosystems.

ECOLOGICAL CHARACTERIZATION OF *FESTUCA RUBRA*

Festuca rubra L. is one of the most widespread perennial grasses in the temperate zone of Europe and a defining element of mountain, subalpine, and hilly grasslands. Its ecological plasticity—reflected in the diversity of its growth forms and its tolerance to a wide range of edaphic conditions—explains the central role it plays in numerous semi-natural ecosystems. Both European and Romanian literature recognize it as a keystone species, capable of thriving in oligotrophic as well as moderately fertilized habitats without compromising the functioning of traditional grassland communities.

The taxonomic complex of the species includes rhizomatous forms, which produce a dense turf and high regenerative capacity, alongside tussock forms adapted to different soil conditions. This variability accounts for its wide distribution across Romania and Europe, from the mountain grasslands of the Carpathians to colline and mesotrophic meadows. Studies from the Apuseni Mountains—particularly from the Ghețari, Gârda, and Padiș areas—show that *Festuca rubra* behaves as a stable species in extensively used grasslands, responding predictably to fertilization regimes (Păcurar et al., 2008; Rotar et al., 2003; Morea et al., 2008).

Ecologically, *Festuca rubra* prefers soils of low to moderate fertility, with slightly acidic to neutral pH, and tolerates humid mountain climates and low temperatures. It persists in oligotrophic grasslands, together with *Agrostis capillaris* or *Nardus stricta*, as well as in mesotrophic or moderately fertilized systems (Vîntu et al., 2011a; Samuil et al., 2013). Low doses of organic fertilization enhance turf density without markedly reducing diversity, whereas intensive mineral fertilization favors replacement by nitrophilous grasses such as *Dactylis glomerata* or *Poa trivialis* (Păcurar & Rotar, 2014; Rotar et al., 2014; Vaida et al., 2016).

Morphologically, the rhizomatous form confers resilience to mowing and grazing, enabling rapid recovery of the sward. Its fine, waxy leaves improve drought tolerance and contribute to fodder value. An essential ecological trait of the species is its association with arbuscular mycorrhizal fungi, which enhance nutrient uptake and support ecosystem functioning in low-fertility environments. Studies from HNV grasslands in the Apuseni indicate high levels of mycorrhizal colonization under extensive management, with significant reductions under intensive mineral fertilization (Corcoz et al., 2021; Stoian et al., 2014, 2019).

Due to its moderate competitiveness and tolerance of typical pastoral disturbances, *Festuca rubra* contributes substantially to grassland stability. By maintaining a dense turf and balanced competition levels, it enables the coexistence of mesotrophic and oligotrophic forbs and legumes, making *Festuca rubra*-dominated grasslands some of the most stable pastoral ecosystems in mountain regions (Gârda et al., 2010; Vaida et al., 2021). At the same time, its distribution and vigor accurately reflect soil fertility and land-use history, which is why the species is frequently used as an indicator.

Recent research employing modern technologies—near-infrared (NIR) spectrometry and hyperspectral imaging—has confirmed the species' importance for assessing forage quality and the condition of semi-natural ecosystems (Dale et al., 2012; Dale et al., 2013b). Moreover, *Festuca rubra* often occurs in habitats that host species of conservation value, such as *Arnica montana*, further emphasizing the ecological and cultural significance of these grasslands (Michler et al., 2005b; Morea et al., 2008, 2013; Vârban et al., 2011; Sângeorzan et al., 2024).

Overall, *Festuca rubra* is one of the most versatile and ecologically relevant species in mountain grasslands. Its capacity to respond to management changes while maintaining the stability of semi-natural ecosystems makes the studies conducted in the Apuseni Mountains a valuable reference for understanding vegetation dynamics in the context of contemporary transformations affecting mountain agriculture.

STRUCTURE AND FUNCTIONING OF *FESTUCA RUBRA*-DOMINATED GRASSLANDS

Grasslands dominated by *Festuca rubra* represent some of the most characteristic and stable semi-natural ecosystems in the mountain regions of Romania and Europe. They arise from the interplay between environmental conditions, agro-pastoral land-use history, and the ecological traits of the dominant species. Depending on soil fertility, mowing frequency, grazing pressure, and successional dynamics, these grasslands range from species-rich mesotrophic communities to more impoverished but highly resilient systems.

In the humid mountain zones of the Apuseni Mountains, where long-term studies have monitored vegetation dynamics under contrasting management regimes, *Festuca rubra* grasslands exhibit a relatively stable floristic composition. The dominance of *Festuca rubra* is accompanied by a consistent assemblage of species—*Agrostis capillaris*, *Trisetum flavescens*, *Lotus corniculatus*, *Anthoxanthum odoratum*, *Poa pratensis*, and *Ranunculus acris*—all typical of Carpathian mesotrophic grasslands (Gârda et al., 2010; Brinkmann et al., 2009). This mixture of species confers high ecological elasticity, as dominant and co-dominant plants respond differently to variations in fertility and land-use pressure.

A defining structural element of these grasslands is the dense sward formed by the rhizomatous system of *Festuca rubra*. This stabilizes the vegetation layer, reduces soil exposure, enhances organic matter accumulation, and maintains a uniform microclimate near the soil surface—conditions that support high companion-species diversity. At the same time, the compact turf limits erosion and contributes to a relatively constant rate of mineralization, particularly in low-input systems (Păcurar & Rotar, 2011; Marușca et al., 2021).

From an ecosystem functioning perspective, *Festuca rubra*-dominated grasslands are efficient resource users and can maintain high levels of diversity under extensive management. The moderate growth rate of the dominant species facilitates the coexistence of mesotrophic and oligotrophic grasses and forbs, generating stable and functionally diverse communities. However, increased nitrogen inputs favor competitive grasses such as *Dactylis glomerata* and *Poa trivialis*, reducing structural complexity and biodiversity (Mălinaș et al., 2013; Păcurar et al., 2014; Rotar et al., 2014; Vaida et al., 2016).

Vegetation succession plays a key role in the dynamics of these grasslands. Under irregular management or abandonment, *Festuca rubra* communities may transition toward stages dominated by robust species like *Agrostis capillaris* or *Calamagrostis arundinacea*, and woody vegetation may gradually appear in the absence of mowing or grazing (Păcurar et al., 2015; Gliga et al., 2013). Although *Festuca rubra* often remains present in early successional stages, its competitive ability diminishes over time relative to taller, more aggressive species (Vaida et al., 2016; Moș & Brînzan, 2024).

Belowground interactions further influence grassland functioning. Root colonization by arbuscular mycorrhizal fungi enhances nutrient uptake efficiency and supports ecosystem stability in low-fertility environments. Studies from the Apuseni Mountains show that these symbiotic relationships persist under extensive management but decline significantly under intensive mineral fertilization (Corcoz et al., 2021; Stoian et al., 2014, 2019).

Another key functional attribute is the moderate to good forage value of these grasslands, supported by the fine foliage and rapid regrowth capacity of *Festuca rubra* after mowing or grazing. In traditional pastoral systems, these grasslands provide consistent, balanced forage, which has contributed to their long-term persistence in mountain landscapes (Sima & Păcurar, 2002). Modern analytical tools—such as near-infrared (NIR) spectrometry and hyperspectral imaging—have demonstrated that forage-quality variation can be accurately monitored and is closely linked to species composition and fertilization regimes (Dale et al., 2012, 2013a).

Overall, *Festuca rubra*-dominated grasslands combine structural stability, resistance to moderate disturbance, and sensitivity to intensification, giving them a central role in sustaining long-term ecosystem functioning and biodiversity (Vîntu et al., 2011b). They can be considered true ecological nuclei within pastoral mountain landscapes, and their responses to management changes serve as key indicators of agro-ecological sustainability in mountain regions.

RESPONSES OF *FESTUCA RUBRA*-DOMINATED GRASSLANDS TO MANAGEMENT AND FERTILIZATION

Grasslands dominated by *Festuca rubra* exhibit a complex ecological behavior, sensitive to fertilization regimes and land-use practices, yet relatively stable under traditional management systems.

Numerous studies from the Apuseni Mountains and other European mountain regions show that the response of this species—and of the communities it dominates—is strongly influenced by the intensity and type of inputs, as well as by mowing and grazing frequency. This sensitivity makes *Festuca rubra* a valuable indicator of management-induced ecological changes.

Under low fertilization regimes, *Festuca rubra* grasslands maintain their traditional floristic and functional structure. Moderate organic fertilization, especially with well-decomposed manure, enhances vegetation cover by stimulating growth and favoring associated mesotrophic species, without major biodiversity losses. Experiments from the Apuseni Mountains show that small annual doses maintain a favorable balance between productivity and diversity, whereas excessive organic inputs produce the first signs of community simplification (Păcurar & Rotar, 2006; Vaida et al., 2017; Morea et al., 2008). In such cases, *Festuca rubra* remains dominant, but oligotrophic species decline gradually, and functional diversity decreases.

Mineral fertilization induces a much faster and more pronounced ecological response (Nazare et al., 2024). Low doses may resemble the effects of moderate organic fertilization, but increasing nitrogen inputs accelerates competition among grasses. Long-term experiments from the Apuseni Mountains show that medium NPK levels visibly shift dominance patterns by promoting nitrophilous species (*Dactylis glomerata*, *Poa trivialis*), which tend to replace *Festuca rubra* in more fertile areas (Păcurar et al., 2014; Rotar et al., 2014; Păcurar et al., 2012). As soil fertility rises, grasslands lose their semi-natural character and species richness declines. These processes are confirmed not only by floristic analyses but also by functional indicators—functional diversity, functional dispersion, and Fourth Corner analysis—highlighting reduced trait variability and the emergence of an ecological "threshold" at medium fertilization levels.

Over the long term, high mineral fertilization results in marked community simplification, transforming grasslands into systems dominated by a few fast-growing, highly competitive species. Studies by Rotar et al. (2003, 2005b) and Păcurar et al. (2012) show that excessive fertilization alters not only floristic composition but also soil properties and root system functioning, reducing mycorrhizal colonization and tolerance to water or mechanical stress. Under such conditions, *Festuca rubra* gradually loses competitiveness and may be replaced in highly fertile zones, although it often remains present within the sward structure.

Management practices—particularly mowing and grazing—play a decisive role in shaping *Festuca rubra* grasslands. Annual mowing at the optimal phenological stage maintains openness and supports regeneration of valuable species. In traditionally mown grasslands, *Festuca rubra* forms a dense, persistent sward, renewing aerial biomass continuously, which confers a competitive advantage compatible with species coexistence and biodiversity maintenance (Sima & Păcurar, 2002). By contrast, intensive or unregulated grazing reduces biomass and vigor, favoring species tolerant to repeated defoliation, such as *Agrostis capillaris*, or even invasive taxa. Moderate grazing, combined with rotational management, creates a mosaic-like structure that allows *Festuca rubra* to coexist with diverse forbs and legumes of floristic and fodder importance.

Grassland abandonment represents one of the most significant challenges in mountain landscapes. In the absence of mowing or grazing, *Festuca rubra* grasslands enter slow successional pathways characterized by increased vegetation height and density, alongside gradual loss of competitiveness among species adapted to moderate disturbance. In early successional stages, *Festuca rubra* persists, but it is progressively replaced by taller, more robust species or by young woody vegetation. Studies from the Apuseni Mountains show that abandoned grasslands rapidly exhibit biodiversity loss and structural degradation (Păcurar et al., 2015; Vaida et al., 2016; Moș & Brînzan, 2024). Pedoclimatic factors and belowground processes also play a critical role. Research on mycorrhizal colonization under contrasting fertilization regimes shows that symbiotic relationships with soil fungi contribute to the resilience of *Festuca rubra* grasslands. Under moderate organic fertilization, mycorrhizal associations remain active and support diversity, whereas intensive mineral fertilization significantly reduces colonization levels (Corcoz et al., 2021; Stoian et al., 2014, 2019). Thus, the functioning of *Festuca rubra* ecosystems depends not only on aboveground vegetation dynamics but also on belowground processes that regulate nutrient fluxes and long-term stability.

Overall, *Festuca rubra* grasslands exhibit a wide spectrum of responses to management and fertilization. They remain stable and productive under extensive systems and tolerate low-input fertilization but become rapidly sensitive to intensification. Their ecological responses reflect shifts in the balance between biodiversity conservation, productivity, and modern agricultural pressures, making them a valuable reference system for understanding mountain ecosystem functioning and for designing sustainable grassland management practices in Romania and Europe.

SUSTAINABLE MANAGEMENT AND RECOMMENDATIONS FOR *FESTUCA RUBRA*-DOMINATED GRASSLANDS

Festuca rubra-dominated grasslands represent a cornerstone of mountain pastoral landscapes, forming an ecological and agronomic resource whose long-term stability depends on management practices tailored to their specific functioning. Although these grasslands are resilient to moderate disturbances, they remain vulnerable to intensification, abandonment, and rapid changes in agricultural practices. Effective nutrient management is particularly important in mountain systems, as nitrogen use efficiency strongly influences both productivity and community stability. Recent research on nitrogen use efficiency in temporary grasslands shows that moderate fertilization rates optimize ecosystem performance without causing substantial losses through leaching or volatilization (Mălinaș et al., 2020)—a principle equally applicable to semi-natural *Festuca rubra* grasslands. Sustainable management must therefore aim to balance productivity with biodiversity conservation and ecosystem functionality.

1. Principle of Extensive Use: Annual Mowing and Moderate Grazing

Traditional mowing—performed after flowering but before stems become lignified—supports sward regeneration and promotes the dispersal of valuable species. In *Festuca rubra* grasslands, this timing synchronizes the life cycle of the dominant species with that of companion plants, preventing excessive litter accumulation or the establishment of undesirable species. Studies from the Apuseni Mountains demonstrate that such practices maintain a stable balance between productivity and diversity, supporting both mesotrophic and oligotrophic species (Sima & Păcurar, 2002; Păcurar & Rotar, 2011). **→ Key principle: maintain traditional mowing at optimal phenological stages.**

2. Principle of Controlled Grazing

Moderate grazing—especially with cattle or horses—maintains grassland openness and limits excessive competition among grasses. In *Festuca rubra*-dominated grasslands, controlled grazing prevents overdominance of the species and encourages coexistence with ecologically important forbs and legumes. Intensive or irregular grazing weakens the sward and promotes species tolerant to repeated defoliation or even invasive taxa (Rotar et al., 2010; Păcurar et al., 2018).

→ Key principle: use moderate, rotational grazing to maintain structural diversity.

3. Principle of Rational Nutrient Management

Moderate organic fertilization is the most appropriate strategy for maintaining the balance between productivity and species richness. Small annual doses of well-decomposed manure increase soil organic matter, improve soil structure, and support mycorrhizal communities—critical in oligotrophic mountain ecosystems.

In contrast, mineral fertilization—particularly at high nitrogen rates—accelerates vegetation succession, simplifies community structure, and promotes aggressive nitrophilous species (Păcurar et al., 2014; Rotar et al., 2014; Samuil et al., 2025; Ghețe et al., 2025).

→ Key principle: apply moderate, intermittent organic fertilization; avoid high mineral inputs.

4. Principle of Preventing Abandonment

Abandonment rapidly leads to the loss of semi-natural character. In the absence of mowing or grazing, *F. rubra* grasslands evolve toward stages dominated by tall species such as *Calamagrostis arundinacea* or *Deschampsia cespitosa*, followed by the establishment of woody vegetation. Restoring traditional structure afterwards becomes difficult and costly (Păcurar et al., 2015; Vaida et al., 2016; Moș & Brînzan, 2024). → **Key principle: ensure continuity of use to prevent successional degradation.**

5. Principle of Integrating Agricultural Policy Measures

Sustainable management cannot be decoupled from agricultural policy instruments. Payments for High Nature Value (HNV) grasslands, agri-environmental schemes, and measures aimed at preventing abandonment—such as those included in PNDR 2014–2020 and PNS 2023–2027—provide essential economic support for maintaining extensive practices (Balázsi et al., 2018; Rușdea et al., 2011; PNDR, 2019; National Strategic Plan, 2023).
→ **Key principle: link economic support with ecologically sound practices.**

6. Principle of Integrated and Adaptive Management

The conservation of *Festuca rubra* grasslands requires an approach that harmonizes agricultural techniques with ecological characteristics of the habitat. In mountain regions, local knowledge and traditional practices have played a central role in ecosystem stability. *Festuca rubra* dominates not through aggressiveness, but through adaptability and ecological balance, embodying a functional coexistence between agriculture and nature. → **Key principle: adopt adaptive, site-specific management grounded in ecological understanding.**

CONCLUSIONS

Festuca rubra-dominated grasslands represent a defining component of European and Romanian mountain landscapes, reflecting the persistence of traditional agro-pastoral systems. They form ecosystems that are stable yet sensitive to management changes, and their dynamics serve as a reliable indicator of the overall condition of semi-natural grasslands.

The literature shows that these grasslands perform best under moderate use, where annual mowing or controlled grazing maintains sward structure and supports the conservation of floristic diversity. Low-input organic fertilization provides a sustainable compromise between productivity and biodiversity, whereas intensive mineral fertilization rapidly simplifies the plant community and diminishes ecosystem functionality. At the same time, abandonment remains one of the major threats, accelerating successional processes and undermining the semi-natural character of the habitat.

Through its ecological traits—rhizomatous growth, resilience to moderate disturbance, and strong regenerative capacity—*Festuca rubra* plays a fundamental role in the stability of mountain grasslands. Its association with mycorrhizal networks and its contribution to nutrient cycling emphasize the importance of belowground processes in maintaining ecosystem functioning. Furthermore, the species' compatibility with conservation-relevant flora enhances the value of these grasslands as key habitats.

In the current context of agricultural intensification and socio-economic change, *Festuca rubra* grasslands hold strategic importance for mountain landscapes. They demonstrate that moderate productivity, biodiversity, and cultural value can coexist when management is adapted to local conditions and guided by ecological principles. Agricultural policies targeting HNV grasslands and extensive systems can support the preservation of these ecosystems, but their effectiveness depends on a deep understanding of the mechanisms underpinning grassland stability.

Viewed as a whole, *Festuca rubra*-dominated grasslands are complex and valuable systems that integrate ecological processes, agronomic functions, and cultural identity. Their conservation represents both an ecological responsibility and an opportunity to sustain pastoral traditions and cultural landscapes across the Carpathians and other European mountain regions.

REFERENCES

1. Auch, E., Păcurar, F., & Goia, A. (2001). Economic and technological aspects of the agricultural systems in Țara Moților (Ghețar, Gârda de Sus). *Buletinul USAMV, Seria Agricultură, 55–56*, 215.
2. Balázsi, Á., Păcurar, F., Mihu-Pintilie, A., & Konold, W. (2018). How do public institutions on nature conservation and agriculture contribute to the conservation of species-rich hay meadows? *International Journal of Conservation Science, 9*, 549–564.
3. Balázsi, Á., Păcurar, F., Rotar, I., & Vidican, R. (2016). Alternative management for oligotrophic grassland conservation in the Apuseni Mountains. *Proceedings*, 678–680.
4. Brinkmann, K., Păcurar, F., & Reif, A. (2009). Secondary succession and fluctuations in meadows of the Apuseni Mountains under different fertilisation regimes. *Transylvanian Review of Systematical and Ecological Research, 7*, 41–58.
5. Corcoz, L., Păcurar, F., Pop-Moldovan, V., Vaida, I., Stoian, V., & Vidican, R. (2021). Mycorrhizal patterns in the roots of dominant *Festuca rubra* in a high-natural-value grassland. *Plants, 11*, 112.
6. Dale, L. M., Thewis, A., Boudry, C., Rotar, I., Păcurar, F. S., Abbas, O., Dardenne, P., Baeten, V., Pfister, J., & Fernández Pierna, J. A. (2013a). Discrimination of grassland species and their classification in botanical families by laboratory scale NIR hyperspectral imaging: Preliminary results. *Talanta, 116*, 149–154.

7. Dale, L., Fernández, J. A., Vermeulen, P., Lecler, B., Bogdan, A. D., Păcurar, F., Rotar, I., Thewis, A., & Baeten, V. (2012). Research on crude protein and digestibility of *Arnica montana* using NIR spectrometry and hyperspectral imaging. *Journal of Food, Agriculture & Environment, 10*(1).
8. Dale, L., Thewis, A., Rotar, I., Boudry, C., Păcurar, F. S., Lecler, B., Agneessens, R., Dardenne, P., & Baeten, V. (2013b). Fertilization effects on chemical composition and in vitro organic matter digestibility of semi-natural meadows predicted by NIR spectrometry. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41*, 58–64.
9. Gaga, I., Păcurar, F., Vaida, I., Plesa, A., & Rotar, I. (2022). Responses of diversity and productivity to organo-mineral fertilizer inputs in a high-natural-value grassland, Transylvanian Plain. *Plants, 11*, 1975.
10. Gârda, N. T., Păcurar, F., Rotar, I., & Bogdan, A. (2010). Floristic and stational characterisation of the *Agrostis capillaris + Trisetum flavescens* grassland subtype in the Apuseni Mountains. *Research Journal of Agricultural Science, 42*, 454–457.
11. Gârda, N., Rotar, I., Păcurar, F., & Vidican, R. (2009). The role of pastoral landscape in defining the mountainous space in Apuseni Mountains. *Lucrări Ştiinţifice, Seria Agronomie, 52*.
12. Gheţe, I., Rotar, I., Pleşa, A., Gheţe, A., Şerban, C., & Stoian, V. (2025). Effect of mineral fertilization on vegetation of HNV pastures in Apuseni Mountains. *Plants, 14*, 3564.
13. Gliga, A., Rotar, I., Vidican, R., Păcurar, F., & Balázsi, A. (2013). Evolution of semi-natural grasslands in Europe: A bibliographical review. *Romanian Journal of Grasslands and Forage Crops, 16*, 17–22.
14. Mălinas, A., Rotar, I., Vidican, R., Iuga, V., Păcurar, F., Mălinas, C., & Moldovan, C. (2020). Designing a sustainable temporary grassland system by monitoring nitrogen use efficiency. *Agronomy, 10*, 149.
15. Mălinas, A., Rotar, I., Vidican, R., Păcurar, F., & Balazsi, A. (2013). Phosphorus in grassland systems. *Romanian Journal of Grasslands and Forage Crops, 16*, 23–29.
16. Maruşca, T., Păcurar, F. S., Scrob, N., Vaida, I., Nicola, N., Taulescu, E., Dragoş, M., & Lukács, Z. (2021). Contributions to the assessment of grasslands productivity in Apuseni Natural Park (ROSCI002). *Romanian Journal of Grasslands and Forage Crops, 24*, 23.
17. Maruşca, T., Păcurar, F. S., Taulescu, E., Vaida, I., Nicola, N., Scrob, N., & Dragoş, M. (2022). Indicative species for agrochemical properties of mountain grasslands soil in Apuseni Natural Park. *Romanian Journal of Grasslands and Forage Crops, 25*, 31.
18. Michler, B., Käthe, W., Schmitt, S., Rotar, I., & Păcurar, F. (2005a). Conservation of Eastern European medicinal plants: *Arnica montana* in Romania. In *Proceedings of the XXXXVIII Scientific Symposium – Agriculture and Environment* (Iaşi).
19. Michler, B., Rotar, I., Păcurar, F., & Goia, A. (2006). Biodiversity and conservation of medicinal plants in Apuseni Mountains. *Bulletin UASVM Agriculture, 62*, 86–87.

20. Michler, B., Rotar, I., Păcurar, F., & Stoie, A. (2005b). *Arnica montana* habitats: Biodiversity and productivity. In *Grassland Science in Europe, 10,* 336–339.
21. Morea, A., Rotar, I., & Păcurar, F. (2008). Drying possibilities of *Arnica montana* flower heads. *Hop and Medicinal Plants, 16*(1–2), 210–212.
22. Morea, A., Rotar, I., Vidican, R., & Păcurar, F. (2013). Influence of different management types upon *Arnica montana* grasslands. *Bulletin UASVM Agriculture, 70*(1).
23. Morea, A., Rotar, I., Vidican, R., Păcurar, F., & Stoian, V. (2008). Changes in vegetation in a *Festuca rubra* meadow due to organic fertilization. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 36,* 120–124.
24. Moș, A., & Brînzan, C. (2024). Dinamica utilizării pajiștilor și tendințe de abandon în Parcul Natural Apuseni. *Romanian Journal of Grasslands and Forage Crops, 30.*
25. Păcurar, F. (2005). *Cercetări privind dezvoltarea durabilă a satului Ghețari prin îmbunătățirea pajiștilor naturale* (Teză de doctorat). USAMV Cluj-Napoca.
26. Păcurar, F. S., Rotar, I., & Vaida, I. (2019). Wild boar disturbances and agronomical value of semi-natural grasslands. *Romanian Journal of Grasslands and Forage Crops, 20*, 27.
27. Păcurar, F. S., Rotar, I., Michler, B., & Vidican, R. (2008). Traditional management of *Arnica montana* grasslands. In *Grassland Science in Europe, 13,* 297–300.
28. Păcurar, F., & Rotar, I. (2006). Evolution of biodiversity in a *Festuca rubra* meadow following technological inputs. *Bulletin UASVM Agriculture, 62,* 124–127.
29. Păcurar, F., & Rotar, I. (2011). Effect of low-input management on semi-natural grasslands. *Lucrări Științifice, Seria Agronomie, 54*(2).
30. Păcurar, F., & Rotar, I. (2014). *Metode de studiu și interpretare a vegetației pajiștilor*. AcademicPres.
31. Păcurar, F., Balázsi, Á., Rotar, I., Vaida, I., Reif, A., Vidican, R., Rușdea, E., Stoian, V., & Sângeorzan, D. (2018). Technologies for maintaining oligotrophic grasslands. *Romanian Biotechnological Letters, 23*(10).
32. Păcurar, F., Morea, A., & Gârda, N. (2008). Productivity and biodiversity evolution in *Festuca rubra* grasslands during 7 years. *Bulletin UASVM Agriculture, 65, 5.*
33. Păcurar, F., Reif, A., & Rusdea, E. (2023). Conservation of oligotrophic grassland through sustainable use of *Arnica montana*. In *Medicinal Agroecology*. Taylor & Francis.
34. Păcurar, F., Rotar, I., Balázsi, Á., & Vidican, R. (2014). Long-term organic and mineral fertilization effects on *Festuca rubra* grassland. In *EGF Proceedings – The Future of European Grasslands*, 294.
35. Păcurar, F., Rotar, I., Bogdan, A. D., Vidican, R. M., & Dale, L. (2012). Influence of fertilization on *Festuca rubra–Agrostis capillaris* grassland. *Journal of Food, Agriculture & Environment, 10*(1).

36. Păcurar, F., Rotar, I., Gârda, N., & Morea, A. (2009). The management of oligotrophic grasslands. *Transylvanian Review of Systematical and Ecological Research, 7,* 59.
37. Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New directions in the study of oligotrophic grasslands. *Lucrări Științifice – Seria Agronomie* (Iași).
38. Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New possibilities for sustainable use of oligotrophic grasslands. *Bulletin UASVM Agriculture, 66.*
39. Păcurar, F., Rotar, I., Vaida, I., Vidican, R., & Mălinas, A. (2017). Indicator species of fertilization intensity. In *EGF Proceedings, 22,* 378–381.
40. Păcurar, F., Rotar, I., Vidican, R., & Gârda, N. (2007). Organic fertilization and biodiversity of *Festuca rubra* grasslands. In *Grassland Science in Europe, 12*, 363–366.
41. Păcurar, F., Rotar, I., Vidican, R., Vaida, I., Pleșa, A., Stoian, V., Tomoș, L., & Ghețe, A. (2025). Density-based assessment of *Adonis vernalis* in native habitats. *Scientific Papers Series A. Agronomy, 68*(1).
42. Păcurar, F., Rotar, I., Pleșa, A., Balázsi, Á., & Vidican, R. (2015). Study of floristic composition in secondary grasslands under succession. *Bulletin UASVM Agriculture, 72*.
43. PNDR. (2019). *Programul Național de Dezvoltare Rurală 2014–2020*. MADR.
44. Planul Național Strategic. (2023). *Planul Național Strategic 2023–2027 al României*. MADR.
45. Reif, A., Auch, E., Bühler, J., Brinkmann, K., Goia, A., Păcurar, F., & Rusdea, E. (2005). Landscape and land use in Apuseni Mountains. *Carinthia II, 195,* 161–201.
46. Reif, A., Brinkmann, K., Goia, A., Hoernstein, H., Jaeckle, S., Mohr, B., Păcurar, F., Rotar, I., Rusdea, E., & Schmidt, U. (2008). Development patterns in Central/Eastern European mountain regions. *Bulletin UASVM Agriculture, 65.*
47. Reif, A., Rusdea, E., Păcurar, F., Rotar, I., Brinkmann, K., Auch, E., Goia, A., Bühler, J., & Aronsson, M. (2008). A traditional cultural landscape in transformation. *Mountain Research and Development, 28,* 18–22.
48. Rotar, I., Huygens, D., Vidican, R., Carlier, L., Păcurar, F., & Mălinaș, A. (2013). Effects of low-input management on *Arnica montana*. *ProEnvironment, 6,* 13.
49. Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2014). Effects of low-input treatments on *Agrostis capillaris–Festuca rubra* grasslands. In *EGF Proceedings, 17*.
50. Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2013). Influence of limestone on *Festuca rubra–Agrostis capillaris* grasslands. *Romanian Journal of Grasslands and Forage Crops, 15,* 31–36.

51. Rotar, I., Păcurar, F., Stoie, A., Gârda, N., & Dale, L.-M. (2010). Evolution of *Arnica montana* grasslands under different management. *Scientific Papers Series Agronomy, 53*, 221–226.
52. Rotar, I., Păcurar, F., Vidican, R., & Morea, A. (2010). Organic-mineral fertilization of *Festuca rubra* grasslands. *Romanian Journal of Grasslands and Forage Crops, 2*, 55–60.
53. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2003). Effects of manure/sawdust fertilisation on *Festuca rubra* meadows at Ghețari. In *EGF Proceedings, 8*, 192–194.
54. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2005a). Agricultural use and biodiversity of a *Festuca rubra* meadow. In *XX International Grassland Conference*, 616.
55. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2005b). Organic and organo-mineral fertilization of *Festuca rubra* meadows. *Lucrări Științifice – Seria Agronomie, 48*, 355–359.
56. Rotar, I., Toth, G., Vaida, I., Mălinaș, A., Stoian, V., & Deac, V. (2016). Ecological and agronomical value of *Festuca rupicola–Bromus erectus* grasslands. *Romanian Journal of Grasslands and Forage Crops, 19*, 81–87.
57. Rotar, I., Vaida, I., & Păcurar, F. (2020). Species with indicative values for management of mountain grasslands. *Romanian Agricultural Research, 37*, 2067–5720.
58. Rotar, I., Vidican, R., Ciure, A., Păcurar, F., Gliga, A., & Balázsi, A. (2014). Behavior of a grass mixture under mineral fertilization. *Romanian Journal of Grasslands and Forage Crops, 9*, 87.
59. Rotar, I., Vidican, R., Păcurar, F., Mălinaș, A., & Vaida, I. (2016). A forage mixture with red clover in the fourth experimental year. *Bulletin UASVM Agriculture, 73*(2).
60. Rușdea, E., Reif, A., Höchtl, F., Păcurar, F., Rotar, I., Stoie, A., Dahlström, A., Svensson, R., & Aronsson, M. (2011). Grassland vegetation and management—Interface between science and education. *Bulletin UASVM Agriculture, 68*(1).
61. Samuil, C., Nazare, A.-I., Sîrbu, C., Grigoraș, B., & Vîntu, V. (2025). Impact of fertilizer gradient on HNV grasslands. *Plants, 14*, 3397.
62. Sângeorzan, D. D., Păcurar, F., Reif, A., Weinacker, H., Rușdea, E., Vaida, I., & Rotar, I. (2024). Detection of *Arnica montana* inflorescences using drone-based CNNs. *Remote Sensing, 16*, 2012.
63. Sângeorzan, D., Rotar, I., Vidican, R., & Păcurar, F. (2018a). Romania's diet and ecological footprint (1961–2013). *Romanian Journal of Grasslands and Forage Crops, 20*, 65–74.
64. Sângeorzan, D., Rotar, I., Păcurar, F., Vaida, I., Šuteu, A., & Deac, V. (2018b). The definition of oligotrophic grasslands. *Romanian Journal of Grasslands and Forage Crops, 20*, 17.
65. Sima, N., & Păcurar, F. (2002). Forage quality influenced by phenophase and management. In *EGF Proceedings, 7*, 160–161.
66. Stoian, V., Vidican, R., Crișan, I., Puia, C., Șandor, M., Stoian, V. A., Păcurar, F., & Vaida, I. (2019). Sensitive approach and future perspectives in microscopic patterns of mycorrhizal roots. *Scientific Reports, 9*, 10233.

67. Stoian, V., Vidican, R., Rotar, I., Păcurar, F., & Morea, A. (2014). Development of mycorrhizal fungi in *Festuca rubra* under fertilization. *Romanian Journal of Grasslands and Forage Crops, 10,* 85.
68. Stoian, V., Vidican, R., Rotar, I., Păcurar, F., & Nițte, M. (2014). Disturbance and stability of mycorrhizal colonisation in mountain meadows. *Romanian Journal of Grasslands and Forage Crops, 9,* 11.
69. Vaida, I., Păcurar, F., Rotar, I., Tomoș, L., & Stoian, V. (2021). Changes in diversity due to long-term management in HNV grasslands. *Plants, 10,* 739.
70. Vaida, I., Rotar, I., & Păcurar, F. (2017). Cumulative effect of manure for 15 years on a *Festuca rubra* grassland. *Bulletin UASVM Agriculture, 74*(2).
71. Vaida, I., Rotar, I., Păcurar, F., Vidican, R., Pleșa, A., Mălinaș, A., & Stoian, V. (2016). Impact of abandonment on semi-natural grasslands. *Bulletin UASVM Agriculture, 73*(2).
72. Vârban, D., Păcurar, F., Vârban, R., & Odagiu, A. (2011). Research concerning the germination of *Arnica montana*. *Hop and Medicinal Plants*.
73. Nazare, A. I., Stavarache, M., Samuil, C., & Vîntu, V. (2024). The improvement of Nardus stricta L. Permanent meadow from the Dorna depression through mineral and organic fertilization. *Scientific Papers. Series A. Agronomy, 67*(2).
74. Vîntu, V., Samuil, C., Rotar, I., Moisuc, A., & Razec, I. (2011b). Influence of the management on the phytocoenotic biodiversity of some Romanian representative grassland types. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 39*(1), 119-125.
75. Vîntu, V., Samuil, C., Sirbu, C., Popovici, C. I., & Stavarache, M. (2011a). Sustainable Management of Nardus stricta L. Grasslands in Romania's Carpathians. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 39*(2), 142-145.
76. Samuil, C., Vintu, V., Sirbu, C., & Stavarache, M. (2013). Influence of Fertilizers on the Biodiversity of Semi-natural Grassland in the Eastern Carpathians. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41*(1), 195-200.

AN INTEGRATED NDVI, SAVI AND LAI BASED APPROACH FOR ASSESSING GRASSLANDS IN THE POIANA RUSCĂ MOUNTAINS

Loredana COPĂCEAN[1], Nicolae Marinel HORABLAGA[1,2], Cristian BOSTAN[2], Christianna ISTRATE-SCHILLER[1], Ionel SAMFIRA[1,2], Veronica SĂRĂȚEANU[1], Carmen DURĂU[1], Dorin RECHIȚEAN[2], Luminiţa COJOCARIU[1,2]*

[1]University of Life Sciences "King Mihai I" from Timisoara, 300645, 119, Calea Aradului, Timisoara, Romania
[2]Agricultural Research and Development Station Lovrin, 307250, 200, Principala, Lovrin, Romania
**Corresponding author: luminita_cojocariu@usvt.ro*

Abstract

This study evaluates the condition of grassland vegetation in the protected areas of the Poiana Ruscă Mountains (altitudes >500 m) using vegetation indices derived from Sentinel-2A imagery acquired in June 2024. NDVI, SAVI and LAI were applied to assess photosynthetic activity, vegetation cover and leaf density. NDVI values ranged from 0.32 to 0.75 (mean 0.59), indicating vigorous vegetation, while SAVI varied between 0.28 and 0.63 (mean 0.48), showing good plant coverage with minimal soil influence. LAI values ranged from 0.9 to 2.3 (mean 1.96), suggesting high biomass accumulation potential. Classification into five classes showed that most surfaces were in the "good" or "very good" vegetation state (72% according to NDVI, 77% SAVI, 65% LAI). Vegetation development was most favorable below 1100 m. Results highlight the usefulness of combining indices for ecological monitoring and sustainable pasture management.

Keywords: NDVI, SAVI, LAI, mountain grasslands, altitudinal analysis, vegetation classification.

INTRODUCTION

Grasslands are key ecosystems for maintaining biodiversity (CĂLUȘERU et al., 2013; KACHLER et al., 2023; GIGANTE et al., 2024), ecosystem services (COJOCARIU et al., 2010) and agro-pastoral activities (COPĂCEAN et al., 2020; VIDICAN et al., 2020), while also being highly sensitive to land-use changes and climate change (XIONG et al., 2019). In this context, remote sensing methods have become essential tools for monitoring vegetation status, biomass, and degradation processes on a regional and global scale (AYVAZYAN et al., 2024), providing synoptic and repeatable information over time at low cost compared to classic ground based monitoring. Numerous studies synthesize the role of remote sensing in estimating essential grassland parameters, aerial biomass, primary productivity, vegetation cover, and Leaf Area Index (LAI) and highlight the usefulness of satellite imagery (Sentinel, Landsat, MODIS) in assessing the condition and management of natural and cultivated grasslands (REINERMANN et al., 2020; WANG et al., 2022; BANGIRA et al., 2023). The application of remote sensing techniques in the study of grasslands is mainly based on multispectral optical data, supplemented, increasingly, by radar sensors and high spatial resolution platforms (UAVs), which allow detailed capture of the structure of the vegetation carpet and its seasonal dynamics (TARAVAT et al., 2019; VERRELST et al., 2019; SIMON et al., 2020). These technologies make it possible to continuously monitor the functional parameters of vegetation, including seasonal growth, drought effects, grazing intensity or degradation processes, being particularly useful in mountainous or hard to reach areas (SIMON et al., 2021). Recent reviews highlight the shift from simple thematic mapping to the assessment of ecological processes and grassland management, through the integration of satellite imagery time series and indicators derived from them (ALI et al., 2017; YAN et al., 2025). Among the indicators derived from remote sensing, vegetation indices play a central role, providing a quantitative characterization of the state of the vegetation carpet based on the spectral contrast between the red and near-infrared domains. The Normalized Difference Vegetation Index (NDVI) is the most widely used index in grassland studies, being recognized for its ability to restore vegetation vigor, coverage, and productivity dynamics, including in the modeling of aboveground biomass and primary productivity (BALATA et al., 2022; SERRANO et al., 2024; WANG et al., 2025). NDVI is frequently used for monitoring grassland production, predicting vegetation status, and assessing response to climate variability in various regions (XUE and SU, 2017; PANG et al., 2020; MILAZZO et al., 2024; ZHAO and QU, 2024). However, NDVI can be significantly influenced by soil reflectance, especially in areas with sparse or discontinuous vegetation cover. To mitigate this limitation, Huete (1988) proposed the Soil-Adjusted Vegetation Index (SAVI), which introduces a soil background correction factor into the index formula, thus reducing variations induced by soil brightness and moisture. SAVI is especially recommended for grasslands with variable grassland density or in early stages of regeneration, being successfully used in monitoring vegetation growth and production conditions in different types of grasslands and crops (WANG et al., 2024). On the other hand, the Leaf Area Index (LAI) is a fundamental structural parameter, defined as the ratio between the total leaf area and the corresponding land area, which can be directly correlated with the photosynthetic potential and biomass accumulation. Remote sensing LAI estimation has been intensively developed for both agricultural crops and forests and grasslands, with studies showing close relationships between LAI, aerial biomass and grassland productivity. The integration of multispectral and, more recently, radar or UAV data, allows for detailed spatial maps of LAI, useful in assessing the conservation status of ecosystems and in planning pastoral use (WANG et al., 2019; XU et al., 2020; WU et al., 2025).The literature highlights the advantages of combining several remote sensing indices in grassland analysis, as each index captures a different facet of vegetation status: NDVI is sensitive to photosynthetic vigor, SAVI reduces soil influence in areas with partial cover, and LAI describes leaf density and biomass accumulation capacity. Recent studies on estimating biomass, productivity and grassland degradation show that models based on combined sets of indices, including NDVI, SAVI and LAI, are more accurate than those using a single index, making them particularly useful for grassland resource management on a regional scale (PANG et al., 2020; BU et al., 2022; WANG et al., 2022; MĂGUREANU et al., 2023; PANEK-CHWASTYK et al., 2024). In this context, the mountain grasslands of the Poiana Rusca Mountains, located in protected areas and at altitudes above 500 m, represent an appropriate framework for the application and testing of an integrated approach based on NDVI, SAVI and LAI. The aim of this study is to assess the vegetation status of the grasslands in the Poiana Rusca Mountains, located at altitudes above 500 m and included in protected areas, through an integrated approach based on remote sensing indices (NDVI, SAVI and LAI). By combining information on vegetation vigor (NDVI), soil influence (SAVI) and leaf density (LAI), the analysis aims to highlight spatial variations of the vegetation cover and identify areas with high productive potential or susceptible to degradation. The results obtained are intended to support the effective monitoring and sustainable management of mountain pastoral ecosystems.

MATERIAL AND METHOD

1. Study area

The study area includes the grasslands of the Poiana Ruscă Mountains (Figure 1), whose limits were defined according to the Mountain Law no. 197/2018 and the geomorphological delimitation made by Posea and Badea (1984). According to the Mountain Law, they fall into Mountain Group 8 and also integrate some depressions and marginal hilly areas. The analysis is focused exclusively on grasslands located above 500 m altitude and overlapping protected areas, which total an area of 3319.13 ha, according to Corine Land Cover (CLC 2018) data (COPERNICUS LAND MONITORING SERVICE, 2022).

2. Research methodology

The workflow applied in the research is shown in Figure 2. The satellite imagery used for grassland vegetation analysis comes from the Sentinel-2A platform, acquired in June 2024 (COPERNICUS OPEN ACCESS HUB, 2025).

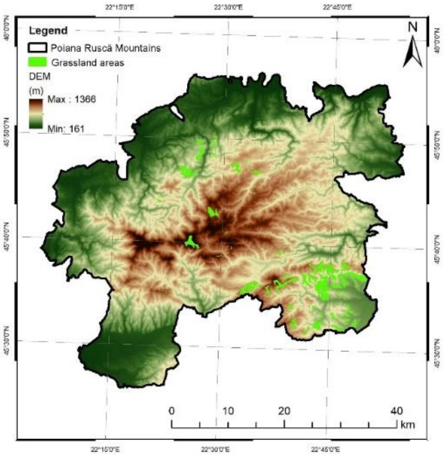


Fig. 1. Spatial distribution of grasslands in the Poiana Ruscă Mountains by relief units (Posea and Badea, 1984; Law nr. 197/2018; Geospatial, 2021; Copernicus Land Monitoring Service, 2022; Ministry of Agriculture and Rural Development, 2025)

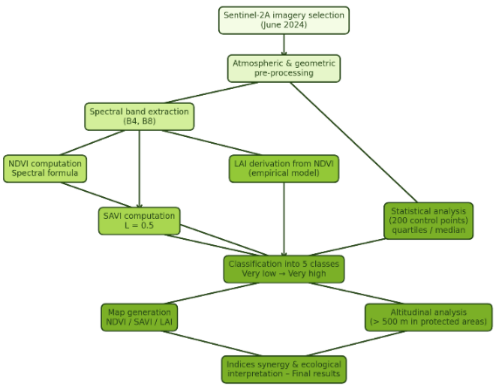


Fig. 2. Research methodology

The period of active vegetation for mountain grasslands was selected in order to obtain relevant values of vegetation indices.

Calculated vegetation indices

Three remote sensing indices were calculated as follows:

- NDVI, according to relation 1, widely used to estimate vegetation vigor (BALATA et al., 2022; SERRANO et al., 2024):

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}}$$

where: NIR - near-infrared band (for Sentinel-2A, B8); RED - red stripe (B4);

- SAVI, according to relation 2 (HUETE, 1988); reduces the effects of soil brightness in areas with low vegetation cover; L = 0.5 is used (WANG et al., 2024):

$$\mathrm{SAVI} = \left(\frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED} + \mathrm{L}}\right) \times (1 + \mathrm{L})$$

where "L" is a correction factor for the influence of the soil;

- LAI was derived from NDVI based on empirical relations reported in the literature (BAJOCCO et al., 2022):

$$\mathrm{LAI} = \mathrm{a} \times \mathrm{NDVI} + \mathrm{b}$$

where: a and b are coefficients determined by local linear regression; the statistical correlation was verified by the coefficient of determination R^2. The geospatial data processing was done with the ArcGIS for Desktop software, version 10.8, and the statistical data processing was done in the IMB SPSS program.

Establishment of thresholds for classification of vegetation indices In order to ensure a realistic classification of the consistency of grassland vegetation, the thresholds for classification in classes were defined based on the distribution of the values of the indices calculated in control points (200 points) located in the Poiana Rusca Mountains. The LAI, NDVI and SAVI values (minimum, maximum, median and quartiles) were statistically analyzed, and the thresholds were established so as to reflect both the literature on the usual ranges of these indices for grassland ecosystems, and the local reality captured in the datasets (Table 1).

Table 1.

Classification thresholds of the NDVI, SAVI and LAI indices for the grasslands of the Poiana Ruscă Mountains

Class	LAI	NDVI	SAVI
Very weak	< 1.0	< 0.35	< 0.30
Weak	1.0 – 1.5	0.35 – 0.45	0.30 – 0.40
Moderate	1.5 – 1.9	0.45 – 0.55	0.40 – 0.48
Good	1.9 – 2.1	0.55 – 0.62	0.48 – 0.55
Very good	> 2.1	> 0.62	> 0.55

The classes were divided into five categories: very weak, weak, moderate, good and very well vegetated, corresponding to the distribution of the values recorded: the values below the lower quartile were considered "weak", those around the median, "moderate", and those above the upper quartile, "good" and "very well" vegetated. This approach allowed locally calibrated thresholds to be defined.

Benchmarking and exporting results After calculating the indices and classifying the areas in the defined vegetation classes, the thematic maps of NDVI, SAVI and LAI were superimposed to allow the spatial assessment of the vegetation consistency, the identification of areas of interest (e.g. with high productive potential or with little vegetation) and the generation of statistics on altitudinal floors and for the protected areas concerned. In this way, the integration of data at the surface level and the preparation for ecological and agronomic interpretation was ensured.

RESULTS AND DISCUSSIONS

1. Evaluation of the grasslands in Poiana Ruscă through the NDVI, SAVI and LAI indices

The analysis of the vegetation indices at the level of the Poiana Ruscă Mountains highlights a good general condition of the vegetation carpet, with spatial differentiations related to altitude and local environmental conditions.

NDVI values (Figure 3), ranging from –0.22 to 0.76 and an average of 0.59, indicate well-represented vegetation with large areas where potential productivity is high. The relatively concentrated distribution of values suggests that most areas are covered with vigorous vegetation, but there are also limited areas where grass mat is less frequent or in a state of regeneration. The results provided by the SAVI index (Figure 3), which vary between –0.23 and 0.78, with an average of 0.50, confirm the trends captured by the NDVI, but bring added relevance by reducing the influence of soil in areas with partial cover. Thus, land with lower vegetation density is better differentiated, and the spatial structure of the grass carpet is more clearly outlined. The LAI index (Figure 3), with values between –0.91 and 2.62 and an average of 2.03, completes the overall picture, highlighting the leaf density of the vegetation. The high level of the average reflects a well-developed grass carpet with a high productive potential. At the same time, the existence of lower values, located especially in marginal areas or at higher altitudes, also shows the vulnerabilities of ecosystems, where climatic and edaphic conditions limit the development of vegetation. The interpretation of the NDVI, SAVI and LAI values for the entire region of the Poiana Ruscă Mountains highlights an extensive and vigorous vegetation cover, with the predominance of well-forested areas and dense grass cover, which reflects a good state of mountain ecosystems and a high productive potential of plant resources (Figure 3).

1.1. Analysis of grasslands in Poiana Ruscă Mountains based on NDVI values

The NDVI values for the grasslands of the Poiana Ruscă Mountains (figure 4) vary between 0.22 and 0.76, with an average of 0.59, which reflects a well-developed vegetation carpet and a good overall vegetation condition. The distribution of values is relatively close, dominated by the high positive range, which indicates that most grasslands have a consistent degree of cover and adequate vegetative vigor for their agronomic use. The Kruskal–Wallis test confirmed the existence of significant differences between the NDVI values of the grasslands of the Poiana Ruscă Mountains on altitudinal levels ($H = 63.08$; $p < 0.001$), which shows that the degree of coverage and vigor of the vegetation cover vary with altitude. The highest values are specific to the range 701-1100 m, where moderate temperatures and a relatively balanced rainfall regime support the development of dense and productive vegetation. At higher altitudes, above 1300 m, post-hoc tests showed a significant decrease in NDVI values, associated with limiting the growing season and reducing accumulated biomass. From an agronomic point of view, the grasslands on the lower and middle floors are the most valuable, having a dense and productive grass carpet, while those on the upper floors are characterized by a lower forage potential and are mainly used for summer grazing.

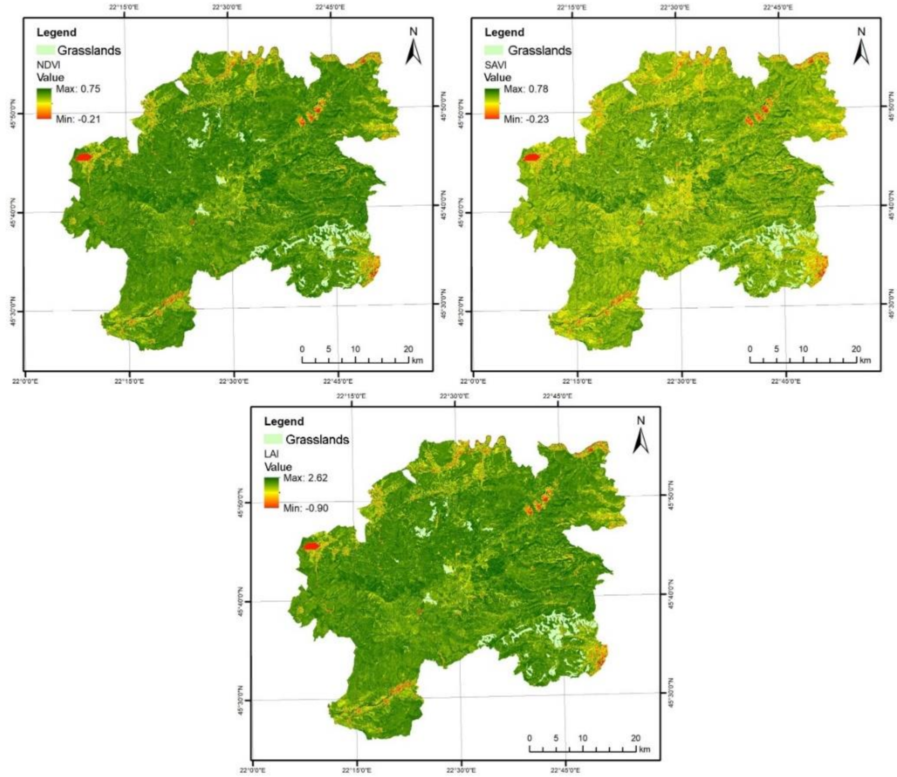


Fig. 3. Spatial representation of the indices NDVI (A), SAVI (B) and LAI (C) in the Poiana Ruscă Mountains

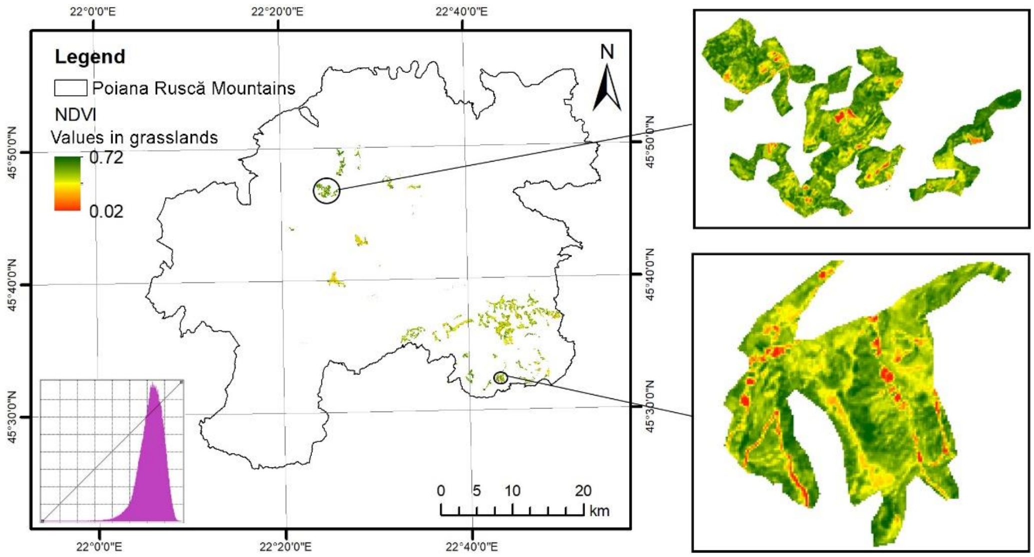


Fig. 4. Distribution of NDVI values in the meadows of the Poiana Rusca Mountains, with details for two representative areas

The classification of the NDVI map for the grasslands of the Poiana Ruscă Mountains shows that most of the area falls into the "high" and "very high" coverage classes (Table 2). About 47% of the grasslands have a dense vegetation carpet, and 22.7% have a very high cover, which indicates an excellent state of vegetation and a great forage potential. Together, these two classes account for almost 70% of the area, confirming the importance of these grasslands as an agricultural and pastoral resource

Table 2.

Distribution of grasslands in the Poiana Rusca Mountains by cover classes, according to NDVI values

Classes of grasslands with cover	Surface (ha)	% of total
Very weak	12.57	0.3
Weak	92.00	2.7
Moderate	896.32	26.9
Large	1564.31	47.1
Very Large	755.03	22.7

The "moderate" class of coverage comprises 26.9% of the surface, representing areas where the vegetation carpet is well developed, but with a lower density, possibly due to edaphic conditions or more intense exploitation. In contrast, grasslands with poor and very poor cover are extremely small in extent (below 3%), which shows that degraded areas or areas with sparse vegetation are marginal and do not significantly affect the pastoral landscape of the region.

Overall, the structure of the NDVI classes demonstrates that the grasslands of the Poiana Ruscă Mountains have a very high degree of vegetation cover, which reflects a good conservation of the grass cover and a considerable agronomic potential.

1.2. Analysis of grasslands in the Poiana Ruscă Mountains based on SAVI values

The SAVI values obtained for the grasslands in the Poiana Ruscă Mountains vary between 0.03 and 0.71 (Figure 5), with a mean of 0.48 and a standard deviation of 0.06, which shows a tight distribution around moderate and high values. This situation reflects uniform vegetation with good density and a low degree of degraded areas or with scarce vegetation.

Compared to NDVI, SAVI values are slightly more temperate, but confirm the same general picture of a well-represented carpet, with the difference that this index more clearly highlights areas where soil influence is stronger and vegetation is more discontinuous.

The statistical analysis of the SAVI values on altitudinal levels in the Poiana Ruscă Mountains shows significant differences (H = 65.77; p

< 0.001), with higher values at low and medium altitudes and a clear decrease above 1300 m. From an agronomic point of view, it confirms that the most productive grasslands are located at lower and medium altitudes, where the climate favours the accumulation of biomass, while at high altitudes, low temperatures and the short growing season limit vegetation density and productivity.

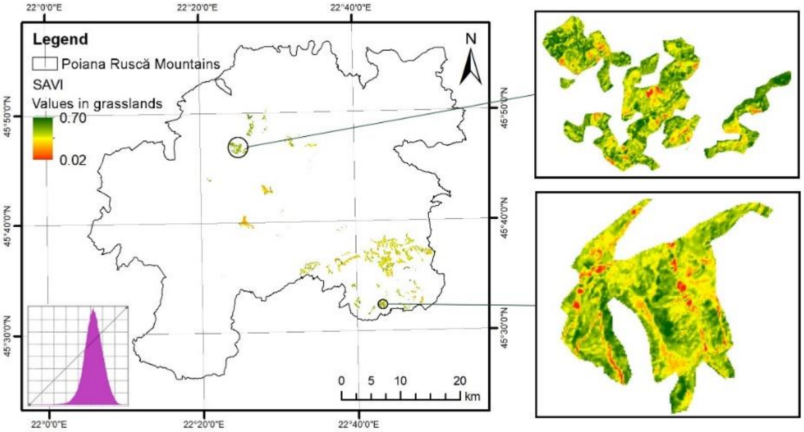


Fig. 5. Distribution of SAVI values in the meadows of the Poiana Rusca Mountains, with details for two representative areas

The classification of SAVI values for the meadows of the Poiana Ruscă Mountains (Table 3) highlights a predominance of vegetation carpet with moderate and high cover, which together represent almost 80% of the total area. Grasslands with moderate cover occupy the largest share, 41.2% (1369.39 ha), followed by those with high cover, 36.1% (1199.09 ha), which shows a good general condition of vegetation. Grasslands with very high cover are present on 12.6% of the area (420.11 ha), indicating areas with high biomass density, favorable for mowing and intensive grazing. On the other hand, the areas with poor or very poor cover are reduced, totaling only 9.9%, which confirms that the degradation of vegetation has a limited and punctual character.

Table 3.

Distribution of grasslands in the Poiana Rusca Mountains by cover classes, according to SAVI values

Classes of grasslands with cover	**Surface (ha)**	**% of total**
Very weak	21.85	0.6
Weak	309.79	9.3
Moderate	1369.39	41.2
Large	1199.09	36.1
Very Large	420.11	12.6

Overall, the data suggest that the grasslands of Poiana Ruscă have a high productive potential, especially in low and medium altitude areas, where climatic conditions support the development of a consistent grass carpet.

1.3. Analysis of grasslands in the Poiana Ruscă Mountains based on LAI values

For the analysis of the grasslands in the Poiana Ruscă Mountains based on LAI values, the statistics indicate values between 0.03 and 2.50 (Figure 6), with an average of 1.96 and a standard deviation of 0.21, on a total area of 3319.13 ha.

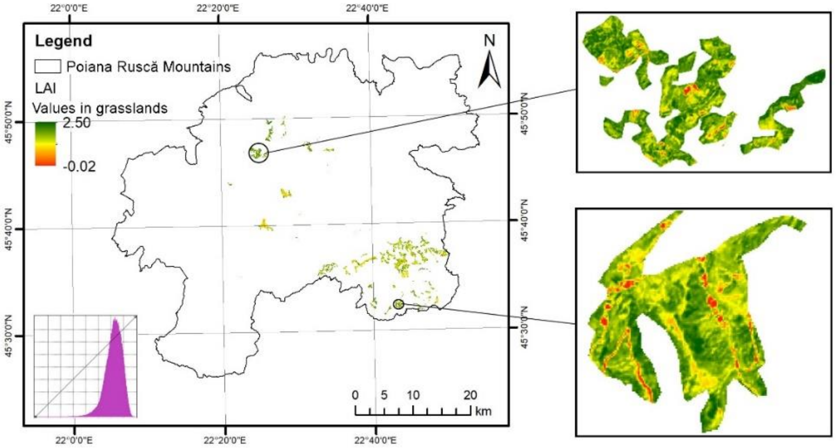


Fig. 6. Distribution of LAI values in the meadows of the Poiana Rusca Mountains, with details for two representative areas

The LAI distribution shows a strong concentration of values around the average, which suggests that most grasslands are characterized by a relatively high leaf density, favorable to photosynthetic processes and biomass accumulation. From an agronomic point of view, these results reflect a considerable productive potential, grasslands with LAI values close to 2 indicating a well-developed grassy structure with a consistent and uniform cover.

Compared to the NDVI and SAVI values, LAI brings a more detailed picture of vegetation density, highlighting areas where grass mat plays an important role in ecosystem stability and in supporting agro-pastoral activities.

The results for the analysis of the LAI values in the Poiana Ruscă Mountains show statistically significant differences between the altitudinal levels ($H = 63.08$; $p < 0.001$). The average values are higher at low and medium altitudes: between 701–900 m (1.99) and 901–1100 m (1.93), followed by the range of 501–700 m (1.88), suggesting a high leaf density and a well-developed grass carpet.

At higher altitudes, between 1101–1300 m and 1301–1500 m, the average values gradually decrease to 1.85 and 1.66 respectively, indicating limitations related to lower temperatures and short vegetation period.

From an agronomic perspective, these results confirm that the most productive grasslands with the best regenerative capacity are located at low and medium altitudes, where the climate favors the accumulation of biomass. At high altitudes, grasslands have less cover and are more suitable for extensive grazing with low productivity and shorter use period.

The classification of LAI values for the grasslands in the Poiana Ruscă Mountains (Table 4) shows a very good general condition of the vegetation, with the predominance of the large and very large cover categories, which together account for 65.2% of the area (2167.35 ha). Grasslands with moderate cover occupy 31.7% (1054.29 ha), which confirms the existence of large areas with constant leaf density and high productivity. The areas with poor and very poor cover are almost insignificant, representing only 2.8% of the total, which shows that the degradation of the vegetation is punctual and does not affect the entire area.

Table 4.

Distribution of grasslands in the Poiana Ruscă Mountains by cover classes, according to LAI values

Classes of grasslands with cover	Area (ha)	% of total
Very weak	5.98	0.1
Weak	92.61	2.7
Moderate	1054.29	31.7
Large	1267.27	38.1
Very Large	900.08	27.1

From an agronomic point of view, the distribution of these classes reflects a pastoral resource of great value, with a compact and uniform grass cover, which supports both intensive grazing and mowing, being characteristic of favorable climatic conditions and efficient land management.

Compared to NDVI and SAVI, which mainly indicate variations in vigor and vegetation cover, the LAI values in the Poiana Ruscă Mountains highlight more clearly the differences in leaf density, confirming the general trend of higher grassland productivity at low and medium altitudes and a gradual reduction in vegetation cover with increasing altitude.

2. Synergy of vegetation indices in grassland assessment

The integrated analysis of the NDVI, SAVI and LAI indices highlights a clear convergence of the results, confirming a very good general state of the vegetation carpet in the Poiana Rusca Mountains. All three indices indicate predominantly high values of vegetation, both from the perspective of photosynthetic vigor and foliar density, with spatial differences strongly correlated with the altitudinal gradient.

NDVI and SAVI revealed similar distributions of areas with rich vegetation, but SAVI provided a more nuanced differentiation in areas with less cover, by diminishing the influence of the soil. Thus, areas classified with poor and very poor coverage are reduced for all indices, but are slightly more clearly distinguishable in the SAVI analysis. LAI complements the other two assessments with additional information on biomass and foliar structure, highlighting a high density of herbaceous vegetation on most of the investigated area, where grasslands are well developed and with high productive potential.

As for the variation on altitudinal levels, all three indices indicate maximum values at low and medium altitudes (701–1100 m), where climatic conditions favor vegetation development, followed by a gradual decrease with the increase in altitude, above 1300 m. This pattern confirms that environmental variables are a major determinant of grass carpet productivity.

The similarities between NDVI, SAVI and LAI in spatial distributions robustly validate the observation that grasslands with high agronomic potential are predominantly located in the lower and middle levels of mountains.

The integration of the three indices allows a more complete picture of the state of the vegetation, indicating both its vitality and the capacity for biomass production and regeneration.

The comparative results demonstrate that the grasslands of the Poiana Ruscă Mountains are in a very good ecological and productive state, with large areas characterized by a dense and uniform vegetation cover, which underlines their importance as a pastoral and ecological resource. Altitudinal differences are obvious and must be taken into account in sustainable land management strategies.

Overall, the results obtained for the grasslands of the Poiana Ruscă Mountains confirm that the combined use of the NDVI, SAVI and LAI remote sensing indices is a robust and extremely useful tool for ecological and agronomic analyses, as it allows a fine spatial quantification of the state of the vegetation carpet and the productive potential along the altitudinal gradient, in full agreement with the conclusions formulated in the specialized literature on the estimation of biomass and grassland productivity (SCHAEFER and LAMB, 2016; REINERMANN et al., 2020; ANDREATTA et al., 2022; WANG et al., 2022; NETSIANDA and MHANGARA, 2025)

CONCLUSIONS

The grasslands in the Poiana Ruscă Mountains register high values of vegetation indices, with an average NDVI of 0.59 and a cumulative share of almost 70% of the areas classified in the "high" and "very high" cover classes, which indicates a well-developed and extremely valuable vegetation carpet from a productive point of view.

The SAVI values, with an average of 0.48, confirm this trend, 77.3% of the area being in the moderate and high cover classes, demonstrating a consistent plant development even in areas where the soil influence could be more pronounced. At the same time, the LAI distribution, with an average of 1.96 and over 65% of grasslands framed in high and very high levels of foliar density, highlights a high capacity for biomass accumulation and an increased vitality of the herbaceous vegetation. The observed altitudinal differences (with maximums in the lower floors and a gradual decrease above 1300 m) reveal the decisive influence of climatic conditions on the structure of the mountain vegetation.

Overall, remote sensing means prove effective in rapidly assessing and monitoring the state of the vegetation carpet, providing a solid basis for supporting measures for the conservation and sustainable use of pastoral resources.

Acknowledgments

The research in this article is part of the ADER project 15.3.3., entitled "Multifunctional management of grasslands to ensure the economic and ecological sustainability of their production"

REFERENCES

1. Ali I., Cawkwell F., Dwyer E., Green S. (2017) Modeling managed grassland biomass estimation by using multitemporal remote sensing data – a machine learning approach. IEEE J Sel Top Appl Earth Obs Remote Sens, 10: 3254–3264.
2. Andreatta D., Gianelle D., Scotton M., Dalponte M. (2022) Estimating grassland vegetation cover with remote sensing: A comparison between Landsat-8, Sentinel-2 and PlanetScope imagery. Ecological Indicators, 141: 109102.
3. ArcGIS Documentation (2022) ArcGIS Desktop Documentation. Available online: https://desktop.arcgis.com/en/documentation/ (accessed on 25.10.2022).
4. Ayvazyan G., Muradyan V., Medvedev A., Khlghatyan A., Asmaryan S. (2024) Exploring multisource remote sensing for assessing and monitoring the ecological state of the mountainous natural grasslands in Armenia. Appl Sci, 14: 10205.
5. Bajocco S., Ginaldi F., Savian F., Morelli D., Scaglione M., Fanchini D., Raparelli E., Bregaglio S.U.M. (2022) On the use of NDVI to estimate LAI in field crops: Implementing a conversion equation library. Remote Sens, 14: 3554

6. Balata D., Gama I., Domingos T., Proença V. (2022) Using satellite NDVI time-series to monitor grazing effects on vegetation productivity and phenology in heterogeneous Mediterranean forests. Remote Sens, 14: 2322
7. Bangira T., Mutanga O., Sibanda M., Dube T., Mabhaudhi T. (2023) Remote sensing grassland productivity attributes: a systematic review. Remote Sens, 15: 2043
8. Bu L., Lai Q., Qing S., Bao Y., Liu X., Na Q., Li Y. (2022) Grassland biomass inversion based on a random forest algorithm and drought risk assessment. Remote Sens, 14: 5745
9. Călușeru A.L., Cojocariu L., Horablaga M.N., Bordean D.M., Horablaga A., Cojocariu A., Borozan A.B., Iancu T. (2013) Romanian National Strategy for the conservation of biodiversity 2013–2020 – integration of European environmental policies. SGEM Conf Proc, 2: 723–728
10. Cojocariu L., Horablaga M., Marian F., Bostan C., Mazăre V., Stroia M.S. (2010) Implementation of the ecological European network Natura 2000 in the area of grasslands and hayfields. Res J Agric Sci, 42: 398–404
11. Copăcean L., Cojocariu L., Simon M., Zisu I., Popescu C. (2020) Geomatic techniques applied for remote determination of the hay quantity in agro-silvo-pastoral systems. PESD, 14(2): 89–101
12. Copernicus Land Monitoring Service (2022) Corine Land Cover – CLC. Available online: https://land.copernicus.eu/pan-european/corine-land-cover (accessed on 20.05.2022)
13. Copernicus Open Access Hub (2025) Copernicus Open Access Hub. Available online: https://scihub.copernicus.eu/dhus/#/home (accessed on March, 2024)
14. Geospatial (2021) România: seturi de date vectoriale generale. Available online: http://geo-spatial.org/vechi/download/romania-seturi-vectoriale (accessed on 10.11.2021)
15. Gigante D., Angelucci S., Bonini F., Caruso F., Di Cecco V., Donnini D., Morbidini L., Pauselli M., Valenti B., Tassi A. et al. (2024) Seminatural grasslands: an emblematic challenge for nature conservation in protected areas. Land, 13: 386
16. Huete A.R. (1988) A soil-adjusted vegetation index (SAVI). Remote Sensing of Environment, 25(3): 295–309.
17. IBM SPSS Statistics (Version 26) Available online: https://www.ibm.com/products/spss
18. Kachler J., Benra F., Bolliger R. et al. (2023) Can we have it all? The role of grassland conservation in supporting forage production and plant diversity. Landsc Ecol, 38: 4451–4465
19. Legea nr. 197/2018 din 20 iulie 2018, Legea muntelui. Available online: https://static.anaf.ro/static/10/Anaf/legislatie/L_197_2018.pdf
20. Măgureanu M., Sfîrcoci M., Copăcean L., Cojocariu L. (2023) Monitoring the vegetation coverage of the grasslands in the Poiana

Ruscă Mountains using different remote sensing indices. PESD, 17: 189–199
21. Milazzo F., Brocca L., Vanwalleghem T. (2024) NDVI prediction of Mediterranean permanent grasslands using soil moisture products. Agronomy, 14: 1798
22. Ministerul Agriculturii şi Dezvoltării Rurale (2025) Harta Grupei de Munți Banat și Poiana Ruscă. Available online: https://azm.gov.ro/harta-grupei-de-munti-banat-si-poiana-rusca/ (accessed on 14.09.2025)
23. Ministerul Mediului, Apelor şi Pădurilor (2025) Arii naturale protejate de interes național și internațional. Available online: https://mmediu.ro/portal-gis/date-spatiale/arii-naturale-protejate-de-interes-national-si-international/ (accessed on 14.10.2025)
24. Netsianda A., Mhangara P. (2025) Aboveground biomass estimation in a grassland ecosystem using Sentinel-2 satellite imagery and machine learning algorithms. Environ Monit Assess, 197: 138
25. Panek-Chwastyk E., Ozbilge C.N., Dąbrowska-Zielińska K., Wróblewski K. (2024) Assessment of grassland biomass prediction using AquaCrop model: Integrating Sentinel-2 data and ground measurements in Wielkopolska and Podlasie regions, Poland. Agriculture, 14: 837
26. Pang H., Zhang A., Kang X., He N., Dong G. (2020) Estimation of the grassland aboveground biomass of the Inner Mongolia Plateau using the simulated spectra of Sentinel-2 images. Remote Sens, 12: 4155
27. Posea Gr., Badea L. (1984) România. Unitățile de relief (Regionarea geomorfologică). Ed. Științifică și Enciclopedică
28. Reinermann S., Asam S., Kuenzer C. (2020) Remote sensing of grassland production and management – a review. Remote Sens, 12: 1949
29. Schaefer M.T., Lamb D.W. (2016) A combination of plant NDVI and LiDAR measurements improve the estimation of pasture biomass in tall fescue (*Festuca arundinacea* var. Fletcher). Remote Sens, 8: 109
30. Serrano J., Shahidian S., Paixão L., Marques da Silva J., Paniágua L.L. (2024) Pasture quality assessment through NDVI obtained by remote sensing: a validation study in the Mediterranean silvo-pastoral ecosystem. Agriculture, 14: 1350
31. Simon M., Popescu C.A., Copăcean L., Cojocariu L. (2020) Complex model based on UAV technology for investigating pastoral space. Present Environment and Sustainable Development, 14: 139–150
32. Simon M., Copăcean L., Popescu C., Cojocariu L. (2021) 3D mapping of a village with a WingtraOne VTOL tailsitter drone using Pix4D mapper. Res J Agric Sci, 53: 228
33. Taravat A., Wagner M.P., Oppelt N. (2019) Automatic grassland cutting status detection in the context of spatiotemporal Sentinel-1 imagery analysis and artificial neural networks. Remote Sens, 11: 711

34. Verrelst J., Malenovský Z., Van der Tol C., Camps-Valls G., Gastellu-Etchegorry J-P., Lewis P., North P., Moreno J. (2019) Quantifying vegetation biophysical variables from imaging spectroscopy data: a review on retrieval methods. Surv Geophys, 40: 589–629
35. Vidican R., Carlier L., Rotar I., Mălinaș A. (2020) Exploitation and management of low input grassland systems. Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca – Agriculture, 77(1): 49–56
36. Wang J., Xiao X., Bajgain R., Starks P., Steiner J., Doughty R., Chang Q. (2019) Estimating leaf area index and aboveground biomass of grazing pastures using Sentinel-1, Sentinel-2 and Landsat images. ISPRS Journal of Photogrammetry and Remote Sensing, 154
37. Wang Z., Ma Y., Zhang Y., Shang J. (2022) Review of remote sensing applications in grassland monitoring. Remote Sens, 14: 2903
38. Wang R., Dong J., Jin L., Sun Y., Baoyin T., Wang X. (2024) Improving the accuracy of vegetation index retrieval for biomass by combining ground-UAV hyperspectral data – a new method for Inner Mongolia typical grasslands. Phyton, 93: 387–411
39. Wang Z., Wang J., Wang W., Zhang C., Mandakh U., Ganbat D., Myanganbuu N. (2025) An explanation of the differences in grassland NDVI change in the eastern route of the China–Mongolia–Russia economic corridor. Remote Sens, 17: 867
40. Wu D., Bao S., Tong Y., Fan Y., Lu L., Liu S., Li W., Xue M., Cao B., Li Q. et al. (2025) Leaf area index estimation of grassland based on UAV-borne hyperspectral data and multiple machine learning models in Hulun Lake Basin. Remote Sens, 17: 2914
41. Xiong Q., Xiao Y., Halmy M.W.A., Dakhil M.A., Liang P., Liu C., Zhang L., Pandey B., Pan K., El Kafraway S.B. et al. (2019) Monitoring the impact of climate change and human activities on grassland vegetation dynamics in the northeastern Qinghai-Tibet Plateau of China during 2000–2015. J Arid Land, 11: 637–651
42. Xu J., Quackenbush L.J., Volk T.A., Im J. (2020) Forest and crop leaf area index estimation using remote sensing: Research trends and future directions. Remote Sens, 12: 2934
43. Xue J., Su B. (2017) Significant remote sensing vegetation indices: A review of developments and applications. Journal of Sensors, Article ID 1353691, 17
44. Yan K., Si G., Yan G., Ma X., Chen X., Zhu P., Li J., Gao S., Gastellu-Etchegorry J., Myneni R., Wang Q. (2025) A global systematic review of remote sensing vegetation indices. International Journal of Applied Earth Observation and Geoinformation, 139: 104560
45. Zhao Q., Qu Y. (2024) The retrieval of ground NDVI (Normalized Difference Vegetation Index) data consistent with remote-sensing observations. Remote Sens, 16: 1212.

RESEARCH REGARDING INFLUENCE OF GRAZING WITH YOUNG CATTLE ON A COMPLEX MIXTURE OF SOWED GRASSLANDS

Teodor MARUŞCA

Research-Development Institute for Grasslands, Braşov
email: maruscat@yahoo.com

Abstract

In this paper, the effect of different ways of using a meadow sown with a mixture of 4 perennial grasses (Festuca pratensis, Lolium perenne, Phleum pratense and Poa pratensis, together with a perennial legume Trifolium repens of the Ladino type, was investigated, as well as the yield in live weight gain of the young female brood in three distinct experiments that totaled 11 years. On the variants harvested in a haymaking regime, 3-4 mowing were obtained on average over 4 years 11.1 t/ha dry matter (DM) and on the remaining variants mowed or grazed with cattle more often in 6-8 cycles, DM production was 12-18% lower. In return, the production of crude protein per hectare was 17-19% higher in the mowed and grazed more often compared to the hayfield variant, where 1900 kg/ha was obtained. The initial components of the sown mixture were preserved in a proportion of 93% in the version effectively grazed by the animals and only 65% was preserved in the version mowed as hay. In the pre-mountain area of the Braşov Depression located at 600 m altitude in the 3 experiments with 12-14 month old female , on the grasslands sown with complex mixtures fertilized with 190 kg/ha N and 50 kg/ha P, K, an average of 9.15 t/ha DM was achieved, 7 calves (4.9 LU/ha) were maintained in 150-160 days of the grazing season, when they achieved 835 g/day/head with 9.7 kg SM/1 kg gain at a rate of 6.1 kg/ha/day, totaling 941 kg/ha total animal weight gain yield, with high economic efficiency.

Keywords: sown grassland, use method, weight gain yield, grazing, young cattle

INTRODUCTION

The sown grasslands represent one of the most efficient means of intensifying feed production, especially for cattle, as green mass during the grazing season, or by mowing as hay, semi-silage or silage for stables, semi-silage or silage for stables (Anghel, 1984). By grazing, the animals influenced positively or negatively the productivity of vegetal cover grassland (Klapp, 1956; Simtea 1972). In this paper, we try to explain some aspects regarding sown grassland in the premountainous areas. In our country, there are few comparative studies on the effect of animal grazing and mowing on the grassy carpet of sown (temporary) grasslands. In this paper, the effect of different methods of use, respectively intervention, on the grassy carpet of a complex mixture of perennial grasses and legumes was studied, expressed through botanical composition, production, forage quality and finally, yield in live weight gain in young cattle in the Braşov Depression.

MATERIAL AND METHOD

The experiments were carried out at Magurele Braşov, situated at 600 m. a.s.l., with annual average temperatures of 7.5oC and rainfalls of 753 mm, in forest belt of beech and durmast oak on a chernozem, medium acid, rich in humus and medium supplied in nutritive elements. Three trials were carried out with young cattle of Bălţată Românească on sown grassland (Maruşca 1974-1977, Proca 1980-1982 and 1986-1989).

The sown grassland comprised three grassland mixtures located on 8 plots, each mixture was grazed by a group of young cattle of 12-14 months age, counting liveweight gain in the first trial, during four years (Maruşca Letiţia, 1977).

The composition of the complex mixture was as follows: *Festuca pratensis* – Local de Braşov (30%), *Lolium perenne* – Banat (20%), *Phleum pratense* – Suceava (20%), *Poa pratensis* – Transylvania (10%) and *Trifolium repens* – Ladino (20%).

At the beginning and the end of the experiments, soil samples were taken on the depth of 0-20 cm for agrochemical analyses (Maruşca, Proca, 1992).

The size of a grazing plot was 1,380 m.p. x 8 plots, of which in numbers 1, 4, 7 the variants were subdivided into 4 repetitions of 2 m.p.:

1. Mowing in haymaking regime (3-4 harvests);
2. Mowing more often, grazing simulation, without animals (6-8 harvests);
3. Mowing, grazing simulation, trampling and animal manure;
4. Normal grazing, 6-8 cycles, mowing unconsumed residues.

Botanical observations were carried out before each harvest on the 2 m2 plots, before the samples were harvested for dry matter and chemical analyses of forage quality.

In addition, the pastoral value was evaluated based on a floristic survey (Maruşca 2019).

The pastoral value of the grassland use options brings new possibilities for comparing their productivity.

Finally, a synthesis was prepared for 11 years (1974-77; 1980-82 and 1986-89) of three experiments with young cattle on grasslands sown with complex mixtures in the same experimental site from Măgurele-Braşov, for the rational grazing option on 8 plots 6-8 cycles and mowing of unconsumed residues.

Fertilization with chemical fertilizers was 30-60 kg/ha N per grazing cycle, on a background of 50kg/ha P_2O_5 and 50 kg/ha K_2O.

The average level of nitrogen fertilization was 190 kg/ha, at which the contribution brought by animal manure on pasture (Lançon 1978 et al.) and that brought by symbiosis with white clover (Breazu et al. 1987) were also calculated.

The experimental animals, 12-14 month old heifers, were weighed at the beginning of grazing and every two weeks, establishing the yield in live weight gain per animal and area. Before the start of the animal experiments (1973) and at the end of the 3 experiments (1989), soil samples were taken at a depth of 0-20 cm, for agrochemical analyses. Finally, the pastoral value of the temporary meadow with complex mixture was evaluated according to the new method based on floristic survey (Marușca 2019, 2022). The score for the forage value of the species was 9 (very good) for *Festuca pratensis, Lolium perenne, Phleum pratense* and *Dactylis glomerata*, 8 (good) for *Poa pratensis* and *Trifolium repens*, 7 (average) for *Agrostis capillaris, Festuca rubra, Poa annua* and *Taraxacum officinale*, 6 (mediocre) for *Agropyron repens* and the rest of the forage species.

RESULTS AND DISCUSSIONS

Before presenting the results of the influence of use modes on sown meadows, it is necessary to recall the positive or negative effect of animals on the grassy carpet through trampling, grazing and manure (Table 1). The presentation of these effects of the presence of animals on meadows compared to their absence when the green mass crop is mowed is quite suggestive, with some aspects that are more difficult to determine, so we will not insist on the. A first, more visible influence of animals occurs on the botanical composition of the grassy carpet of the grasslands (Table 2).

Thus, the botanical composition after 4 years of experimentation (1974-77) underwent major changes depending on the mode of use.

The lowest participation of the sown species was in the variant harvested by mowing in the hayfield regime where only 65%survived and the highest in the variant grazed with animals and mowed the refuse where 93% participation was recorded compared to the sown mixture. Even more important changes were between the initial components of the sown mixture.

Festuca pratensis from the initial 30% is maintained at 21% by mowing in the hayfield regime and 19% by actual grazing and by mowing more often in the pasture regime only 4-7% remains in the grassy vegetal carpet.

Lolium perenne from 20% increases to 22% in variant 4, normal grazing, and mowed refuse after grazing and between 7-11% in mowed variants (1, 2, 3).

Phleum pratense with 20% initially, is maintained at 19% by mowing in a hayfield regime and 14% by grazing followed by 6-10% in the mowed variants more often, which imitate grazing. *Poa pratensis* from 10% by vegetative propagation increased in all variants by 1.4 times in variant 1 (mowing, hayfield) to 2.4 -3.3 times in the remaining variants.

Table 1

Influence of cattle on pastures

Treading	Grazing	Dung + urine
Positive effects		
- Increase, density of vegetal conveere to a medium trampling - Stimulation of germination of seeds - Destruction of rodent habitat	- higher height of plant harvested, maintained basal leaflet and faster regrowth - stimulation of legumes fixing nitrogen - consumption of weeds useless pasture	- more supply in nutritive elements - maintained agrochemical factors of soils - stimulation of microorganism activity - spreading of seed herbage, especially legumes
Negative effects		
- decline of permeability soil for water and air - stimulation of erosion process on slope land and germination of weed seeds - destruction of vegetal cover as roads, surroundings of shelter, etc.	- partially decline of production due to more frequent cuts - rarer cover due to wrest plants - spreading of weeds uneaten of animals - spreading of specific pests	- feed refusals of ruminants - “stifle” of plants due to dung - “burning” of plants due to urine - super fertilization in stationary sites - spreading of weed seeds and stimulation its development

Trifolium repens from 20% increased to 30% in variant 3 (frequent mowing and trampled by animals) and by barely 4% in variant 1 (hayfield).

Among the spontaneous species *Agropyron repens, Agrostis capillaris* and *Poa annua* have a more significant participation

Table 2

Botanical composition of complex mixture after 4 years and pastoral value of different utilization

Botanical composition	Initial sown mixture (%)	Uses Variant			
		1	2	3	4
		Cutting hay regime	Simulation grazing by cutting	Simulation grazing and animal influence	Grazing with cattle – cutting refusals
Sown species (%)	(100)	(65)	(76)	(80)	(93)
Festuca pratensis	30	21	7	4	19
Lolium perenne	20	7	11	9	22
Phleum pratense	20	19	10	6	14
Poa pratensis	10	14	33	31	24
Trifolium repens	20	4	15	30	14
Spontaneous sp. (%)	(0)	(35)	(24)	(20)	(7)
Agropyron repens	X	11	8	3	1
Agrostis capillaris	X	4	1	1	1
Dactylis glomerata	X	3	+	-	+
Festuca rubra	X	3	+	+	1
Poa annua	X	-	4	11	1

Taraxacum officinale	X	2	5	3	2
Other species	X	12	5	2	1
Pastoral value (ind)	96.6	88.3	88.0	88.7	88.1
% of initial sown	100	91.4	91.1	91.8	91.2

From the point of view of botanical composition, variant 4, grazing with animals, mowing unconsumed residues is the most balanced compared to the proportion of species in the sown mixture.

Another indicator of the grassy carpet was the very good and constant pastoral value that reaches 88-88.7 in all variants, being 8-9% lower than the initial mixture which has an index of 96.6 pastoral value.

The average dry matter (DM) production of the variant mowed in the hay regime reached 11.1 t/ha on average over 4 years and 12-18% lower in the remaining variants (Table 3).

In contrast, crude protein production per hectare is 17-19% higher in variants 2, 3, 4 mowed and grazed more often compared to variant 1, mowed in a hayfield regime, where an average of almost 1900 kg/ha was achieve.

Table 3

Production and quality of sown grassland at different utilization modes

Mode of utilization: -cutting (3-4 cuts/year) - grazing (6-8 cycles/year)	Dry matter		Crude protein (N*6.25)		
	Total t/ha	Relative %	% DM	Total kg/ha	Relative %
Cutting utilization	11.1	100	17.1	1898	100
Simulation grazing by cutting	9.8	88	23.1	2264	119
Simulation grazing-let under cattle influence	9.1	82	24.7	2248	118
Grazing with cattle-cut feed refusals	9.5	86	23.4	2223	117

NB – sown grassland with complex mixtures at Măgurele Brașov

-annual fertilization with chemical fertilizers (250 N, 50 P_2O_5 and 50 K_2O kg/ha).

These exceptional results were also achieved as a result of fertilization with chemical fertilizers, namely 250 kg/ha N applied fractionally at 50 kg/ha per grazing cycle, on a background of 50 kg/ha P2O5 and K2O.Of particular interest is the expression of the productivity of these sown grasslandsin animal production, namely the yield in live weight gain.

To begin with, the average level of fertilization with chemical fertilizers of the 3 experiments and the additional biological input of animal manure and symbiotic fixation are presented (Table 4). From these data it results that fertilization with chemical fertilizers reaches 48% and organic fertilization reaches 52% of the total nutrient elements of 650 kg/ha. Chemical fertilizers in a quantity of 310 kg/ha active substance are composed of 190 N, 60 P2O5 and 60 K2O and organic fertilizers 340 kg/ha of which 79 kg of fertilizer elements from dung, 164 kg of urine and 98 kg from the presence of white clover.

Table 4

Final level fertilization of intensive sown grassland, grazed with young cattle
Măgurele Braşov, 1974-77, 1980-82, 1986-89

Specification	Fertilizers				
	N	P_2O_5	K_2O	Total	%
A. Chemical ferilizers	190	60	60	310	48
B. Natural resources on pasture – TOTAL	196	25	120	341	52
-dung	37	22	20	79	(12)
-urine	61	3	100	164	(25)
- -white clover contribution	98	+	+	98	(15)
TOTAL (A + B)	385	85	180	651	100
Proportion of natural resources %	51	30	67	52	*

Elements to count: ► Dung 1.6 kg DM/day and urine 8 l/day/head
► Mean content: - dung 2.4% N, 1.4% P_2O_5, 1.3% K_2O
-urine: 0.8% N, 0.04% P_2O_5, 1.3% K_2O/l
► Grazing season: 8.5% from 1130 days-head (155 days grazed)
► Mean white clover content: 28%
► Annual quantity N fixed by white clover: 3.5 kg N for 1% white clover
► Fertilizers of rainfalls, those resulted from the mineralization of organic matter and other natural resources were not taken into account.

These data confirm the special role of grazing animals, that of "fertilizer" and of white clover that of "manufacturer" of nitrogen from the atmosphere. These high levels of mineral and organic fertilizers, administered from outside or produced on the pasture, had a main effect on grass production and the yield in live weight gain of sown grasslands (table 5).

Table 5

General date and results from herbage production
and animal performances of sown grassland, Măgurele Braşov

Specification	**U.M.**	**Mean**
Chemical fertilization during grazing with cattle (mean 1l years) *) - N - P_2O_5 - K_2O	kg/ha kg/ha kg/ha	190 60 60
- Dry matter yield grazed	t/ha	9.15
- Stocking rate (Livestock Unit) - Grazing season - Days grazing	L.U./ha days no.	49 154 1127
- Liveweight gain - Rhythm of liveweight	g/head/day kg/ha/day	835 6.1

-	Forage consumption for 1 kg liveweight	kg DM	9.7

*) Grazing season 1974-77, 1980-82, 1986-89.

Thus, the average production over 11 years of the sown complex mixtures reaches 9.15 t/ha dry matter, which in 150-160 days of grazing with an average load of 4.9 LU/ha young bulls achieve 835 g/head, growth, between-4.1 kg/rhythm/6.1 rhythm. kg/ha, with 9.7 kg DM/kg weight gain, more than very economically advantageous.These results only influenced to a small extent the agrochemical constituents in the soil (Table 6).

Table 6

Main agrochemical characteristics of soil pastures

-depth of 0-20 cm-

Specification	UM	Soil pastures		Difference	
		natural (1973)	sown (1989)	+, -	%
Acidification, pH $_{H2O}$	units	5.8	5.8	0	100
Saturation in bases, V_{Ah}	%	73.6	80.0	+ 6.4	109
Humus	%	5.29	4.58	- 0.71	87
N index, IN	-	3.92	3.66	- 0.26	93
Available phosphorus, (P_{Al})	ppm	9.7	26.9	+ 17.2	277
Available potassium (K_{Al})	ppm	129.8	111.4	- 18.4	86

Compared to the initial, at the beginning of these experiments and that at their completion, the soil reaction was contained with pH index 5.8 and other compounds such as humus, N index and potassium have decreases of 7-14% and phosphorus, the supporter of white clover 8th compared to 2 initially.

All these results demonstrate the superiority of grasslands sown with complex mixtures used rationally by grazing animals.

CONCLUSIONS

Referring to sown intensive grassland, utilized by grazing, the ruminants by treading, grazing and dung etc., exert a positive influence and less negative on vegetal cover.

Harvest under cutting had as a consequence the utilization of sown grassland during 4-5 years. Under rational grazing, after the same period, the components of sown mixtures were maintained in proportion of 90%, and the grassland could be utilized economically for a longer period.

Under grazing, 23-24% crude protein was obtained, as compared to 17% CP under cutting. Crude protein yield exceeded 2200 kg/ha under grazing, being 18% higher than that under cutting.

As result of the medium chemical fertilization during 3-4 years under grazing with young cattle, an average of 9.15 t/ha DM and 941 kg/ha live weight gain were obtained, respectively 835 g/head/day during 150-160 days of grazing. he general balance sheet of fertilizing elements on sown grassland, under intensive grazing with cattle, showed that over 50% were natural resources (dung, urine, white clover contribution, etc.), so it is not correctly to report the herbage production or animal performances to chemical fertilizers applied to area unit.

REFERENCES

1. Anghel, Gh., 1984 – Pajişti intensive, Ed. "Ceres"Bucureşti.
2. Breazu I., Georgeta Oprea, Constantina Chiper, 1987 – Contribuţia trifoiului alb la aprovizionarea pajiştilor cu azot, Lucr. Şt. ale ICPCP Măgurele Braşov, vol. XII, Red. de prop. tehnică agricolă, Bucureşti.
3. Daniliuc D., Popovici D., Ciubotariu C., 1988 – Influenţa fertilizării îndelungate cu azot asupra însuşirilor chimice ale solului şi a vegetaţiei, Lucr.şt.ale ICPCP Braşov, vol. XIII, Red. de prop. tehnică agricolă, Bucureşti.
4. Klapp E., 1956 – Wiesen and Weiden. Berlin and Hamburg, Paul Parey.
5. Lançon J., 1978 – Les restitutions du betail au paturage et leur effet, Fourrages no.75 et 76, France.
6. Maruşca Letiţia, 1977 – Influenţa modului de folosire asupra producţiei, compoziţiei floristice şi chimice la câteva tipuri de pajişti temporare (Referat teza de doctorat, Inst. Agr. Cluj).
7. Maruşca T., 1980 – Randamentul în produse animale (spor greutate vie) a conveierelor de pajişti. Lucr.şt.ale SCCP Măgurele Braşov, vol. VI, Red. de prop. tehnică.
8. Maruşca T., Proca M., 1992 – Influenţa folosirii de lungă durată prin păşunat cu taurine a pajiştilor intensive asupra indicilor agrochimici ai unui sol cernoziomoid din Ţara Bârsei, "Realizări şi perspective în zootehnie", vol.XVIII, partea a II-a, U.S.A. Cluj-Napoca.
9. Maruşca T., 2019 – Contributions to the evaluation of pasture productivity, using the floristic releve, Romanian Journal of Grassland and Forage Crops, nr.19, Cluj-Napoca, pp. 33, 47.
10. Maruşca T., 2022 – Praticultură şi pastoralism în cercetarea ştiinţifică, Ed. Universităţii "Transilvania"din Braşov.
11. Proca M., Krauss M., Constantina Chiper, 1984 – Randamentul în spor greutate vie al unor conveiere de pajişti temporare, Lucr. şt. ale ICPCP Măgurele Braşov, vol. IX, Red. de prop. tehnică agricolă, Bucureşti.
12. Simtea N., Maruşca T., Şerban V., 1972 – Ameliorarea pajiştilor din Elveţia. Agricultura pe glob, Ed. "Ceres"Bucureşti.

SUBALPINE GRASSLANDS IMPROVEMENT METHODS DEGRADATION OF NARDUS STRICTA AFTER 30 YEARS OF APPLICATION IN THE CARPATHIAN MOUNTAINS OF ROMANIA

Teodor MARUȘCA *, Marcela MM DRAGOȘ*,, Andreea C. ANDREOIU * , Vasile MOCANU *, Paul M. ZEVEDEI *, Mihai St. COSTESCU***

** Research and Development Institute for Grasslands Brașov, Cucului No. 5*
****** *Corresponding author: marceladragos@yahoo.com*

Abstract
Experiments on the improvement of subalpine grasslands degraded by Nardus stricta through various surface and radical methods were carried out in the Bucegi Mountains at 1800 m altitude in the juniper (Pinus mugo). The paper analyzed the last 3 years (2023-2025) of the 30 experiments, started in 1995. There were no significant differences between the mineral, organo -mineral and organic fertilization factors on the production of dry matter (DM) which reached an average of 2.58-2.63 t/ha and crude protein (CP) which reached 287-305 kg/ha. Overseeding was 4.6% higher than the semi-natural grass carpet and reseeding was 1% lower than the control, for DM production, while for CP production the semi-natural variant was better. The most prolonged and strong effect was had by calcium amendment with very significant results of 21-25% higher than the unamended variants, even after 30 years. In the grassy carpet, improvement methods have produced profound changes in the sense of replacing the unvalued species Nardus stricta with Poa pratensis in the best variants of amendment and organic fertilization. Also, the sown species Phleum pratense survives vegetatively for over 30 years in the grassy carpet without reaching maturity in the subalpine layer of the Carpathians. Three-factorial experiments (3x3x2) applied to permanent grasslands can still provide surprising results as in the present work.

Keywords: *Nardus stricta* grasslands, improvement methods, DM and CP production, longevity

INTRODUCTION

Degraded grasslands of *Nardus stricta* are widespread in the Romanian Carpathians, especially in the mountainous area, where due to improper management and use they have replaced more valuable grasslands dominated *by Festuca nigrescens, Festuca rubra, Agrostis capillaris* and others (PUSCARU *et al*., 1956; SAFTA *et al*., 1962; SAMOILĂ, 1979; MARUȘCA, 1982; BĂRBULESCU and MOTCĂ, 1983). In this research, several methods of improvement were used through surface means, such as fertilization with mineral and organic fertilizers, calcium amendment, herbicides, etc., or radical works to replace the degraded grassy carpet with another more valuable forage by over-seeding or re-seeding with mixtures of perennial grasses. The experiments usually lasted 3-5 years, during which significant results were obtained in increasing feed production and quality. In the middle mountain area, through calcium amendment and mineral or organic fertilization (mulching), in 2-5 years the degraded grassy carpet of *Nardus stricta* gradually evolved towards *Festuca rubra* and further *Agrostis capillaris*, satisfactory stage of evolution (MOTCĂ *et al.*, 1994).

Through total renovation, the productivity of these grasslands is further intensified, the grassy carpet with species from the spontaneous flora being replaced with improved varieties of perennial grasses and legumes (MARUȘCA, 1976, 1977).

This paper presents the long-term effect of calcium amendment, overseeding and reseeding, mineral and organic fertilization, of a *Nardus stricta* grassland under the climatic conditions of the Bucegi Mountains subalpine in the Southern Carpathians.

MATERIAL AND METHOD

Overall results

First, an overview of the results is presented before the analysis of variance considering the very large volume of data.

In this sense, the data of factor A (fertilization) are presented separately on the three graduations: mineral, organo - mineral and organic. The average production of all mineral fertilized variants (100) in 5 stages in 30 years, in the last 3 years was 2.63 t/ha dry matter (DM) and 305 kg/ha crude protein (CP) in which *Agrostis capillaris* dominates (37%), *Festuca nigrescens* (14%), *Poa pratensis* (12%), *Phleum grassland*, sown (6 %) and *Trifolium repens* (5 %) (Table 1).

The semi-natural unamended, mineral-fertilized grassland (111) with the lowest productivity (1.63 t/ha DM and 197 kg/ha CP) after 30 years is dominated by *Festuca nigrescens* (35%) and through total renovation (overseeding, reseeding) the production of DM increases by 59-63% and CP by 41-55%, the floristic composition being dominated by *Agrostis capillaris* (58-59 %) and the sown grassland specie *Phleum pratense* did not survive.

Between the overseeded and reseeded variants (120, 130) there are small differences in DM production (2.82-2.84 t/ha) but higher in CP in the overseeded variants (325 kg/ha) by 10% higher than in the reseeded ones (311 kg/ha). The factor with the greatest effect on productivity after 30 years was calcium amendment (102), when on average a 29% higher DM and 35% higher CP production was achieved compared to unamended variants, a result previously unknown in the literature.

Organo - mineral fertilization (200) had a different influence on the productivity of improved variants of *Nardus stricta* degraded grasslands compared to mineral fertilization (Table 2).

Thus, the highest average production of DM and CP was recorded in the variants with semi-natural grass carpet (210) compared to the over-seeded or re-seeded ones (220, 230) by 16-21%.

Table 1

Average dry matter and crude protein production of mineral fertilized variants (Average 2023-2025)

ABC variants	Production of DM		Forage species (%)					Crude protein (N x 6.25)	
	t/ha	%	1. *Agrostis capillaris*	2. *Festuca nigrescens*	3. *Poa pratensis*	4.* *Phleum pratense*	5. *Trifolium repens*	kg/ha	%
111	1.63	100	6	**35**	2	X	6	197	100
121	2.66	163	**59**	5	2	0	2	305	155
131	2.59	159	**58**	6	0	0	1	277	141
112	2.82	100	8	20	**45**	X	7	360	100
122	2.97	105	**40**	6	10	28	5	345	96
132	3.09	110	**50**	12	11	9	8	344	96
Mediate									
100	2.63	100	**37**	14	12	6	5	305	100
110	2.23	100	7	**28**	24	X	7	279	100
120	2.82	126	**50**	6	6	14	4	325	116
130	2.84	127	**54**	9	6	5	5	311	111
101	2.29	100	**41**	15	1	0	3	260	100
102	2.96	129	**33**	13	22	12	7	350	135

*) Species remaining from the original mixture

The variant with the highest productivity was 212 (semi-natural carpet, amendment) with 3.05 t/ha DM and 352 kg/ha CP, with a botanical composition dominated by *Poa pratensis* (53%) and *Trifolium repens* (28%) very valuable forage.

And in this case, the calcium amendment factor (202) after 30 years ensures an average increase of 15% for both DM and CP compared to the unamended variants (201).

Table 2

Average dry matter and crude protein production of organo-mineral fertilized variants (Average 2023-2025)

ABC variants	Production of DM		Forage species (%)					Crude protein (N x 6.25)	
	t/ha	%	1. *Agrostis capillaris*	2. *Festuca nigrescens*	3. *Poa pratensis*	4.* *Phleum pratense*	5. *Trifolium repens*	kg/ha	%
211	2.75	100	14	7	**53**	X	14	347	100
221	2.18	79	**42**	6	19	12	9	244	70
231	2.31	84	**53**	7	13	7	7	261	75
212	3.05	100	5	3	**53**	X	28	352	100
222	2.83	93	**30**	9	23	17	17	299	85
232	2.44	80	**28**	8	19	9	27	294	84
Mediate									
200	2.59	98.7	29	7	**30**	8	17	299	98.3
210	2.90	100	10	5	**53**	X	21	350	100
220	2.51	87	**36**	8	21	15	13	272	78
230	2.38	82	**41**	8	16	8	17	277	79
201	2.41	100	**36**	7	28	6	10	284	100
202	2.77	115	21	7	**32**	9	24	315	111

*) Species remaining from the original mixture

On the exclusively organically fertilized variants (300), in general, the factors improving grassland productivity behaved the same as those fertilized with organo -mineral fertilizers (200) (Table 3). Organic fertilization favorably influenced the over-seeded variants (320) where a 7% higher DM production was recorded compared to the semi-natural variants (310). Reseeded variants achieve a 6% lower DM production compared to the semi-natural variants, considered as a control. The highest DM production in the entire trifactorial experience is 3.19 t/ha in variant 322 with a balanced botanical composition: *Agrostis capillaris* (37%), *Phleum pratense* (19 %), *Trifolium repens* (19 %), *Poa pratensis* (15%) and *Festuca nigrescens* (5 %). The highest CP production was recorded in variant 312, semi-natural carpet, amended, organically fertilized, 370 kg/ha CP, where *Poa pratensis* (31%) and *Trifolium repens* (30 %) dominates.

The calcium amendment factor (302) ensured the highest increases, respectively 21% in DM and 26% in CP per hectare compared to the unamended one (301).

Table 3

Average dry matter and crude protein production of organically fertilized variants (Average 2023-2025)

ABC variants	Production of DM		Forage species (%)					Crude protein (N x 6.25)	
	t/ha	%	1. *Agrostis capillaris*	2. *Festuca nigrescens*	3. *Poa pratensis*	4.* *Phleum pratense*	5. *Trifolium repens*	Kg/ha	%
311	2.44	100	**33**	10	28	X	14	282	100
321	2.30	94	**48**	9	10	13	12	229	81
331	2.29	94	**48**	12	11	8	9	234	82
312	2.72	100	9	16	**31**	X	30	370	100
322	3.19	117	**37**	5	15	19	19	314	85
332	2.54	93	**39**	9	10	17	15	294	79
Mediate									
300	2.58	98.1	**36**	11	17	10	16	287	94.2
310	2.58	100	21	13	**30**	X	22	326	100
320	2.75	107	**43**	7	13	14	16	272	83
330	2.42	94	**44**	11	11	8	12	264	81
301	2.34	100	**43**	10	16	7	12	248	100
302	2.82	121	**28**	10	19	12	21	326	131

*) Species remaining from the original mixture

These results obtained through quantitative and qualitative determinations on average over 3 years (2023-2025) from the last 30 researches, confirm the results evaluated over 28 years based on floristic surveys on average over 5 years (2019-2023) published in the current journal, where the floristic composition and agrochemical properties of the soil were presented in more detail (MARUȘCA, 2024).

Analysis of variance of dry matter (DM) production

The analysis of variance of the DM production of the trifactorial experience (3x3x2) expressed by the F test is presented in Table 4.

Table 4.

Analysis of variance for dry matter (DM) production

Source of variation	**SSP [SP]**	**Degrees of freedom**	**Amount weighted squares [s ^{2}]**	**Test F**		**Meaning**
				value	**p**	
A	0.0312	2	0.0156	0.129	0.878860	yes
B	0.2795	2	0.1398	1,161	0.320913	yes
C	4.5267	1	4.5267	37,597	0.000000	***
A*B	3.2871	4	0.8218	6,825	0.000160	***
A*C	0.2788	2	0.1394	1,158	0.321807	yes
B*C	0.3908	2	0.1954	1,623	0.206795	yes
A*B*C	1.2792	4	0.3198	2,656	0.042596	*
Error	6.5017	54	0.1204			
Total	16.5751					

*ns p>0.05; * p≤0.05;** p≤0.01;*** p≤0.001*

Similar to the data from the general presentation in tables 1, 2, 3, it is found that factor C (calcium amendment) is assessed as very significant as well as within the interaction between factors A x B (fertilization x grassy carpet), followed by a significant assessment for the interaction between all three factors studied (A x B x C). Factors A and B did not have a statistically significant influence on dry matter production. In order to know the residual effect of the improvement factors of these degraded *Nardus stricta* grasslands their graduations were statistically analyzed (Table 5).

Table 5.

Factor-level variance analysis for DM production, Average 2023-2025

Factor A. Fertilization	**SU**		**Diff . t/ha**	**Meaning**
	t/ha	%		
A1: Mineral (NPK) (100)	**2.63**	**100**	**mt**	
A2: Organo -mineral (PK-Paddocking) (200)	2.59	98.7	- 0.04	ns
A3: Organic (Paddocking) (300)	2.58	98.1	- 0.05	ns
DL 5% = 0.20 t/ha; DL 1% = 0.27; DL 0.1% = 0.53				
Factor B. Grassy carpet	**SU**		**Diff . t/ha**	**Meaning**
	t/ha	%		
B1: Semi-natural (Witness) (010)	**2.57**	**100**	**mt**	
B2: Overseeding (020)	2.69	104.6	0.12	ns
B3: Reseeding (030)	2.54	99.0	- 0.03	ns
DL 5% = 0.20 t/ha; DL 1% = 0.27; DL 0.1% = 0.53				
Factor C. Calcium amendment	**SU**		**Diff . t/ha**	**Meaning**
	t/ha	%		
C1: Unamended (Witness) (001)	**2.35**	**100**	**mt**	
C2: Amended 2/3 Ah (002)	2.85	121.3	0.50	***
DL 5% = 0.16 t/ha; DL 1% = 0.22; DL 0.1% = 0.28				

From these statistical analyses it results that the graduations of factors A and B are not significant at the end of 30 years of influence, with the exception of factor C in which calcium amendment is very significant, ensuring an average increase in DM production of 21.3%. Also, a slight superiority of 4.6% of the overseeded variants b2 (020) compared to the semi-natural variants b1 (010) is noted, as well as a 1% decrease of the reseeded variants, compared to the same control, b1, a fact also found in the evaluation based on floristic surveys (MARUȘCA, 2024).

The graphic expression of the influence of factors A, B, C with their graduations more clearly suggests the long-term effect (Figure 1).

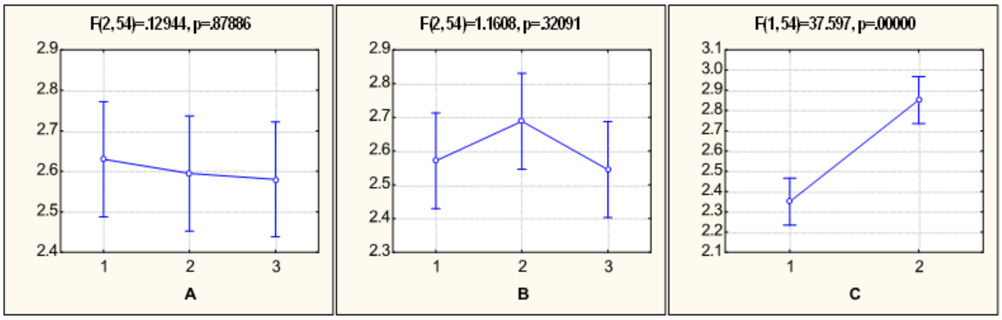


Fig.1. Influence of factors on DM production (t/ha)

A special result is represented by the percentage contribution of the factors and the interaction between them on the production of DM (Figure 2).

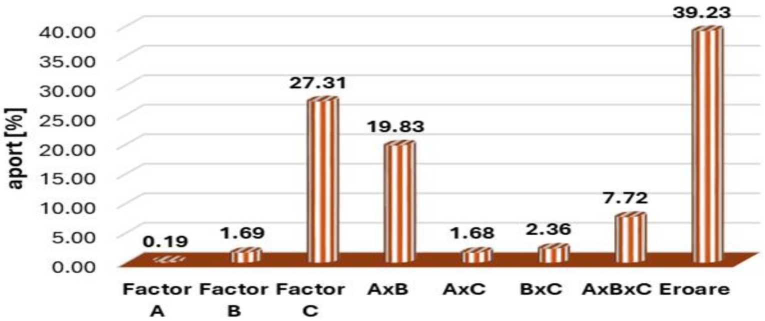


Fig. 2. Contribution of factors and interactions for the production of DM

From this graphic representation, the highest ratio (27.31%) of factor C (amendment) and the interaction A x B (fertilization, overseeding) (19.83%) on DM production is noted.

Analysis of variance of crude protein (CP) production

Similar to DM, analysis of variance was performed for crude protein (Table 6). From these data it follows that factor A (fertilization) and the interaction between A x C are significant and factors B (grass cover) and C (amendment) are highly significant.

Table 6.

Analysis of variance for crude protein (CP kg/ha)

Source of variation	SSP [SP]	Degrees of freedom	Weighted Mean Square [s^2]	Test F value	Test F p	Meaning
A	3976	2	1988	1,139	0.327780	ns
B	16140	2	8070	4,623	0.014020	*
C	78518	1	78518	44,980	0.000000	***
A*B	41678	4	10419	5,969	0.000472	***
A*C	11398	2	5699	3,265	0.045869	*
B*C	3427	2	1713	0.982	0.381295	ns
A*B*C	16948	4	4237	2,427	0.058891	ns
Error	94263	54	1746			
Total	266347					

In order to know the residual effect of the improvement factors of these degraded *Nardus stricta* grasslands on CP/ha, their graduations were statistically analyzed (Table 7).

Table 7.

Factor-level variance analysis for PB production, Average 2023-2025

Factor A. Fertilization	PB kg/ha	PB %	Dif. kg/ha	Meaning
A1: Mineral (NPK) (100)	**305**	**100**	**mt**	
A2: Organo -mineral (PK-Paddocking) (200)	299	98.3	-5	ns
A3: Organic (Paddocking) (300)	287	94.2	-18	ns
DL 5% = 24 kg/ha; DL 1% = 32; DL 0.1% = 42				
Factor B. Grassy carpet	**PB** kg/ha	**PB** %	**Dif. kg/ha**	**Meaning**
B1: Semi-natural (Witness) (010)	**318**	**100**	**mt**	
B2: Overseeding (020)	289	91.0	-29	*
B3: Reseeding (030)	284	89.3	-34	**
DL 5% = 24 kg/ha; DL 1% = 32; DL 0.1% = 42				
Factor C. Calcium amendment	**PB** kg/ha	**PB** %	**Dif.** kg/ha	**Meaning**
C1: Unamended (Witness) (001)	**264**	**100**	**mt**	
C2: Amended 2/3 Ah (002)	330	125.0	66	***
DL 5% = 20 kg/ha; DL 1% = 26; DL 0.1% = 34				

At the level of improvement factors with their residual effect on the amount of CP per hectare, mineral fertilization A (100) was on average 2-6% higher without being significant. In contrast, the semi-natural grassy carpet type B (010) is significantly superior after 30 years to overseeding (020) and distinctly significant to reseeding (030). As expected, the C (002) amendment factor is very significant compared to the non-amendment (001), ensuring a very large increase of 25% CP/ha. For a better understanding of the general influence of factors A, B, C, a graphic expression of them was made (Figure 3).

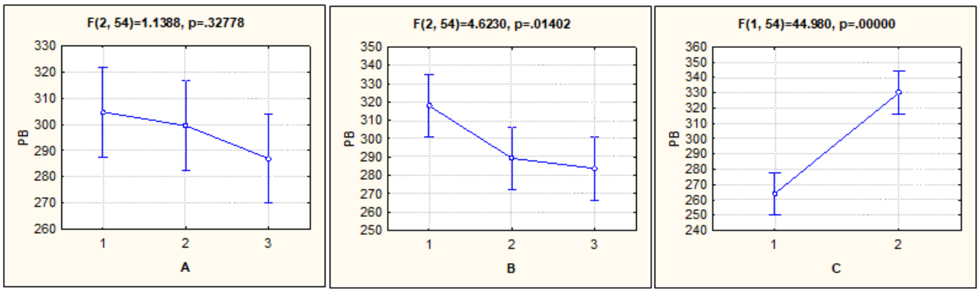


Fig. 3. Influence of factors on CP production (kg/ha)

The percentage contribution of factors and the interaction between them for achieving CP production is another important element resulting from variance analysis.

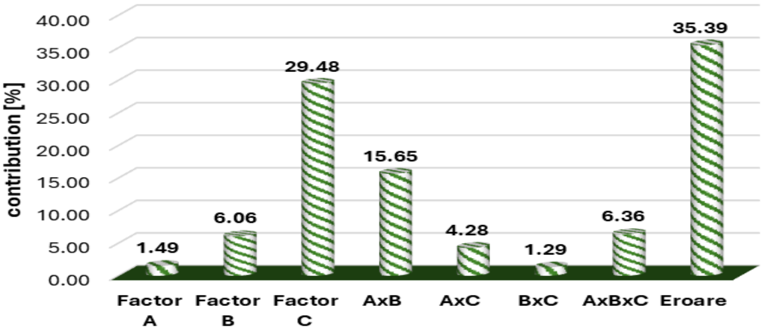


Fig. 4. Contribution of factors and interactions for crude protein (CP kg/ha)

From this graphic representation it results that calcium amendment (C) has the highest contribution (24.48%) followed by A x B with 15.65%, in achieving CP production per hectare, similar to the factors that influence DM production. The results on the long-term influence obtained through quantitative and qualitative determinations in the experimental field and laboratory fully confirmed the previous assessments of green mass production and pastoral value based on floristic surveys, both working methods complement each other.

CONCLUSIONS

The The factors improving subalpine grasslands degraded by *Nardus stricta* have a long-lasting effect on DM (t/ha) and CP (kg/ha) production with major changes in floristic composition.

After 30 years of mineral, organo - mineral and organic fertilization in 5 stages, the best results were obtained with organic fertilization (mulching).

The semi-natural grass carpet type in the last 3 years of the 30 experiments was generally superior to overseeding or reseeding, which have completed their biological lifespan with the exception of the sown species *Phleum pratense* which still survived.

Calcium amendment with lime dust has a very significant effect of 25% greater on the production of DM and CP compared to no amendment, even after 30 years, a fact less known until now.

Fertilization and calcium amendment after 30 years have removed the unvalued species *Nardus stricta,* replacing it with very valuable forage species such as *Poa pratensis, Festuca nigrescens, Agrostis capillaris, Trifolium repens* and others.

REFERENCES

1. Bărbulescu C, Motcă Gh., 1983, *Pășunile munților înalți*, Ed. "Ceres".
2. Marușca T., 1976, *Tehnologia de înființare a pajiștilor semănate după tratarea cu erbicidul Gramoxone a pajiștilor dominate de Nardus stricta*, Lucrări științifice ale SCCP Măgurele Brașov vol. II.
3. Marușca T., 1977, *Sisteme de înființare a pajiștilor temporare pe suprafețele dominate de Nardus stricta,* Lucrări științifice ale SCCP Măgurele Brașov, vol. III
4. Marușca T., 1982, *Studiul geobotanic și tipologic al nardetelor din județul Brașov,* Teza de doctorat, Institutul Agronomic "Nicolae Bălcescu"București.
5. Marușca T**.** 2022, *Praticultură și pastoralism în cercetarea științifică*, Editura Universității Transilvania din Brașov, 311 pagini, ISBN 978-606-19-1565-1
6. Marușca, T., 2024, *Long-term influence of improvement factors of montaneous Nardus stricta grasslands evaluated by floristic survey*. Romanian Journal of Grassland and Forage Crops, 30, 7.
7. Motcă Gh., Oancea I., Geamănu Lidia-Ivona, 1994, *Pajiștile României, Tipologie și tehnologie,* Ed. Tehnică Agricolă, București.
8. Pușcaru D., Pușcaru-Soroceanu Evdochia, Păucă Ana, Șerbănesu I., Beldie Al., Ștefureac Tr., Cernescu N., Saghin F., Crețu V., Lupan L., Tașcenco V., 1956, *Pășunile Alpine din Munții Bucegi,* Edit. Acad. Române, București.
9. Safta I., Pavel C., Pavel A., 1960, *Procedeul Rânca pentru combaterea năgarei (Nardus stricta) și pentru ridicarea productivității pajiștilor de munte,* "Probleme actuale de biologie și științe agricole", Editura Academiei RSR, București.
10. Samoilă Z., (sub coord.), 1979, *Pajiștile din Banat, sporirea producției și îmbunătățirea calităților*, Redacția de propagandă tehnică agricolă, București.

EVALUATION OF DROUGHT RESISTANCE OF SOME GRASSES AND LEGUMES SPECIES GROWN ALONE OR IN MIXTURES, UNDER CLIMATE CHANGE CONDITIONS

Bogdan-Ioan GRIGORAŞ*,, Adrian-Ilie NAZARE*, Mihaela CHIRILĂ*, Vasile VÎNTU*, Costel SAMUIL***

** Ion Ionescu de la Brad Iaşi University of Life Sciences (IULS), 3 Mihail Sadoveanu Alley, 700490 Iași, România*
***Collaborator e-mail address bogdan.grigoras@iuls.ro*

Abstract

Currently, drought is the factor with the most negative influence on spontaneous flora and fauna. By 2100, air temperatures are expected to rise by 1.8°C to 4.0°C. Continuous research is needed on the drought resistance of perennial grasses and leguminous fodder crops. Legumes can be sown in pure culture, but grasses are most often sown in Romania in mixture with legumes. It is therefore necessary to study the drought resistance of pure crops, but especially of mixtures of perennial grasses and legumes. The experiment was conducted at the Ezăreni Farm and studied 10 simple and complex mixtures of perennial grasses and legumes, with 4 levels of fertilization. Romanian varieties with good adaptability to the cultivation conditions in our country were used to set up the experiment.

Keywords: forage mixtures, fertilization, grassland management, landscape, low input.

INTRODUCTION

The effects of climate change are increasingly being felt through long periods of high temperatures above 30°C associated with a lack of rainfall.

Among the fodder plants most affected by these phenomena of drought and aridity are legumes, which suffer during long periods without rainfall. Their increased sensitivity to drought requires continuous research into increasing drought tolerance (Ilić et al., 2025).

Prolonged drought has negative effects on shoot length, biomass yield, and photosynthesis (a process that is halted at high temperatures to prevent water loss), but the symbiotic capacity of Rhizobium sp. bacteria is also diminished, so inoculation with Synthetic microbial communities (SynComs) has been studied to reduce the negative effects of drought on leguminous plants (Shipar et al., 2025).

It is necessary to understand the mechanisms by which alfalfa responds to stress, as this is an essential characteristic for the creation of new varieties with increased drought resistance. It has therefore been concluded that the experiments carried out in the open field are currently insufficient (Daud et al., 2025). Perennial grasses reacted better to drought conditions than perennial legumes. Grasses managed to create a larger number of roots with a diameter between 0 and 1 mm (Wang et al., 2020). Plants respond differently to soil and climate conditions. In the case of *Bromus inermis* L, which was subjected to a prolonged period of drought, both root mass and stolon number were found to increase (Kroeger and Otfinowski., 2025). It was observed that in terms of plant height and number of shoots, drought-tolerant species were less affected compared to species with lower resistance. The decrease in height and number of shoots represents the adaptation of species to water stress conditions, thus reducing water losses through evapotranspiration (Petcu et al., 2019). Drought also has negative effects on protein content, leading to a decrease in the crude protein content of the feed obtained. At the same time, a decrease in NDF and ADF content was also observed (Kuchenmeister et al., 2013). Recent research shows the importance of using salicylic acid on the positive influences on the growth, productivity, and yield of plants subjected to water stress (Melenciuc., 2015).

Another method studied was the application of chemical or organic fertilizers. Following these experiments, an improvement in drought resistance was observed, as well as a reduction in weeds within the vegetation cover that could damage the vegetation cover through high water consumption compared to cultivated plants. Plants gain a greater ability to use nutrients from the soil. The number of beneficial microbes in grasslands also increases (Lewin et al., 2024).

MATERIAL AND METHOD

The experiment was conducted at the Ezăreni educational farm. It is a two-factor experiment. Factor A: a_1 – *Onobrychis viciifolia* Scop. (100%) (control); a_2 – *Onobrychis viciifolia* Scop. (75%) and *Bromus inermis* Leyss. (25%); a_3 – *Onobrychis viciifolia* Scop. (50%) and *Bromus inermis* Leyss. (50%); a_4 - *Onobrychis viciifolia* Scop. (25%) and *Bromus inermis* Leyss. (75%); a_5 – *Medicago sativa* L. (100%); a_6 – *Medicago sativa* L. (75%) and *Festuca pratensis* (25%); a_7 – *Medicago sativa* L. (50%) and *Festuca pratensis* (50%); a_8 – *Medicago sativa* L. (25%) and *Festuca pratensis* (75%); a_9 – *Medicago sativa* L. (20%), *Lotus corniculatus* L. (15%); *Festuca pratensis* (30%); *Lolium perenne* L. (10%) and *Dactylis glomerata* L. (25%). a_{10} – *Onobrychis viciifolia* Scop. (20%), *Lotus corniculatus* L. (15%); *Agropyron pectiniforme* L. (30%); *Bromus inermis* Leyss. (25%) and *Lolium perenne* L. (10%).

Factor B represents the degree of fertilization applied with the following 4 gradations: b_1 – unfertilized (control);

b_2 – $N_{50}P_{50}K_{50}$; b_3 – $N_{75}P_{75}K_{75}$; b_4 – $N_{100}P_{100}K_{100}$.

The harvestable area is 8m^2, measuring 1x9m. The plants used in the experiment are of Romanian origin, with seeds purchased from Research and Development Station for Meadows Vaslui,, N.A.R.D.I Fundulea, and the Research and Development Institute for Grassland Brașov. The geographical coordinates of the Ezăreni farm, which belongs to the "Ion Ionescu de la Brad" University of Life Sciences in Iași, are: 47°5' - 47°10' north latitude and 27°28' - 27°33' east longitude. To assess the drought resistance and regeneration capacity of plants in the field, the Methodology for examining agronomic and utilization value (VAU Test) published by The State Institute for Testing and Registration of Varieties in 2008 was used. Drought resistance was assessed in an unirrigated system after a period of more than 3 weeks of drought. Grades from 1 to 9 were used. Grade 1 represented high drought resistance/tolerance. A score of 9 was assigned to variants with very poor drought resistance/tolerance.

The scale used was as follows: Note 1 - very good resistance - variants in which plants have very good development after mowing (100%); Note 3 - good resistance, plants with good development after mowing (75%); Note 5 - medium resistance, plants with medium development after mowing (50%); Note 7 - poor resistance, plants with poor development after mowing (25%); Note 9 – very poor resistance, plants that do not regenerate after mowing.

The assessment of regeneration capacity is expressed in grades from 1 to 9, as follows: Note 1 ->135% – very good regeneration capacity, Note 2 (126-135%) – good to very good regeneration capacity; Note 3 (116-125%) – good regeneration capacity; Note 4 (106-115%) – good to medium regeneration capacity; Note 5 (96-105%) – medium regeneration capacity; Note 6 (86-95%) - average to poor regeneration capacity; Note 7 (76-85%) - poor regeneration capacity; Note 8 (65-75%) - poor to very poor regeneration capacity; Note 9 (< 65%) - very poor regeneration capacity. To determine these two indices, measurements were taken in the field on 10 plants from the control variant and 10 plants from each of the other variants.

RESULTS AND DISCUSSIONS

Drought resistance (on a scale of 1 to 9) was assessed after the first mowing, during a period of prolonged drought. In this context, drought resistance scores were assigned simultaneously with the assessment of plant regeneration capacity. Species grown in monoculture or in mixtures that, after the period of intense drought, showed normal growth 2–3 weeks after mowing were considered to have good resistance and received scores close to 1, while species with reduced regeneration were scored closer to 9. Drought resistance was assessed for *Onobrychis viciifolia* and *Medicago sativa*, grown either alone or in simple and complex mixtures, under different conditions of fertilization with complex mineral fertilizers based on nitrogen, phosphorus, and potassium (Table 1).

The interaction between the species or mixture of perennial grasses and legumes and mineral fertilization in the second year of vegetation showed that the scores obtained varied between 3.3 and 6, depending on the species (or mixture) and fertilization. In the control variant (a_1b_1 – *Onobrychis viciifolia* 100%, unfertilized), the species grown alone showed good drought resistance, with approximately 75% of the plants developing properly after mowing, with scores between 3.3 and 4, depending on fertilization (Table 1).

Regarding the drought resistance of the species, the best emergence and development after drought was recorded in variant a_5 – *Medicago sativa* (100%), regardless of fertilization. Thus, the species grown alone on mineral soil or unfertilized received a constant score of 3.3 in all variants studied (Table 1). For this parameter, the differences from the control variant were insignificant, significant, and very significant, depending on the species and mixture (Table 1).

In parallel with the assessment of drought resistance, in the second year of vegetation, the regeneration capacity of plants after the first mowing was also determined, rated on a scale from 1 to 9 (1 – very good, 9 – very poor), 10–15 days after mowing I.

For the species *Onobrychis viciifolia* and *Medicago sativa*, grown either in monoculture or in simple and complex mixtures, under different conditions of fertilization with complex mineral fertilizers based on nitrogen, phosphorus, and potassium, the regeneration capacity of plants after the first mowing was evaluated (Table 2).

Analysis of the interaction between species or mixture and mineral fertilization showed that the scores obtained ranged from 3.3 to 6, depending on the species, type of mixture, and fertilization variant.

In the control variant (a_1b_1 – *Onobrychis viciifolia* 100%, unfertilized), the species *Onobrychis viciifolia* grown alone showed the best regeneration capacity (medium to good), with scores between 3.3 and 4.7, depending on the fertilization treatment (Table 2).

Regarding the regeneration capacity of plants, both in monoculture and in mixtures of two or more species in different proportions, good regeneration was recorded in variant a5 – *Medicago sativa* (100%), regardless of fertilization.

Table 1

The influence of the interaction between the species or mixture of perennial grasses and legumes and mineral fertilization on drought resistance in the second year of vegetation (scores from 1 to 9)

Variant*		**Drought resistance**	**Difference**		**Significance**
		Note	**Note**	**%**	
		Control: a_1b_1 - *O.v.* (100%), unfertilized			
a_1 - *O.v.* (100%) (mt.)	b_1 - unfertilized (mt.)	3,3	Control	100	Control
	b_2 - $N_{50}P_{50}K_{50}$	4,0	0,7	120,0	
	b_3 - $N_{75}P_{75}K_{75}$	4,0	0,7	120,0	
	b_4 - $N_{100}P_{100}K_{100}$	4,0	0,7	120,0	
a_2 - *O.v.* (75%) + *B.i.* (25%)	b_1 - unfertilized	5,7	2,3	170,0	***
	b_2 - $N_{50}P_{50}K_{50}$	5,7	2,3	170,0	***
	b_3 - $N_{75}P_{75}K_{75}$	5,7	2,3	170,0	***
	b_4 - $N_{100}P_{100}K_{100}$	5,7	2,3	170,0	***
a_3 - *O.v.* (50%) + *B.i.* (50%)	b_1 - unfertilized	6,0	2,7	180,0	***
	b_2 - $N_{50}P_{50}K_{50}$	6,0	2,7	180,0	***
	b_3 - $N_{75}P_{75}K_{75}$	6,0	2,7	180,0	***
	b_4 - $N_{100}P_{100}K_{100}$	6,0	2,7	180,0	***
a_4 - *O.v.* (25%) + *B.i.* (75%)	b_1 - unfertilized	4,0	0,7	120,0	
	b_2 - $N_{50}P_{50}K_{50}$	4,0	0,7	120,0	
	b_3 - $N_{75}P_{75}K_{75}$	4,0	0,7	120,0	
	b_4 - $N_{100}P_{100}K_{100}$	4,0	0,7	120,0	
a_5 - *M.s.* (100%)	b_1 - unfertilized	3,3	0,0	100,0	
	b_2 - $N_{50}P_{50}K_{50}$	3,3	0,0	100,0	
	b_3 - $N_{75}P_{75}K_{75}$	3,3	0,0	100,0	
	b_4 - $N_{100}P_{100}K_{100}$	3,3	0,0	100,0	
a_6 - *M.s.* (75%) + *F.p.* (25%)	b_1 - unfertilized	5,0	1,7	150,0	**
	b_2 - $N_{50}P_{50}K_{50}$	5,0	1,7	150,0	**
	b_3 - $N_{75}P_{75}K_{75}$	5,0	1,7	150,0	**
	b_4 - $N_{100}P_{100}K_{100}$	5,0	1,7	150,0	**
a_7 - *M.s.* (50%) + *F.p.* (50%)	b_1 - unfertilized	5,3	2,0	160,0	**
	b_2 - $N_{50}P_{50}K_{50}$	5,3	2,0	160,0	**
	b_3 - $N_{75}P_{75}K_{75}$	5,3	2,0	160,0	**
	b_4 - $N_{100}P_{100}K_{100}$	5,3	2,0	160,0	**
a_8 - *M.s.* (25%) + *F.p.* (75%)	b_1 - unfertilized	4,3	1,0	130,0	
	b_2 - $N_{50}P_{50}K_{50}$	4,3	1,0	130,0	
	b_3 - $N_{75}P_{75}K_{75}$	4,3	1,0	130,0	
	b_4 - $N_{100}P_{100}K_{100}$	4,3	1,0	130,0	
a_9 - *M.s.* (20%) + *L.c.* (15%) + *F.p.* (30%) + *L.p.* (10%) + *D.g.* (25%)	b_1 - unfertilized	5,0	1,7	150,0	**
	b_2 - $N_{50}P_{50}K_{50}$	5,0	1,7	150,0	**
	b_3 - $N_{75}P_{75}K_{75}$	5,0	1,7	150,0	**
	b_4 - $N_{100}P_{100}K_{100}$	5,0	1,7	150,0	**
a_{10} - *O.v.* (20%) + *L.c.* (15%) + *A.p.* (30%) + *B.i.* (25%) + *L.p.* (10%)	b_1 - unfertilized	5,7	2,3	170,0	***
	b_2 - $N_{50}P_{50}K_{50}$	5,7	2,3	170,0	***
	b_3 - $N_{75}P_{75}K_{75}$	5,7	2,3	170,0	***
	b_4 - $N_{100}P_{100}K_{100}$	5,7	2,3	170,0	***
		LSD 5%	1,3		
		LSD 1%	1,7		
		LSD 0,1%	2,2		

* *Onobychis viciifolia (O.V.); Bromus inermis (B.i.); Medicago sativa (M.s.); Festuca pratensis (F.p.); Lolium perenne (L.p.); Lotus corniculatus (L.c.); Dactylis golomerata (D.g.); Agropyron pectiniforme (A.p.)*

Thus, the species cultivated alone on mineral soil, but also in the unfertilized variant, showed good to medium regeneration, consistently rated at 4.0 in all variants analyzed (Table 2). In the case of the simple mixture of *Onobrychis viciifolia* (50%) + *Bromus inermis* (50%), the plants showed the lowest regeneration capacity (medium to poor), with scores between 5 and 6. For this parameter, the differences from the control variant were, in most cases, negatively significant, but in some variants there were positively significant and distinctly significant differences for all species and mixtures analyzed (Table 2).

Table 2

The influence of the interaction between the species or mixture of perennial grasses and legumes and mineral fertilization on the regeneration capacity of plants after the first cut, in the second year of vegetation (scores from 1 to 9)

Variant*		**Regenerative capacity**	**Difference**		**Significance**
		Note	**Note**	**Meaning**	
		Control: a_1b_1 - *O.v.* (100%), unfertilized			
a_1 - *O.v.* (100%) (mt.)	b_1 - unfertilized (mt.)	4,7	Control	100	Control
	b_2 - $N_{50}P_{50}K_{50}$	3,3	-1,3	71,4	o
	b_3 - $N_{75}P_{75}K_{75}$	3,3	-1,3	71,4	o
	b_4 - $N_{100}P_{100}K_{100}$	3,3	-1,3	71,4	o
a_2 - *O.v.* (75%) + *B.i.* (25%)	b_1 - unfertilized	5,3	0,7	114,3	
	b_2 - $N_{50}P_{50}K_{50}$	4,7	0,0	100,0	
	b_3 - $N_{75}P_{75}K_{75}$	4,7	0,0	100,0	
	b_4 - $N_{100}P_{100}K_{100}$	4,7	0,0	100,0	
a_3 - *O.v.* (50%) + *B.i.* (50%)	b_1 - unfertilized	6,0	1,3	128,6	*
	b_2 - $N_{50}P_{50}K_{50}$	5,0	0,3	107,1	
	b_3 - $N_{75}P_{75}K_{75}$	5,0	0,3	107,1	
	b_4 - $N_{100}P_{100}K_{100}$	5,0	0,3	107,1	
a_4 - *O.v.* (25%) + *B.i.* (75%)	b_1 - unfertilized	5,3	0,7	114,3	
	b_2 - $N_{50}P_{50}K_{50}$	3,7	-1,0	78,6	
	b_3 - $N_{75}P_{75}K_{75}$	3,7	-1,0	78,6	
	b_4 - $N_{100}P_{100}K_{100}$	3,7	-1,0	78,6	
a_5 - *M.s.* (100%)	b_1 - unfertilized	4,0	-0,7	85,7	
	b_2 - $N_{50}P_{50}K_{50}$	4,0	-0,7	85,7	
	b_3 - $N_{75}P_{75}K_{75}$	4,0	-0,7	85,7	
	b_4 - $N_{100}P_{100}K_{100}$	4,0	-0,7	85,7	
a_6 - *M.s.* (75%) + *F.p.* (25%)	b_1 - unfertilized	6,0	1,3	128,6	*
	b_2 - $N_{50}P_{50}K_{50}$	4,3	-0,3	92,9	
	b_3 - $N_{75}P_{75}K_{75}$	4,3	-0,3	92,9	
	b_4 - $N_{100}P_{100}K_{100}$	4,3	-0,3	92,9	
a_7 - *M.s.* (50%) + *F.p.* (50%)	b_1 - unfertilized	6,3	1,7	135,7	**
	b_2 - $N_{50}P_{50}K_{50}$	4,7	0,0	100,0	
	b_3 - $N_{75}P_{75}K_{75}$	5,0	0,3	107,1	
	b_4 - $N_{100}P_{100}K_{100}$	5,0	0,3	107,1	
a_8 - *M.s.* (25%) + *F.p.* (75%)	b_1 - unfertilized	5,0	0,3	107,1	
	b_2 - $N_{50}P_{50}K_{50}$	4,0	-0,7	85,7	

	b3 - $N_{75}P_{75}K_{75}$	4,0	-0,7	85,7	
	b4 - $N_{100}P_{100}K_{100}$	4,7	0,0	100,0	
a9 - *M.s.* (20%) + *L.c.* (15%) + *F.p.* (30%) + *L.p.* (10%) + *D.g.* (25%)	b1 - unfertilized	4,3	-0,3	92,9	
	b2 - $N_{50}P_{50}K_{50}$	4,0	-0,7	85,7	
	b3 - $N_{75}P_{75}K_{75}$	4,0	-0,7	85,7	
	b4 - $N_{100}P_{100}K_{100}$	4,0	-0,7	85,7	
a10 - *O.v.* (20%) + *L.c.* (15%) + *A.p.* (30%) + *B.i.* (25%) + *L.p.* (10%)	b1 - unfertilized	5,7	1,0	121,4	
	b2 - $N_{50}P_{50}K_{50}$	4,7	0,0	100,0	
	b3 - $N_{75}P_{75}K_{75}$	4,7	0,0	100,0	
	b4 - $N_{100}P_{100}K_{100}$	4,7	0,0	100,0	
		DL 5%	1,2		
		DL 1%	1,5		
		DL 0,1%	2,0		

* *Onobychis viciifolia (O.V.); Bromus inermis (B.i.); Medicago sativa (M.s.); Festuca pratensis (F.p.); Lolium perenne (L.p.); Lotus corniculatus (L.c.); Dactylis golomerata (D.g.); Agropyron pectiniforme (A.p.)*

CONCLUSIONS

In terms of species resistance to drought, both in pure culture and in mixtures of two or more species in different proportions, the highest tolerance to water deficit was recorded in variant a_5– *Medicago sativa* (100%), regardless of the fertilization treatment applied. Thus, for the *Medicago sativa* species grown in monoculture, both on mineral soil and in the unfertilized variant, drought resistance was consistently rated 3.3 in all variants analyzed.

According to the results obtained, in the second year of vegetation, good drought resistance, accompanied by satisfactory plant regeneration after mowing (75%), was recorded in the single-cultured species *Onobrychis viciifolia* (100%) and *Medicago sativa* (100%). Along with the assessment of drought resistance, in the second year of vegetation, the capacity of plants to regenerate after the first mowing was also determined, rated on a scale from 1 to 9 (1 – very good, 9 – very poor), 10–15 days after mowing I.

The analysis of the influence of the interaction between the species or mixture of perennial grasses and legumes and mineral fertilization on this parameter in the second year of vegetation showed that the values obtained varied between 3.3 and 6, depending on the species, type of mixture, and fertilization. In the control variant (a1b1 – *Onobrychis viciifolia* 100%, unfertilized), the species *Onobrychis viciifolia* grown alone showed the best regeneration capacity (medium to good), with values between 3.3 and 4.7, depending on the fertilization variant.

Acknowledgments

This work is a part of a research project supported by a grant from This research was supported by Ministry of Agriculture and Rural Development, project number ADER 15.2.2. No. 09/08/2023.

REFERENCES

1. Daud, M., Xu, S., Qiao, H., Hui, X., Adil, M., and Lu, Y. (2025). Understanding abiotic stress in alfalfa: physiological and molecular perspectives on salinity, drought, and heavy metal toxicity. *Frontiers in Plant Science, 16*, 1627599.
2. Ilić, A., Uhlarik, A., and Mamlić, Z. (2025). Drought Stress and Production of Legumes in Europe. In *Marker-Assisted Breeding in Legumes for Drought Tolerance* (pp. 77-105). Singapore: Springer Nature Singapore.
3. Kroeger, N. E., and Otfinowski, R. (2025). Adaptive root morphology as a drought response in *Bromus inermis*. *Plant and Soil*, *510*(1), 407-420.
4. Kuchenmeister, K., Kuchenmeister, F., Kayser, M., WRAGE, M. N., and Isselstein, J. (2013). Influence of drought stress on nutritive value of perennial forage legumes.
5. Lewin, S., Schaller, J., Kolb, S., and Francioli, D. (2024). Amorphous silica fertilization ameliorated soil properties and promoted putative soil beneficial microbial taxa in a wheat field under drought. *Applied Soil Ecology*, *196*, 105286.
6. Melenciuc, M. (2015). Efectul acidului salicilic asupra procesului de adaptăre a plantelor la secetă. *Buletinul Academiei de Ştiinţe a Moldovei. Ştiinţele vieţii*,*327*(3), 75-83.
7. Petcu, E., Schitea, M., Drăgan, L., and Băbeanu, N. (2019). Physiological response of several alfalfa genotypes to drought stress. *Rom Agric Res*, *36*, 107-118.
8. Shipar, S. I., Austin, T., Sikder, M. M., Ofoe, R., Abbey, L., Mátyás, C., and Lumactud, R. A. (2025). Stress-adapted bacterial synthetic community enhances drought resilience and recovery in alfalfa.
9. Wang, G., Liu, S., Fang, Y., and Shangguan, Z. (2020). Adaptive changes in root morphological traits of Gramineae and Leguminosae seedlings in the ecological restoration of the semiarid region of northwest China. *Land Degradation and Development*,*31*(16), 2417-2429.
10. ***Metodologia examinării valorii agronomice şi de utilizare (Testul VAU), 2008.

THE EFFECT OF DIFFERENT TYPES OF CHEMICAL FERTILIZERS ON THE GERMINATION OF SEEDS IN HERB MIXTURES FOR RENATURATION AND ANTI-EROSION PROTECTION

Teodor MARUȘCA, Monica Alexandrina TOD

Research-Development Institute for Grasslands, Brașov
email: maruscat@yahoo.com

Abstract

Seeds from 4 grass species (Bromus inermis, Festuca pratensis, Lolium perenne, Phleum pratense), 3 perennial legumes species (Lotus corniculatus, Onobrychis viciifolia, Trifolium repens) and a cereal (Hordeum distichon) were mixed with 10 different chemical fertilizers and germination was determined after 90, 180 and 270 days. The chemical fertilizers had different influence upon the seed germination. The most aggressive were the ammonium sulphate and concentrate superphosphate and the harmless were the potassium salt and urea. The fertilizers effect is determinate by their acidity and other factors which will be studied on. Among the species there are great germination differences due to the morphological and physiological characteristics. The most consistent are barley and perennial ryegrass and the most affected by the contact with the fertilizer are the sainfoin and the timothy. Generally, the grasses are more resistant than the legumes. The result proves the possibilities of the achievement of complex mixtures, seeds-chemical fertilizer, with a known viability, for the antierozionale protection – dry variant or hydro sowings – and other utilization.

Keywords: *Compatibility of grass seeds - chemical fertilizers, contact time, germination effect.*

INTRODUCTION

The reseeding or overseeding of grasslands degraded by erosion (Motoc and colab.1975, Dumitrescu and colab.1979) and other lands devoid of vegetation (Marusca,1995,2007, Marusca and colab.2000 5, 6) constitutes a major problem with particular implications for preserving the ecological and economic balance, with the integrity of the natural and anthropogenic landscape. The improvement of current methods of grassing is possible by using complex mixtures between perennial grasses and chemical fertilizers through which, in a single administration, both the seeds and the nutrients necessary for the rapid establishment and consolidation of the grass carpet are provided in the harshest environmental and applicability conditions (Marușca., 1991, 1995, 2007, Marușca and colab. 1990, 2009, 2020, 2021). Preliminary research on the possibilities of creating seed mixtures with ammonium nitrate or complexes (15-15-15) has highlighted the need to store them in dry, tightly closed conditions to prolong germination and their shelf life ((Marușca. and colab., 1990). In this paper, studies are continued on the formation of complex seed-fertilizer mixtures, with deadlines for preserving the germination of perennial grasses and legumes in direct contact with the main types of chemical fertilizers in order to broaden the area of applicability of anti-erosion protection grasses of degraded meadows or other surfaces devoid of grassy vegetation such as tailings dumps, flotation, ores, slag and ash, etc. in different pedoclimatic conditions in our country. Following these preliminary studies on the compatibility between mineral fertilizers and seeds in complex mixtures for sowing, anti-erosion vegetation after land improvement works (slopes, canals, etc.) (Maruşca, 1995), industrial dumps such as slag and ash deposits from thermal power plants (Maruşca et al., 2000, 2009, 2021), mining tailings dumps (Maruşca and colab. 2020) and ski slopes (Maruşca, 2007) were successfully renatured.

MATERIAL AND METHOD

The seeds of 4 perennial grasses (*Bromus inermis, Festuca pratensis, Lolium perenne, Phleum pratense*), 3 perennial legumes (*Lotus corniculatus, Onobrychis viciifolia, Trifolium repens*) and winter barley (*Hordeum distichon*) were studied and were maintained in these conditions with 10 types of chemical fertilizers for a duration of 3, 6 and 9 months of direct contact, after which analyses were performed on the energy and germination capacity of the seeds according to the usual methods (Marușca, 1990, 1988).

When choosing the seeds, their adaptation to different climate and trophic conditions was taken into account, such as obsiga and sainfoin for warmer-drier areas, timothy and tifoli for wetter, cooler areas, as well as ryegrass with white clover with higher demands for soil fertility. The introduction of winter barley is motivated by its faster rooting, which serves to fix the superficial layer of soil until the emergence and consolidation of the protective grassy carpet (Maruşca, 1995). The main types of chemical fertilizers produced in our country were: simple nitrogenous (ammonium nitrate, nitrolime, ammonium sulfate, urea), phosphate (concentrated superphosphate), potash (potassium salt), binary complexes (27.0-13.5-0 and 22-22-0) and ternary complexes (22-11-11 and 16-16-16), which practically cover almost all the fertilization needs of soils from acidic to alkaline with different degrees of supply in nutrients. Also, the possibilities of renaturing industrial dumps were taken into account, which have a very wide range of substrates from very acidic ones (non-ferrous ore flotation sands, pyrite ashes, etc.) to basic or alkaline ones (slag and ashes from coal-fired power plants) and many other conditions and situations of surfaces stripped of vegetation, generating air, water, soil, landscape pollution, etc., which require urgent ecological restoration, according to European standards.

In forming the mixture samples for analysis, several principles were respected, namely:
- sample size calculated for an area of 10 m2;
- perennial grass seeds in double quantity compared to the norm per hectare in pure culture and for barley a norm of 50 kg/ha;
- chemical fertilizers calculated at the level of 100 kg/ha N for simple nitrogenous, binary and ternary ones, as well as 100 kg/ha P2O5 or K2O only for simple ones with these active principles.

The seed mixtures with perfectly dry fertilizers were kept in tightly closed plastic bags, so as to prevent air and humidity from entering, as the hygroscopicity of chemical fertilizers is known. The samples thus packaged were kept in a dry store from where, at the established deadlines, a set of bags were opened, the seeds from the chemical fertilizers were separated by various methods (sieving, selection, etc.), after which the usual germination analyses were carried out in the Seed Control Laboratory in Braşov. For the chemical fertilizers, their acidity value was established expressed as % HNO3, % H2SO4, % HCl and % P2O5, depending on the type of fertilizer, as well as the pH in aqueous extract (5 g/l liter) according to the current methods at OSPA Braşov .

RESULTS AND DISCUSSIONS

The influence of chemical fertilizer types over time on the germination of perennial grass and grassy cereal (barley) seeds is presented in Table 1.

Thus, the control variants, without chemical fertilizers, have an average germination of 86%, which is reduced by 1% after 270 days. In direct contact with urea and potassium salt, after 90 and 180 days the seeds maintain their germination intact like the control variant and with a slight average decrease of 1-3% after 270 days.

The most “aggressive” chemical fertilizers proved to be ammonium sulfate and concentrated superphosphate, which after 90 days reduce seed germination by 19-21%, at 180 days by 53-58% and after 270 days by 68-71% of the 86%, which represents the average initial germination.

Ammonium nitrate, C 16-16-16 complexes, C 22-22-0 and nitrolim after 270 days of direct and sealed contact with the seeds have a medium influence on germination (-16…-24%). At 180 days, these types of fertilizers reduce average germination by 9% (-7….-11%), and at 90 days by only 2% (-1…-3). Also, a big influence on germination (-27…-33%) after 270 days is had by C 27-13-0 fertilizers, followed by C 22-11-11, with an average effect (-10…-21%) after 180 days and a smaller one (-1…-7%) after 90 days of contact. With the exception of ammonium sulfate and concentrated superphosphate, which at 90 days of contact reduce the average germination of seeds by about 20%, the remaining types of chemical fertilizers affect germination less at this time (90 days) or after 180 days, some even after 270 days.

Table 1

The influence of different types of chemical fertilizers over time on the germination (G) of perennial grass and grassy cereal seeds

Types of Chemical Fertilizers No Fertilizers (Mt)	Seed germination after contact with chemical fertilizers (days)									G loss limit below 20% (days)
	90			180			270			
	G%	Diff.	%	G%	Dif.	%	G%	Dif.	%	
Ammonium Nitrate	86	0	100,0	86	0	100,0	85	-1	98,5	-
Nitrolime	85	-1	98,5	79	-7	91,3	69	-16	80,6	270
Ammonium Sulphate	83	-3	96,1	75	-11	87,5	61	-24	70,6	180
Urea	67	-19	77,9	28	-58	32,6	14	-71	16,5	0
Concentrated Superphosphate	86	0	100,1	86	0	100,3	82	-3	96,3	270
Potassium Salt	65	-21	75,6	33	-53	38,4	17	-68	20,0	0
Types of Chemical	86	0	100,4	86	0	100,4	84	-1	98,4	270
C (complexes) 27-13-0	85	-1	98,3	76	-10	87,9	52	-33	60,7	180
C 22-22-0	85	-14	98,5	79	-7	91,9	63	-22	74,0	180
C 22-11-11	79	-7	91,4	65	-21	76,0	58	-27	68,1	90
C 16-16-16	84	-2	98,0	77	-9	90,0	68	-17	80,3	270

In order to elucidate one of the main causes of the influence of different types of chemical fertilizers, chemical analyses were performed on their acidity, given the known harmful effect of this factor on seed germination (table 2).

Table 2

Acidity valuesof chemical fertilizer types in aqueous extract, 5 g/1 liter

Types of chemical fertilizer	**Acidity expression**	**Acidity value**	**pH aqueous extract**
Ammonium nitrate	% HNO_3	3,62	5,10
Nitrolime	% HNO_3	2,95	7,15
Ammonium sulfate	% H_2SO_4	39,39	1,60
Urea	% HNO_3	0,13	5,45
Concentrated superphosphate	% P_2O_5	36,28	3,30
Potassium salt	% HCl	0,30	4,05
C 27-13-0	% P_2O_5	10,11	5,15
C 22-22-0	% P_2O_5	8,79	5,40
C 22-11-11	% P_2O_5	10,70	5,20
C 16-16-16	% P_2O_5	10,99	5,45

Thus, the acidity value is extremely high in concentrated superphosphate (56.28% P2O5) and ammonium sulfate (39.39% H2SO4) with a pH in H2O of 3.3 and 1.6 respectively, which explains the very strong influence (class I) on the decrease in seed germination. average acidity value of 3-4% (class III) and those with a value below 1% (class IV), which are almost harmless or have a very low effect on seed germination. In order are fertilizers with an acidity value of around 10% with different ways of expression that have a fairly large influence (class II), which includes complex chemical fertilizers, followed by fertilizers with an This class of values of the influence of chemical fertilizers on seed germination was inspired by and is similar to the acute toxicity classes of pesticides, unanimously accepted internationally. Regarding the average germination of various species of perennial grasses and barley to chemical fertilizers in class II - IV of "aggressiveness", a differentiated degree of compatibility is observed depending on the morphology and physiology of the seeds (table 3). Thus, after 90 days of contact with chemical fertilizers, non-arrested fescue and perennial ryegrass even have a 1% increase in germination, a phenomenon explainable by the presence of fertilizer particles on the seeds, which can stimulate germination energy, or by normal deviations from the average of germination determinations (4). A more pronounced decrease in germination is seen in seeds in pods of sainfoin and the more naked seeds of timothy, being quite difficult to explain on morphological criteria the causes of sensitivities to contact with chemical fertilizers. The results obtained allow the formulation of complex mixtures of seeds with chemical fertilizers for different pedoclimatic conditions and known shelf life (use) (table 4).

Table 3

Germination of some perennial grass and grassy cereal seeds after different periods of contact with chemical fertilizers (without ammonium sulfate and concentrated superphosphate) from sealed dry mixtures

Species	Initial germination (G%)	Duration of contact with chemical fertilizers (days)									Limit of G losses below 20% (days)
		90			**180**			**270**			
		G%	**Diff.**	**%**	**G%**	**Diff.**	**%**	**G%**	**Diff.**	**%**	
Bromus inermis	92	93	+1	100,7	91	-1	98,8	89	-3	97,0	270
Festuca pratensis	95	95	0	100,4	92	-3	96,7	87	-8	91,8	270
Lolium perenne	94	95	+1	100,7	94	0	99,5	91	-3	96,7	270
Phleum pratense	94	88	-6	93,5	84	-10	89,2	59	-35	63,0	180
Lotus corniculatus	64	61	-3	95,3	52	-12	81,1	41	-20	63,5	180
Onobrychis viciifolia	77	72	-5	92,9	53	-24	68,7	32	-45	41,6	90
Trifolium repens	76	73	-3	95,9	66	-10	86,2	48	-28	63,5	180
Hordeum distichon	96	96	0	100,1	93	-3	97,3	92	-4	95,4	270
Average	86	84	-2	97,8	78	-8	90,8	67	-19	78,5	-

These preliminary studies allowed the classification of chemical fertilizer types according to their acidity values into 4 groups of incompatibility with seeds in complex mixtures.

Table 4

Possibilities for formulating complex seed mixtures with chemical fertilizers

Degree of incompatibility (acidity values)	Group I (over 20%)			Group II (11-20%)			Group III (1-10%)			Group IV (below 1%)		
Types of chemical fertilizers	▲ammonium sulfate ▲concentrated superphosphate			▲complex C 27-13-10 ▲C 22-11-11 ▲C 16-16-16			▲ammonium nitrate ▲nitrolime ▲C 22-22-0			▲potassium salt ▲urea		
Mixture validity *) duration days	90	180	270	90	180	270	90	180	270	90	180	270
Seeds *Bromus inermis*	0	0	0	+	+	0	+	+	+	+	+	+
Festuca pratensis	0	0	0	+	+	0	+	+	+	+	+	+
Lolium perenne	+	0	0	+	+	+	+	+	+	+	+	+
Phleum pratense	0	0	0	+	0	0	+	+	0	+	+	+
Lotus corniculatus	+	+	0	+	+	0	+	+	0	+	+	+
Onobrychis viciifolia	0	0	0	+	0	0	+	0	0	+	+	+
Trifolium repens	+	+	+	+	+	0	+	+	0	+	+	+
Hordeum distichon	+	0	0	+	+	+	+	+	+	+	+	+
% by total species	50	25	12	100	75	25	100	87	60	100	100	100

*) Calculate for a maximum 20% reduction in seed germination compared to the initial one.

After determining the acidity of a chemical fertilizer, it falls into the respective group where the duration of validity of a mixture with a seed species from the presented list is indicated. Complex seed-fertilizer mixtures can be used as such by spreading on the soil surface and manual incorporation, mechanized sowing and fertilization with seeders adapted for this purpose, hydroseeders for uneven, rugged terrain, specially formulated bioplates made of various materials containing seeds and chemical or organic fertilizers that partially replace more expensive concrete slabs, biorolls made of geotextiles, paper, peat, vegetable carpets, etc., as well as other systems and methods for grassing surfaces devoid of vegetation.

CONCLUSIONS

Complex mixtures made up of perennial grass seeds (grasses and legumes) and cereals (barley) together with different types of chemical fertilizers can be formulated and stored in sealed polyethylene bags, guaranteed for different shelf lives until grassing works for anti-erosion protection or ecological restoration of heavily anthropogenically degraded lands, such as industrial dumps. The biggest influence on seed germination is the acidity of chemical fertilizers, the most aggressive being superphosphate and ammonium sulfate, and among the most sensitive seeds it turned out to be, in order: sainfoin (*Onobrychis viciifolia*), timothy (*Phleum pratense*), white clover (*Trifolium repens*) and common vetch (*Lotus corniculatus*) and the most resistant are perennial ryegrass (*Lolium perenne*), brome (*Bromus inermis*), barley and orchard fescue (*Festuca pratensis*).

The advantages of formulating such complex mixtures are countless, starting with the uniformity of seed spreading through the simultaneous application of fertilizers that also act as diluents, the possibility of applying them in a dry state by manual, mechanical or aircraft means, having reduced volume and weight, as well as through hydroseeding and many other.

REFERENCES

1. Dumitrescu, N., Grâneanu A., Sârbu Gh., 1979: "*Pajişti degradate de eroziune şi ameliorarea lor*", Ed. "Ceres" Bucureşti;
2. Maruşca T., Stănilă Amalia, Maruşca Pop Letiţia, 1990: "*Influenţa condiţiilor de păstrare asupra calităţii seminţelor de Lolium perenne şi Trifolium repens din amestecurile cu îngrăşăminte chimice destinate înierbărilor de protecţie antierozională*", Rev. Cereale şi plante tehnice, nr. 5-6, Bucureşti;
3. Maruşca, T., 1991: *"Germinaţia seminţelor de ierburi perene şi cereale păioase în funcţie de durata contactului direct cu îngrăşăminte chimice din amestecurile de protecţie antierozională"*, Buletin informativ ASAS, nr.20, pag. 79-91, Bucureşti;
4. Maruşca, T., 1995: "*Contribuţii la perfecţionarea metodelor de înierbare şi consolidare a solului după lucrările de îmbunătăţiri funciare*", A 2-a Conferinţă de protecţia mediului, pag. 335-341, Braşov;
5. Maruşca, T., Chiosa V., Constantinescu M., Helerea Elena, Spârchez Gh., 2000: "*Principii şi metode noi de restaurare ecologică a haldelor de zgură şi cenuşă de la centrala pe lignit – Braşov*", Simpozionul Managementul Mediului Urban şi Industrial în contextual integrării europene, pg. 43-49, Ed. Universităţii "Transilvania"din Braşov;
6. Maruşca T., 2007: *"Contribution to the ecological reconstruction of the sky slopes in the Predeal – Poiana Braşov area"* Scientifical Papers Faculty of Agriculture XXXIX, Part II, Pp. 23-26, Ed. Agroprint, Timişoara;
7. Maruşca T., Mocanu V., Hermenean I., Blaj V.A., Filip (Tod) Monica, Maruşca Silvia V., 2009: *Research regarding establishment of the sown grassland for the antierosion protection of a thermal power station ash dump,* Symposion EGF, Volume 14, Pp 173-176, Brno, Cehia;

8. Maruşca T., Blaj V.A., Zevedei P.M., Brejea B.P., Petreanu Antonela, Bârlădeanu B., Rogojan C., 2020, "*Contribution to restoration of waste dumps of sulfur from the Călimani Mountains*", Annals of the University of Oradea, Fascicule: Enviromental Protection doi.org/10.5281/Zenodo.436307, vol.XXXV;
9. Maruşca T., Mocanu V., Blaj V.A., Andreoiu C. Andreea, Tătăruş A., 2021, *"The evolution of restoration by grassing metod of ash and slag dumps from lignite Thermal Power Plant of Brasov, Romania"* Journal of Grassland and Forage Crops, Cluj-Napoca, nr. 23, Pp 91-98.
10. Moţoc M., Munteanu S.A., Băloiu V., Stănescu P., Mihaiu Gh., 1975:"*Eroziunea solului şi metode de combatere*", Editura "Ceres" Bucureşti.

ECONOMIC EFFICIENCY OF PRODUCTIVITY OF AGROSILVOPASTORAL SYSTEMS WITH OAK (*QUERCUS ROBUR*, Mattuschka Liebl) IN THE BRAȘOV DEPRESSION

Elena TAULESCU[*], Teodor MARUȘCA[**], Elena MIHĂILĂ[*,****], Cristina I. PORR[**], Elena ACHIM[***]**

* Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov
** Research-Development Institute for Grasslands Brasov
***National Institute for Research and Development in Forestry "Marin Drăcea", Bucharest
***** *Corresponding author:* lilianmihaila@yahoo.co.uk

Abstract
Studies on oak pastures (Quercus robur, Mattuschka Liebl) as the agrosilvopastoral (ASP) system in the Brașov Depression (550 m altitudine), highlight their superiority from all perspectives compared to treeless pastures. On a surface of 45.0 ha in Dobolii village (Ilieni commune, Covasna County), 292 oak and wild pear trees were inventoried, in a ratio of 9:1, unevenly distributed, with an average crown projection of 1,811 m² per hectare. The grass cover under the tree crowns, dominated by Lolium perenne, has a yield of 16.66 t/ha of green mass (GM), a pastoral value index (PV) of 82.9, and 9,020 liters of milk per hectare. On the treeless pasture, dominated by Agrostis capillaris, a yield of 14.92 t/ha GM, a PVI of 77.3, and 7,420 liters of milk were assessed. The total wood volume per hectare is 56.7 m³ for oak and 1.3 m³ for wild pear. The total economic value (milk, wood, acorns) of the ASP system reaches €4,879/year/ha, which is 32% higher than that of the treeless pasture.

Keywords: agrosilvopastoral system with *Quercus robur*; milk production; wood volume; economic value

INTRODUCTION

Agrosilvopastoral (ASP) systems with oak (*Quercus robur*, Mattuschka Liebl), sessile oak (*Quercus petraea*), beech (*Fagus sylvatica*), and wild pear (*Pyrus pyraster*) are widespread in Transylvania, providing shade for livestock during the grazing season on communal pastures. Used for centuries, and still today, these systems are particularly valuable for both livestock and the herbaceous layer, especially in the context of global climate warming and its negative effects on pasture productivity and animal products.

ASP systems (pastures with trees) are well represented in the warm and arid climates of Mediterranean countries, known as "dehesa" in Spain and "montado" in Portugal, and as "agroforestry" in English-speaking countries (Sharrow et al. 1994; Olea et al. 2006; Hartel et al. 2017). In Romania, such pastures are traditionally known as "rariște" or "dumbravă" (Mihăilă et al. 2010; Marușca 2012). In recent years, the first studies have assessed the yield and forage quality of the herbaceous layer beneath the tree canopy and in open pasture, highlighting the productivity of ASP systems (Taulescu et al. 2024), with these data also supporting the economic evaluation of such systems (Marușca et al. 2025a, b). The present work continues the comprehensive economic assessment of vegetation productivity expressed through milk, timber (construction and firewood), and acorn production in ASP systems with oak in the Brașov Depression.

MATERIAL AND METHOD

The productivity studies of the herbaceous pasture layer and the assessment of both primary and secondary woody biomass production were conducted on the communal pasture of Dobolii village, Ilieni commune, Covasna County, on a 45.0-ha area of private land belonging to the "Înfrățirea" Association (Figure 1).

Fig. 1. Dobolii Pasture with trees, Ilieni Commune, Covasna County, Romania

The oak ASP system, located at 550 m altitude presents site-specific characteristics, herbaceous layer composition and several forage quality parameters that are improved under the trees crown (table 1).

From these data, a small difference can be observed between the soil characteristics and the floristic composition of the herbaceous layer in open field and under trees, because in both situations the vegetation is dominated by highly valuable forage species such as *Lolium perenne*, *Agrostis capillaris*, and *Cynosurus cristatus*.

Table 1

General data on ASP systems with oak (*Quercus robur*)

Pasture condition	Soil		Dominant species	Fodder		
	pH (indicator)	Humus (%)		CP	CF	OMD
Open field (Sun)	5.50	6,15	*Agrostis capillaris Lolium perrene Cynosurus cristatus*	17.5	27.9	63.0
Under trees (Shade)	5.60	7,09	*Festuca rubra Agrostis capillaris Trifolium repens*	18.8	27.0	63.4
Difference Shade-Sun (%)	102	115	X	107	97	101
Symbols: CP – crude protein (Nitrogen x 6.25); CF – crude fiber; OMD – organic matter digestibility						

This confirms the very good management of the studied grasslands, which are capitalized through rational grazing with cattle. The grasslands are grazed by dairy cows of the “Romanian Spotted” (*Simmental*) breed and “Angus” cattle, for a period of approximately 160 days. The actual assessment of grassland productivity, highlighted by the pastoral value (PV) and the green mass (GM) yield under trees and in open fields, was carried out based on a floristic survey (Marușca 2019, Marușca et al. 2020).

The potential milk production was evaluated using the formula:

Milk production (L/ha) = PV x GSD x 0.6 (Marușca et al. 2018, Marușca 2022)

where:

- PV = pastoral value index
- GSD = grazing season duration (days)
- 0.6 = milk coefficient achieved on pasture, determined after 20 years of long-term experiments with dairy cows.

After establishing the projection of the tree crown on the pasture, the weighted average of milk production under trees and in open fields (without trees) was calculated. The determination of the number of trees by species, the volume of timber and firewood, and the acorn production was carried out for the entire area under study (45.0 ha).

The benefits of trees on pastures are both ecological, economic, and social, and therefore the services provided by tree-covered pastures include both quantifiable and non-quantifiable elements.

The microclimate created by trees on the pasture is an important ecological benefit, but difficult to quantify. By contrast, the timber and non-timber products obtained from trees on pastures are quantifiable, and their economic evaluation is important for promoting the maintenance and care of existing pastures or the establishment of new ones. Tree products frequently used by local communities include: acorns for feeding pigs or sheep, as well as for handicraft work, and foliage for supplementing animal feed when grass is scarce during certain periods. However, the highest revenues can be obtained from the sale of timber resulting from the selective removal of certain trees from pastures, as long as these removals do not affect the stability and ecological balance of the existing pastures. To quantify the revenues that can be obtained from the sale of timber harvested from pastures, it is necessary to determine the volume of wood mass of the removed trees.

The volume of trees can be calculated using formulas that take into account the trunk diameter and the height of the tree. The most commonly used general formula for calculating the volume of a tree is:
where:

$V = BA \times H \times f = 0.7854 \times DBH^2 \times H \times f$ (Giurgiu 1979, Leahu 2001)

- V = tree volume (m^3)
- BA = basal area (m^2)
- DBH = diameter at breast height (cm)
- H = total tree height (m)
- f = form factor, accounting for trunk shape (typically ranging from 0.4 to 0.7 for forest trees).

Given the fact that the isolated trees in pastures are generally old, over 100 years, the value of the form factor "f" was adjusted to 0.40–0.35. It should also be noted that the volume calculated with this formula does not include the volume of branches and secondary limbs, but only the volume of the tree trunk, from the base up to the tip of the main stem. To include the volume of branches, an additional correction coefficient must be added, which for broadleaf species is 0.30–0.45% of the trunk volume. For the ASP system at Dobolii, the trunk volume of the oak and wild pear trees present on the pasture was determined by applying the formula presented above, using a form factor value of f = 0.38 for oak and f = 0.35 for wild pear, since their trunks show, in some specimens, defects such as hollows, rot cavities, or irregular shape.

However, oak and wild pear provide fruits (acorns and pears) that are important sources of nutrients such as proteins, lipids, carbohydrates, mineral salts, and vitamins. (Corlățeanu, 1984; Nesterov et al., 2006). In pastures where oak trees have more light and space, they fruit more frequently and abundantly, although the acorns may be smaller than those produced by oaks in forests. Oak typically begins to produce fruit at 30–40 years of age. It fruits abundantly every 5–8 years in the so-called "mast years," but produces smaller quantities of acorns almost every year. Heavy fruiting depends on factors such as climate (temperature, drought), soil, and tree stress (dryness, pruning, diseases). No estimates were made of the acorn production in the analyzed areas, but forest oaks produce, depending on the fruiting cycle, between 600 and 1,200 kg per hectare (Nesterov et al., 2006).

The labor cost for harvesting one kilogram of acorns varies between 8 and 10 lei, the higher value being due to the difficulty of collection. These values were calculated using the Unified Time and Production Norms for Forestry Operations Unified (MAPPM_RNP, 1997), assuming average fruiting conditions. The labor cost is increased by the commercial markup of the seller, resulting in a final price of approximately 15 lei/kg of oak acorns. As for wild pear, it produces fruit regularly starting from 8–10 years of age and yields between 25 and 50 kg of fruit per tree annually (Nesterov et al., 2006; Stănescu et al., 1997, Șofletea and Curtu, 2001). The labor cost for harvesting one kilogram of pears ranges from 2.5 to 3.5 lei, calculated using the above-mentioned standards, under conditions of average fruiting. A commercial markup is added by the seller, resulting in a final price of 4–5 lei/kg for wild pears. The fruits are used as feed both for wildlife and for domestic animals.

Due to the very small number of pear specimens in the ASP system at Dobolii, their fruits have no economic relevance; most likely, the fruits are consumed by domestic or wild animals. It is important to note that both oak and wild pear are valued for their silvoprotective and landscape functions in pastures. They can be valued for their ecosystem services, such as improving the microclimate and providing shelter for grazing animals.

RESULTS AND DISCUSSIONS

The main components underlying the economic evaluation of the ASP system with oaks were: green mass (GM) production, pastoral value (PV), cow milk production during the grazing season, the quantity of construction-grade timber and firewood, acorns and wild pears, as well as the annual yield. The productivity of the grassland in the ASP system was ultimately expressed through milk production (Table 2).

Table 2

Evaluation of the main pasture productivity indices in the oak ASP system during the 160-day grazing season

Specification	Open grassland	Under trees	Difference (%)
Green forage mass production (t/ha)	14.92	16.66	112
Optimal livestock load (LU/ha)	1.43	1.60	112
Pastoral value (Ind)	77.31	82.91	107
Cow milk production (L/ha)	7420	7960	107

From these data, it follows that the green mass production beneath the trees is 12% higher than on a treeless pasture, due to the higher concentration of animal droppings and the protection from intense heat. The floristic composition under the trees, dominated by *Lolium perenne*, has a higher fodder value compared to that of open pasture without tree protection, which is dominated by *Agrostis capillaris*. Under these conditions, 7,960 liters of milk were estimated under the tree canopy, representing a 7% increase compared to the treeless pasture. To this, one must add the improved animal welfare provided by tree shade during periods of excessive summer heat, which can contribute an additional 20–40% increase in milk production compared to pastures without trees. Regarding the economic evaluation of the woody vegetation in the ASP system under study, a series of measurements and assessments were performed to determine tree composition and volume (Table 3). On the pasture, a total of 292 oak (*Quercus robur*) and wild pear (*Pyrus pyraster*) trees are unevenly distributed, corresponding to an average density of 8 trees/ha. A number of 103 trees were inventoried across the entire pasture, representing approximately one third of the total tree population. Of these, 94 are oak and 9 are wild pear, giving a species ratio of 91% and 9%, respectively. Therefore, the pasture composition can be expressed as 9Oak 1Pear.

Table 3

Main dendrometric parameters of the Dobolii oak ASP system

Analyzed characteristic	ST	PĂ	Total
No. of trees / 15 ha	94	9	103
Mean DBH (cm)	**96**	**53**	
Min	51	12	
Max	150	73	
CV (s%)	17	41	
Mean H (m)	**20,9**	**12,5**	
Min	14,4	6,0	
Max	28,9	18,4	
CV (s%)	17	32	
Crown (% of total height)	**84**	**77**	
Min	77	70	
Max	91	85	
CV (s%)	19	26	
Σ A crown projection (m2)	**15 315,5 / 51 trees**	**590,0 / 6 trees**	**15 905,5/ 57 trees**
Mean crown projection (m²)	**300,3**	**98,3**	**279,0**
Min	112	79	
Max	518	117	
CV (s%)	31	18	
Σ A crown projection / ha (m²)	**1742**	**69**	**1811**

Symbols: ST – pedunculate oak, PĂ – wild pear
Mean DBH – Mean of diameter of breast height; Mean H – Mean height; Min –Minimum recorded value, Max – Maximum recorded value, CV – Coefficient of variation, %, Σ A crown projection – Cumulative sum of crown area projection

Analysis of dendrometric parameters indicates a good vegetation condition of the trees on the pasture, with high coefficients of variation for both diameter and height (17–19%), a perfectly normal condition for oak specimens growing outside forest stands. Horizontal crown projections were measured for 57 trees distributed across the entire pasture (45.0 ha), representing 19.5% of the total 292 trees. The total sum of crown projection areas was 15,905.5 m², corresponding to an average projection of 279 m²/tree. Since they did not grow in dense stands, the trees developed crowns in all directions (N, S, E, W), and tree heights are also high, ranging from 11.7 to 25.5 m, with a coefficient of variation of 19%. The degree of ground coverage is expressed through the canopy coverage index (Ia), calculated as the ratio between the total crown projection area (15,905.5 m²) and the total pasture area (450,000 m²) (Ciubotaru and Păun, 2018). Thus, Ia = 3.53, corresponding to a stand density of 0.35 — a medium–high density typical for tree–pasture systems. Crown projection per hectare was estimated at 1,811 m² (1,742 m² for oak and 69 m² for wild pear). Milk production per hectare in the ASP system was determined using a weighted average between the milk production assessed under tree cover and in open pasture.

Additionally, for cows benefiting from shade in the ASP system, it was estimated that shade contributes at least 20% additional milk yield compared to cows grazing and resting in open sun, where a considerable share of energy is redirected towards thermoregulation during periods of excessive heat in the grazing season. Furthermore, ASP systems support nesting of numerous bird species that feed on insects and rodents harmful to both pasture productivity and biodiversity. Using available data on pasture productivity, expressed as cow milk yield in ASP systems with and without trees, together with wood volume (stem and branches), acorn production, and their economic value in Euro (1€ = 5 lei), an integrated economic evaluation of all ASP components was carried out (Table 4). From these data, it follows that milk production calculated strictly based on the pastoral value of the grass cover, 7,520 L/ha, is only 2% higher in the ASP system compared to treeless pasture, as a result of rational management and sustainable use of the studied area by the beneficiaries.

Table 4

The comparative economic value of the ASP system dominated by oak versus a treeless pasture (TLP)

Specification	***Pasture system***		
	ASP	*TLP*	*%*
Cow milk production (L/ha/an)	7520	7420	101,3
Value (x 0,5 €/Liter)	**3760**	**3710**	**101,3**
Timber m³/ha at 120 years old	35,4	-	X
Timber m³/year	0,30	-	X
Value (x 170 €/m3)	**51**	-	X
Firewood (Oak & Wild Pear), m³/ha/year	0,80	-	X
Value (x 60 €/m3)	**48**	-	X

Acorn kg/ha/year	150	-	X
Value (x 1.8 €/kg)	**270**	**-**	X
Estimated additional milk production under tree shade, minimum 20% (l/year/ha)	1500	-	-
Milk value (x 0,5 €/Liter)	**750**	**-**	**-**
Total annual value (€)	**4879**	**3710**	**131,5**
Symbol: TLP – treeless pasture – open field			

When including the estimated 20% additional milk production for cows benefiting from tree shade, the yield reaches 9,020 L/ha, which is 22% higher than in the treeless pasture. Ultimately, in the ASP system with oaks, milk production accounts for 92.4% and woody vegetation for 7.6% of the total value of €4,879/ha.

CONCLUSIONS

- Pastures in oak-dominated agrosilvopastoral (ASP) systems (*Quercus robur*) are superior in both productivity and economic value compared to treeless pastures.
- Cow milk production in the ASP system is estimated at 9,020 L/ha on pastures dominated by *Lolium perenne*, which is 22% higher than that of treeless pastures dominated by *Agrostis capillaris*.
- The economic value of milk production in the ASP system, €4,510/ha/year, together with the value of wood production, €369/ha/year, is 32% higher than that of neighboring treeless pastures, with additional benefits that are harder to quantify, such as enhanced biodiversity and improved pastoral landscapes.

REFERENCES

1. Ciubotaru A., Păun M., (2018) Structura arboretelor. Editura Universității Transilvania din Brașov.
2. Corlățeanu S., (1984) Produsele accesorii ale pădurii. Editura Ceres, București.
3. Giurgiu V., (1979) Dendrometrie și auxologie forestieră. Editura Ceres, București.
4. Hartel T., Măcicășan V., Maloș C., Rákosy L., (2017) Lessons learnt: Wood-pastures in Transylvania, Romania.
5. Leahu I., (2001) Amenajarea pădurilor. Editura Didactică şi Pedagogică, Bucureşti, 616 p.
6. MAPPM_RNP, (1997) Norme de timp și producție unificate pentru lucrări din silvicultură.
7. Maruşca T., (2012) *Sistemul agrosilvopastoral durabil, în contextul încălzirii globale a climei*. Revista de Silvicultură şi Cinegetică, XVII (30). Editura Societatea Progresul Silvic, Braşov.

8. Maruşca T., Blaj V. A., Andreoiu Andreea C., Zevedei P. M., (2018) Long term influence of botanical composition of alpine pastures on cow milk production, Proceeding of the 27th General Meeting of the European Grassland Federation, EGF, (23): 283 - 285, Cork, Ireland, 17 - 21 iunie.
9. Marușca T., (2019) Contributions to the evaluation of pasture productivity using the floristic releve. Romanian Journal of Grassland and Forage Crops BDI (19), Cluj – Napoca: 33- 47.
10. Marușca T., Taulescu Elena, Memedemin D., (2020) Preliminary study of agrosilvopastoral systems from Romania, Romanian Journal of Grassland and Forage Crops (22), Iași: 25-32.
11. Marușca T. (2022) Praticultură și pastoralism în cercetarea științifică, Editura Universității Transilvania din Brașov, (311).
12. Mihăilă Elena, Costăchescu C., Dănescu F., Drăgoi S., (2010) Sisteme agrosilvice, Editura Silvică, București.
13. Nesterov V., Negruțiu A., Ionescu O., Gărgărea P., Adămoaia I., (2006) Furaje și ogoare pentru vânat. Editura Orion.
14. Olea L., San Miguel-Ayanz A., (2006) The spanish dehesa. A traditional Mediterranean silvopastoral system linking production and natural conservation, 21st. General Meeting of EGF :3-13, Badajoz, Spain.
15. Sharrow S.H., Flechter R.A., (1994) Trees and Pastures: 40 years of agrosilvopastoral experience in Western Oregon, USA, Agroforesty Symposium, National Agroforesty Center.
16. Stanescu V., Șofletea N., Popescu O., (1997) Flora forestieră lemnoasă a României. Editura Ceres, București.
17. Șofletea N., Curtu L., (2001) Dendrologie. Editura ”Pentru Viață”, Brașov.
18. Taulescu Elena, Marușca T., Zevedei P.M., Andreoiu Andreea Cristina, Comșia Cristina Carmen, (2022). Interractions between Pyrus piraster trees (Wild pear) and grassland in an agrosolvopastoral system, Academy of Romanian Scientists Series on Agriculture, Silviculture and Veterinary Medicine Sciences, 11(1): 28 – 37.

CONTRIBUTIONS TO THE EVALUATION OF THE PRODUCTIVITY OF GRASSLANDS ON SANDBANKS AND MICRO-DEPRESSIONS OF THE DANUBE DELTA

Daniyar MEMEDEMIN[*,], Teodor MARUȘCA[*,***], Cristina I. PORR[*], Cristina C. COMȘIA[*]**

[*]Research-Development Institute for Grasslands, 5 Cucului St., Brasov, 500128, Romania
[**] Ovidius University of Constanta, 1 Universitatii Alley, 900470, Constanta, Romania
*** Corresponding author e mail: maruscat@yahoo.com

Abstract

Having a special conservation importance due to the difficult vegetation conditions, the permanent grasslands on the sandbanks and micro-depressions of the Danube Delta suffer a constant depreciation in terms of the quality and quantity of green mass. Comparative analysis of historical data sets with more recent data shows a continuous and constant decrease in quality and productivity. Thus, if the average green mass production in the 1960s was about 4.9 t/ha and the pastoral value index was 34, in the 1990s the grasslands of the Festucion vaginatae and Puccinelion limosae alliances, the most valuable from grazing point of view, recorded a production of 2.9 t/ha MV and a pastoral value index of 22, highlighting a 41% reduction in green mass production, respectively a 65% decrease in pastoral value. Overgrazing until the 1990s, followed by uncontrolled extensive grazing in the following period, are among the most important factors that led to the sharp degradation of these grasslands.

Keywords: Danube Delta grasslands, pastoral value, green mass and milk production

INTRODUCTION

An emblematic area due to the biodiversity elements hosted, the Danube Delta also represents the area where we can find a unique mix of human communities (Boja & Popescu 2000, Petrescu 2007, Gastescu 2009, Parau 2012, Doroftei & Covaliov 2013, Tănăsescu & Constantinescu 2020, Rus et al. 2025). This heterogeneity also leaves its mark on the economic activities in the area, many of which are still carried out according to ancestral rules. Fishing, reed harvesting, animal husbandry are some of these activities that still use techniques and methods inherited from the ancestors, thus ensuring the sustainability and charm of the place (Titov & Chiselev 2015, Covaliov et al. 2023). Accelerated development in recent times brings with it the abandonment of traditional practices and the adoption of modern and more efficient methods, which however have a significant impact on biodiversity and, implicitly, on human communities. (Doroftei et al. 2011, Giosan et al. 2013, Vaidianu et al. 2015).

An activity with a significant negative effect on biodiversity in general and on vegetation in particular is overgrazing (Wang et al. 2020, Gonzales & Ghermandi, 2021, Wang et al. 2023). Previous studies on this subject highlight the negative effect of overgrazing on the grasslands of the Danube Delta (Trifanov et al. 2018, Marusca et al. 2024, Memedemin & Marusca 2024) and recommend the need to respect both the principles of scientific grazing and traditional practices, especially the optimal stocking rate, to preserve the remarkable biodiversity of this area (Torok et al. 2016, Fynn & Jackson 2022, Marusca et al. 2024, Shipley et al. 2024).

In order to assess the impact of human activities on natural habitats, the study of changes in the structure of the specific composition of vegetation can be a very useful tool (Josefsson et al. 2009, Zinnen et al. 2021). Thus, the comparative analysis between historical data and the current situation can be of real help in understanding the phenomena and in more efficient management of natural or anthropogenic induced changes. (Kapfer et al. 2017, Straubinger et al. 2023).

MATERIAL AND METHOD

To evaluate the productivity of grasslands located on the sandbanks and in the micro-depressions of the Danube Delta, we analyzed the paper "Natural Meadows in the Danube Delta" prepared by Viorel Vasiu, Mircea Pop and Flavius Floca and published in 1963 in the journal "Hidrobiologia" of Romanian Academy Publishing House.

The aforementioned paper presented the study on the vegetation of the Danube Delta grasslands carried out between 1958 and 1960. The study presents the situation before the collectivization of agriculture, during which time there was a better balance between green mass production and animal loading as a result of respecting traditional animal husbandry practices in the delta area. The working method used by the authors for the study of grassland vegetation was that of the Zurich-Montpelier Floristic School, using the Braun Blanquet evaluation scale for scoring the abundance-dominance of species in the vegetal layer. (Cristea et al. 2004).

In the evaluated study, for each floristic survey in the mentioned work, the species were grouped into grasses, legumes and species from other botanical families. Also, vegetation cover degree, vegetation height, station data, location and type of landuse were presented. For some surveys, productivity elements were also, empirically, estimated.

Primary data from the most important surveys in terms of the quality of the vegetation layer on the 7 sandbanks (Fig. 1) formed the basis for the evaluation of green fodder production and pastoral value according to the method developed by Marușca. (2019, 2022).

Assessment of the productivity elements using information from the studied material allowed calculating the optimal animal load and determining milk production, as the main economic parameters for grasslands (Marușca et al. 2018) for the period in which the initial study was conducted.

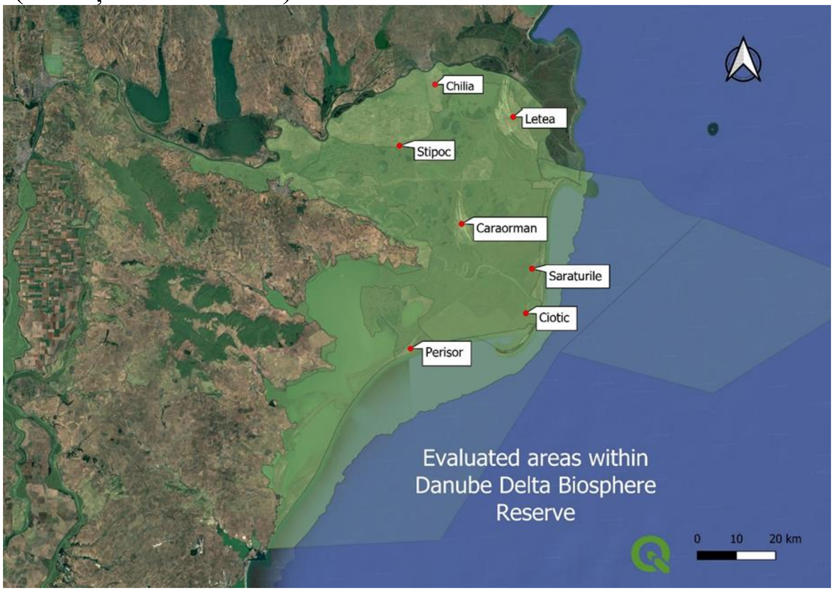


Fig. 1 – Areas studied within the DDBR

RESULTS AND DISCUSSIONS

The database with the information necessary for productivity calculations allowed the evaluation, based on the floristic survey, of 6 grassland plant associations on 7 sandbanks, also analyzing the micro-depressions from this areas (Table 1).

From the evaluated study, information was extracted for 66 floristic surveys, in which an average of 21 species of cormophytes were recorded. The most plant species, 34 in number, were recorded in the grasslands with sandy soils in micro-depressions and the fewest, only 8 species in the Association with *Salicornia herbacea*. Vegetation coverage was quite low, on average 68%, with limits between 39% in the Association with *Festuca vaginata* to 90% in the Association with *Agrostis stolonifera*. The table 1 presents only species with fodder value that are consumed by animals, totaling an average of 52% participation (76.5% of the total), the rest being represented by species without fodder value.

The average green fodder production (GFY) of the 6 evaluated plant associations is just over 5 tons per hectare, being able to provide fodder for only 0.60 LU/ha in 130 days of optimal grazing duration. The highest production of 10.53 t/ha GFY with 1.25 LU/ha was evaluated in the association with *Agrostis stolonifera* and the lowest of 1.65 t/ha GFY in sandy grasslands in microdepressions with an animal load of barely 0.2 LU/ha, for the same duration of the grazing season.

Table 1

Productivity of the main grassland plant associations (A1-A6) on the sandbanks and micro-depressions of the Danube Delta, in 130 days of grazing season (average numbers for 1958-1960 period)

Specification	A_1	A_2		A_3	A_4	A_5	A_6	Average
Location	C,L	Cio,L,P,S		C,Chi,L,Sti	P	Chi,L,P,S,Sti,	L,S,Sti	
Nr. of relevees (∑)	5	24		8	10	10	9	66
Avg. number of sp.	30	34		11	30	11	8	21
Vegetation coverage (%)	39	41		90	66	85	85	68
Forage sp participation (%)	27	20		73	59	55	78	52
Poaceae (%)								
Agropyrum elongatum		0.2			47.8	0.2		8
Agropyrum repens				1.2				0.2
Agrostis stolonifera				56.3		4.1	0.1	10
Apera spica venti	0.1	9.6		2.8		0.2		2.1
Bromus comutatus		0.1			0.1			0.1
Bromus tectorum	0.7	6.3						1.1
Crysopogon gryllus	0.1							0.1
Cynodon dactylon	1.0	2.3		1.3	1	2.0	0.1	1.2
Festuca arundinacea					0.1	0.1		0.1
Festuca vaginata	23.2	0.1						3.8
Poa angustifolia		0.1						0.1
Poa bulbosa		0.2						0.1
Poa pratensis					0.1			0.1
Puccinellia distans				4.3	5.7	40.8	6.5	9.5
Fabaceae (%)								
Lotus corniculatus				0.1				0.1
Medicago falcta	1.3	0.2			0.1			0.2
Medicago lupulina		0.1						0.1
Medicago minima	0.2	0.1			0.1			0.1
Melilotus albus	0.1	0.3		0.4	0.2	0.1		0.2
Trifolium fragiferum				5.6				0.9
Vicia craca	0.4							0.1
Other plant fam.(%)								
Carex distans				0.1	2.4	0.1		0.4
Daucus carota					0.1			0.1
Echium vulgare	0.2							0
Juncus gerardi				1	0.9	7.2		1.5
Plantago lanceolata		0.2			0.1			0.1
Plantago media				0.1				0.1
Salicornia herbacea							71.8	11.9
Harmful plants participation (%)	12	21		17	7	30	7	16
Green Fodder (GFY t/ha)	2.21	1.65		10.53	9.13	3.54	3.43	5.08
Optimal load	LU/ha	0.26	0.20	1.25	1.08	0.42	0.41	0.60
	%	44	33	208	180	70	68	100
Pastoral Value (ind. PV)	15.57	11.45		55.70	37.78	39.85	37.07	32.84
Milk production	L/ha	1240	890	4350	2950	3110	2890	2570
	%	48	35	169	115	121	112	100

LEGEND

Location	Grassland plant species associations
C = Caraorman	A_1 - Association with *Festuca vaginata*
L = Letea	A_2 – Micro-depression grasslands with sandy soils
S = Sărăturile	A_3 – As. with *Agrostis stolonifera*
Sti = Stipoc	A_4 – As. with *Agropyrum elongatum*
Chi = Chilia	A_5 – As. with *Puccinellia distans*
Cio = Ciotic	A_6 – As. with *Salicornia herbacea*
P = Perișoru	

The average pastoral value (PV) with an index of almost 33 (poor) can provide 2570 liters of milk/ha. The minimum is represented by a PV index of 11.45 with 890 l/ha in the microdepression plant association and the maximum of 55.7 PV index with 4350 l/ha, 5 times more, in *the Agrostis stolonifera* association.

Of the described grassland associations, the one with *Elymus giganteus* from the Sărăturile, Letea and Caraorman marine sand dunes was omitted, due to the fact that the vegetal layer coverage represents barely 9%, with a number of 11 species, which provide barely 30 kg/ha GFY and 0.37 PV, being appreciated as a pioneer association without forage value. Particular importance was given to evaluating the production of GFY for assessed grassland associations, separately for each analyzed sandbank, in order to know the optimal animal load during the grazing season (Table 2).

In each sandbank and the associated micro-depressions, 1-4 distinct plant associations with different areas each were recorded. To evaluate the average productivity of the vegetation on each sandbank, it is necessary to map the area of each association and calculate the weighted average. Thus, the table above presents the arithmetic mean of the data from these plant associations as if they were present in equal proportions on each location. The highest vegetation coverage of 87-88% was recorded on the Stipoc and Chilia sandbanks, and the lowest of 53% on the Ciotic sandbank. The highest GFY production of 8.35 t/ha was evaluated at the Caraorman sandbank, which allows an optimal loading of 1 LU/ha and PV of 42, allowing 3300 l/ha of cow's milk to be obtained. The highest milk production, of 3930 l/ha, was evaluated on the Chilia sandbank where there are associations with *Agrostis stolonifera* and *Puccinellia distans*. These associations have a production potential of 5.69 t/ha GFY and a PV index of 50.4, which expresses the best forage quality of all the associations identified. The lowest milk production, of 1530 l/ha, was evaluated on the Ciotic sandbank, related to associations of sandy soils and micro depressions, with 3.32 t/ha GFY and a PV index of 19.7. On average, on the 7 sandbanks and micro-depressions, a productivity of 4.8-5 t/ha GFY was evaluated with a capacity of 0.57-0.60 LU/ha and a PV index of 33-34. With these productivity data, 2570-2660 liters of milk per hectare can be obtained in 130 days of optimal grazing season, considering also the prolonged drought period during the summer. The analysis of grassland productivity carried out by Marușca et al. (2024) using the information provided by Popescu et al. (1997) compared with the data of Vasiu et al. (1963) evaluated in this paper indicates a degradation of production, forage quality and implicitly of the biodiversity of these grasslands. Thus, if in the 1960s the average production of GFY was about 4.9 t/ha and a PV index of 34, in the 1990s the grasslands from the phytosociological alliances *Festucion vaginatae* and *Puccinelion limosae* recorded 2.9 t/ha GFY (59% of the initial value) and 22 PV index (65% of the value in the 1960s).

Table 2

Productivity of grasslands on the main sandbanks and micro-depressions in the Danube Delta in 130 days of grazing season (1958-1960)

Specification	Sandbank and micro-depression							Average
	Caraorman	Letea	Sărăturile	Stipoc	Perișoru	Chilia	Ciotic	
Plant association	A_1,A_3	A_1,A_2, A_3,A_5, A_6	A_2,A_5,A_6	A_3,A_5, A_6	A_2A_4, A_5	A_3,A_5	A_2	
Nr. of relevees	5	15	11	7	20	4	4	66
Avg. species no	24	16	20	11	30	8	27	19
Vegetation coverage (%)	72	64	70	87	63	88	53	71
Forage plants participation (%)	61	49	48	64	40	68	33	52
Harmful plant participation (%)	11	15	22	23	23	20	20	19
Green Fodde (GFY t/ha)	8.35	4.73	2.69	4.72	4.33	5.69	3.32	4.83
Animal load (LU/ ha)	0.99	0.56	0.32	0.56	0.51	0.67	0.39	0.57
Animal load %	173	98	56	98	90	118	69	100
Pastoral Value (ind. PV)	42.32	32.08	26.63	40.07	27.47	50.39	19.68	34.09
Milk production (l/ha)	3300	2500	2080	3120	2140	3930	1530	2660
Milk production %	124	94	78	117	80	148	58	100

These substantial decreases in GFY and PV index in the 1990s compared to the 1960s are mainly due to overgrazing with large animal herds, a widespread approach during the period of centralized socialist agriculture (Decree 92 of 1983). The aforementioned document required that the agricultural area in the delta was to increase from 66,185 ha in 1983 to 144,000 ha by 1990, of which 50,365 ha were permanent grassland. Thus, this grasslands on the sands were to be improved and provide partial food for 200,000 sheep and 20,000 cattle – an enormous additional pressure on extremely sensitive habitats.

CONCLUSIONS

The evaluation of the productivity of grasslands on the sandbanks and in the micro-depressions of the Danube Delta using information collected over 60 years ago and their comparative analysis with assessments based on more recent data shows a sharp degradation of the quality of the vegetation cover.

The calculation of productivity indicators, namely pastoral value and green fodder and milk production based on the floristic survey method unequivocally supports the statement regarding this decrease in the quality of the vegetation cover.

This degradation can be explained by the overexploitation of these areas in the period before the 1990s and by the abandonment of scientific methods and chaotic grazing that followed this period.

Comparative analysis of historical data can be a particularly useful tool for the rapid assessment and efficient management of changes that may occur in the structure of the vegetation cover, allowing the implementation of adequate conservation or restoration measures.

REFERENCES

1. Boja, V., & Popescu, I. (2000). Social ecology in the Danube Delta: theory and practice. *Lakes & Reservoirs: Research & Management*, 5(2), 125-131.
2. Cristea V., Gafta D., Pedrotti F., 2004, *Fitosociologie*, Editura Presa Universitară Clujeană
3. Doroftei, M., & Covaliov, S. (Eds.) (2013) „Handbook of... Danube Delta", Guide for field staff of the Danube Delta Biosphere Reserve Administration and Environmental Guard, Edit. Danube Delta Technological Information Center, Tulcea, 482.
4. Doroftei, M., Chirilă, S. D., Hanganu, J. (2023). Stufărişurile din Delta Dunării. Centrul de Informare tehnologică Delta Dunării ISBN: 978-606-8896-07-6. DOI: 10.5281/zenodo.10570838
5. Doroftei, M., Mierlă, M., & Lupu, G. (2011). Approaches to habitat disturbances in the Danube Delta Biosphere Reserve. *SCSB Veg. Biol*, 20(1), 45-56.
6. Fynn, R., & Jackson, J. (2022). Grazing management on commercial cattle ranches: Incorporating foraging ecology and biodiversity conservation principles. *Rangelands*, 44(2), 136-147.
7. Gâştescu, P. (2009). The Danube Delta biosphere reserve. Geography, biodiversity, protection, management. *Rev Roum Géogr*, 53(2), 139-52.
8. Giosan, L., Constantinescu, S., Filip, F., & Deng, B. (2013). Maintenance of large deltas through channelization: Nature vs. humans in the Danube delta. *Anthropocene*, 1, 35-45.
9. Gonzalez, S. L., & Ghermandi, L. (2021). Overgrazing causes a reduction in the vegetation cover and seed bank of Patagonian grasslands. *Plant and soil*, 464(1), 75-87.
10. Josefsson, T., Hörnberg, G., & Östlund, L. (2009). Long-term human impact and vegetation changes in a boreal forest reserve: implications for the use of protected areas as ecological references. *Ecosystems*, 12(6), 1017-1036.

11. Kapfer, J., Hédl, R., Jurasinski, G., Kopecký, M., Schei, F. H., & Grytnes, J. A. (2017). Resurveying historical vegetation data–opportunities and challenges. *Applied Vegetation Science*, 20(2), 164-171.
12. Marușca T. 2022, Praticultură și pastoralism în cercetarea științifică, Editura Universității Transilvania din Brașov, 311 pagini, ISBN 978-606-19-1565-1
13. Marușca T., 2019, Contributions to the evaluation of pasture productivity using the floristic releve, *Romanian Journal of Grassland and Forage Crops*, Nr. 19, 33- 47.
14. Marușca T**.**, Andreoiu C. Andreea, Dragoș M. Marcela, Comșia C. Cristina, Porr I. Cristina 2024, Contributions to the assessment of the productivity of fourage grass vegetation in the Danube Delta, *Romanian Journal of Grassland and Forage Crops*, nr.29, 71-84.
15. Marușca T., Blaj V. A., Mocanu V., Andreoiu Andreea C., Zevedei P. M., 2018, Long term influence of botanical composition of alpine pastures on cow milk production, Proceedings of the 27th General Meeting of the European Grassland Federation, EGF, Volume 23, Pp. 283-285, Cork, Ireland, 17-21 iunie, ISBN 978-1-84170-643-6
16. Memedemin, D., Marușca T., 2024*,* Assessment of grassland productivity in marine sand dune areas of the Danube Delta*, Romanian Journal of Grassland and Forage Crops*, 30, 77-84.
17. Parau, S. (2012). Ethnic communities in the Danube Delta. A cultural dialogue. *Journal of Danubian Studies and Research,* 1(1).
18. Petrescu, M. (2007) Dobrogea and Danube Delta: conservation of flora and habitats. Eco-Muzeal Research Institute, Tulcea.
19. Popescu A., Sandală V., Oroian Silvia, (1997). Vegetația Deltei Dunării, *Marisia*, Vol.XXV, Studii și materiale, Supliment, Tg.Mureș
20. Rus, M. I., Munteanu, I., Vaidianu, N., & Aivaz, K. A. (2025). Research Trends Concerning the Danube Delta: A Specific Social-Ecological System Facing Climate Uncertainty. *Earth*, 6(1), 7.
21. Shipley, J. R., Frei, E. R., Bergamini, A., Boch, S., Schulz, T., Ginzler, C., ... & Rixen, C. (2024). Agricultural practices and biodiversity: Conservation policies for semi-natural grasslands in Europe. *Current Biology*, 34(16), R753-R761.
22. Straubinger, C., Reisch, C., & Poschlod, P. (2023). Effects of historical management on the vegetation and habitat properties of wet meadows in Germany. *Restoration Ecology*, 31(5), e13839.
23. Tănăsescu, M., & Constantinescu, S. (2020). The human ecology of the Danube Delta: A historical and cartographic perspective. *Journal of environmental management*, 262, 110324.
24. Titov, I., & Chiselev, A. (2015). Meșteșuguri tradiționale în Delta Dunării. Raport de cercetare. 55pp. ISBN987-973-0-19168-4. Bucuresti
25. Török, P., Hölzel, N., van Diggelen, R., & Tischew, S. (2016). Grazing in European open landscapes: how to reconcile sustainable land management and biodiversity conservation?. *Agriculture, Ecosystems & Environment*, 234, 1-4.

26. Trifanov, C., Romanescu, G., Tudor, M., Grigoras, I., Doroftei, M., Covaliov, S., & Mierla, M. (2018). Anthropisation degree of coastal vegetation areas in Danube Delta Biosphere Reserve. *Journal of Environmental Protection and Ecology*, 19(2), 539-546.
27. Vasiu V., Pop M. & Floca F. (1963). Pajistile Naturale din Delta Dunarii. *Hidrobiologia*, Extras, Vol IV. Ed. Academia R.P.R.
28. Văidianu, N., Paraschiv, M., Saghin, I., & Braghină, C. (2015). Social-ecological consequences of planning and development policies in the Danube Delta Biosphere Reserve, Romania. *Carpathian Journal of Earth and Environmental Sciences*, 10(3), 113-124.
29. Wang, L., Delgado-Baquerizo, M., Zhao, X., Zhang, M., Song, Y., Cai, J., ... & Xin, X. (2020). Livestock overgrazing disrupts the positive associations between soil biodiversity and nitrogen availability. *Functional Ecology*, 34(8), 1713-1720.
30. Wang, Y., Zhao, Q., Wang, Z., Zhao, M., & Han, G. (2023). Overgrazing leads to decoupling of precipitation patterns and ecosystem carbon exchange in the desert steppe through changing community composition. *Plant and Soil*, 486(1), 607-620.
31. Zinnen, J., Spyreas, G., Erdős, L., Berg, C., & Matthews, J. W. (2021). Expert-based measures of human impact to vegetation. *Applied Vegetation Science*, 24(1), e12523.
32. *** Decret al Consiliului de Stat nr 92 din 28 martie 1983 privind aprobarea Programului de amenajare si exploatare integrala a Deltei Dunarii, Buletinul Oficial nr. 17 din 28 martie 1983.

CONTRIBUTIONS TO THE ASSESSMENT OF THE PRODUCTIVITY OF GRASSLANDS IN THE HYDROGRAPHIC BASIN OF BISTRIȚA – VÂLCII (OLTENIA)

Teodor MARUȘCA [1*], Ioana SIMION[2], Marcela DRAGOȘ[1], Monica Alexandrina TOD[1], Cristina COMȘIA[1], Cristina PORR[1]

[1] *Research-Development Institute for Grasslands, Brașov*
[2]*University of Craiova*

email: maruscat@yahoo.com

Abstract

In the Romanian Carpathians, numerous geobotanical studies have been carried out on the vegetation of primary and secondary permanent grasslands. The vast majority of these studies had as their main objective the identification and classification of grassland associations and less the production of green mass and the quality of fodder needed by homesteads. By evaluating productivity based on floristic surveys, vegetation data are complemented with economic data such as production and pastoral value, presented as case studies in this paper. The productivity of the grasslands in the hydrographic basin of the Bistrița-Vâlcii River with a special biodiversity, of 78 cormophytes on average for the 355 surveys had a production of 6.28 t/ha green mass and 36.7 index of pastoral value. This allows obtaining a production of 3710 liters cow milk per hectare in 160-day average grazing season and a livestock density of 0.55 LU per hectare. The data obtained are used to draw up projects for the development of grasslands and their proper management in the future.

Keywords: *permanent grasslands, pastoral value evaluation, green mass, production of milk*

INTRODUCTION

The evaluation of the productivity of the grasslands is absolutely necessary for the preparation of pastoral development projects (Marușca et al., 2014).

For this major economic objective are the well-known direct methods of harvesting the production of green mass and detailed chemical analysis of fodder quality (Motcă et al., 1994).

Direct determination of the production of grasslands used by grazing is done mostly in fenced areas with rather high expenses and more expensive laboratory analyses.

Along with the evaluation of the production of green fodder mass and the pastoral value based on a well-prepared floristic survey, the productivity of a glassland can be evaluated with quite high accuracy (Marușca, 2019).

So far, a number of 33 mountain massifs from the Carpathians and 19 resorts from the plain area of Romania have been evaluated in terms of productivity, based on which a first approximation of the grassland habitats at the European level was made (Marușca, 2022 a,b).

For this purpose, several thousand floristic surveys existing in the Romanian specialized literature (scientific articles and syntheses, doctoral theses, books, etc.) were studied, to which, for completion, the new evaluation method based on geobotanical data was applied, some also published in this journal (Marusca et al., 2021; Taulescu el al., 2022). The present work is a continuation of the evaluation of grassland productivity at the level of phytosociological associations and alliances, for the second approximation of evaluation with a higher degree of precision.

After a larger number of assessments and an increase in the precision of the productivity of grassland habitats, we will be able to compare them with other habitats at the Balkan and European level. Finally, these economic indicators serve for the development program of the mountain area.

MATERIAL AND METHOD

For The working material for the evaluation of productivity was a doctoral thesis entitled "Floristic and geobotanical study of the Bistrica - Vâlcii Watershed" drawn up in 1974 by biologist Gheorghe Gh. Popescu under the guidance of prof. university Traian Ștefureac from the Faculty of Biology of the University of Bucharest.

The following associations were drawn up:

- VEGETATION OF MESOPHYLOUS GRASSLANDS -
Cls. *MOLINIO - ARRENATHERETEA* Tx.1937
Ord. *MOLINIETALIA* W.Koch 1926
Al. *Agrostion stoloniferae* Soó (1933) 1940
1. As. *Agrosteto - Poetum trivialis* Soó 1938
2. As. *Alopecureto - Festucetum pratensis* Ujv. 1947
- *alopecureto - festucetosum*
- *pöetosum pratensis* Soó 1957
3. As. *Festucetum pratensis* Soó 1938
- *festucetosum pratensis*
- *pöetosum pratensis* Soó 1957
- *festucetosum valesiacae* nova subass
4. As. *Pöetum silvicolae* Buia, Păun, Safta et Pop 1959
5. As. *Agrostetum caninae* Harg 1942
6. As. *Caricetum distantis-vulpinae* Todor 1947
7. As. *Ranunculeto (strigulosi) - Equisetetum palustris* nova ass.prov.
Ord. *ARRHENATHERETALIA,* Pawl. 1928
Al. *Arrhenetherion elatioris* Br-Bl. 1925, Pavl. 1928
8. As. *Pöetum pratensis* Burd et al. 1956
Al. *Cynosurion* Tx.1947 em Jurko 1969
9. As. *Agrostetum tenuis* Szafer, Pawl. et Kulkz.1923

10. As. *Festuco*(*rubrae*) - *Agrostietum* Csűrős et Kaptalan 1964
11. As. *Agrosti* - *Chamaespartietum sagittalis* Boșcaiu 1970

- VEGETATION OF XEROPHYLOUS GRASSLANDS -

Cls. ***FESTUCO – BROMETEA*** Br-Bl. 1943

Ord. *FESTUCETALIA VALESIACAE* Br-Bl et Tx. 1940

Al. Festucion rupicolae *(sulcatae)* Soó 1940

12. As. *Botriochloetum ischaemi* Krist 1937
13. As. *Festucetum valesiacae* Burd. et al. 1956
    - *festucetosum valesiacae*
    - *agrostidetosum* Turcu 1970

Al. ***Juniperion sabinae*** Csűrős et Pop 1964

14. As. *Juniperetum sabinae* Csűrős 1958

Al. ***Seslerio - Festucion pallentis*** Klika 1937

15. As. *Melico* - *Festucetum rupicolae* nova ass.prov.
16. As. *Festuco (rupicolae)* - *Seslerietum coerulentis* nova ass.prov.

Ord. *BRACHYPODIO* - *CHRISOPOGONETALIA* (Hic 1958) Boșcaiu 1971

Al. ***Danthonio - Brachipodion*** Boșcaiu 1970

17. As. *Festuco (rubrae)* -*Danthonietum* (Gancev 1961 n.n), Csűrős, Pop, Hodișan, Csűrős - Kaptalan 1968

Cls. ***SEDO - SCLERANTHETEA*** Br.- Bl.1955, Moravec 1967

(Pioneer vegetation on gravel and stony soils)

Ord. *THERO* - *AIRETALIA* Oberd.1957

Al. ***Thero - Airion*** Tx. 1951

18. As. *Filagini* - *Vulpietum* Oberd. 1938
19. As. *Ventenata dubia* - *Xeranthemum festicum* Borza 1950

Cls. ***PLANTAGINETEA MAJORIS*** Tx. et Prsg 1950

(weeds from hardened land of ruderalized grasslands)

Ord. PLANTAGINETALIA MAJORIS Tx. (1947), 1950

Al. ***Polygonion avicularis*** Br.- Bl. 1931

20. As. *Cynodontetum dactyloni* Rapeics 1926
21. As. *Polygonetum avicularis* Br.- Bl. 1931
22. As. *Lolio* - *Plantaginetum majoris* (Linkola1921), Berger 1930

Al. ***Agropyro - Rumicion crispi*** Nordh. 1940

23. As. *Lolio* - *Potentilletum anserinae* Knapp 1946
24. As. *Juncetum effusi* Eggler 1933
25. As. *Junco inflexi* - *Menthetum longifolies* Lohmayer 1953
26. As. *Agrostetum pisidicas* Buia, Păun, Safta et Pop 1959

The floristic surveys and vegetation classification were made according to the method of the Braun - Blanquet Phytosociological School also called Zürich - Montpellier (Anghel et al. 1971; Coldea 1991; Doniță et al. 1992).

The transformation of the scale of appreciation of the abundance - dominance of the species marked with "+" to "5" into participation percentages was carried out according to the new method of evaluating productivity based on floristic survey (Marușca, 2019).

According to this method, two works have already appeared in this journal, so we will not return to the applied method (Marușca, Taulescu 2021, Taulescu, Marușca 2022).

Based on the durations of average daily air temperatures (A.d.t.), the optimal grazing period was established, described in a synthesis paper (Marușca, 2001).

From these data there is a similarity between the duration A.d.t. equal to or greater than 10 degrees Celsius, with the optimal grazing period at altitude of - 7.5 days /100 m in areas with assured humidity (precipitation, phreatic water, irrigation) from 205 (0-200 m) to 55 days (2000-2200 m).

Table 1

Optimum grazing period with animals of altitude grasslands and milk conversion coefficient per hectare

Altitude	Duration		Grazing season (days)	Transformation coefficient milk/ha
	A.d.t. ≥ 10 °C (days)	A.d.t. ≥ 20 °C (days)		
2000 - 2200	55	0	55	35
1800 - 2000	70	0	70	44
1600 - 1800	85	0	85	53
1400 - 1600	100	0	100	62
1200 - 1400	115	0	115	71
1000 - 1200	130	0	130	80
800 - 1000	145	0	145	89
600 - 800	160	0	160	98
400 - 600	175	0	175	107
200 - 400	190	45	145	89
0 - 200	205	90	115	71
Gradients for 100 m altitude	- 7.5 days (0 – 2400 m)	- 22.5 days (0 – 400 m)	+ 15 days (0 – 400 m) - 7,5 days (400 – 2400 m)	+ 9 days (0 – 400 m) - 4,5 days (400-2200 m)

In areas with a drier climate where we have A.d.t. ≥ 20 degrees Celsius from 0 -200 m alt. with 115 days of grazing, the optimal duration increases by 15 days/100 m alt. up to 400 m alt. after which it gradually decreases by - 7.5 days, having the humidity provided by the more abundant precipitation of the mountain area (Marușca, 2001).Milk production per hectare (Table 1) was calculated according to the formula:

Milk (litres/ha) =
PV x Conversion coefficient
PV = pastoral value

The transformation coefficient is dependent on the duration of the grazing season (Marușca, 2022c), determined in a 25 years' experience with milk cows in Bucegi Mountains.

Pastoral value is a synthetic parameter regarding the production and quality of the grassy carpet of a grassland, widely used in French (Daget, Poissonet, 1971) and English specialized literature, with a working method well known in grassland culture, so it is not necessary to be presented in detail.

RESULTS AND DISCUSSIONS

In the Bistrița-Vâlcii hydrographic basin, based on 355 floristic surveys, 26 phytosociological associations belonging to 10 alliances, 6 orders and 5 vegetation classes were outlined (Table 2).

On average, 78 species of cormophytes were determined in a floristic survey, valued as rich, starting with 14 at As. *Lolio - Potentilletum anserinae* to 174 *Festucetum pratensis*.

Table 1

General data on vegetation, forage structure, production and the pastoral value of grassland phytocoenoses

№.	Association	Surveys (no.)	Cormophyte	Coverage (%)	Species participation (%)		Green mass production (t/ha)	Pastoral value
					Forage	Harmful		
	Al. *Agrostion stoloniferae*							
1.	*Agrosteto - Pöetum trivialis*	4	51	100	74	26	11,63	58,7
2.	*Alopecureto - Festucetum pratensis*	9	76	100	79	21	14,10	68,4
3.	*Festucetum pratensis*	62	174	100	63	17	14,11	69,3
4.	*Pöetum silvicolae*	16	108	100	87	13	14,40	75,1
5.	*Agrostetum caninae*	3	50	100	86	14	9,76	60,5
6.	*Caricetum distantis-vulpinae*	23	109	100	57	43	5,90	34,9
7.	*Ranunculeto (strigulosi)- Equisetetum palustris*	8	50	88	9	79	0,52	4,6
	Al. *Arrhenetherion elatioris*							
8.	*Pöetum pratensis*	14	102	100	77	23	9,38	59,5
	Al. *Cynosurion*							
9.	*Agrostetum tenuis*	17	99	100	79	21	11,10	61,3
10.	*Festuco*(*rubrae*) *- Agrostietum*	33	138	100	74	28	9,36	56,3
11.	*Agrosti - Chamaespartietum sagittalis*	36	147	100	62	38	5,99	42,8
	Al. Festucion rupicolae							
12.	*Botriochloetum ischaemi*	19	122	100	21	79	1,49	14,3
13.	*Festucetum valesiacae*	8	97	100	48	52	3,35	28,8
	Al. *Juniperion sabinae*							
14.	*Juniperetum sabinae*	5	43	100	8	92	0,59	5,8
	Al. *Seslerio - Festucion pallentis*							

15.	*Melico - Festucetum rupicolae*	15	79	55	32	23	2,20	16,3
16.	*Festuco (rupicolae) - Seslerietum coerulentis*	7	57	85	52	33	4,20	25,7
	Al. *Danthonio – Brachipodion*							
17.	*Festuco (rubrae) - Danthonietum*	19	110	100	87	13	11,00	59,7
	Al. *Thero - Airion*							
18.	*Filagini - Vulpietum*	15	114	100	30	70	1,80	19,3
19.	*Ventenata dubia - Xeranthemum festicum*	5	69	82	43	39	1,75	27,3
Al. *Polygonion avicularis*								
20.	*Cynodontetum dactyloni*	6	31	82	63	19	2,92	42,2
21.	*Polygonetum avicularis*	4	17	88	84	4	6,59	48,7
22.	*Lolio - Plantaginetum majoris*	6	59	100	89	11	14,54	75,5
Al. *Agropyro - Rumicion crispi*								
23.	*Lolio - Potentilletum anserinae*	3	14	400	16	84	1,19	12,6
24.	*Juncetum effusi*	14	84	100	31	69	3,52	24,7
25.	*Junco inflexi - Menthetum longifolies*	2	25	100	9	91	1,04	4,6
26.	*Agrostetum pisidicas*	2	16	100	18	82	0,74	13,5
TOTAL - AVERAGE		**355**	**78**	**95**	**53**	**42**	**6,28**	**38,9**

The average soil coverage with vegetation is 95%, being rated as very good. The participation of forage species in the grassy carpet averaged 53%, quite low with variations from 8% in *Juniperetum sabinae* to 87% in *Lolio - Plantaginetum majoris*.

Low percentages of only 9% forage species participation were observed in the associations *Ranunculeto (strigulosi) - Equisetetum palustris* and *Junco inflexi - Menthetum longifolies*.

A high percentage of 87% forage plants was recorded for *Pöetum silvicolae* and *Festuco (rubrae) - Danthonietum*.

The degree of participation of forage species in the grass carpet directly influences the productivity of a grassland. Thus, the associations with the highest production (14.40 - 14.54 t/ha) of green mass are *Pöetum silvicolae* and *Lolio - Plantaginetum majoris*, and the lowest (0.52 - 0.59 t/ha) with *Ranunculeto (strigulosi)- Equisetetum palustris* and *Juniperetum sabinae*.

The average production of green mass (GM) of the associations is 6.28 t/ha, being considered quite low. Likewise, the pastoral value (PV) is weak to mediocre, registering an average index of 38.9 at the level of the 28 associations described in this hydrographic basin. With values of 75.1 - 75.5 PV index are the same associations that also record the highest GM productions, likewise the lowest with 4.6 PV are with the lowest GM productions per hectare, presented before. Since data on GM production and PV indices at the level of grassland association are less representative for the characterization of European-level habitats, phytosociological alliances that are easier to assimilate with habitats are further analysed (Gafta, Mountford, 2008). Thus, the 10 alliances with grassland vegetation, located between 200 - 1100 m altitude in the study area, can optimally use 160 days of grazing with animals with an average load of 0.55 LU per hectare (Table 3).

Table 3

Spread of alliances, average green mass production and grazing livestock density index

Alliance	Altitude (m)	Green mass production		Grazing season (days)	Grazing livestock density index (LU/ha)
		(t/ha)	%		
Agrostion stoloniferae	(200)400-600(800)	10,06	177	175	0,88
Arrhenetherion elatioris	250 - 650	9,38	165	170	0,85
Cynosurion	(300)400-800(1100)	8,82	155	165	0,88
Festucion rupicolae	300 - 650	2,42	43	165	0,23
Juniperion sabinae	800 - 900	0,59	10	150	0,06
Seslerio-Festucion pallentis	(650)700-1000(1100)	3,20	56	145	0,34
Danthonio - Brachipodion	500 - 700	11,00	193	170	1,00
Thero - Airion	300	1,78	31	145	0,19
Polygonion avicularis	(300)400-600(700)	8,02	141	175	0,71
Agropyro - Rumicion crispi	300 - 400 (800)	1,62	28	155	0,17
Average	**200 - 1100**	**5,69**	**100**	**160**	**0,55**

With GM productions of 10-11 t/ha it was evaluated in the *Agrostion stoloniferae* and *Danthonio - Brachipodion* alliances that support an optimal load of 0.88 - 1.00 LU/ha in 170-175 days grazing season.The weakest results regarding GM production were assessed in *Juniperion sabinae* and *Agropyro - Rumicion crispi* with 0.59 - 1.62 t/ha supporting a grazing livestock density index of only 0.06-0.17 LU/ha in 150- 155-day grazing season.Similarly, the evaluation of milk production at the level of grassland alliance (habitat) is presented (Table 4.). The highest milk production was evaluated in *Danthonio - Brachipodion* with 6210 liters/ha at 59.7 PV index, and the lowest in *Juniperion sabinae* with 530 liters/ha and 5.8 PV.

On average, at the 10 practical alliances, 3710 liters of milk per hectare was evaluated, having 36.7 PV and a transformation coefficient of 104 for the 160 days optimal grazing season with dairy cows.

Table 4

Pastoral value and yield of possible cow's milk at the alliance level

Alliance	Coverage (%)	Pastoral value (indices)	Milk conversion indices (indices)	Milk production	
				(liter/ha)	%
Agrostion stoloniferae	68	53,1	107	5680	153
Arrhenetheretalia elatioris	77	59,5	104	6190	167
Cynosurion	72	53,5	101	5400	146
Festucion rupicolae	35	21,6	101	2180	59
Juniperion sabinae	8	5,8	92	530	14
Seslerio - Festucion pallentis	42	21,0	89	1870	50
Danthonio - Brachipodion	87	59,7	104	6210	167
Thero - Airion	37	23,3	89	2070	77
Polygonion avicularis	79	55,5	107	5940	160
Agropyro - Rumicion crispi	19	13,9	95	1320	36
Average	**52**	**36,7**	**101**	**3710**	**100**

These economic data are the basis for the drawing up of pastoral development projects and the correct management of permanent grasslands.

CONCLUSIONS

The vegetation of the permanent grasslands in the basin of the Bistrița-Vâlcii River, tributary of the Olt River, is particularly rich in species, recording an average of 78 cormophytes on a survey in the 26 associations belonging to 10 alliances, 6 orders and 5 phytosociological classes.

The average production of green mass was evaluated at 6.28 t/ha average of associations and 5.69 t/ha average of alliances, which allow a grazing livestock density index of 0.55 LU/ha in 160 days of grazing season.

The average pastoral value has an index of 36.7, which allows the production of 3710 liters of cow's milk per hectare during the grazing season, on average on grasslands located between 200 - 1100 m altitude.

REFERENCES

1. Anghel Gh. and M. Răvăruţ, 1971. Turcu Gh., Geobotanica, Editura Ceres, Bucureşti.
2. Gafta D. and J. O. Mountford - Coord., 2008. Manual de interpretare a habitatelor Natura 2000 din România, Ed. Risoprint, Cluj Napoca
3. Coldea Gh., 1991. Documents phytosociologiques, Nouvelle Série, Volume XIII, Università degli Studi, Camerino.
4. Daget P., Poissonet J., 1971, Une méthode d'analyse phytologique des prairies. Critéres d'application. Annales Agronomiques, 22(1): 5–41, INRA France.
5. Doniță N, Ivan Doina, Coldea Gh., Sanda V., Popescu A., Chifu Th., Pancă-Comănescu Mihaela, Boscaiu N., 1992: Vegetația României. Ed. Tehn. Agr. București.
6. Marușca T., 2001. Elemente de gradientică si ecologie montană, Editura Universității "Transilvania" din Brașov,130 pagini, ISBN 973-8124-27-1.
7. Marușca T., V. Mocanu, E. C. Haș, M. A. Tod, A. C. Andreoiu, M. M. Dragoș, V. A. Blaj, T. Ene, D. Silistru, E. Ichim, P. Zevedei, C. Constantinescu and S. Tod, 2014. Ghid de întocmire a amenajamentelor pastorale, Editura Capolavoro, Brașov, 248 pagini.
8. Marușca, T., 2019. Contributions to the evaluation of pasture productivity using the floristic releve, Romanian Journal of Grassland and Forage Crops Nr. 19, pp. 33- 47Cluj – Napoca.
9. Marușca T. and E. Taulescu, 2021, The need for grassland productivity assessment for the economical development of mountain area (Case study, Ciucaș Mountains), Journal of Mountain Agriculture on the Balkans, 24 (6), pp. 313-329 ISSN1311-0489 (Print) Research Institute of Mountain Stockbreeding and Agriculture, Troyan, Bulgaria.
10. Marușca T., 2022a. Evaluation of the Natura 2000 grassland habitats productivity from the Romanian Carpathians (First approach), Romanian Journal of Grassland and Forage Crops, Cluj Napoca, nr.25, pp. 59-72, ISSN 2068-3065.
11. Marușca T., 2022b. Evaluation of the Natura 2000 grasslands habitats productivity of the Romanian Plains and hills, Journal of Grassland and Forage Crops, Cluj Napoca, nr. 26 pp. 67-76, ISSN 2068-3065.
12. Marușca T., 2022c. Praticultură și pastoralism în cercetarea științifică, Editura Universității Transilvania din Brașov, 311 pagini, ISBN 978-606-19-1565-1.

13. Marușca T., 2023. Evaluation of Cow Milk Production during the Grazing period of Natura 2000 Grassland Habitats, Academy of Romanian Scientists Series on Agriculture, Silviculture and Veterinary Medicine Sciences, 12, (2), pp. 38-44.
14. Motcă Gh., I. Oancea and L-I. Geamănu, 1994. Pajiștile României, Tipologie și tehnologie, Ed. Tehnică Agricolă, București.
15. Taulescu E., T. Marușca, P. Zevedei, A. Andreoiu, C. C. Comșia, 2022. Interractions between Pyrus piraster trees (Wild pear) and grassland in an agrosolvopastoral system, Academy of Romanian Scientists Series on Agriculture, Silviculture and Veterinary Medicine Sciences, Volume 11, Number 1, pp. 28-37.

RESEARCH ON VEGETATIVE PROPAGATION CAPACITY OF THE *Bromus inermis* Leyss. SPECIES

Mihai STAVARACHE, Simona DUMITRIU, Elena-Manuela BĂDRĂGAN, Cristian-Sorin GAVRILĂ

Research and Development Station for Meadows Vaslui, Romania
Corresponding author e-mail: scdp_vs@yahoo.com

Abstract
Bromus inermis Leyss. *species is a rustic one, very well adapted to less favorable pedoclimatic conditions. High production capacity and extended vivacity, due to vgegetative multiplication, make this species used for various purposes such as: feed production, degraded permanent meadows improvement, slope soil fixiation, greening of polluted areas and others more. The purpose of the research conducted during the 2022-2025 agricultural period, at the Research and Development Station for Meadows Vaslui, was to select the best Bromus inermis* Leyss. *genotypes in terms of vegetative propagation capacity. Of the 155 transpanted genotypes, 22 did not survive, and a total of 38 did not develop a bush larger than 15 cm, even after 2 years of vegetation. Of the 95 genotypes with vegetative multiplication, were selected a number of 10 clones with bush diameter between 103 and 158 cm, respectively clones with the codes R9P6, R9P7, R9P9, R15P4, R16P10, R20P7, R22P6, R24P2, R3P4 and R15P6, which will be further studied in terms of productive potential.*

Keywords: transplantation, rooting, bush diameter, expandability

INTRODUCTION

Bromus inermis Leyss. species (smooth brome or awnless bromegrass) is a rustic one, very well adapted to less favorable pedoclimatic conditions. High production capacity and extended vivacity, due to vegetative multiplication, make this species used for various purposes.

It can be used to obtain feed, grown alone or mixed with sainfoin (*Onobrychis vicifolia* Scop.) for setting up temporary meadows used by mowing or mixed (this mixture also has an anti-erosional role) (Lazaridou M., 2008; Saeidnia F. et al, 2019; Ahmed A.I. et al, 2020; Ciobanu Cătălina, 2021).

This species has a very important role to improve the composition of vegetation, production capacity and quality of feed on degraded permanent meadows in steppe and forest-steppe areas, in spcial on slopes, being used for overseeding, alone or in mixtures together with other valuable perennial grasses and legumes species (Dumitrescu N. *et al*, 2014; Lardner H.A. *et al*, 2015; Samuil C. *et al*, 2019; Stavarache M. *and* Naie Margareta, 2024).

In the context of the Romanian Order No. 80/2023 can be used to make grassy bands between the rows of trees in orchards. It can be used for the greening of polluted areas (for example, on areas cleared of waste, from the outskirts of localities, etc.), for the rapid fixing of terraces, dams, banks of irrigation canals or other land improvement works, for the fast and long-term fixing of areas of modelled land, as a result of road or highway construction and in aquaculture, as well it can be used for rapid grassing and creating optimal conditions in fish breeding pools (Marușca T. *et al*, 2010; Shi W. *et al*, 2017). *Bromus inermis* Leyss. spreads vegetatively primarily through underground stems called rhizomes. This allows it to form dense, spreading sods, especially in disturbed areas. It also reproduces sexually by seeds, but its vegetative spread via rhizomes is the primary way it maintains and expands its populations aggressively. This feature can be improved, and may be created varieties that are recommended for the cultivation of land with erosion problems, in order to fix them. The researches carried out in the 2022-2025 agricultural period, within the Moara Grecilor location of the Research and Development Station for Meadows (RDSM), Vaslui, was represented by the analysis of the influence of *Bromus inermis* Leyss. genotype on the vegetative propagation capacity, under the conditions of Moldavian Forest Steppe.

MATERIAL AND METHOD

The research was carried out in the 2022-2025 agricultural period at the Research and Development Station for Meadows (RDSM), Vaslui, Moara Grecilor location. The purpose of the research was to select the best *Bromus inermis* Leyss. genotypes in terms of vegetative propagation capacity.

A total of 155 genotypes (clones) were selected and studied in the *Bromus inermis* Leyss. species, from the field collection of the RDSM Vaslui. In the spring of 2023 (02.05.2023), genotypes were transplanted, in the form of a monolith measuring L = 10 cm, l = 10 cm and h = 15 cm, in the middle of a plot of 4 m^2 (2 m × 2 m) available surface for vegetative development. After the establishment of the experimental field, the care works consisted only in performing a number of 2 cleaning cuts per year. The diameter of the bush was measured in two perpendicular directions and the average (cm) was made, and the comparison of the provenances between them was carried out (notes from 1 to 5) taking into account the height of the bush (cm), the number of shoots and the shape of the bush.

Tabel 1 shows how the experimental field is organised and the codification of the 155 genotypes. The experimental field of the Vaslui SCDP has an eastern exhibition with a slope of 3-5 %, and the soil is typical cambic chernozem with a content, in the layer of 0-25 cm, of 3.42 humus, 0.16 total N, 37.6 ppm P, 151.7 ppm K and a pH of 6.3.

Table 1.

Experimental field organization and the codification of the genotypes

E	D	C	B	A	
R1P1	R1P3	R1P8	R1P9	R1P10	1
R2P3	R2P4	R2P5	R3P1	R3P4	2
R3P9	R4P3	R4P4	R4P9	R5P9	3
R6P3	R6P4	R7P6	R7P9	R7P10	4
R8P1	R8P2	R8P8	R8P9	R8P10	5
R9P6	R9P7	R9P9	R9P10	R10P4	6
R10P5	R11P1	R11P3	R11P4	R11P9	7
R12P2	R12P3	R12P4	R12P7	R13P10	8
R14P5	R15P2	R15P3	R15P4	R15P10	9
R16P1	R16P3	R16P8	R16P9	R16P10	10
R17P3	R17P4	R18P1	R19P1	R19P8	11
R20R1	R20P3	R20P7	R20P10	R21P8	12
R22P6	R22P8	R23P1	R23P3	R23P9	13
R24P1	R24P2	R24P3	R24P8	R25P1	14
R24P1	R26P3	R26P7	R27P1	R27P2	15
R27P6	R27P7	R27P9	R27P4	R27P7	16
R28P1	R28P2	R29P3	R29P8	R29P9	17
R29P1	R29P2	R29P3	R30P1	R30P2	18
R30P7	R31P8	R32P7	R32P8	R33P9	19
Is	Ms	R1P3	R1P4	R2P9	20
R3P4	R3P5	R3P9	R4P8	R4P9	21
R5P9	R5P10	R6P2	R6P5	R6P6	22
R6P7	R6P9	R7P6	R7P7	R7P8	23
R7P9	R8P6	R8P9	R9P5	R9P10	24
R10P6	R10P9	R11P7	R12P5	R12P6	25
R13P1	R13P6	R13P10	R14P9	MIH.	26
R15P1	R15P2	R15P3	R15P4	R15P6	27
R15P8	R16P9	R17P2	R17P6	R17P9	28
R18P9	R19P7	R20P6	R20P10	R21P2	29
R22P1	R22P4	R23P8	R23P10	R24P10	30
R25P7	R26P9	R27P7	R27P9	DOV.	31

Figure 1 shows the climatic conditions during the research. The variability of climatic conditions may be observed, depending on the year, but also depending on the month of each year. Water stress periods are relevant, the most important being those in the summer and autumn of 2023, but which contributed to a better selection among the 155 genotypes analyzed.

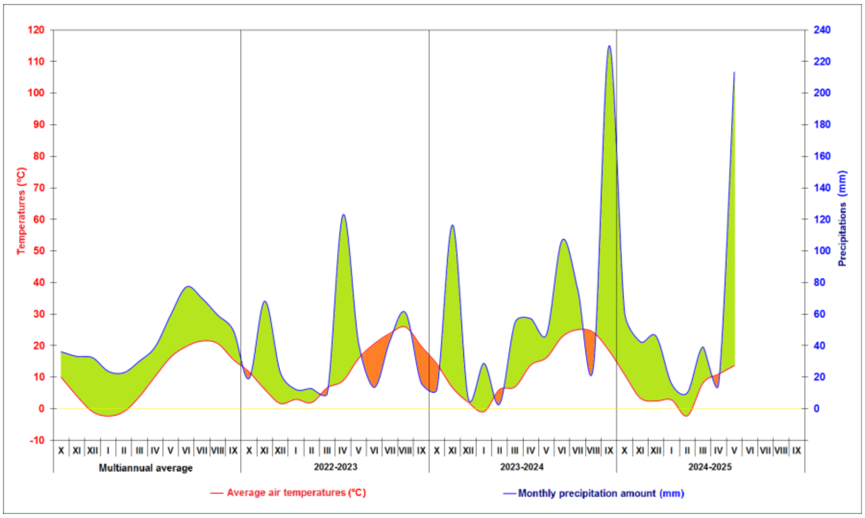


Figure 1. Climate conditions in the 2022-2025 agricultural period (RDSM Valui - Moara Grecilor location)

RESULTS AND DISCUSSIONS

At the time of transplanting, the irrigation work was not carried out, to see also the potential for installation of new clones. For this reason, in the year of establishment of the experience (determination being carried out at the end of 2023 - year 0) a number of 22 genotypes did not survive (R1P9, R6P3, R6P4, R7P6, R7P10, R8P10, R8P1, R8P2, R20P10, R23P3, R23P1, R28P1, R27P7, R30P7, R32P7, R5P9, R7P9, R10P6, R11P7, R12P5, R20P10 and DOV.). In figure 2 are presented the results of measurements regarding the diameter of the bush in the genotypes studied, in the year 1 (2024) and year 2 (2025) of development. The results obtained showed that, in addition to the 22 clones that did not survive, a number of 38 clones almost did not show the vegetative multiplication trend, their diameter being 10 cm in the year 1 and maximum 15 cm in the year 2. The other clones generated bushes with a diameter of up to 82 cm in year 1 and up to 158 cm in year 2. Of the 95 genotypes with obvious vegetative multiplication, in year 2, were selected a number of 10 clones with bush diameter greater than 100 cm (between 103 and 158 cm), respectively clones with the codes R9P6, R9P7, R9P9, R15P4, R16P10, R20P7, R22P6, R24P2, R3P4 and R15P6. They are to be transplanted into a degraded meadow of *Dichanthium ischaemum* (L.) Roberty, where the vegetative propagation capacity will be tested, under conditions different from those in arable land. The ultimate goal is to create a new genotype of *Bromus inermis* Leyss., with a high capacity of fixing degraded soils, including those on which permanent grasslands are installed.

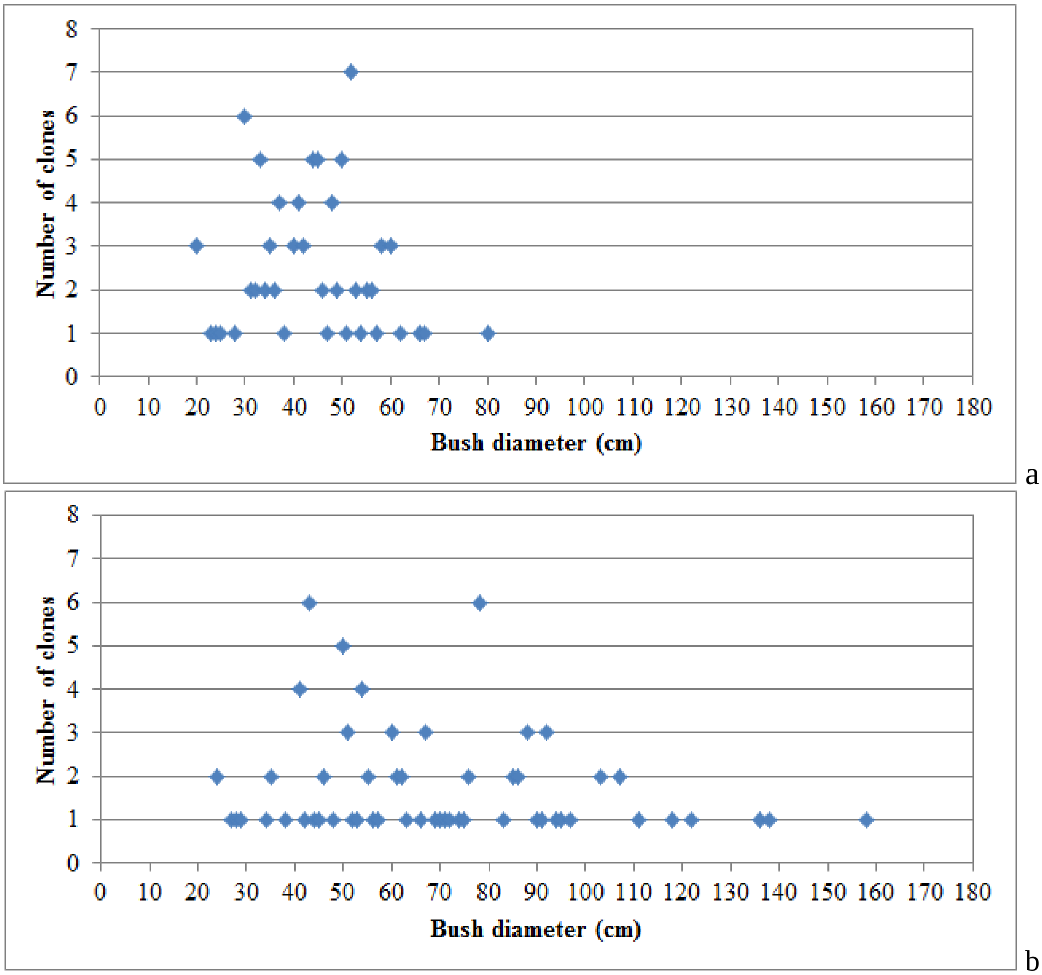


Figure 2. The diameter of the bush (cm) at the ground level,
at the 95 genotypes that survived: a - year 1 (2024) and b - year 2 (2025)

The evolution of the bush diameter at the 10 genotypes with a large diameter of 100 cm, selected, is shown in figure 3. General aspects from the installation of the experience and the following years of vegetation are shown in figure 4. Vegetative multiplication capacity and productivity are usually dependent on each other. As a perspective, the research needs to be extended, because the correlation between vegetative propagation capacity and the productive potential in the 10 selected genotypes must be established.

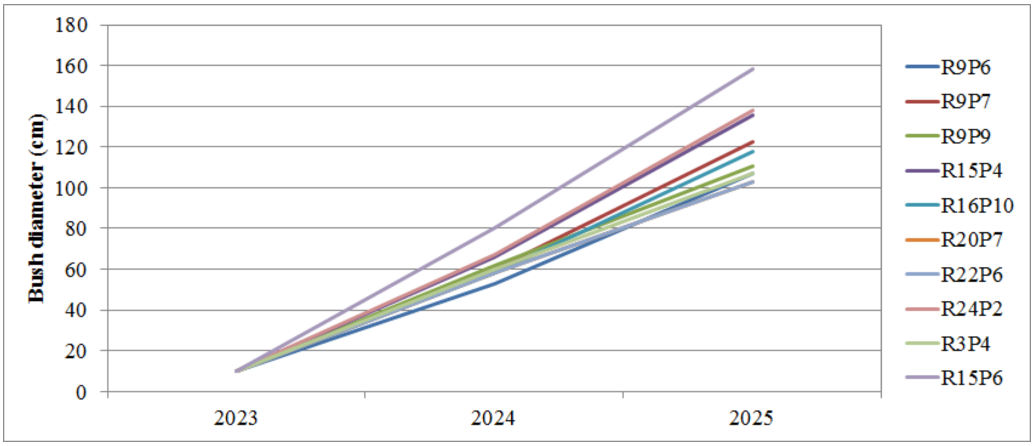


Figure 3. Evolution of the bush diameter at the 10 genotypes selected, with a large diameter of 100 cm

Figure 4. Aspects from the installation of the experience (year 0) and the following years (year 1 and year 2) of vegetation

CONCLUSIONS

Of the 155 transpanted genotypes, 22 did not survive in the first year of vegetation.

A total of 38 genotypes did not develop a bush larger than 15 cm, even after 2 years of vegetation.

Of the 95 genotypes with vegetative multiplication, were selected a number of 10 clones with bush diameter between 103 and 158 cm, respectively clones with the codes R9P6, R9P7, R9P9, R15P4, R16P10, R20P7, R22P6, R24P2, R3P4 and R15P6.

The main recommendation is to continue the research and to determine the correlation between vegetative propagation capacity and the productive potential in the 10 selected genotypes.

REFERENCES

1. Ahmed A.I., Hou L., Yan R., Xin X., Zainelabdeen Y.M., 2020 - *The joint effect of grazing intensity and soil factors on aboveground net primary production in Hulunber Grasslands Meadow Steppe*. Agriculture, 10, 263.
2. Ciobanu Cătălina, 2021 - *Teză d e doctorat: Cercetări cu privire la comportarea speciilor de obsigă nearistată (Bromus inermis* Leyss.*) şi sparcetă (Onobrychis viciifolia* Scop.*) în cultură pură și amestecuri simple în condiţiile din depresiunea Jijia-Bahlui*, USAMV Iași.
3. Dumitrescu N., Vîntu V., Samuil C., Iacob T., 2014 - *Ameliorarea pajiștilor degradate din zona de silvostepă*. Editura Ion Ionescu de la Brad Iaşi, 188 p., ISBN 978-973-147-148-8.
4. Lardner H.A., Damiran D., McKinnon J.J., 2015 - *Evaluation of 3 bromegrass species as pasture: herbage nutritive value, estimated grass dry matter intake and steer performance*. Livest. Sci., 175:77-82.
5. Lazaridou M., 2008 - *Grass and legume productivity oscilations in a binary mixture,* Biodiversity and Animal Feed 'Future Challenges for Grassland Production', Sweden, ISBN 978-91-85911-47-9, 22:269-271.
6. Maruşca T., Bărbos M.I., Blaj V.A., Cardașol V., Dragomir N., Mocanu V., Rotar I., Secelean I., Rusu Mariana, 2010 - *Tratat de reconstrucţie ecologică a habitatelor de pajişti şi terenuri degradate montane*, Editura Universităţii "Transilvania", 359 p. ISBN 9789735987879.
7. Saeidnia F., Majidi, M.M., Mirlohi A., Bahrami S., 2019 - *Inheritance and combining ability of persistence and drought recovery in smooth bromegrass* (*Bromus inermis* Leyss.), Euphytica, 215, 177.

8. Samuil C., Vîntu V., Stavarache M., 2019 - *Producerea și conservarea furajelor*, Editura „Ion Ionescu de la Brad” Iaşi.
9. Shi W., Zhang X., Jia H., Feng S., Yang Z., Zhao O., Li Y., 2017 - Effective remediation of aged HMW-PAHs polluted agricultural soil by the combination of *Fusarium* sp. and smooth bromegrass (*Bromus inermis* Leyss.), J. Integr. Agric., 16:199-209.
10. Stavarache M., Naie Margareta, 2024 - *Gestionarea durabilă a pajiștilor permanente*, Editura Pim, Iași, 306 p., ISBN 978-606-13-8143-2.
11. *** Order No. 80/2023, available on-line at: (27.11.2025) https://legislatie.just.ro/Public/DetaliiDocumentAfis/268432.

RESEARCH ON THE INSTALLATION OF *Bromus inermis* Leyss., *Onobrychis vicifolia* Scop. SPECIES AND MIXTURES BETWEEN THEM ON SANDY SOILS

Elena (STAVARACHE) PRICOP*, Călin SĂLCEANU, Aurel Liviu OLARU****

**Research and Development Station for Meadows Vaslui, Romania*
***University of Craiova, Faculty of Agronomy, Craiova, România*
**Corresponding author e-mail: scdp_vs@yahoo.com*

Abstract

In Romania, sand and sandy soils occupy about 500,000 hectares, or over 2% of the country's territory. Of the regions with sandy soils, the Oltenia Plain has the highest share, with 170,000 ha. Bromus inermis Leyss. *and Onobrychis vicifolia* Scop. *species are adapted to arid climate conditions and grow well on nutrient-deficient soils, being successfully cultivated on eroded land in the forest-steppe area, and limiting the expansion of sandy soils and creating a suitable layer of vegetation, can be an option by using these species. The research conducted during the 2024-2025 agricultural year, at the Experimental Didactic Station through the Experimental Center of Tamburesti, belonging to the University of Craiova was to establish the best technological option for fixing sandy soils with the help of the Bromus inermis* Leyss.*, Onobrychis vicifolia* Scop. *species, and mixtures between them. Following the study, it was found that Bromus inermis* Leyss.*, Onobrychis vicifolia* Scop. *species and mixtures between them can be installed on sandy soils but keeping them in culture is difficult.*

Keywords: mixture ratio, seeding method, vegetation coverage

INTRODUCTION

In Romania, sand and sandy soils occupy about 500,000 hectares, or over 2% of the country's territory. Of these, 150,000 hectares of movable and semi-mobile sands.

Their formation is due to the natural factors that contributed to their formation, in particular wind, temperature, pluviometric regime and flowing waters. These surfaces are located in the west and south-west of the Romanian Plain, known as the sands of southern Oltenia east and north-east of Baragan, on the right side of the Ialomita, Calmatui and Buzau rivers, as well as the Tecuciului Plain, in the Danube Delta and in the north-west of the country, at Carei-Valea lui Mihai, the western part of the Banat Plain (Coteț P., 1976; Iancu P. *and* Bonciu P., 2010; Stănilă A.N. *et al*, 2020).

Of the regions with sandy soils, the Oltenia Plain has the highest share, with 170,000 ha.

Bromus inermis Leyss. and *Onobrychis vicifolia* Scop. species are adapted to arid climate conditions and grow well on nutrient-deficient soils, being successfully cultivated on eroded land in the forest-steppe area. Thus, limiting the expansion of sandy soils and creating a suitable layer of vegetation, can be an option by using these species, especially since on sandy lands, species with close characteristics, such as *Bromus tectorum* L. (Lehnhoff E.A. *et al*, 2019) and *Onobrychis Arenaria* (Kit.) DC. (Țîței V., 2021). The research was carried out in the Romanati Plain (left of the Jiu River, which owns 81,000 ha of sandy soils) at the Experimental Didactic Station through the Experimental Center of Tamburesti, belonging to the University of Craiova and they aimed to research the fixing of sandy soils with the help of *Bromus inermis* Leyss., *Onobrychis vicifolia* Scop. species, and mixtures between them.

MATERIAL AND METHOD

The research was carried out in the 2024-2025 agricultural year at Experimental Center of Tamburesti, belonging to the University of Craiova. The purpose of the research was to establish the best technological option for fixing sandy soils, within the Experimental Didactic Station - Experimental Center Tamburesti, belonging to the University of Craiova, with the help of the *Bromus inermis* Leyss., *Onobrychis vicifolia* Scop. species, and mixtures between them. In order to achieve the purpose, the analysis of the installation capacity of cultivated species and the analysis of the vegetation coverage and its evolution were followed.

The experimental factor was the species or mixture cultivated with 5 graduations, respectively:

v_1 - sown with *Bromus inermis* Leyss. 100 % (control variant);

v_2 - sown with *Bromus inermis* Leyss. 75 % + *Onobrychis viciifolia* Scop. 25 %;

v_3 - sown with *Bromus inermis* Leyss. 50 % + *Onobrychis viciifolia* Scop. 50 %;

v_4 - sown with *Bromus inermis* Leyss. 25 % + *Onobrychis viciifolia* Scop. 75 %;

v_5 - sown with *Onobrychis viciifolia* Scop. 100 %.

The experience was placed in randomized blocks with the area of a plot of 36 m^2 (12 m × 3 m), the area of a repetition of 180 m^2 (15 m × 12 m) and the area of the experience of 600 m^2 (40 m × 15 m) (Jitareanu G. *and* Onisie T., 1998).

The varieties created at the Research and Development Station for Meadows Vaslui SCDP were used: at sainfoin, the Sersil variety - 2018 - at a density of 600 germinable grains/m^2; at the smooth brome variety Mihaela - 2009 - at a density of 1200 germinable grains/m^2. The date of sowing was 14.03.2025 and the date of emergence was 7.04.2025 (when 75% of the plants came out).

The appreciation of the emergence (16.04.2025) and the degree of vegetation coverage (16.06.2025) they were made by performing, in each repetition, a number of 3 determinations using the metric frame with the side of 0.5 m (0.25 m^2). The percentages determined at each observation were also compared with those initially established by each mixture.

The results were statistically interpreted by analyzing variance and calculating last significant differences (LSD). There were also analyzed the regressions between the determined parameters and the percentage of mixed participation of each species. The soil on which the experience was established is an eutric psamosol, which is part of the protisoles class, heavily leached soil (decarbonated), with sandy texture, formed on wind deposits consisting of coarse materials (sand), having as underlying rocks unconsolidated or poorly consolidated silicate rocks.

This soil type has, in the Ao horizon (0-23 cm) the pH value of 6.31, the $CaCO_3$ content - 0 %, the humus content 0.64 %, the total nitrogen 0.032 % (IN 0,46), 53.3 ppm P_{AL}, 41.0 ppm K_{AL}, 1.6 me/100g Ah, 4.0 me/100g SB and 13.53 C/N ratio (Popa I. *et al*, 2025). The climatic conditions of the experimentation period, namely 2024-2025 agricultural year, from the Research and Development Station for Plant Culture on Sandy Soils Dabuleni (located 17 km from the experimental field), showed that rainfall amount was normal in October, in excess in November and in deficit in the rest of the analyzed months, and the average monthly temperatures were close to the multiannual ones (average of 1956-2025 period) (figure 1).

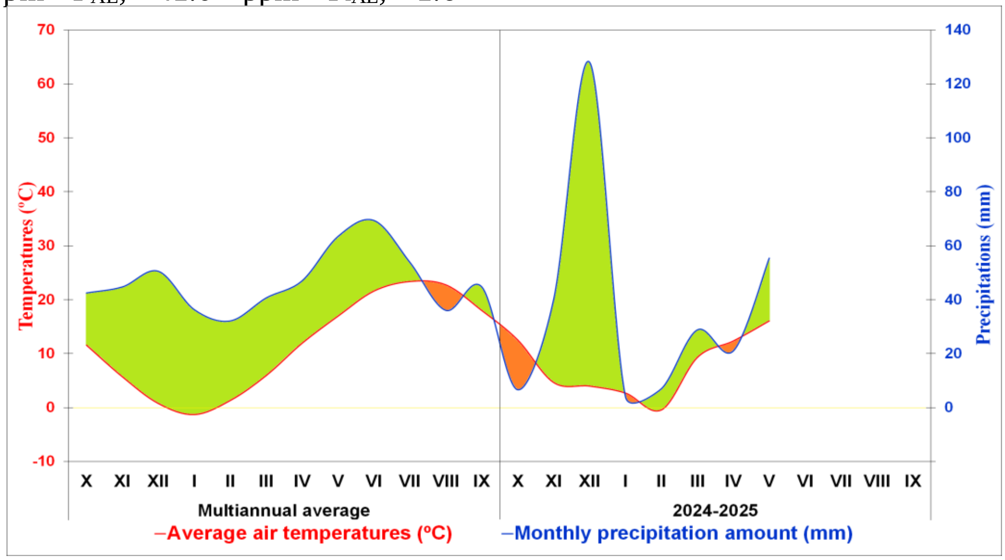


Figure 1. Climadiagram of agricultural year 2024-2025 (SCDCPN Dabuleni)

RESULTS AND DISCUSSIONS

Installing any species on sandy soils is difficult, because on these soils there is no humus and nutrients in sufficient quantities and water retention capacity is very small. Although in the experimental field there is the possibility of irrigation, this was not necessary due to favorable climatic conditions in spring 2025. Compared to the initial sowing ratio, established for each variant, for both *Bromus inermis* Leyss. and *Onobrychis viciifolia* Scop. species the percentage of emerged plants was lower (table 1). In *Onobrychis vicifolia* Scop. the percentage of emerged plants was higher than *Bromus inermis* Leyss. by 5.1-16.1 %, at the same percentage of participation in the mixture. Figure 2 shows the correlations between the percentage of participation in the mixture and the percentage of emerged plants where can be seen more clearly the differences between the initial and the resulting percentage.

Table 1

Appreciation of the plants emergence (16.04.2025)

Variant	*Bromus inermis* Leyss.				*Onobrychis viciifolia* Scop.			
	Participation (%)		Difference (%)	Significance	Participation (%)		Difference (%)	Significance
	initial	*final*			*initial*	*final*		
v_1 (c)	*100*	66.7	Control	Control	*0*	0	-	-
v_2	*75*	38.3	-28.4	o	*25*	24.8	-41.9	oo
v_3	*50*	26.1	-40.6	oo	*50*	36.1	-30.6	o
v_4	*25*	19.7	-47.0	oo	*75*	54.4	-12.3	ns
v_5	*0*	0	-	-	*100*	77.8	11.1	ns
	LSD	*0.5 %*	*23.5*		*LSD*	*0.5 %*	*23.5*	
		0.1 %	*34.1*			*0.1 %*	*34.1*	
		0.01 %	*51.2*			*0.01 %*	*51.2*	

After 61 days from the plants emegence, the vegetation coverage in the two cultivated species was very small, compared to the percentage initially set for each variant, (table 2) between the initial and final percentage having negative deviations between 17.8-88.3 % of *Bromus inermis* Leyss. and 9.4-69.8 % of *Onobrychis viciifolia* Scop. species.

Figure 3 shows the correlations between the percentage of participation in the mixture and the soil degree of coverage with vegetation where to see more clearly the differences between the initial and the resulting percentage.

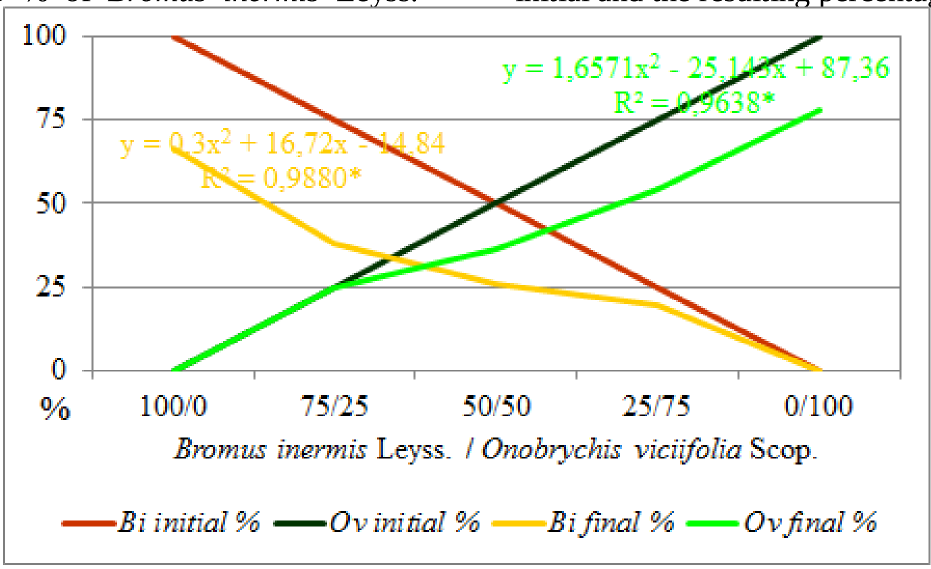


Figure 2. Correlations between the percentage of participation in the mixture and the percentage of emerged plants

Table 2

Appreciation of the degree of vegetation coverage (16.06.2025)

Variant	*Bromus inermis* Leyss.				*Onobrychis viciifolia* Scop.			
	Participation (%)		Diffe-rence (%)	Signifi-cance	Participation (%)		Diffe-rence (%)	Signifi-cance
	initial	*final*			*initial*	*final*		
v_1 (c)	*100*	11.7	Control	Control	*0*	0	-	-
v_2	*75*	11.6	-0.1	ns	*25*	15.6	3.9	
v_3	*50*	7.4	-4.3	ns	*50*	20.0	8.3	*
v_4	*25*	7.2	-4.5	ns	*75*	26.9	15.2	**
v_5	*0*	0	-	-	*100*	30.2	18.5	***
	LSD	*0.5 %*	*7.2*		*LSD*	*0.5 %*	*7.2*	
		0.1 %	*10.5*			*0.1 %*	*10.5*	
		0.01 %	*15.7*			*0.01 %*	*15.7*	

The advantage of the cultivation of the two species in the mixture is given by their biological and morphological peculiarities. Thus, the *Bromus inermis* Leyss. species develop stolons, which contributes to the soil fixation, and the *Onobrychis viciifolia* Scop. species fix by symbiosis nitrogen, although this on sandy soils can be more difficult due to the lack of soil symbiosis bacteria. This can be solved by inoculating the seed material before sowing.

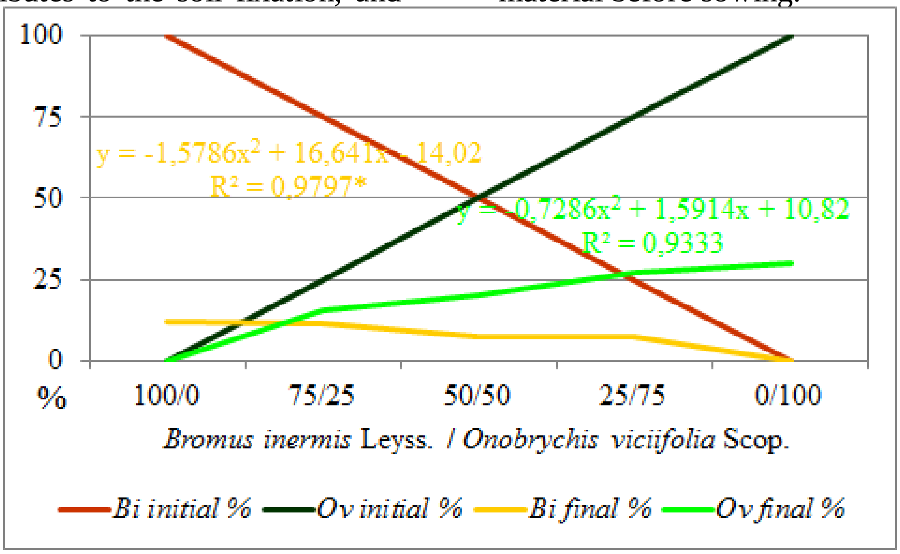


Figure 2. Correlations between the percentage of participation in the mixture and the soil degree of coverage with vegetation

CONCLUSIONS

In both species, the percentage of emergent plants was lower than originally set, in each of the 5 studied variants, but in *Onobrychis vicifolia* Scop. the percentage of emerged plants was higher than *Bromus inermis* Leyss. by 5.1-16.1

%, at the same percentage of participation in the mixture.

In both species, the degree of vegetation coverage was much lower than originally established, regardless of the variant studied, being between 17.8-88.3 % of *Bromus inermis* Leyss. and 9.4-69.8 % of *Onobrychis viciifolia* Scop. species.

Bromus inermis Leyss., *Onobrychis vicifolia* Scop. species and mixtures between them can be installed on sandy soils within Experimental Didactic Station - Experimental Center Tamburesti but keeping them in culture is difficult.

REFERENCES

1. Coteț P., 1976 - R*omanian Plain. Integrated geomorphology study, Publisher Ceres, Bucharest*.
2. Iancu P., Bonciu P., 2010 - *Case study concerning the cultivation of the sandy soil from Oltenia*. Analele Universităţii din Craiova, seria Agricultură-Montanologie-Cadastru, 40(2):164-169.
3. Jitareanu G., Onisie T., 1998 - *Tehnică experimentală, Lucrări practice*. Institutul Agronomic „Ion Ionescu de la Brad” Iasi, pag. 81-98.
4. Lehnhoff E.A., Rew L.J., Mangold J.M., Seipel T., Ragen D., 2019 - *Integrated management of cheatgrass (Bromus tectorum) with sheep grazing and herbicide*. Agronomy, 9(315):1-21. https://doi.org/10. 3390/agronomy9060315.
5. Popa I., Iordache L., Gheonea I., Buică I., Iordache L., 2025 - *Studiu pedologic pentru „Înființarea unei plantații pomicole în cadrul Stațiunii Didactice Experimentale Tâmbureşti, judetul Dolj" pe suprafaţa de 4,0 ha, amplasate în extravilan U.A.T. Rojiște, sat Tâmbureşti, Jud. Dolj*. OSPA Dolj, Craiova.
6. Stănilă A.N., Simota C.C., Dumitru M., 2020 - Contributions to the knowledge of sandy soils from Oltenia Plain, Rev. Chim. 71(1):192-200.
7. Țiței V., 2021 - *Some agrobiological peculiarities and potential uses of Glycyrrhiza glabra* L. *and Onobrychis Arenaria* (Kit.) DC. *in the Republic of Moldova*. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 21(4):593-598, Print ISSN 2284-7995.

THE ROLE OF PASTURES IN THE GROWTH PERFORMANCE OF PUREBRED TURCANA AND CROSSBRED LAMBS: A REVIEW

Mirela RANTA, Andrada IHUȚ *

Department of Plant Crops. Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Manastur street, 3-5, 400372, Romania.
**Department of Technological Sciences, Faculty of Animal Science and Biotechnologies University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Manastur street, 3-5, 400372, Romania*
**Corresponding author: ihut.andrada@usamvcluj.ro*

Abstract

The sheep sector in Romania is an important part of the national livestock industry and relies heavily on permanent pastures as the main source of feed for sheep farms. The way in which permanent pastures are used directly influences the growth performance of lambs, as they are the main source of feed for sheep farming in Romania. This article summarizes data from the scientific literature on the average daily gain (ADG) of purebred Turcana lambs and hybrids resulting from crossbreeding with specialized meat breeds, in different types of pastures and feeding systems. Analysis of the results shows that Turcana lambs have a moderate growth rate in extensive grazing based systems, reflecting their ability to utilize feed resources with medium or low nutritional value. The application of feed supplementation in the early stages of growth leads to significant increases in average daily gain (ADG), highlighting the importance of nutritional management in the early postnatal stages. In most of the studies analyzed, Turcana × specialized meat breeds lambs show higher average daily gains than purebred lambs, both in semi-intensive and extensive systems, with these differences being more pronounced in situations of limited feeding. The scientific basis for choosing meat production strategies in sheep farming is provided by these results, which confirm how growth performance is affected by feed quality, supplementation levels, and genetic structure.

Keywords: *permanent grasslands; Turcana bred; crossbreeding; average daily gain (ADG); feeding system;*

INTRODUCTION

The sheep farming sector in Romania is an essential component of national animal husbandry, being integrated into extensive and semi-extensive farming systems where permanent pastures provide the main source of feed. According to official data published by the National Institute of Statistics, Romania's total sheep population is around 11.87 million, but these reports lack a breed-specific breakdown, hindering the accurate estimation of each breed's share of the national population (https://insse.ro/cms/ro). Several scientific studies suggest

that the Turcana breed accounts for 70-80% of the total sheep population, but these values are only estimates (Sauer M. et al., 2013; Gavojdian et al., 2016; Neață and Vintilă, 2023, https://www.anarz.eu).
Approximately 4.9 million hectares of permanent pasture are spread across the country. These areas are relatively evenly divided between pastures and hayfields: 68% are used as pastures and 32% for hay production. Around 79% of these pastures are situated in hilly and mountainous regions. These areas have significant livestock potential. However, researchers often do not exploit them properly (Samuil, C. and Vîntu, V., 2012; Mocanu, V. et al. 2021; Cojocariu Luminita, 2022; Rotar, I. and Vidican Roxana, 2003;). At the same time, Romania's sheep sector has experienced an overall upward trend between 2014 and 2024, positively impacting the economy. According to data published by the National Institute of Statistics (INS), the total sheep population was approximately 10.94 million in 2014, increasing to 11.87 million in 2024 (Table 1). This indicates a gradual increase in the popularity of the species (https://insse.ro).

Table 1

Evolution of sheep and goat livestock in Romania between 2014 and 2024 (thousand heads) and year to year differences

Year	Sheep and goats – total	Differences (±) compared to the previous year	Sheep, ewes, and goats	Differences (±) compared to the previous year
2014	10935.4	-	8521.3	-
2015	11249.7	+314.3	8704	+182.7
2016	11358.6	+108.9	8730.5	+26.5
2017	11485.1	+126.5	8833.9	+103.4
2018	11715.7	+230.6	8921.4	+87.5
2019	11953.6	+237.9	9166	+244.6
2020	11893.3	-60.3	9052.2	-113.8
2021	11580	-313.3	8941.3	-110.9
2022	11730.5	+150.5	10093.5	+1152.2
2023	11721.2	-9.3	10063.7	-29.8
2024	11869.5	+148.3	10232.7	+169

Note: the data are expressed in thousands (INSSE, 2024). In this paper, the values are also presented in millions for ease of interpretation (e.g., 11,869.5 thousand = 11.87 million) Source: https://insse.ro

The scientific consensus is that the Turcana breed is the most widespread in the sheep sector. It is excellently adapted to the conditions of the Carpathian Mountains and hilly areas, where grazing remains the main source of fodder. Pastures used by sheep flocks exhibit distinct differences in terms of floristic composition, green mass production, vegetation density, the developmental stage of dominant species and dry matter content (Tafta V., 2003; Pădeanu I., 2003; Voia S., 2005; Pașca I. and Roman M., 2007; Păcurar F. and Rotar I., 2014).

In sheep farming systems that use permanent pastures, the growth performance of lambs is an important indicator of biological efficiency. This is expressed as average daily gain (ADG) and is influenced by the quality of the feed, the level of supplementation and the genetic potential of the animals. The growing interest in meat production has led to the diversification of farming practices through the use of the Turcana breed, both purebred and crossbred with meat specialised breeds, while maintaining adaptability to farming on permanent pastures. In the context of both the national and European situations, this paper aims to evaluate the influence of pasture type and feeding systems on the growth performance of Turcana breed lambs and Turcana × specialized meat breeds, as measured by average daily gain (ADG).

The study aims to establish effective meat production guidelines in extensive and semi-intensive sheep farming systems. The study aims to perform a comparative analysis of ADG according to pasture type and feed supplementation level, evaluate the influence of genetic potential on growth rate and highlight the relationships between feed resource quality and lamb growth performance (Tafta V. et al., 1997; Pascal C., 2007a; Pascal C., 2007b; Pădeanu I., 2010).

MATERIAL AND METHOD

This analysis was conducted through systematic bibliographic research, focusing on average daily gain (ADG) in Turcana lambs, as well as in lambs resulting from crosses between Turcana and other meat breeds (Turcana × Ile de France, Turcana × Lacaune, Turcana × Norwegian White, Turcana × German Blackheaded Mutton and Turcana × Blackheaded Mutton). The studies were identified in academic databases such as Google Scholar, PubMed, Web of Science and Scopus, using keywords: "Turcana lambs, Turcana crossbreeding, pasture fed lambs, Turcana feeding systems, average daily gain". Indexed Romanian journals and relevant academic literature were also consulted. Eligible studies had original data on body weight and ADG, analysed the Turcana breed or Turcana × specialized meat breeds, described the rearing conditions (type of pasture, feed supplementation and duration of the experiment) and provided clear information on the number of animals and their age range. Studies without quantitative data, papers without scientific evaluation, and articles unrelated to the objectives of the paper (e.g. exclusively focusing on lactation, pathology or molecular genetics) were excluded. The following data were extracted for each study:

number of animals; age range analysed; type of pasture; feeding system; duration; and ADG values. The data were summarised in two tables: the first for the pure Turcana breed and the second for the Turcana × specialized meat breeds. This approach enabled a direct comparison of the influence of genotype, pasture and feeding on growth performance.

RESULTS AND DISCUSSIONS

The results obtained are summarised in Tables 2 and 3, which present the growth performance of Turcana lambs and Turcana × specialized meat breeds, expressed as average daily gain (ADG), depending on the type of pasture and feeding system.

The data presented in Table 2 provides a overview of the results obtained from various studies on the growth performance of Turcana lambs under different feeding conditions and farming systems. In a study by Pădeanu et al. (2004), 12 purebred Turcana lambs were monitored from birth until they were 155 days old. Their body weight was recorded at 0, 14, 30, 60, 80, 100, 120 and 155 days. Initially, the lambs were fed maternal milk and hay, and from two weeks of age they were switched to a concentrate feed containing 16% crude protein. They were subsequently switched to a semi-intensive feed mixture containing 12.18% crude protein and 0.76 nutrient units/kg. Analysis of the growth rate showed average daily gains of 232 g between days 0 and 30, 192 g between days 0 and 60, 182 g between days 0 and 80, 170 g between days 0 and 100, 166 g between days 0 and 120, 164 g between days 0 and 140 and 168 g for the entire period from days 0 to 155. This describes the growth trajectory specific to this batch of lambs under semi-intensive conditions. Pascal et al. (2009) conducted another experiment on young Turcana sheep (black and white varieties), both male and female, with 25 animals in each group. The sheep were fattened for 175 days in a semi-intensive system with uniform housing conditions and feeding adapted to technological stages (10 days of adaptation, 135 days of fattening, and 30 days of finishing). Growth performance was monitored by weighing the animals at the start and end of each phase. The results showed average daily gains of 125 ± 7.9 g for black males, 112 ± 7.1 g for black females, 116 ± 6.1 g for white males, and 108 ± 7.3 g for white females. At slaughter, yields ranged from approximately 44.1% for black Turcana males to 39-40% for white Turcana female. Pădeanu et al. (2009) evaluated 35 white Turcana lambs over an age range of 0-8 months, taking body weight measurements at birth and at 60, 90, 180 and 240 days. The lambs were raised in a maternal system with free access to milk. From three weeks of age, they received an additional 250 g/day of concentrates identical in structure to those used in the hybrid batch.b

Table 2

The growth performance (ADG - average daily gain) of purebred Turcana lambs in different feeding systems

Reference	Breds/Lot-number/ Ages	Weighings	Pasture/ Feeding system	ADG - average daily gain (g/day)
Pădeanu et al., 2004	Turcana purebreds (12 heads); during the period between lambing and 5 months of age	Frequent weighings from birth to 155 days	Milk and hay + concentrated semi-intensive feeds type, 12.18% crude protein (CP) and 0.76 nutritional units (NU) kg	168 g/day
Pascal et al., 2009	Turcana black variety and Turcana white variety (males group, females groups)	-	Semi-intensive system; same conditions for all lots	Turcana black -males (125.5 g/day); Turcana white -males (116 g/day); Turcana black - females (112 g/day); Turcana white - females (108 g/day)
Pădeanu et al., 2009	White Turcana; 35 young ewes; 0-8 months	Weaning at :birth 2 -3-6-8 months	Suckling: ad libitum milk; after 3 weeks until weaning: 250 g/day concentrates (50% barley, 50% corn); After weaning: only improved natural pasture	White Turcana: 123 g/day
Nagy et al., 2010	Turcana; 5 lambs ages beginning: 154 days end: 233 days; duration of the study: 79 days	Start of fattening End of fattening Additional measurements at slaughter	65 days- alfalfa hay ad libitum; the last 14 days- finishing diet consisting of alfalfa hay + compound feed for young sheep	Turcana 171.4 g/day (total ADG for the 79 days)
Gavojdian et al., 2011	Turcana purebreds (33 heads)	0, 28, 240 days	Hay + pasture; after 28 days, only natural pastures (after weaning), lambs were kept on pastures 24/7, and were fed only with green fresh feed from natural-unimproved pasture of low quality; no concentrated feed	194 g/day (0-28 days); 138 g/day (0-240 days) average body weight was 37.00 kg.
Zaharia et al., 2012	Turcana breed; 20 weaned lambs of the (aged 3 to 6 months)	Monthly	Traditional system of breeding / Semi-intensive system of breeding + supplements	59,3 g/day vs 152,5 g/day; final live weight 20.94 g/day vs. 29.46 g/day kg
Gavojdian et al., 2016	Turcana purebreds; 20 heads after weaning	-	Conventional pasture; Organic pasture	Turcana 206,0 g/day (conventional pasture); Turcana 182,7 g/day (organic pasture)

Source: (data from the specialized literature)

After weaning, maintenance was carried out exclusively on improved natural pasture. Average daily gains were 205 g/day in the first two months, 150 g/day between two and three months, 100 g/day between three and six months, and 70 g/day between six and eight months. This corresponds to an average daily gains (ADG) of 95 g/day for the two-to-eight-month interval, and 123 g/day for the zero to eight month interval. Additional data are provided by Nagy et al. (2010), who analysed a control group of five Turcana breed rams over a period of 79 days and took body weight measurements at the beginning and end of the interval.

The feeding regimen included 65 days of alfalfa hay, followed by 14 days of alfalfa hay supplemented with feed for young sheep. The average daily gain was 171.4 g/day, and data obtained at slaughter included live weight, slaughter yield, and anatomical measurements of the carcass.

Gavojdian et al. (2011) monitored a group of 33 purebred Turcana lambs from birth until they were 240 days old, taking body weight measurements at 0, 28, and 240 days. The animals were not given any concentrates, instead being fed hay and green fodder from the pasture until weaning. They were then maintained exclusively on unimproved natural pasture. Average daily weight gains were 194.12 g/day for the first 28 days and 138.45 g/day for the full 0-240 day period. Zaharia et al. (2012) also highlight differences determined by feeding systems by comparing two groups of weaned Turcana lambs with an average age of three months and an initial weight of 15 kg. One group was fed a traditional diet of natural hay and wheat bran (150 g per day), while the second group was raised on improved pasture supplemented with wheat (150 g per day). The respective average daily weight gains were 59.3 g and 152.5 g. In a later study, Gavojdian et al. (2016) examined 40 purebred Turcana lambs that were separated from their mothers at around 65 days of age. The lambs were acclimatised to grassland for approximately 10 days, after which they were reared exclusively on grassland for four months without any concentrates being provided. Monitoring by weighing at the beginning and end of the period showed average daily weight gains of 206 g/day and 182.7 g/day in the conventional and organic systems, respectively. The data presented in Table 3 summarises the results obtained in several studies on the growth performance of hybrid lambs resulting from the crossbreeding of the Turcana breed with specialized meat breeds, evaluated under different feeding conditions and farming systems.In the study conducted by Pădeanu et al. (2004), a group of 12 F1 Turcana × Ile de France lambs was monitored over a period of 155 days, with successive weighings at 0, 14, 30, 60, 80, 100, 120, and 155 days. Until weaning at 80 days of age, the animals were fed maternal milk, hay administered from approximately two weeks of age, and a concentrate with 16% crude protein, and subsequently received a semi-intensive feed mixture with 12.18% crude protein. The growth dynamics calculated at intervals indicated average daily gains of 246 g/day between 0-30 days, 202 g/day between 0-60 days, 196 g/day between 0-80 days, 189 g/day between 0-100 days, 184 g/day between 0-120 days, 184 g/day between 0-140 days, and 192 g/day for the entire 0-155 day interval, values that reflect the body evolution specific to this genotype under the semi-intensive conditions of the study. Another experiment, reported by Pădeanu et al. (2009), followed a group of 14 Turcana × Lacaune hybrid lambs from birth to 8 months of age, with body weight measurements at 0, 60, 90, 180, and 240 days.

Table 3

The growth performance (ADG - average daily gain) of Turcana × crossbred lambs for meat in different feeding systems

Reference	Breds/Lot- number/ Ages	Weighings	Pasture/ Feeding system	ADG - average daily gain (g/day)
Pădeanu et al., 2004	F1 Turcana × Ile de France; 12 heads- during the period between lambing and 5 months of age	Frequent monitoring from birth to 155 days	Milk and hay + concentrated semi-intensive feeds type, 12.18% crude protein (CP) and 0.76 nutritional units (NU) kg	192 g/day
Pădeanu et al., 2009	White Turcana × Lacaune; 14 young ewes; 0-8 months	Weaning at :birth 2 -3-6-8 months	Suckling: ad libitum milk; after 3 weeks until weaning: 250 g/day concentrates (50% barley, 50% corn); After weaning: only improved natural pasture	White Turcana × Lacaune: 137 g/day
Nagy et al., 2010	Norwegian White × Turcana; 5 lambs; ages beginning: 154 days end: 233 days; duration of the study: 79 days	Start of fattening; End of fattening; Additional measurements at slaughter	65 days- alfalfa hay ad libitum; the last 14 days- finishing diet consisting of alfalfa hay + compound feed for young sheep	Norwegian White × Turcana 212 g/day (total ADG for the 79 days)
Gavojdian et al., 2011	German Blackheaded Mutton × Turcana; (48 heads)	0, 28, 240 days	Hay + pasture; after 28 days, only natural pastures (after weaning), lambs were kept on pastures 24/7, and were fed only with green fresh feed from natural-unimproved pasture of low quality; no concentrated feed	229 g/day (0–28 days); 168 g/day (0–240 days) Weight at 240 days in F1 German Blackheaded Mutton x Turcana lambs was on average 45.13 kg
Gavojdian et al., 2016	F1 × 20	-	Conventional pasture; Organic pasture	F1 German Blackheaded x Turcana 258,0 g/day (conventional pasture); F1 German Blackheaded x Turcana 227,3 g/day organic pasture)

Source: (data from the specialized literature)

The animals were initially kept in a maternal system, with ad libitum milk consumption, and from the age of three weeks they received an additional 250 g/day of barley and corn-based concentrates. After weaning, maintenance was carried out exclusively on improved natural pasture. Average daily gains were 209 g/day in the first two months, 170 g/day between 2-3 months, 120 g/day between 3-6 months, and 80 g/day between 6-8 months, corresponding to an ADG of 113 g/day for the 2-8 month interval and a total average daily gain of 137 g/day for the entire 0-8 month interval. Additional data are provided by Nagy et al. (2010), who evaluated a batch of 5 F1 Norwegian White × Turcana ram lambs in a 79-day fattening cycle. Body weight was determined at the beginning of the period, at an average age of 154 days, and at the end, at 233 days. The animals were fed exclusively alfalfa hay for the first 65 days and, for the last 14 days, received a finishing ration based on alfalfa hay supplemented with compound feed intended for young sheep. The average daily gain calculated for the entire interval was 212 g/day, and the data obtained at slaughter included final weight, slaughter yield, and carcass conformation. Under extensive restrictive conditions, Gavojdian et al. (2011) monitored a batch of 48 F1 German Blackheaded Mutton × Turcana lambs over a period of 0-240 days, with body weight measurements at 0, 28, and 240 days. The animals were raised without concentrate supplementation, having access to hay and green fodder until weaning, and subsequently to continuous grazing on low-quality natural pasture. Average daily gains were 229.46 g/day over the 0-28 day period and 168.35 g/day for the entire 0-240 day period. In a subsequent study, Gavojdian et al. (2016) analyzed a batch of 40 F1 German Blackheaded × Turcana lambs, weaned at 65 ± 5 days and adapted for approximately ten days to grazing. The animals were raised for four months in an extensive system, exclusively on pasture, without the administration of concentrates, but with access to water and salt. Weighings performed at the beginning and end of the period showed average daily gains of 258 g/day in the conventional system and 227.3 g/day in the organic system. In Romania, the Turcana breed forms the basis of the national sheep population and is primarily used in extensive and semi-intensive systems. In terms of productive performance, lambs of this breed have lower growth potential than breeds specialised for meat production due to their genetic characteristics and the level of intensification of the rearing system. Growth rate is influenced by maintenance systems and nutrition levels, particularly the structure and balance of feed rations. Under grazing conditions without supplementary concentrated feed, daily weight gain is limited. These characteristics highlight the adaptability of the Turcana breed to extensive conditions at the expense of superior growth and fattening performance (Pădeanu I., 2003; Voia S., 2005; Coroian C. et al., 2009; Pascal C. et al., 2009).

CONCLUSION

The average daily gain (ADG) of Turcana lambs depends directly on their nutritional intake. Higher values are seen in systems with feed supplements, while lower values are seen in extensive conditions without concentrates. In systems based exclusively on permanent pastures, the Turcana breed exhibits a moderate and stable growth rate, reflecting its capacity to utilise feed resources of medium or low nutritional value. Applying feed supplementation in the early stages of growth leads to significant increases in ADG, highlighting the importance of nutritional control during the early postnatal period. Hybrid lambs from the Turcana × specialized specialized meat breeds record higher average daily gains than purebred lambs under comparable feeding conditions in both semi-intensive and extensive systems. Performance differences between genotypes are accentuated under limited feeding conditions, indicating the higher biological efficiency of hybrids in utilising available feed resources. Using the purebred Turcana breed is justified in extensive systems based on permanent pastures, whereas crossbreeding with specialized meat breeds is an effective technological option for increasing ADG in systems with meat production objectives. Lamb growth performance is the result of the interaction between pasture quality, supplementation level and genetic structure. These parameters must be correlated with the farming system to optimise meat production.

REFERENCES

1. Cojocariu, L. (2022). Cultura pajiștilor și a plantelor furajere, Note de curs, partea I. Timișoara: Universitatea de Științe Agricole și Medicină Veterinară a Banatului „Regele Mihai I al României" din Timișoara.
2. Coroian, C., Dărăban, S., Pop, A., Cătoi, C., Odagiu, A. and Pece, A. (2009). The study of intensive fattening of youth sheep from different breeds in Romania. ABAH Bioflux, 1(1), pp. 49–56.
3. Gavojdian, D., Padeanu, I., Sauer, M., Dragomir, N., Ilisiu, E., Kusza, S. and Rahmann, G. (2016). Lamb meat production under organic and conventional systems in Turcana breed. Landbauforschung – Applied Agricultural and Forestry Research, 66(4), 290-297.
4. Gavojdian, D., Sauer, M., Pacala, N., Padeanu, I. and Voia, S. (2011). Improving growth rates in Turcana Indigenous Sheep Breed Using Ger-man Blackheaded Mutton Rams. Scientific Papers: Animal Science and Biotechnologies, 44(2), pp. 379-382.
5. Mocanu, V., Dragomir, N., Blaj, V. A., Ene, T. A., Tod, M. A. and Mocanu, V. (2021). Pajiștile României. Resurse, strategii de îmbunătățire și valorificare. Brașov: Institutul de Cercetare-Dezvoltare pentru Pajiști.
6. Nagy, B., VLAIC, A., MIREȘAN, V., ODAGIU, A. (2010). Research concerning the fattening performances of Norwegian White × Turcana Hybrids Compared to Turcana Pure Breed. Note II. Bulletin UASVM Animal Science and Biotechnologies, 67(1-2)/2010. Print ISSN 1843-5262; Electronic ISSN 1843-536X, pp. 49–53.
7. Neață, D.-I. and Vintilă, T. (2023). The Origins of the Țurcana Sheep Breed Varieties and the Migration of the Populations. Scientific Papers: Animal Science and Biotechnologies, 56(1), 203–207.
8. Pașca, I. and Roman, M. (2007). Animal breeding and rearing systems. Romania: Editura Risoprint.
9. Păcurar, F. and Rotar, I. (2014). Study methods and interpretation of meadow vegetation. Cluj-Napoca, Romania: Risoprint.
10. Pădeanu, I. (2003). Technical evaluation and genetical improvement of sheep productions. Timișoara, Romania: Editura Mirton.
11. Pădeanu, I. (2003). Evaluare tehnică și ameliorare genetică a producțiilor la ovine. Timișoara, Romania: Editura Mirton.
12. Pădeanu, I. (2010). Producția de carne la ovine. Timișoara, Romania: Editura Mirton, pp. 3–6.

13. Pădeanu, I., Sauer, M., Voia, O. and Dumitrescu, G. (2004). Evolution of the body weight and absolute growing rate of Turcana × Ile de France hybrid from lambing up to 5 months of age. Biotechnology in Animal Husbandry, 20(3–4), pp. 92–96.
14. Pădeanu, I., Sauer, M., Voia, S., Daraban, S., Cîrnu, I. and Pascal, C. (2009). Evolution of the growth speed up to the age of 8 months of the Turcana X Lacaune Hybrid young ewes compared to Turcana ones. Lucrări ştiinţifice Zootehnie şi Biotehnologii, 42(2), pp. 495-499.
15. Pascal, C. (2007a). Breeding of sheep and goats. Iași, Editura PIM.
16. Pascal, C. (2007b). Study regarding indigenous sheep populations reared in the north-eastern part of Romania and possibilities of improving meat production. Project PNII, Romania.
17. Pascal, C., Gîlcă, I., Pădeanu, I., Nacu, Gh., Daraban, S.V., Iftimie, N. and Costică, C. (2009). Researches concerning the meat production improvement at the indigenous sheep populations, through the appliance of certain appropriate fattening technologies. Scientific Papers – Animal Science Series, University of Agricultural Sciences and Veterinary Medicine Iași, 52, pp. 340-346.
18. Pascal, C., Ivancia, M. and Gilca, I. (2009). Researches concerning the possibilities to improve the quality of the carcasses of the sheep obtained through cross-breeding. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Animal Science and Biotechnologies, 66(1–2), pp. 194–199.
19. Rotar, I. and Vidican, R. (2003). Cultura pajiştilor. Cluj-Napoca: Editura Poliam. ISBN 973 99930 0 1.
20. Samuil, C. and Vîntu, V. (2012). Environmental impact and yield of permanent grasslands: an example of Romania. In Organic Farming and Food Production. InTech. https://doi.org/10.5772/52006.
21. Sauer, M., Pădeanu, I., Radu, R., Găvojdian, D., Sauer, W.-I., Stanciu, M., Vîcovân, G. and Rațiu, D.I. (2013). Reproductive performance of native Romanian Turcana sheep breed reared for organic meat production under highlands conditions. Scientific Papers: Animal Science and Biotechnologies, 46(1), pp. 354–357.
22. Tafta, V., Vintilă, I. and Zamfirescu, S. (1997). Producția, ameliorarea și reproducția ovinelor. Bucharest, Romania: Editura Ceres, pp. 35–44.
23. Tafta, V. (2003). Breeding sheep in small and medium sized farms. București, Romania: Editura Ceres.
24. Voia, S. (2005). Sheep and goats productions – Evaluation techniques. Timișoara, Romania: Editura Marineasa.
25. Voia, S. (2005). Ovine şi caprine. Ghid practic de creștere. Timișoara, Romania: Editura Waldpress, pp. 68–70.
26. Zaharia, R., Pascal, C., Zaharia, N., Lazăr, R. and Salamon, S. (2012). The influence of the fattening system on growth rate and dressing percentage of the Turcana lambs bred in mountain area in the North-East of Romania. Lucrări Ştiinţifice – Seria Zootehnie, 57, pp. 190–196.
27. ***https://insse.ro
28. ***https://www.anarz.eu

TRACKING THE CANOPY DEVELOPMENT OF RIPARIAN GRASSLANDS IN TARGOVISTE PIEDMONT PLAIN ON DÂMBOVIȚA RIVER WITH REMOTE SENSING RESOURCES

**Daniel DUNEA[*], Adrian Nicușor FILIP[**], Niculae DINCĂ[**], Ana-Maria STANCIU[**], Ana-Maria GLOD-LENDVAI[*], Cristina MANTEA[****]

[*]Valahia University of Targoviste, Faculty of Environmental Engineering and Food Science, Aleea Sinaia no.13, Targoviste, Romania.
[**]University of Agronomic Sciences and Veterinary Medicine Bucharest, Faculty of Agriculture, Blv. Mărăşti nr.59, Sector 1, Bucureşti, Romania,

Corresponding author: adrian.filip@valahia.ro

Abstract
The study aimed to track the canopy development of riparian grasslands in Targoviste piedmont plain on Dâmbovița River, both with remote sensing resources and in-situ not destructive methods such as the use of a canopy analysis system. The experiments were performed in the Northwest part of Targoviste Piedmont Plain on the Dâmbovița River. Dragomiresti village (44°53'08.1"N 25°24'09.2"E, 285 m a.s.l.) was selected as a pilot area. Leaf area index (LAI) was the key indicator selected to estimate the canopy dimension and function during the May-July period of each year from 2022 to 2025. The Terrascope platform provided the Sentinel-2 LAI data that was compared with the average values provided by the canopy analysis system. Field measurements are highly consistent. Coefficients of Variation are low across all months (≈2.6–4.8%), indicating stable interannual behavior. Satellite variability is month-dependent, being very high in April (28.7%) and elevated in July (16.2%), and moderate in June (13.1%), respectively.

Keywords: riparian grassland, leaf area index, floristic composition, Terrascope, ESA's Sentinel

INTRODUCTION

Riparian grasslands represent highly fertile transitional zones located along rivers, streams, and wetlands. They are characterized by moist soils and hydrophilic plant communities that play critical ecological roles, including pollutant filtration, bank stabilization, flood regulation, and provision of diverse habitats (DUNEA et al., 2021). Despite their ecological importance, these ecosystems are increasingly vulnerable to anthropogenic pressures such as land-use change, biological invasions, and the impacts of climate change (BAUDRY and THENAIL, 2004). Functioning as essential green corridors, riparian grasslands connect aquatic and terrestrial ecosystems, create unique microclimatic conditions, and sustain high levels of biodiversity, even though they typically occupy a relatively small proportion of the landscape. Assessing the productivity of riparian grasslands requires a comprehensive understanding of the interactions among environmental factors, vegetation types and properties, and anthropogenic activities (DINCĂ and DUNEA, 2018). In most riparian grasslands, vegetation has established spontaneously, exhibiting high diversity due to the dynamic nature of its component species (ONETE et al., 2022). Seasonal fluctuations in species composition within the grassland canopy generate varied structural and functional patterns throughout the growing season, largely influenced by plant phenology (SZYMURA et al., 2009).

Riparian grasslands dominated by *Lolium perenne* (perennial ryegrass) and *Trifolium repens* (white clover) occur in limited areas within river valleys, typically on flat or gently sloping terrain. These grasslands exhibit a complex species composition that enhances their ecological and agronomic value. In addition to the dominant species, they host a range of high-quality forage plants such as *Poa pratensis, Agrostis stolonifera, Alopecurus pratensis, Dactylis glomerata, Trifolium pratense, Medicago falcata, and Medicago minima*. Species with lower forage value, including *Cynodon dactylon, Plantago lanceolata,* and *Taraxacum officinale*, are also present, contributing to the overall biodiversity of the sward (MOTCĂ et al,, 1994). Such communities are characterized by high productivity, with green biomass yields ranging from 6 to 10 tons per hectare, and exhibit excellent palatability, making them suitable for grazing and hay production. The presence of legumes such as *Trifolium repens* improves soil nitrogen status through biological fixation, enhancing the sustainability of these ecosystems. Due to their restricted distribution and high forage potential, these grasslands represent valuable resources for livestock systems and warrant targeted management strategies to maintain productivity and ecological integrity (BĂRBULESCU et al., 1991). Annual phenological changes in natural grassland vegetation occur in response to meteorological conditions, flowering periods, and other developmental phases. Nevertheless, several key attributes defining the *phytocoenosis*, such as canopy structure and floristic composition, remain relatively stable over time (VÎNTU et al., 2010; SAMUIL et al., 2018).

The dominant vegetation of natural grasslands consists primarily of perennial species. These species form complex functional associations that confer distinctive characteristics to grasslands, both in terms of interspecific relationships and interactions with the biotope. Perennial species also determine specific economic values and influence opportunities for improvement and utilization. To address emerging challenges associated with climate change and increasing anthropogenic disturbances, recent studies have emphasized biodiversity conservation, grassland restoration, sustainable resource management, and the enhancement of grasslands' multifunctional roles. Among the 38 major research themes identified by ZHAO G. (2023), topics were classified into four categories: substantial increase (12 themes), moderate increase (7 themes), moderate decrease (5 themes), and substantial decrease (14 themes). Themes related to ecology and environment - such as biodiversity conservation, land use and soil erosion, climate change, and paleoenvironments -have expanded rapidly, with biodiversity conservation showing the fastest growth since 1900. Technology-oriented themes, including remote sensing and numerical modeling, have also risen significantly in recent decades. Conversely, traditional topics -such as biological nitrogen fixation, grazing, plant nutrition, germplasm and reproduction, forage cultivation, and livestock production - have exhibited a marked decline.

By performing a bibliographic review using the Clarivate Web of Science database, it indicates that research on riparian grasslands is gaining increasing attention. A search using the term *"riparian grassland"* yielded 1,326 articles, including three highly cited papers. These studies primarily address interactions between land use/land cover (LULC) and water pollution levels or other environmental processes.

A more targeted search using *"riparian grassland canopy"* returned 96 records (90 articles, 4 conference proceedings, 1 book chapter, and 1 review). Finally, the expression *"riparian grassland canopy development"* returned five articles, from which 4 of them focused on the riparian forests and various ecological factors, and one shows the effects of pasture development on the ecological functions of riparian forests in a Japanese region, i.e., *DOI:10.1016/j.ecoleng.2005.01.010* (date: December 1st, 2025).

This scarcity of literature highlights the originality of the proposed research topic and its potential for integrating modern technologies for monitoring and modeling the growth and development of riparian grassland canopies. Experimental approaches will involve establishing field trials to evaluate mixtures of grasses and valuable legumes within riparian zones or adjacent areas along the Dâmbovița River. Monitoring of designated pilot grasslands will be conducted through in situ measurements and at the watershed scale using the validated remote sensing products.

MATERIALS AND METHODS

The experiments were performed in the Northwest part of Targoviste Piedmont Plain on the Dâmbovița River. Dragomiresti village (44°53'08.1"N 25°24'09.2"E, 285 m a.s.l.) was selected as a pilot area to showcase the particularities of grasslands both near the Dambovita River and outside this area. Dragomirești Commune is situated within the transitional zone between the Subcarpathian hills and the Romanian Plain, forming part of the Ploiești–Târgoviște–Pitești alignment that delineates the major geomorphological units of southern Romania. This positioning confers a mixed relief structure, where lowland plains dominate but are interspersed with hilly landforms of decreasing elevation toward the east. The commune comprises six villages arranged symmetrically along the Dâmbovița River, which serves as the principal hydrographic axis. On the right bank, following the river's flow, lie Decindeni, Râncaciov, and Ungureni, while the left bank hosts Dragomirești, Geangoești, and Mogoșești. This linear settlement pattern reflects the historical dependence on riparian resources and the suitability of alluvial soils for agriculture.

The Dâmbovița River, characterized by a relatively high discharge, traverses the commune from north to south, receiving tributary input from Tisa-Andolia, which originates in the northern sector near Dragomirești village and assumes the name Iezer in the Geangoești area. In addition to these permanent watercourses, the hydrographic network includes intermittent streams such as Suța-Mică, Suța-Mare, Cobiuța, and Vulcana—formed during periods of heavy precipitation. Historically, the commune was covered by extensive forest tracts such as Marghioala, Corneasa, Misleanu, and Obreaja, which constituted a significant ecological and economic resource.

Topographically, the area is intersected by two hills running east–west, parallel to the Dâmbovița River. These hills not only shape the local landscape but also define portions of the commune's administrative boundaries. Their elevations diminish progressively within the commune, illustrating the transition from Subcarpathian relief to the lowland plain. Viișoara Hill, the most prominent feature, extends across the northern sector and intersects the Târgoviște–Câmpulung road at the commune's entry point. Its altitude decreases markedly toward the east, reaching approximately half its initial height at the Târgoviște–Pitești road, and eventually merging into the plain near Produlești village (Fig. 1 - a).

This geomorphological configuration influences land use patterns, vegetation distribution, and hydrological dynamics, positioning Dragomirești as a representative example of a transitional landscape between hill and plain environments in southern Romania (Pastoral Arrangement Project, 2020). The vegetation zone encompassing the grasslands of Dragomirești village corresponds to the hill–plain floor (Fig. 1 - b). This zone is characterized by a heterogeneous relief with altitudes ranging from 281 m to 346 m. The soils identified in the studied areas belong to a single major class: the Luvisol class. The Luvisol class is present across the 212.09 hectares surveyed. Within this class, the following soil types and subtypes were recorded:

- Preluvosol, with the stagnic subtype.
- Luvisol, with the stagnic and albic stagnic subtypes (Pastoral Arrangement Project, 2020).

The plant cover within the area exhibits considerable diversity, including species that are representative of both hill and plain ecotypes. Species identification was conducted during the field survey, which confirmed the presence of grass species with panicle-type inflorescences, such as:

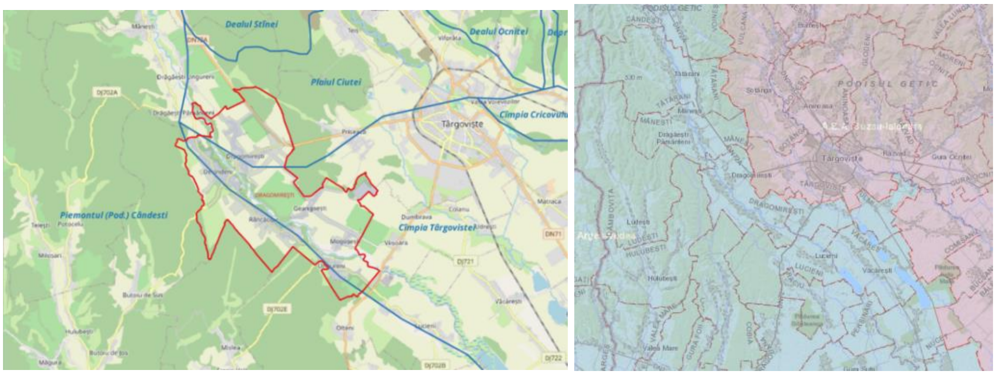
- *Festuca pratensis* (meadow fescue),
- *Poa pratensis* (Kentucky bluegrass),
- *Lolium* spp. (various ryegrass species),
- *Agrostis stolonifera* (creeping bentgrass)
- *Agrostis capillaris* (common bentgrass),

as well as leguminous species, notably:

- *Trifolium repens* (white clover).
- *Lotus corniculatus* (bird's-foot trefoil) – see Table 1.

Leaf Area Index (LAI) quantifies the amount of leaf material in a canopy. It is a dimensionless metric representing the total leaf area relative to the ground surface area beneath it. LAI is crucial for understanding canopy function and biosphere-atmosphere exchanges. It is used in biogeochemical, hydrological, and ecological models. LAI also measures crop, grassland, and forest growth and productivity. LAI was assessed by using remote sensing platforms and direct measurements based on the Delta-T Devices Sunscan System (DUNEA and MOISE, 2008; FILIP et al., 2023).

Terrascope, Belgium's Earth Observation Data Space, constitutes a platform designed to facilitate access to satellite-based geospatial information for research, policy, and operational applications (https://viewer.terrascope.be/). Managed by the Flemish Institute for Technological Research (VITO) under the mandate of the Belgian Federal Science Policy Office (BELSPO), Terrascope provides free and open access to Earth Observation datasets, primarily from the European Space Agency's Sentinel missions within the Copernicus program, as well as complementary archives from other satellite sources.



a) **b)**

Fig. 1. Dragomiresti commune a) administrative boundaries and geomorphological units; b) boundaries of the Argeș-Vedea River Basin Administration (source https://portal-gis.rowater.ro/)

Fig. 2. Example of grassland in Mogosesti village near the Dambovita River; in-situ monitoring and animals grazing

Table 1.

Floristic Composition by Plot in Dragomiresti commune

Plot No.	Grassland Type	Area (ha)	%
1	*Festuca* species (fescue), *Poa* species (bluegrass), *Dactylis glomerata* (orchard grass)	45.34	60
	Lotus corniculatus (bird's-foot trefoil), *Trifolium* species (various clovers), *Vicia cracca* (tufted vetch)		40
2	*Festuca* species (fescue), *Festuca valesiaca* (sheep fescue)	39.63	70
	Trifolium species (clover), *Lotus corniculatus* (bird's-foot trefoil)		30
3	*Festuca* species (fescue), *Dactylis glomerata* (orchard grass)	57.69	60
	Trifolium species (clover), *Vicia cracca* (tufted vetch)		40
4	*Festuca* species (fescue), *Dactylis glomerata* (orchard grass)	34.28	60
	Trifolium pratense (red clover), *Vicia cracca* (tufted vetch)		40
5	*Festuca* species (fescue), *Dactylis glomerata* (orchard grass), *Poa* species (bluegrass)	35.14	70
	Lotus corniculatus (bird's-foot trefoil), *Vicia cracca* (tufted vetch), *Trifolium* species (clover)		30

Beyond raw imagery, the platform delivers a suite of derived geoinformation products, including land cover classifications, vegetation indices such as NDVI and LAI, and atmospherically corrected surface reflectance data, thereby supporting advanced environmental monitoring and modeling.

To enhance usability, Terrascope integrates interactive visualization tools like Terraviewer and offers computational resources, including virtual machines and application programming interfaces (APIs) that enable users to process large-scale datasets and generate customized analytical outputs. This combination of open data, value-added products, and cloud-based processing capabilities positions Terrascope as a critical infrastructure for Earth system science, precision agriculture, climate research, and sustainable land management at the international level. In this paper, the Sentinel 2 – LAI layers were used to extract the LAI values for the periods considered for this study.

Vegetation dynamics at the investigated sites have been monitored continuously since March 2022. For the purpose of this study, the analysis focuses on the most important months considering the canopy development (the interval between April and July) for 2022-2025, capturing the progression through the principal phenological stages that govern growth and development within the riparian grassland ecosystem. Besides the SunScan measurements, light availability measurements were conducted using precision solarimeters manufactured by Delta-T Devices and Kipp & Zonen, ensuring accurate quantification of incident solar radiation throughout the observation period. In this paper, the data from the Mogosesti grassland were analyzed.

RESULTS AND DISCUSSION

The analysis showed a functional balance: across the five plots (total 212.08 ha), the swards are grass-dominated (≈63.5%) with a substantial legume component (≈36.5%), which is a favorable balance for forage quality, biological nitrogen input, and soil cover. Regarding the species, it can be noted that *Festuca* spp. (including *F. valesiaca*) signal stress-tolerant, drier microsites (especially Plot 2), while *Poa* spp. and *Dactylis glomerata* indicate productive, mesic patches with good early-season growth and higher carrying capacity. *Trifolium* spp., *T. pratense*, *Lotus corniculatus*, and *Vicia cracca* provide N-fixation, protein enrichment, and pollinator resources. Regarding the riparian context, the present mixtures buffer erosion (due to dense fibrous roots of *Festuca/Poa species*) while legumes boost N inputs without mineral fertilizer, aligning with low-input, nature-positive management of riparian grasslands near the Dambovita River.

Figure 3 presents the LAI estimations in the Mogosesti grassland near the Dambovita River based on Sentinel-2 data extracted from Terrascope. Table 2 shows the Leaf area index (LAI) assessed between April and July from 2023 to 2025 (average values) in the Mogosesti grassland, both from satellite-derived estimations and field measurements. Field measurements are highly consistent. CVs are low across all months (≈2.6–4.8%), indicating stable interannual behavior. Satellite variability is month-dependent, being very high in April (28.7%) and elevated in July (16.2%), and moderate in June (13.1%), respectively. It was very low in May (2.7%), nearly matching field stability. There is a systematic positive bias in the summer months. Satellite values tend to exceed field values in June and July (mean biases +0.42 and +0.29, respectively), with sizeable year-by-year percentage differences (e.g., June 2022: +48%; July 2024: +40%). April shows a mismatch in interannual patterns. Despite a small average bias (+0.17), year-to-year alignment is weak and even negatively correlated (r = −0.63): satellite is high when field is low (2023), and vice versa (2022).

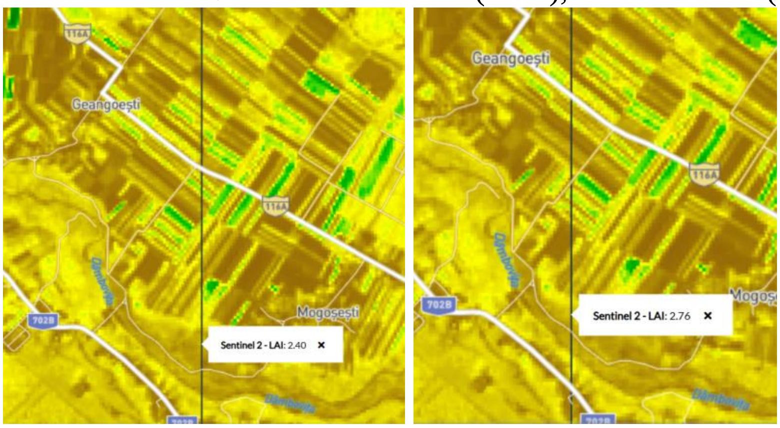


Fig. 3. LAI estimations in the Mogosesti grassland near the Dambovita River based on Sentinel-2 data extracted from Terrascope (Belgium's Earth Observation Data Space)

Figure 4 shows a significant correlation between assessments. Table 3 captures a well-composed functional blend of the Dragomiresti composing grasslands: grasses are delivering stability and structure, and legumes provide biological nitrogen and quality, all highly aligned with riparian conservation and low-input agronomy suitable for rational grazing. With attentive timing of defoliation, soil reaction management, and light overseeding where needed, this species mixture can sustain productive, erosion-resistant, and biodiverse grasslands. Figure 5 provides examples of floristic compositions.

Table 2.

Leaf area index assessed between April and July from 2023 to 2025 (average values) in Mogosesti grassland

Month	Satellite-derived estimations					Grassland (field measurements)				
	2022	**2023**	**2024**	**2025**	**Coeff. of Variation (%)**	**2022**	**2023**	**2024**	**2025**	**Coeff. of Variation (%)**
April	1.03	2.2	1.76	1.8	28.71	1.55	1.44	1.57	1.55	3.87
May	2.67	2.56	2.72	2.6	2.71	2.56	2.47	2.51	2.62	2.55
June	2.37	1.76	1.88	2.04	13.14	1.6	1.49	1.66	1.64	4.75
July	1.96	1.61	2.36	1.84	16.16	1.7	1.63	1.68	1.59	3.01

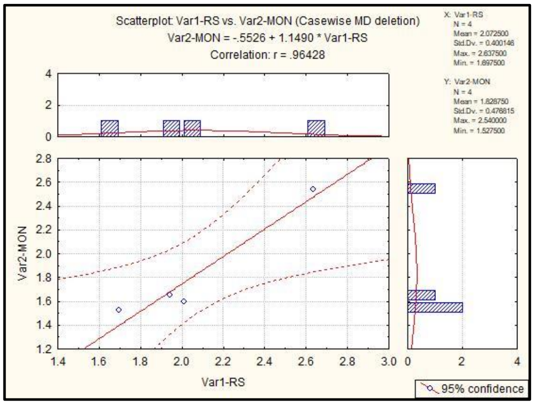


Fig. 4 Correlation between satellite-derived estimations and field measurements using multiannual averages (significant r = 0.96)

Table 3.

Ecological Roles of Identified Species

No.	**Species**	**Ecological Roles**
1	*Festuca* spp. (fescues)	Soil stabilization; drought tolerance; carbon sequestration; continuous forage supply
2	*Festuca valesiaca* (sheep fescue)	Indicator of dry, nutrient-poor soils; resilience under grazing and drought
3	*Poa* spp. (bluegrasses)	Dense turf prevents erosion, improves water infiltration, and supports soil fauna.
4	*Dactylis glomerata* (orchard grass)	High productivity; deep roots enhance soil aeration and organic matter incorporation
5	*Trifolium* spp. (clovers) – especially white clover	Nitrogen fixation improves soil fertility, supports pollinators, and increases forage protein content
6	*Trifolium pratense* (red clover)	Soil enrichment; erosion control; nectar source for pollinators
7	*Lotus corniculatus* (bird's-foot trefoil)	Nitrogen fixation; adapted to poor soils; tannins reduce methane emissions in ruminants
8	*Vicia cracca* (tufted vetch)	Nitrogen enrichment; structural diversity; habitat for insects

Figure 6 shows the spatial pattern of the grasslands (light green patches) that are concentrated in riparian zones along the Dâmbovița River and its tributaries. These areas form elongated strips following the river course, indicating floodplain grasslands and pastures adapted to periodic moisture and fertile alluvial soils.

Larger continuous grassland blocks occur near Dragomirești–Geangoești–Mogoșești, suggesting extensive managed pastures or hayfields in the central valley.

Fragmentation increases toward the eastern and northern margins, where grasslands transition into arable fields and mixed land uses.

Fig. 5. Floristic composition in the Mogosesti grassland (white clover reached a valuable abundance)

Fig. 6. Distribution of vegetation in the grasslands of Dragomiresti commune near the Dambovita River and location of the Mogosesti grassland (Copernicus adapted layers)

CONCLUSIONS

Grasses ensure soil protection, carbon storage, and a continuous forage supply.

Legumes enhance soil fertility, biodiversity, and ecosystem services like pollination. Together, they create a resilient pasture system that supports livestock productivity and environmental sustainability.

The floristic composition is valuable, but it is under pressure from overgrazing. Consequently, altered LAI impacts albedo (surface reflectivity) and implicitly the radiative balance.

In summary, LAI is an essential variable for predicting carbon, water, and energy fluxes in climate models, and it is very useful for predicting grasslands' canopy development. Proximity to villages suggests dual use: grazing for livestock and hay production, with potential pressure from conversion to arable land in flatter sections.

Maintaining continuous riparian grassland strips is critical for flood mitigation and water quality protection.

Buffer zones should be preserved to prevent nutrient runoff from adjacent croplands.

Grassland patches near forest edges (west and southwest) could serve as ecotones, supporting species diversity and reducing habitat isolation.

ACKNOWLEDGEMENTS

The research leading to these results received support for publishing from the CNFIS-FDI2025-F-0421 project, financed by the Romanian Ministry of Education and implemented by Valahia University of Targoviste.

REFERENCES

1. Baudry J., Thenail C. (2004) Interaction between farming systems, riparian zones and landscape patterns: a case study in western France. Landscape and Urban Planning, 67, 121–129.
2. Bărbulescu C., Puia I., Motcă Gh., Moisuc Al. (1991) Cultura pajiștilor și a plantelor furajere, Ed. Didactică și Pedagogică, București.
3. Dincă N., Dunea D. (2018) On the assessment of light use efficiency in alfalfa (*Medicago sativa* L.) in the eco-climatic conditions of Targoviste piedmont plain. Romanian Agricultural Research 35, 59-69.

4. Dunea D., Moise V. (2008) Artificial neural networks as support for leaf area modelling in crop canopies, New Aspects of computers, Proceedings of the 12th WSEAS International Conference on COMPUTERS, 440-446.
5. Dunea D., Bretcan P., Purcoi L., Tanislav D., Serban G., Neagoe A., Iordache V., Iordache Ș. (2021) Effects of riparian vegetation on evapotranspiration processes and water quality of small plain streams, Ecohydrology & Hydrobiology, 21 (4), 629-640.
6. Filip A.N., Brețcan P., Tanislav D., Serban G., Dunea D. (2023) Availability of solar radiation resources at the level of a riparian grassland in a changing climate, Proceedings, Climat, eau et société: changements et défis: 36 ème Colloque de l'Association Internationale de Climatologie : actes du colloque: 3-7 juillet 2023, Bucarest, Roumanie coord.: Liliana Zaharia. - Târgovişte: Transversal, 2023, ISBN 978-606-605-229-0, 49-52.
7. Mihalache M., Ilie L., Marin D.I. (2015) Romanian Soil Resources - Healthy Soils for a Healthy Life, AgroLife Scientific Journal 4 (1), 101-110.
8. Motcă Gh, Oancea I., Geamănu L.I. (1994) Pajiștile României, tipologie și tehnologie, Ed. Tehnica Agricolă, București.
9. Onete M., Mountford J.O., Bodescu F.P, Chiriac L.S., Manu M. (2022) The vegetation characteristics of a polluted small river (Glavacioc river) from Romanian plain, Scientific Papers. Series A. Agronomy, 65(1), 681-690.
10. Samuil C., Stavarache M., Sirbu C., Vîntu V. (2018) Influence of sustainable fertilization on yield and quality food of Mountain Grassland, Notulae Botanicae Horti Agrobotanici Cluj-Napoca 46 (2), 410-417.
11. Szymura M., Szymura T., Dunajski A., Wolski K. (2009) The grass vegetation of watercourses as a biodiversity refuge in an agricultural landscape. Grassland Science in Europe, Vol. 14, 253-256.
12. Vîntu V., Talpan I., Ionel A., Samuil C. (2010) Influence of mixture and fertilization on the behaviour of some grasses and perennial legume species on temporary pastures in the Moldavian forest steppe, Romanian Journal of Grasslands and Forage Crops 1, 81-91
13. Zhao G. (2023) Trends in grassland science: Based on the shift analysis of research themes since the early 1900s. Fundamental Research 3 201–208.
14. *** (2020) Proiect de Amenajament Pastoral - Comuna Dragomirești, Județul Dâmbovița.

ECOLOGICAL RESTORATION OF DEGRADED MOUNTAIN GRASSLANDS THROUGH MULCHING AND OVERSEEDING IN THE CINDREL MOUNTAINS (ROMANIA)

Claudiu ŞERBAN, Ioan ROTAR and Ioana GHEŢE

***Faculty of Agriculture. Department of Plant Crops. University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Manăstur street, 3-5, 400372, Romania.**

[*] Corresponding author, e-mail: ioana.ghete@usamvcluj.ro

Abstract

Degradation of semi-natural mountain grasslands represents a major threat to biodiversity and forage quality in Central and Eastern Europe. Ecological restoration practices such as mulching and overseeding are increasingly applied to counteract grassland degradation, yet their floristic effects under mountain conditions remain insufficiently documented. The present study evaluated the impact of different restoration measures on the floristic composition of a degraded grassland at the Păltiniş Experimental Station (Cindrel Mountains, Romania). The experiment was established in a randomized block design with five treatments: abandoned grassland (control), mulching, mulching combined with organic fertilization, mulching with overseeding using Dactylis glomerata and Lolium perenne, and mulching with overseeding using Phleum pratense. Vegetation surveys were conducted in 2023, two years after the installation of the experiment, and data were processed using PC-ORD software. The control variant was characterized by a Festuca rubra grassland type, representative for the study area. Mulching alone promoted a shift toward a Festuca rubra – Agrostis capillaris grassland, while the combination of mulching and organic fertilization resulted in the installation of an Agrostis capillaris grassland with Festuca rubra. Overseeding treatments significantly increased the proportion of Poaceae and led to the establishment of mixed grassland types dominated by Dactylis glomerata or Phleum pratense, respectively. The results demonstrate that mulching and overseeding are effective restoration techniques for degraded mountain grasslands, contributing to improved floristic structure and enhanced forage potential under high-altitude conditions.

Keywords: mountain grasslands, ecological restoration, mulching, overseeding, floristic composition, Cindrel Mountains

INTRODUCTION

Semi-natural mountain grasslands are among the most valuable agroecosystems in Europe, due to their exceptional floristic diversity, high ecological stability and long-term co-evolution with traditional agricultural practices. In the Carpathian region, these grasslands represent biodiversity hotspots, hosting a large proportion of endemic and subendemic plant species and maintaining complex ecological networks shaped by extensive land use (Reif et al., 2005; Reif et al., 2008; Păcurar & Rotar, 2011; Gliga et al., 2013). Numerous studies conducted in Romanian mountain areas emphasize that the conservation value of these grasslands is directly linked to their management history and ecological continuity (Păcurar et al., 2008;

Ruşdea et al., 2011; Păcurar et al., 2018).

In Romania, mountain grasslands play a crucial role not only in biodiversity conservation but also in sustaining rural livelihoods, providing forage resources, maintaining soil stability and preserving cultural landscapes (Plăias, 1994; Reif et al., 2008; Păcurar et al., 2014). Semi-natural grasslands with High Nature Value (HNV) status are particularly important, as they combine low-input management with high species richness and ecological resilience (Păcurar et al., 2018; Păcurar & Reif, 2023; Vaida et al., 2021). However, these ecosystems are highly sensitive to changes in land use and management intensity (Rotar et al., 2010; Vaida et al., 2016). During recent decades, socio-economic transformations in Central and Eastern Europe have led to significant pressures on mountain grasslands, resulting in processes such as agricultural intensification, overgrazing, nutrient imbalance and, most critically, land abandonment (Rotar et al., 2013; Păcurar et al., 2015; Vaida et al., 2016; Moş & Brînzan, 2024). Abandonment disrupts the traditional disturbance regime, accelerates secondary succession and favors the expansion of competitive or unpalatable species, leading to a decline in species richness and forage quality (Brinkmann et al., 2009; Reif et al., 2008; Păcurar et al., 2014).

Numerous studies conducted in the Apuseni Mountains and other Romanian mountain regions have demonstrated that changes in management strongly affect the floristic composition and functional structure of Festuca rubra and Agrostis capillaris grasslands (Păcurar & Rotar, 2006; Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2014). Long-term abandonment or inadequate management leads to a reduction in Fabaceae species, an increase in stress-tolerant grasses and a simplification of vegetation structure (Păcurar et al., 2007; Rotar et al., 2016; Vaida et al., 2017).

In this context, ecological restoration has become a key strategy for maintaining and recovering the ecological and agronomic value of degraded mountain grasslands. Restoration approaches aim to re-establish favorable environmental conditions and promote the reinstallation of characteristic species assemblages (Török et al., 2011; Blakesley & Buckley, 2016). In Romanian grasslands, restoration measures are often adapted to local ecological conditions and traditional management practices, as highlighted by multiple experimental studies coordinated by Păcurar and collaborators (Păcurar et al., 2009; Păcurar et al., 2012; Păcurar et al., 2014). Mulching represents one of the most frequently applied low-impact restoration techniques in abandoned grasslands, being used to control excess biomass, reduce litter accumulation and stimulate natural regeneration processes (Hopkins, 1954; Rotar et al., 2014; Wu et al., 2024). Previous research has shown that mulching can significantly influence species composition, light availability and soil microclimate, leading to measurable changes in floristic structure (Brinkmann et al., 2009; Păcurar et al., 2018; Rotar et al., 2020).

In addition to mulching, overseeding is widely applied as an active restoration method, particularly in grasslands with limited natural regeneration capacity. Overseeding with well-adapted forage species can enhance sward density, increase the proportion of Poaceae and Fabaceae and improve overall forage value (Rotar et al., 2014; Scotton, 2019; Rotar et al., 2016). However, the success of overseeding depends on site-specific conditions, species selection and interactions with existing vegetation, especially in mountain environments characterized by acidic soils and harsh climatic conditions (Păcurar et al., 2012; Rotar et al., 2014).

Several long-term experiments conducted in Romanian mountain grasslands have demonstrated that combined management approaches, including mulching, fertilization and overseeding, lead to distinct floristic trajectories and functional changes in vegetation (Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2010; Ghețe et al., 2025). Nevertheless, despite the extensive body of research on Festuca rubra grasslands in the Apuseni Mountains, data from other mountain regions, such as the Cindrel Mountains, remain comparatively scarce.

Therefore, the present study aims to assess the floristic response of degraded mountain grasslands at the Păltiniș Experimental Station (Cindrel Mountains, Romania) to different restoration measures, including mulching, mulching combined with organic fertilization and mulching associated with overseeding. The specific objectives were to characterize the initial floristic composition of the abandoned grassland, to evaluate vegetation changes induced by mulching-based management and to determine the effectiveness of overseeding in restoring grassland structure and forage potential. The results contribute to the broader understanding of sustainable restoration strategies for mountain grasslands under high-altitude conditions.

MATERIAL AND METHOD

The research was conducted at the Păltiniș Experimental Station, located on the north-eastern ridge of the Cindrel Mountains, near the Păltiniș resort, Romania, at an altitude of 1,348 m a.s.l. The study area belongs to the upper montane belt and is characterized by specific climatic conditions, including low annual average temperatures, a persistent snow cover during winter and a relatively high annual precipitation regime.

The soils are classified as submesotrophic brown acidic soils, typical for mountain grasslands developed on siliceous parent material, with moderate fertility and acidic reaction. The Cindrel Mountains cover an area of approximately 900 km², with a maximum altitude of 2,244 m (Cindrel Peak). From a geomorphological perspective, the mountain range is bordered by the Sadu River to the east and south, separating it from the Lotru Mountains, and by the Frumoasa and Sebeș rivers to the west, separating it from the Șureanu Mountains (Anghel & Doniță, 1980).

Experimental design

To achieve the objectives of the study, an ecological restoration experiment was established in 2021 on degraded mountain grasslands within the Păltiniș Experimental Station. The experiment was designed according to a randomized block layout, including five experimental treatments with four replications each. The surface area of each experimental plot was 20 m², allowing for adequate control of spatial variability and reliable interpretation of results.

Floristic assessments presented in this study are based on vegetation surveys conducted in 2023, two years after the establishment of the experimental treatments, a period considered sufficient to evaluate the initial floristic responses to the applied restoration measures.

Experimental treatments

The five experimental variants included in the study were as follows:

- **V1 – Control (abandoned grassland):**
  No management interventions were applied. This variant was used as a reference for assessing the degree of grassland degradation and the natural dynamics of vegetation.

V2 – Mulching: The grassland was managed exclusively through mulching, aimed at fragmenting accumulated plant biomass and stimulating natural regeneration processes.

V3 – Mulching combined with organic fertilization: In addition to mechanical management, organic fertilization was applied to improve soil properties and stimulate vegetation recovery.

V4 – Mulching combined with overseeding using *Dactylis glomerata* (60%) and *Lolium perenne* (40%): Overseeding was applied to accelerate grassland restoration by introducing productive forage species adapted to mountain conditions.

V5 – Mulching combined with overseeding using *Phleum pratense*: A forage species well adapted to cool climatic conditions and acidic soils was used, characterized by good establishment capacity and persistence under mountain environments.

Data processing and analysis

Floristic data were processed using PC-ORD software, version 7. Vegetation data were organized into two matrices: one containing species abundance values and another coding the experimental variants. The software was used for vegetation classification, ordination and graphical representation of results. The methodological details and analytical procedures implemented in PC-ORD have been described extensively in the literature (McCune, 2002; Peck, 2010).

RESULTS AND DISCUSSIONS

Results regarding the establishment capacity of plant species after overseeding

In the control variant, represented by the abandoned grassland, the vegetation was classified as a *Festuca rubra* grassland type, which is characteristic for oligotrophic mountain grasslands in Romania. This grassland type is widely distributed in the Carpathian region and has been repeatedly described as a reference phytocenosis for semi-natural mountain grasslands maintained under low-input or abandoned conditions (Păcurar & Rotar, 2006; Păcurar et al., 2012; Rotar et al., 2014).

The floristic composition of the *Festuca rubra* grassland was dominated by Poaceae, which accounted for 33.8% of the total plant cover. The dominance of grasses, particularly *Festuca rubra*, together with the relatively low proportion of Fabaceae (4.0%), indicates a simplified trophic structure and a reduced contribution of nitrogen-fixing species. Similar patterns have been reported in abandoned or extensively managed *Festuca rubra* grasslands from the Apuseni Mountains and other Romanian mountain regions (Păcurar et al., 2007; Morea et al., 2008; Vaida et al., 2016).

The reduced share of Fabaceae and the presence of stress-tolerant species such as *Nardus stricta* and *Deschampsia flexuosa* suggest nutrient-poor soil conditions and limited regenerative capacity of the vegetation. According to previous studies, these features are typical for oligotrophic mountain grasslands subjected to long-term abandonment, where litter accumulation and reduced disturbance negatively affect species richness and forage quality (Reif et al., 2005; Brinkmann et al., 2009; Rotar et al., 2016).

Plants from other botanical families (41.0%) contributed substantially to species richness, reflecting the semi-natural character of the grassland. However, many of these species have low forage value, which further confirms the reduced agronomic potential of the abandoned variant. Similar floristic structures have been described in Festuca-dominated grasslands with high nature value (HNV), where biodiversity is preserved, but productivity remains low in the absence of appropriate management (Păcurar et al., 2014; Vaida et al., 2021). Overall, the control variant represents a degraded but ecologically stable reference state, suitable for assessing the effectiveness of restoration measures applied in the experimental variants.

Table 1

Floristic composition of the *Festuca rubra* grassland type and species sensitivity to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	5.1
-	-	-	-	-	-	-	-	-	-	-	-	*Briza media*	0.5
-	-	-	-	-	-	-	-	-	-	-	-	*Danthonia decumbens*	0.5
HT	x	x	2	3	3	4	4	n	4	2 - 3	2	*Deschampsia flexuosa*	4.4
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	17.55
HT	x	x	2	2	3	5	5	n	3	2 - 4	1	*Nardus stricta*	5.8
POACEAE													**33.83**
HT	x	5	3	3	6	4	4	n	4	2 - 3	1	*Luzula multiflora*	1.5
CYPERACEAE AND JUNCACEAE													**1.5**
H	5	4	4	2	4	8	7	n	3	2 - 3	1	*Genistella sagittalis*	3.1
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	0.5
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	0.5
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	0.5
FABACEAE													**4.0**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	0.50
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula serata*	0.50
H	X	4	X	2	3	8	7	n	3	2 - 3	1	*Carlina acaulis*	0.50
												Cerastium glomeratum	0.50
TT	X	5	X	7	3	7	2	n	3	2 - 3	1	*Cuscuta trifolii*	0.50
HS	3	5	4	2	5	6	6	n	4	3 - 4	2	*Hieracium pilosella*	3.1
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	2.6
HR	x	5	x	5	7	7	7	n	5	3 - 4	3	*Leontodon autumnale*	4.4
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	0.50
HR	x	4	8	3	4	8	8	n	5	2 - 4	2	*Plantago media*	1.00
HT	x	x	x	2	3	4	5	n	5	2 - 3	1	*Potentilla erecta*	0.5
HS	x	x	4	x	9	8	8	n	4	3 - 4	2	*Prunella vulgaris*	0.50
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	5.1
HRs	x	x	x	x	6	4	2	n	4	3 - 4	2	*Rumex acetosa*	2.6
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	2.0
ChLT	x	4	5	6	4	4	4	n	3	2 - 3	2	*Thymus pullegioides*	4.4
ChLS	x	x	2	3	1	8	9	n	3	2 - 3	2	*Vaccinium myrtillus*	4.4
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	0.50
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	1.5
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.50
OFB													**41.0**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

In variant V2, where the grassland was managed exclusively through mulching, the floristic composition shifted toward a *Festuca rubra – Agrostis capillaris* grassland type. This transition indicates an early stage of vegetation recovery, characterized by increased species dynamism and improved structural heterogeneity. Similar vegetation shifts following mulching have been reported in mountain grasslands across Romania and Central Europe (Hopkins, 1954; Brinkmann et al., 2009; Rotar et al., 2014).

Mulching resulted in an increase of Poaceae cover to 38.8%, reflecting enhanced competitiveness of grasses under improved light and microclimatic conditions. The increased presence of *Agrostis capillaris* suggests that mulching reduced litter accumulation and facilitated the germination and establishment of species adapted to moderate disturbance regimes. This response is consistent with findings reported by Păcurar et al. (2012) and Rotar et al. (2014), who highlighted the positive role of mulching in restoring grassland structure without inducing excessive intensification. The proportion of Fabaceae increased to 7.1%, compared to the control variant, indicating a gradual improvement in nitrogen availability and ecological functionality. According to Păcurar et al. (2007) and Vaida et al. (2017), the recovery of Fabaceae species is a key indicator of successful restoration in oligotrophic grasslands, as these species contribute to soil fertility and forage quality. The absence of Cyperaceae and Juncaceae species in this variant suggests improved soil aeration and reduced moisture stress, which are favorable conditions for mesophilous grassland species. Similar trends were observed in mulched grasslands from the Apuseni Mountains, where mechanical management reduced the dominance of hygrophilous species and promoted a more balanced floristic composition (Morea et al., 2008; Păcurar et al., 2014). Overall, mulching alone proved to be an effective low-impact restoration measure, leading to measurable improvements in floristic composition and ecological balance, while maintaining the semi-natural character of the grassland. These results confirm previous findings that mulching can serve as an intermediate management strategy between abandonment and more intensive restoration measures (Rotar et al., 2014; Wu et al., 2024) (Table 2).

In variant V3, where mulching was combined with organic fertilization, the floristic composition evolved toward an *Agrostis capillaris* grassland with *Festuca rubra*. This vegetation type reflects a more advanced stage of grassland recovery compared to mulching alone, indicating that the addition of organic nutrients enhanced both structural complexity and species dynamics. Similar successional trajectories have been documented in mountain grasslands subjected to combined mechanical management and fertilization in the Apuseni Mountains (Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2010).

The share of Poaceae increased to 42.2%, confirming the stimulatory effect of organic fertilization on grass growth and competitiveness. *Agrostis capillaris* became the dominant species, benefiting from improved nutrient availability and reduced litter cover.

Table 2

Floristic composition of the *Festuca rubra – Agrostis capillaris* grassland type and species sensitivity to ecological, agronomic and anthropogenic factors

B	T	U	R	N	C	P	S	SO	VF	H	UR	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	16.3
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	0.5
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	0.5
												Poa pratensis	0.5
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	21.1
POACEAE													**38.8**
H	5	4	4	2	4	8	7	n	3	2 - 3	1	*Genistella sagittalis*	1.0
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	1.5
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	3.1
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	1.5
FABACEAE													**7.1**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	3.1
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	1.0
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula abietina*	0.50
												Cerastium glomeratum	0.50
TT	X	5	X	7	3	7	2	n	3	2 - 3	1	*Cuscuta trifolii*	2.0
HS	3	5	4	2	5	6	6	n	4	3 - 4	2	*Hieracium pilosella*	3.1
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	3.8
HR	x	5	x	5	7	7	7	n	5	3 - 4	3	*Leontodon autumnale*	3.8
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	3.1
HT	x	x	x	2	3	4	5	n	5	2 - 3	1	*Potentilla erecta*	0.5
HS	x	x	4	x	9	8	8	n	4	3 - 4	2	*Prunella vulgaris*	0.50
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	4.4
HRs	x	x	x	x	6	4	2	n	4	3 - 4	2	*Rumex acetosa*	2.6
												Ranunculus acris	0.5
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	4.4
ChLT	x	4	5	6	4	4	4	n	3	2 - 3	2	*Thymus pullegioides*	4.4
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	2.6
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	2.0
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.50
												Taraxacum officinale	1.0
OFB													**35.1**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

According to Păcurar and Rotar (2006) and Rotar et al. (2014), *Agrostis capillaris* responds positively to moderate nutrient inputs, especially under mountain conditions where soil fertility is naturally limited.

Fabaceae species reached a coverage of 8.8%, representing a substantial increase compared to both the control variant and the mulched-only treatment. This increase is ecologically significant, as Fabaceae contribute to nitrogen enrichment and enhance forage quality. Similar responses of Fabaceae to organic fertilization have been reported in long-term experiments on *Festuca rubra* grasslands in the Apuseni Mountains (Păcurar et al., 2007; Păcurar et al., 2012; Vaida et al., 2017). The presence of species such as *Trifolium pratense*, *Trifolium repens* and *Lotus corniculatus* indicates an improvement in both trophic status and agronomic value of the grassland. Plants from other botanical families accounted for 46.4% of total cover, reflecting a high level of floristic diversity. This increase suggests that organic fertilization, when applied in moderate doses, does not necessarily reduce biodiversity, but can support a more heterogeneous vegetation structure. Similar conclusions were drawn by Brinkmann et al. (2009) and Păcurar et al. (2014), who showed that low to moderate organic inputs can maintain species richness while improving grassland productivity. The absence of Cyperaceae and Juncaceae species in this variant further indicates improved soil aeration and reduced excess moisture, conditions that favor mesophilous grassland species. According to Rotar et al. (2016) and Păcurar et al. (2018), such changes are typical responses to improved management in previously abandoned mountain grasslands. Overall, the combined application of mulching and organic fertilization proved to be a more effective restoration strategy than mulching alone, leading to increased grass dominance, enhanced presence of Fabaceae and a more balanced floristic composition. These results are consistent with previous studies conducted in Romanian mountain grasslands, which emphasize that moderate organic fertilization can accelerate grassland recovery without compromising biodiversity (Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2014) (Table 3).

In variant V4, where mulching was combined with overseeding using a mixture of *Dactylis glomerata* (60%) and *Lolium perenne* (40%), the floristic composition evolved toward a mixed grassland type dominated by *Dactylis glomerata* with *Agrostis capillaris* and *Lolium perenne*. This vegetation structure reflects a strong response to active restoration measures and indicates a shift toward a more productive grassland system, characterized by high grass dominance and improved sward density.

Table 3

Floristic composition of the *Agrostis capillaris – Festuca rubra* grassland type and species requirements in relation to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	21.1
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	0.5
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	0.5
												Poa pratensis	4.4
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	13.8
POACEAE													**42.2**
H	5	4	4	2	4	8	7	n	3	2 - 3	1	*Genistella sagittalis*	0.5
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	3.8
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	2.0
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	2.5
FABACEAE													**8.8**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	4.4
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula patula*	0.5
												Cerastium glomeratum	0.5
TT	X	5	X	7	3	7	2	n	3	2 - 3	1	*Cuscuta trifolii*	0.5
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	7.3
HR	x	5	x	5	7	7	7	n	5	3 - 4	3	*Leontodon autumnale*	4.4
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	5.8
HS	x	x	4	x	9	8	8	n	4	3 - 4	2	*Prunella vulgaris*	0.5
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	5.1
												Ranunculus acris	0.5
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	3.1
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	7.3
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	2.5
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.5
												Taraxacum officinale	3.1
OFB													**46.4**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

Similar outcomes following overseeding interventions have been reported in mountain and submontane grasslands in Romania and other European regions (Rotar et al., 2014; Török et al., 2011; Scotton, 2019).

The proportion of Poaceae increased markedly to 58.8%, confirming the high establishment capacity and competitive ability of the introduced species. *Dactylis glomerata* became the dominant species, reaching a substantial cover, while *Lolium perenne* also successfully established within the sward. According to Rotar et al. (2014) and Rotar et al. (2016), *Dactylis glomerata* exhibits strong adaptability to mountain environments, particularly when combined with mechanical management, due to its deep root system and high tolerance to low temperatures. The successful integration of *Lolium perenne* further contributed to sward densification and increased forage potential, as previously observed in experimental forage mixtures under

Romanian conditions (Rotar et al., 2014; Rotar et al., 2016).

Despite the strong dominance of Poaceae, Fabaceae species accounted for 4.5% of total cover, a value comparable to that of the control variant. This relatively low proportion of Fabaceae suggests that the aggressive growth of the introduced grasses limited the establishment and expansion of nitrogen-fixing species. Similar competitive interactions between sown grasses and Fabaceae have been reported in overseeded grasslands, where high grass density can suppress less competitive functional groups (Păcurar et al., 2012; Rotar et al., 2014; Scotton, 2019).

Plants from other botanical families represented 29.4% of the vegetation cover, indicating a reduction in overall floristic diversity compared to the previous variants. This decrease is a common consequence of overseeding with highly competitive forage species and reflects a trade-off between biodiversity conservation and forage productivity. According to Păcurar et al. (2014), Rotar et al. (2016) and Vaida et al. (2021), such shifts are typical for grasslands subjected to active improvement measures and must be carefully managed in high nature value (HNV) systems to avoid excessive biodiversity loss.

The absence of Cyperaceae and Juncaceae species in this variant indicates improved drainage conditions and reduced soil moisture, which favor productive grassland species. Similar ecological responses have been documented in grasslands improved through mechanical treatments and overseeding in the Apuseni Mountains (Morea et al., 2008; Păcurar et al., 2014).

Overall, the combined application of mulching and overseeding with *Dactylis glomerata* and *Lolium perenne* proved to be an effective strategy for rapidly increasing grass cover and forage potential. However, the observed reduction in floristic diversity highlights the need for careful consideration of management objectives, particularly in mountain grasslands with conservation value. These findings are consistent with previous studies emphasizing that overseeding enhances productivity but may alter species composition and ecological balance if not properly regulated (Păcurar et al., 2012; Rotar et al., 2014; Török et al., 2011) (Table 4).

In variant V5, where mulching was combined with overseeding using *Phleum pratense*, the floristic composition evolved toward a *Phleum pratense* grassland with *Agrostis capillaris*. This vegetation type reflects a successful establishment of the introduced species and represents an alternative restoration trajectory compared to the grassland dominated by *Dactylis glomerata*. Similar responses to overseeding with *Phleum pratense* have been reported in mountain grasslands characterized by cool climatic conditions and acidic soils, where this species shows good adaptability and persistence (Rotar et al., 2014; Samuil et al., 2025).

Table 4

Floristic composition of the *Dactylis glomerata* grassland with *Agrostis capillaris* and *Lolium perenne* and species sensitivity to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	13.8
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	29.0
												Lolium perenne	8.0
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	1.0
												Poa pratensis	0.5
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	6.5
POACEAE													**58.8**
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	1.0
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	2.0
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	1.5
FABACEAE													**4.5**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	3.1
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
												Alchemila vulgaris	3.1
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula abietina*	0.5
												Cerastium glomeratum	0.5
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	2.0
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	2.0
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	3.3
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	3.1
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	5.1
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	4.6
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.5
												Taraxacum officinale	1.0
OFB													**29.4**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

The proportion of Poaceae reached 58.8%, confirming the strong competitive ability of *Phleum pratense* under improved management conditions. The dominance of this species indicates favorable establishment conditions created by mulching, which reduced litter accumulation and enhanced seed–soil contact. According to Rotar et al. (2014) and Păcurar et al. (2012), *Phleum pratense* performs well in mountain environments when disturbance intensity is moderate and soil fertility is slightly improved.

Fabaceae species accounted for 6.8% of total cover, a higher value compared to variant V4, suggesting that *Phleum* *pratense* exerted a lower competitive pressure on nitrogen-fixing species than *Dactylis glomerata*. This observation is ecologically relevant, as the persistence of Fabaceae contributes to nutrient cycling and forage quality. Similar patterns were reported in grasslands overseeded with *Phleum pratense*, where a more balanced coexistence between grasses and legumes was observed (Păcurar et al., 2012; Rotar et al., 2016; Vaida et al., 2017).

Plants from other botanical families represented 27.8% of the vegetation cover, indicating a moderate reduction in floristic diversity compared to the control and mulched variants, but a level comparable to that observed in V4. According to Păcurar et al. (2014) and Vaida et al. (2021), such reductions are expected following active improvement measures and reflect a shift toward more productive grassland types. Nevertheless, the presence of a relatively diverse assemblage of accompanying species suggests that overseeding with *Phleum pratense* did not lead to excessive floristic simplification. The absence of Cyperaceae and Juncaceae species in this variant further supports the interpretation of improved soil aeration and reduced moisture excess, conditions favorable for productive mountain grasslands. Similar ecological responses were observed in grasslands improved through overseeding and fertilization in the Apuseni Mountains (Morea et al., 2008; Păcurar et al., 2014). Overall, mulching combined with overseeding using *Phleum pratense* proved to be an effective restoration measure, leading to high grass cover, a balanced presence of Fabaceae and a moderate reduction in species richness. Compared to overseeding with *Dactylis glomerata* and *Lolium perenne*, this variant appears more suitable for mountain grasslands where both forage productivity and biodiversity conservation are desired. These findings align with previous studies emphasizing the suitability of *Phleum pratense* for grassland restoration under cool and humid mountain conditions (Rotar et al., 2014; Păcurar et al., 2012; Samuil et al., 2025) (Table 5).

Table 5

Floristic composition of the *Phleum pratense* grassland with *Agrostis capillaris* and species sensitivity to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	21.1
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	0.5
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	29.0
												Poa pratensis	1.0
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	7.3
							POACEAE						**58.8**
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	0.5
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	5.8
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	0.5
							FABACEAE						**6.8**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	4.4
												Cuscuta trifolii	0.5
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
												Cerastium glomeratum	0.5
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	1.5
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	2.0

TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	4.4
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	3.1
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	5.8
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	2.5
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.5
												Taraxacum officinale	2.1
OFB													**27.8**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

Overall, the applied restoration measures induced distinct floristic trajectories across the experimental variants. Mulching alone promoted gradual vegetation recovery while maintaining a relatively high level of floristic diversity. The combination of mulching and organic fertilization accelerated grassland recovery and enhanced forage potential without a marked loss of biodiversity. In contrast, active restoration through overseeding strongly increased grass dominance and productivity, with *Phleum pratense* showing a more balanced response between forage improvement and species conservation compared to *Dactylis glomerata*–based mixtures.

CONCLUSIONS

The abandoned grassland from the Păltiniș Experimental Station was characterized by a *Festuca rubra* grassland type, representative for oligotrophic mountain grasslands in Romania. The dominance of Poaceae and the low proportion of Fabaceae reflected reduced trophicity, limited forage value and the effects of long-term abandonment, confirming its suitability as a reference state for evaluating restoration measures.

Mulching applied as a single management intervention promoted favorable floristic changes, leading to the transition toward a *Festuca rubra* – *Agrostis capillaris* grassland type. This management practice reduced litter accumulation, improved light availability and supported a gradual increase in Fabaceae, demonstrating its effectiveness as a low-impact restoration measure for abandoned mountain grasslands.

The combination of mulching and organic fertilization resulted in a more advanced stage of grassland recovery, characterized by the establishment of an *Agrostis capillaris* grassland with *Festuca rubra*. This treatment enhanced grass dominance, increased the contribution of Fabaceae and maintained a high proportion of species from other botanical families, indicating an improvement in both ecological functionality and forage potential without a pronounced loss of biodiversity.

Active restoration through overseeding significantly altered floristic composition and grassland structure. Overseeding with *Dactylis glomerata* and *Lolium perenne* led to the rapid establishment of a highly productive grassland dominated by Poaceae, but was accompanied by a reduction in floristic diversity, highlighting a trade-off between forage productivity and biodiversity conservation.

In contrast, overseeding with *Phleum pratense* resulted in a grassland type characterized by high grass cover, a more balanced presence of Fabaceae and a moderate reduction in species richness. This variant appears more suitable for mountain grasslands where restoration objectives include both productivity improvement and the preservation of ecological value.

Overall, the results demonstrate that mulching, organic fertilization and overseeding are effective tools for the ecological restoration of degraded mountain grasslands, but their outcomes differ substantially depending on the intensity of intervention and species used. Low-impact measures favor gradual ecological recovery, while active overseeding accelerates productivity at the potential cost of reduced biodiversity. These findings provide valuable guidance for selecting restoration strategies adapted to the ecological conditions and management objectives of mountain grasslands in Romania.

REFERENCES

1. Auch E., F. Păcurar, A. Goia, 2001, Economic and Technological Aspects of the Agricultural Systems in Ţara moţilor (Gheţar, Gârda de Sus), în Buletinul USAMV, Seria Agricultura, vol. 55-56: 215
2. Balázsi, Á., Pacurar, F., Mihu-Pintilie, A., & Konold, W. (2018). How do public institutions on nature conservation and agriculture contribute to the conservation of species-rich hay meadows? *International Journal of Conservation Science, 9,* 549–564.
3. Balázsi, Á., Păcurar, F., Rotar, I., & Vidican, R. (2016). Alternative management for oligotrophic grassland conservation in the Apuseni Mountains. In *Proceedings*, 678–680.
4. Blakesley, D., & Buckley, P. (2016). *Grassland restoration and management*. Pelagic Publishing Ltd.
5. Brinkmann, K., Pacurar, F., & Reif, A. (2009). Secondary succession and fluctuations in meadows of the Apuseni Mountains (Transylvania, Romania) under different fertilisation regimes. *Transylvanian Review of Systematical and Ecological Research, 7,* 41–58.
6. Corcoz, L., Păcurar, F., Pop-Moldovan, V., Vaida, I., Stoian, V., & Vidican, R. (2021). Mycorrhizal patterns in the roots of dominant *Festuca rubra* in a high-natural-value grassland. *Plants, 11,* 112.
7. Dale, L. M., Thewis, A., Boudry, C., Rotar, I., Păcurar, F. S., Abbas, O., Dardenne, P., Baeten, V., Pfister, J., & Fernández Pierna, J. A. (2013). Discrimination of grassland species and their classification in botanical families by laboratory scale NIR hyperspectral imaging: Preliminary results. *Talanta, 116,* 149–154.
8. Dale, L., Fernandez, J. A., Vermeulen, P., Lecler, B., Bogdan, A. D., Pacurar, F., Rotar, I., Thewis, A., & Baeten, V. (2012). Research on crude

protein and digestibility of *Arnica montana* L. using conventional NIR spectrometry and hyperspectral imaging NIR. *Journal of Food, Agriculture & Environment, 10*(1).

9. Dale, L., Thewis, A., Rotar, I., Boudry, C., Păcurar, F. S., Lecler, B., Agneessens, R., Dardenne, P., & Baeten, V. (2013). Fertilization effects on the chemical composition and in vitro organic matter digestibility of semi-natural meadows as predicted by NIR spectrometry. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41*, 58–64.
10. Gaga, I., Pacurar, F., Vaida, I., Plesa, A., & Rotar, I. (2022). Responses of diversity and productivity to organo-mineral fertilizer inputs in a high-natural-value grassland, Transylvanian Plain, Romania. *Plants, 11*, 1975.
11. Gârda, N. T., Păcurar, F., Rotar, I., & Bogdan, A. (2010). The floristic and stational characterisation of the grassland subtype *Agrostis capillaris + Trisetum flavescens* from Apuseni Mountains, Romania. *Research Journal of Agricultural Science, 42*, 454–457.
12. Gârda, N., Rotar, I., Păcurar, F., & Vidican, R. (2009). The role of pastoral landscape in defining the mountainous space in Apuseni Mountains. *Lucrări Științifice vol. 52. Seria Agronomie*.
13. Ghețe, I., Rotar, I., Pleșa, A., Ghețe, A., Șerban, C., & Stoian, V. (2025). Effect of mineral fertilization on vegetation of HNV pastures in the Apuseni Mountains (Romania). *Plants, 14*, 3564.
14. Gliga, A., Rotar, I., Vidican, R., Păcurar, F., & Balazsi, A. (2013). Evolution of semi-natural grasslands in Europe (bibliographical paper). *Romanian Journal of Grasslands and Forage Crops, 16*, 17–22.
15. Hopkins, H. H. (1954). Effects of Mulch Upon Certain Factors of the Grassland. *Rangeland Ecology & Management/Journal of Range Management Archives, 7*(6), 255-258.
16. Mălinas, A., Rotar, I., Vidican, R., Iuga, V., Păcurar, F., Mălinas, C., & Moldovan, C. (2020). Designing a sustainable temporary grassland system by monitoring nitrogen use efficiency. *Agronomy, 10*, 149.
17. Mălinaș, A., Rotar, I., Vidican, R., Păcurar, F., & Balazsi, A. (2013). Phosphorus in grassland systems. *Romanian Journal of Grasslands and Forage Crops, 16*, 23–29.
18. Marușca, T., Păcurar, F. S., Scrob, N., Vaida, I., Nicola, N., Taulescu, E., Dragoș, M., & Lukács, Z. (2021). Contributions to the assessment of grasslands productivity of the Apuseni Natural Park (ROSCI 0002). *Romanian Journal of Grasslands and Forage Crops, 24*, 23.
19. Marușca, T., Păcurar, F. S., Taulescu, E., Vaida, I., Nicola, N., Scrob, N., & Dragoș, M. M. (2022). Indicative species for the agrochemical properties of mountain grasslands soil from the Apuseni Natural Park (ROSCI 0002). *Romanian Journal of Grasslands and Forage Crops, 25*, 31.
20. Michler, B., Käthe, W., Schmitt, S., Rotar, I., & Pacurar, F. (2005). Conservation of Eastern European medicinal plants: *Arnica montana* in Romania. In *Proceedings of the XXXXVIII Scientific Symposium – Agriculture and Environment*, Iași.
21. Michler, B., Rotar, I., Pacurar, F., & Goia, A. (2006). Biodiversity and conservation of medicinal plants: A case study in the Apuseni Mountains in Romania. *Bulletin of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca: Agriculture, 62*, 86–87.

22. Michler, B., Rotar, I., Păcurar, F., & Stoie, A. (2005). *Arnica montana*, an endangered species and a traditional medicinal plant: The biodiversity and productivity of its typical grasslands habitats. In *Grassland Science in Europe* (Vol. 10, pp. 336–339).
23. Morea, A., Rotar, I., & Păcurar, F. (2008). Drying possibilities of *Arnica montana* flower heads using local resources. *Hop and Medicinal Plants, 16*(1–2), 210–212.
24. Morea, A., Rotar, I., Vidican, R., & Păcurar, F. (2013). The influence of different types of management upon the floristic structure of grassland systems, with special attention on *Arnica montana* L. *Bulletin UASVM Agriculture, 70*(1).
25. Morea, A., Rotar, I., Vidican, R., Păcurar, F., & Stoian, V. (2008). Changes in vegetation in a *Festuca rubra* meadow in Apuseni Mountains due to organic fertilization. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 36,* 120–124.
26. Moș, A., & Brînzan, C. (2024). Dinamica utilizării pajiștilor și tendințe de abandon în Parcul Natural Apuseni. Romanian Journal of Grasslands and Forage Crops, 30, (în curs de publicare / sau paginile când le știi).
27. Păcurar, F. (2005). *Cercetări privind dezvoltarea durabilă a satului Ghețari, comuna Gârda, prin îmbunătățirea pajiștilor naturale și a unor culturi agricole* (Teză de doctorat). USAMV Cluj-Napoca.
28. Păcurar, F. S., Rotar, I., & Vaida, I. (2019). The effects of wild boar disturbances on the agronomical value of semi-natural grasslands. *Romanian Journal of Grasslands and Forage Crops, 20,* 27.
29. Păcurar, F. S., Rotar, I., Michler, B., & Vidican, R. (2008). Traditional management of *Arnica montana* grasslands. In *Grassland Science in Europe* (Vol. 13, pp. 297–300).
30. Păcurar, F., & Rotar, I. (2006). The evolution of biodiversity in a *Festuca rubra* meadow following some specific technological inputs to sustainable agriculture. *Bulletin UASVM Agriculture, 62,* 124–127.
31. Păcurar, F., & Rotar, I. (2011). The effect of low-input upon semi-natural grasslands of Apuseni Mountains. *Lucrări Științifice – Seria Agronomie, 54*(2).
32. Păcurar, F., & Rotar, I. (2014). *Metode de studiu și interpretare a vegetației pajiștilor*. AcademicPres.
33. Păcurar, F., Balázsi, Á., Rotar, I., Vaida, I., Reif, A., Vidican, R., Rușdea, E., Stoian, V., & Sângeorzan, D. (2018). Technologies used for maintaining oligotrophic grasslands and their biodiversity in a mountain landscape. *Romanian Biotechnological Letters, 23*(10).
34. Păcurar, F., Morea, A., & Gârda, N. (2008). Productivity and biodiversity evolution of *Festuca rubra* grasslands during a seven-year period. *Bulletin UASVM Agriculture, 65,* 5.
35. Păcurar, F., Reif, A., & Rusdea, E. (2023). Conservation of oligotrophic grassland of high nature value (HNV) through sustainable use of *Arnica montana* in the Apuseni Mountains, Romania. In *Medicinal Agroecology*. Taylor & Francis.
36. Păcurar, F., Rotar, I., Balázsi, Á., & Vidican, R. (2014). Influence of long-term organic and mineral fertilization on *Festuca rubra* L. grassland. In *The Future of European Grasslands* (EGF Proceedings), 294.
37. Păcurar, F., Rotar, I., Bogdan, A. D., Vidican, R. M., & Dale, L. (2012). The influence of mineral and organic long-term fertilization upon the floristic

composition of *Festuca rubra* L.–*Agrostis capillaris* L. grassland in Apuseni Mountains, Romania. *Journal of Food, Agriculture & Environment, 10*(1).
38. Păcurar, F., Rotar, I., Gârda, N., & Morea, A. (2009). The management of oligotrophic grasslands and the approach of new improvement methods. *Transylvanian Review of Systematical and Ecological Research, 7,* 59.
39. Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New directions in the study of oligotrophic grasslands in the mountain area. *Lucrări Științifice – Seria Agronomie* (Iași).
40. Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New possibilities for sustainable use of oligotrophic grasslands in Apuseni Mountains. *Bulletin UASVM Agriculture, 66.*
41. Păcurar, F., Rotar, I., Pleșa, A., Balázsi, Á., & Vidican, R. (2015). Study of the floristic composition of certain secondary grasslands in different successional stages as a result of abandonment. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, 72,* doi:10.15835/buasvmcn-agr:11165.
42. Păcurar, F., Rotar, I., Vaida, I., Vidican, R., & Mălinaș, A. (2017). Indicator species of fertilization intensity in mountain grasslands. In *Grassland Resources for Extensive Farming Systems in Marginal Lands* (EGF Proceedings, Vol. 22, pp. 378–381).
43. Păcurar, F., Rotar, I., Vidican, R., & Gârda, N. (2007). Organic fertilization and biodiversity of *Festuca rubra* grasslands. In *Permanent and Temporary Grassland: Plant, Environment and Economy* (EGF Proceedings, Vol. 12, pp. 363–366).
44. Păcurar, F., Rotar, I., Vidican, R., Vaida, I., Pleșa, A., Stoian, V., Tomoș, L., & Ghețe, A. (2025). Density-based assessment of *Adonis vernalis* abundance in native habitats. *Scientific Papers Series A. Agronomy, 68*(1).
45. Plăias I., 1994, Agricultura montană - Societate,Ed. Libris Cluj-Napoca
46. Planul Național Strategic 2023-2027 al României (2023). Ministerul Agriculturii și Dezvoltării Rurale, București.
47. PNDR. (2019). Programul Național de Dezvoltare Rurală 2014–2020 – versiune actualizată. Ministerul Agriculturii și Dezvoltării Rurale, București.
48. Reif, A., Auch, E., Bühler, J., Brinkmann, K., Goia, A. I., Pacurar, F., & Rusdea, E. (2005). Landschaft und Landnutzung im Apuseni-Gebirge Rumäniens. *Carinthia II, 195,* 161–201.
49. Reif, A., Brinkmann, K., Goia, A., Hoernstein, H., Jaeckle, S., Mohr, B., Păcurar, F., Rotar, I., Rusdea, E., & Schmidt, U. (2008). Differences of development patterns in Central and Eastern European mountain regions: History of land uses and landscapes in the Southern Black Forest (Germany) and the Central Apuseni Mountains (Romania). *Bulletin UASVM Agriculture, 65.*
50. Reif, A., Rusdea, E., Păcurar, F., Rotar, I., Brinkmann, K., Auch, E., Goia, A., Bühler, J., & Aronsson, M. (2008). A traditional cultural landscape in transformation. *Mountain Research and Development, 28,* 18–22.
51. Rotar, I., Huygens, D., Vidican, R., Carlier, L., Pacurar, F., & Mălinaș, A. (2013). The effect of low-input grassland management on *Arnica montana* L. species in Apuseni Mountains, Romania. *ProEnvironment/ProMediu, 6,* 13.
52. Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2014). Effects of low-input treatments on *Agrostis capillaris L.–Festuca rubra* L.

grasslands. In *The Future of European Grasslands* (EGF Proceedings, 17th Meeting, Ghent).

53. Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2013). The influence of limestone upon the vegetation of *Festuca rubra–Agrostis capillaris* semi-natural grassland type in the mountain regions and on dry matter yield. *Romanian Journal of Grasslands and Forage Crops, 15*, 31–36.
54. Rotar, I., Păcurar, F., Stoie, A., Gârda, N., & Dale, L.-M. (2010). The evolution of *Arnica montana* L. grasslands depending on the performed management (Apuseni Mountains, Romania). *Scientific Papers Series Agronomy, 53*, 221–226.
55. Rotar, I., Pacurar, F., Vidican, R., & Morea, A. (2010). The organic-mineral fertilization of a *Festuca rubra* L. grassland in Apuseni Mountains. *Romanian Journal of Grasslands and Forage Crops, 2*, 55–60.
56. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2003). Effects of manure/sawdust fertilisation on *Festuca rubra* type meadows at Ghețari (Apuseni Mountains). In *Optimal Forage Systems for Animal Production and the Environment* (EGF Proceedings, Vol. 8, pp. 192–194).
57. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2005). Impact of the agricultural use on the biodiversity of a *Festuca rubra* meadow. In *XX International Grassland Conference: Offered Papers* (p. 616). https://doi.org/10.3920/978-90-8686-552-9_520
58. Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2005). The influence of organic and organo-mineral fertilization on biodiversity of the *Festuca rubra* meadows in Apuseni Mountains. *Lucrări Științifice – Seria Agronomie, 48*, 355–359.
59. Rotar, I., Toth, G., Vaida, I., Mălinaș, A., Stoian, V., & Deac, V. (2016). Ecological and agronomical value of *Festuca rupicola–Bromus erectus* grasslands. *Romanian Journal of Grasslands and Forage Crops, 19*, 81–87.
60. Rotar, I., Vaida, I., & Păcurar, F. (2020). Species with indicative values for the management of mountain grasslands. *Romanian Agricultural Research, 37*, 2067–5720.
61. Rotar, I., Vidican, R., Ciure, A., Păcurar, F., Gliga, A., & Balázsi, A. (2014). The behavior of the mixture formed by *Trifolium pratense*, *Medicago sativa*, *Lolium perenne*, *Festulolium*, *Phleum pratense* and *Dactylis glomerata* under the influence of mineral fertilization. *Romanian Journal of Grasslands and Forage Crops, 9*, 87.
62. Rotar, I., Vidican, R., Păcurar, F., Mălinaș, A., & Vaida, I. (2016). A forage mixture with red clover in the fourth experimental year. *Bulletin UASVM Agriculture, 73*(2).
63. Rușdea, E., Reif, A., Höchtl, F., Păcurar, F., Rotar, I., Stoie, A., Dahlström, A., Svensson, R., & Aronsson, M. (2011). Grassland vegetation and management—On the interface between science and education. *Bulletin UASVM Agriculture, 68*(1).
64. Samuil, C., Nazare, A.-I., Sîrbu, C., Grigoraș, B., & Vîntu, V. (2025). The impact of fertilizer gradient on high nature value mountain grassland. *Plants, 14*, 3397.
65. Sângeorzan, D. D., Păcurar, F., Reif, A., Weinacker, H., Rușdea, E., Vaida, I., & Rotar, I. (2024). Detection and quantification of *Arnica montana* inflorescences in grassland ecosystems using convolutional neural networks and drone-based remote sensing. *Remote Sensing, 16*, 2012.

66. Sângeorzan, D. D., Rotar, I., Vidican, R., & Păcurar, F. (2018). Romania's diet footprints: Minimum arable land and ecological footprint of consumption (1961–2013). *Romanian Journal of Grasslands and Forage Crops, 20,* 65–74.
67. Sângeorzan, D., Rotar, I., Păcurar, F., Vaida, I., Šuteu, A., & Deac, V. (2018). The definition of oligotrophic grasslands. *Romanian Journal of Grasslands and Forage Crops, 20,* 17.
68. Scotton, M. (2019). Mountain grassland restoration: Effects of sowing rate, climate and soil on plant density and cover. *Science of the Total Environment, 651,* 3090-3098.
69. Șerban, C., Rotar, I., Păcurar, F., Ghețe, I., & Pleșa, A. (2025). Studies on the ecological restoration of grassland ecosystems at the păltiniș experimental station. *Romanian Journal of Grassland and Forage Crops, 31,* 23.
70. Sima, N., & Păcurar, F. (2002). Quality of forage obtained from a mountain pasture as influenced by harvesting phenophase and management. In *Multi-function Grasslands: Quality Forages, Animal Products and Landscapes* (EGF Proceedings, Vol. 7, pp. 160–161).
71. Stoian, V., Vidican, R., Crișan, I., Puia, C., Șandor, M., Stoian, V. A., Păcurar, F., & Vaida, I. (2019). Sensitive approach and future perspectives in microscopic patterns of mycorrhizal roots. *Scientific Reports, 9,* 10233.
72. Stoian, V., Vidican, R., Rotar, I., Păcurar, F., & Morea, A. (2014). The development of mycorrhizal fungi in the roots of *Festuca rubra* under the influence of fertilization and maintenance of a constant climate. *Romanian Journal of Grasslands and Forage Crops, 10,* 85.
73. Stoian, V., Vidican, R., Rotar, I., Păcurar, F., & Niște, M. (2014). Analysis of disturbing impact of management on the stability of mycorrhizal colonization in mountain meadow ecosystems. *Romanian Journal of Grasslands and Forage Crops, 9,* 11.
74. Török, P., Vida, E., Deák, B., Lengyel, S., & Tóthmérész, B. (2011). Grassland restoration on former croplands in Europe: an assessment of applicability of techniques and costs. *Biodiversity and conservation*, *20*(11), 2311-2332.
75. Vaida, I., Păcurar, F., Rotar, I., Tomoș, L., & Stoian, V. (2021). Changes in diversity due to long-term management in a high nature value grassland. *Plants, 10,* 739.
76. Vaida, I., Rotar, I., & Păcurar, F. (2017). The cumulative effect of manure on a *Festuca rubra* grassland for 15 years. *Bulletin UASVM Agriculture, 74*(2).
77. Vaida, I., Rotar, I., Păcurar, F., Vidican, R., Pleșa, A., Mălinaș, A., & Stoian, V. (2016). Impact of the abandonment of semi-natural grasslands from Apuseni Mountains. *Bulletin UASVM Agriculture*, *73*(2).
78. Vârban, D., Păcurar, F., Vârban, R., & Odagiu, A. (2011). Research concerning the study of germination in *Arnica montana* L. species. *ProEnvironment/ProMediu, 4,* 8.
79. Wu, G. L., Li, M., Leite, P. A., Dang, Z., & Zhao, J. (2024). Restoration approach for alpine extremely degraded landscapes: testing direct seeding and mulching with grass clippings. *Restoration Ecology*, *32*(3), e14074.

LONG-TERM EFFECTS OF MINERAL FERTILIZATION ON BIOMASS PRODUCTIVITY AND AGRONOMIC FACTORS IN HIGH NATURE VALUE GRASSLANDS

Ioana GHEȚE and Ioan ROTAR

***Faculty of Agriculture. Department of Plant Crops. University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Manăstur street, 3-5, 400372, Romania.**
[*] Corresponding author, e-mail: ioana.ghete@usamvcluj.ro

Abstract

High Nature Value (HNV) grasslands play a key role in maintaining biodiversity and ecosystem functionality in mountain regions. This study evaluates the long-term effects of mineral fertilization on the agronomic characteristics and biomass productivity of a semi-natural grassland in the Apuseni Mountains, after 17 consecutive years of annual NPK applications (0; $50N25P_2O_525K_2O$; $100N50P_2O_550K_2O$; $150N75P_2O_575K_2O$ kg/ha). Biomass yield increases mainly through the expansion of two species with high competitive capacity: Agrostis capillaris, whose cover rises from 11% in the control to 64.6% under high fertilization, and Trisetum flavescens, which shows maximal development at moderate doses. Agronomic quality improves with fertilization, shifting from class V (medium) in the unfertilized sward to class VI (good) under the highest treatment, due to the installation of taller species with richer foliage. In contrast, grazing and trampling tolerance decrease progressively as mineral inputs intensify, reflecting the replacement of stress-tolerant species by taller, less resistant ones. Overall, the findings indicate that mineral fertilization enhances biomass production and forage quality but reduces structural complexity and tolerance of the sward to pastoral use. In the context of rising temperatures and decreasing precipitation in the study area, these trends underline the need for careful nutrient management to preserve the ecological stability and multifunctionality of HNV grasslands.

Keywords: HNV grasslands, mineral fertilization, biomass production, agronomic factors, forage quality, long-term experiment, Apuseni Mountains.

INTRODUCTION

In recent decades, Romania's mountainous areas have undergone profound transformations driven primarily by the restructuring of their traditional economic system. The drastic reduction of timber resources—the main source of income for local communities—has led to major changes in the way of life of mountain populations (Rotar et al. 2020; Păcurar et al. 2023). A representative example is the Apuseni Mountains, where logging and wood processing once provided approximately 70% of household income, and the strong dependence of Mote communities on this resource has been documented by several authors (Auch et al., 2001; Rușdea et al. 2011; Gliga et al. 2013; Păcurar et al. 2019).

As forest resources have progressively diminished, local populations have increasingly shifted towards agriculture and livestock husbandry. This transition has directly influenced land use patterns, landscape dynamics, floristic composition, and the phytodiversity of grasslands (Brinkmann et al. 2009; Rotar et al. 2010; Păcurar et al. 2023).

Within this context, the assessment and conservation of High Nature Value (HNV) grasslands have become a major national concern. Romanian specialists are developing management methods based on the use of indicator species, adjusted to local site conditions and the intensity of agro-pastoral practices (Vaida et al. 2017; Sângeorzan et al. 2018; Gaga et al. 2022). At the European level, the use of indicator species to assess HNV grasslands has a long tradition, with numerous studies showing that agricultural intensification in Western Europe leads to biodiversity reduction, a trend revealed by shifts in floristic indicators. In Germany, for instance, the effectiveness of agri-environmental measures has been validated through the monitoring of indicator species (Wittig & Zacharias 2006; Balázsi et al. 2018; Milberg et al. 2020).

Climate change represents an additional threat to grassland ecosystems in the Carpathian Mountains, the most extensive mountain range in Central and Eastern Europe (Sângeorzan et al. 2024). These ecosystems host valuable plant communities with high biodiversity and important indicator species (Vaida et al. 2021). Recent climatic trends, including rising temperatures and declining precipitation, influence vegetation dynamics and the capacity of grasslands to maintain stable structures under increasing anthropogenic pressure.

Many researchers now recommend that Common Agricultural Policy measures across the European Community be evaluated based on outcomes rather than actions, and that lists of species indicative of management intensity be developed. In this context, research on HNV grasslands should be carried out through long-term experiments, as short-term studies may fail to capture or may distort real ecological processes. Authors emphasize that knowledge gained from long-term ecological fertilization experiments must be considered before applying additional nutrients to semi-natural grasslands (Păcurar et al. 2023).

Experiments assessing the effect of mineral fertilization on biodiversity are relatively rare, as mineral inputs applied in optimal quantities are considered, at European level, a viable solution for maintaining and even conserving grassland biodiversity in Romania. The wide diversity of HNV ecosystems in mountain regions has been created and maintained through traditional and sustainable agricultural practices, and altering this equilibrium may generate major changes in floristic composition and agronomic parameters of the vegetation cover.

In this context, the present study analyzes how mineral fertilization, applied continuously for 17 years, influences the floristic composition, biomass productivity, and agronomic factors of a mountain grassland in the Apuseni Mountains, providing essential insights into the long-term evolution of phytocoenoses under current climatic and socio-economic transformations.

MATERIAL AND METHOD

The long-term experiences with mineral fertilizers were studied. The mineral experiment consisted of 4 treatments in 4 replications (T1 control, T2 50N25P25K, T3 100N50P50K, T4 150N75P75K). Mineral fertilizers were applied annually in early spring, using the same type of complex fertilizer, namely NPK (nitrogen, phosphorus, potassium) 20:10:10. For the floristic analysis, data from long-term experiments established in Ghețari (Apuseni Mountains, Romania) were used, at an elevation of 1130 m, founded in 2001, using the random blocks method, will be used. The floristic studies were performed according to the Braun-Blanquét method modified by Păcurar and Rotar (2014). This paper presents data from three experimental years (2015, 2016, 2017), but highlights the cumulative effect of mineral inputs 17 years after the placement of the experiments.

Mineral fertilizers were applied annually in early spring, when the snow cover melted, usually around April 15-20. Mineral fertilization was performed on the same day in all experimental variants. The PC-ORD software, version 7 (www.pcord.com), was used to process the floristic data obtained in the experimental fields.

For processing, the data obtained were entered in the form of two matrices. The first matrix contained data on vegetation, while the second matrix contained the experimental variants. PC-ORD software (version 7) was used for vegetation classification and ordination, as well as for randomization tests.

In this paper, the ordering was performed in two dimensions because it provides a clear picture of the phenomenon. The ordering of the floristic surveys of the experimental data was performed using the Principal Coordinates Analysis (PCoA) method. This method is widely used in ordering statistics, even outside the fields of ecology and agronomy. It has been tested over time and has always been adjusted by specialists in statistical processing. (PECK, 2010; Păcurar și Rotar 2014).

Regarding the temperatures recorded at the Ghețari station over the last 17 years, the following aspects can be observed: the multi-year average was around 5.8^{0}C, with a maximum value of 7.7^{0}C recorded in 2012 and 2015 (Gliga et. al 2013), and a minimum value of 3.2^{0}C recorded in 2005 (Apahidean et. al., 2005, Barbara et. al 2006); Table 2 also shows an upward trend in average annual temperatures, particularly between

2012 and 2017 (Brinkmann *et. al*., 2009; Morea *et. al*., 2014).

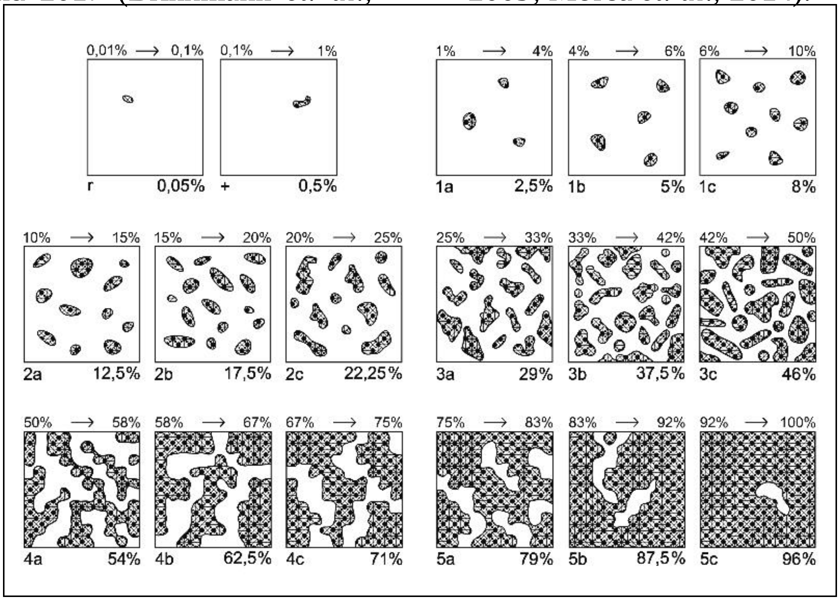


Figure 1. Scheme of appreciation of abundance-dominance by method Braun-Blanquet, using three sub-notes Pacurar and Rotar, 2014)

Table 1.

Scale of appreciation of abundance-dominance Braun-Blanquet, completed Tüxen and Ellenberg (1937), modified with three sub-notes and three sub-ranges byPăcurar and Rotar, (2014)

Nota	Coverage interaval (%)	Central value of class (%)	Sub-note	Sub-interval (%)	Central-adjusted value of sub-interval (%)
5	75 – 100	87.5	5c	92 – 100	96
			5b	83 – 92	87.5
			5a	75 – 83	79
4	50 – 75	62.5	4c	67 – 75	71
			4b	58 – 67	62.5
			4a	50 – 58	54
3	25 – 50	37.5	3c	42 – 50	46
			3b	33 – 42	37.5
			3a	25 – 33	29
2	10 – 25	17.5	2c	20 – 25	22.25
			2b	15 – 20	17.5
			2a	10 – 15	12.5
1	1 – 10	5	1c	6 – 10	8
			1b	4 – 6	5
			1a	1 – 4	2.5
+	0.1 – 1	0.5	-	-	0.5
r	0.01 – 0.1	0.05	-	-	0.05

Note: system Braun-Blanquet, completed by Tüxen and Ellenberg (1937), modified with three sub-notes and three sub-intervals (source Pacurar and Rotar, 2014)

Therefore, the context of climate change in the study area (Ghețari Plateau – Poiana Călineasa) has significant effects on the floristic diversity of oligotrophic grasslands in the Apuseni Mountains.

Table 2

The monthly average temperatures recorded at Gheţari weatherstation (2015-2017)

Year	Months												Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2015	0,8	2	4,7	3,8	10,8	13,5	16,5	16,5	12,7	7,7	3,4	-0,2	7,7
2016	-5,4	0,1	1	8	8,7	14,8	16	15,3	10,9	4,6	0,4	-5,4	5,7
2017	-1,8	6	8,3	6,4	10	14,6	15,5	15,3	10,7	7,9	0,6	-3,2	7,5
Mean	-4,5	-2,7	0,2	5,3	10,5	14,5	15,9	15,4	11,3	6,0	1,4	-3,1	5,8

Regarding the average annual precipitation values recorded at the Ghețari weather station, it was found that the multi-year average (over 17 years) was 1042.1 mm, with the maximum recorded in 2001 (1553 mm; Păcurar et. al., 2004) and the minimum was recorded in 2012 (687 mm; Păcurar et. al., 2017), which was considered the driest year in our study area. Comparing the last 5 years (2012-2017; Rotar et. al., 2020) with the multi-year average in terms of rainfall, it is easy to see that the downward trend in precipitation values is complemented by an increase in temperature values, thus foreshadowing a constantly changing climate, which brings with it new challenges in terms of adapting grassland management in the Apuseni Mountains.

Table 3

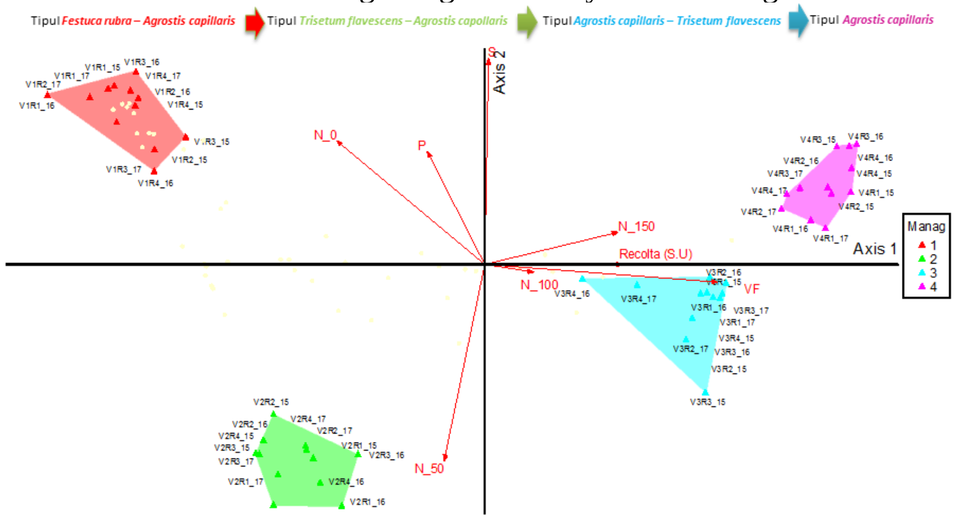
The monthly average precipitations recorded at Gheţari weatherstation (2015-2017)

Year	Months												Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2015	32,6	14,2	23,6	48,6	69,4	78,2	33,8	95	124	38,8	98,4	49,8	706,4
2016	120	111,4	79,4	108,4	67	165,4	58,8	49,4	56	86,6	127	0,2	1030
2017	112	0	86	11,4	116,6	95	37	35	88	100	98	36,2	815,2
Media	67,2	55,9	81,8	77,2	102,4	100,3	137,3	98,4	92,6	86,6	86,5	55,8	1042,1

RESULTS AND DISCUSSIONS

The influence of mineral fertilization on agronomic factors

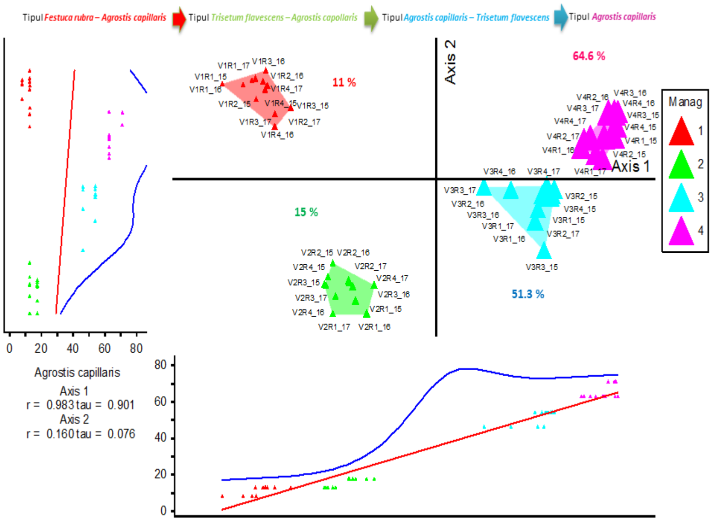
The agronomic factors that correlate with the ordering axes are represented by species tolerance to grazing, trampling, forage value, and yield (Fig. 2). Species preferences in terms of grazing tolerance are inversely proportional to yield and forage value.



1 – V1 (CONTROL); **2** – V2 (50N25P25K); **3** – V3 (100N50P50K); **4** – V4 (150N75P75K); **VF** – Fooder value; **P** – grazing; **S** - crushed

Fig. 2 The influence of mineral fertilization on the agronomic factors

The biomass harvest developed mainly on the basis of two species: *Agrostis capillaris* (Fig. 3) and *Trisetum flavescens* (Fig. 4). The *Agrostis capillaris* species is strongly influenced by the treatments applied and has the highest proportion in the 100N50P50K and 150N75P75K treatments (r = 0.983; Fig. 3). The species increases its share from 11% coverage (control) to 64.6% of the vegetation cover (150N75P75K). Our results are also confirmed by Motcă in 1975, when mineral fertilization of an *Agrostis capillaris* – *Festuca rubra* meadow in the Făgăraş Depression led to a strong establishment of the *Agrostis capillaris* species, which became dominant. Dincă in 1984 shows that mineral fertilization led to an increase in the size of the *Agrostis capillaris* species and lush growth with rich foliage. Our studies are also confirmed by current specialist literature. Thus, the analysis of the effects of mineral fertilization on the floristic composition highlights a clear change in the structure of the vegetation cover with the intensification of nutrient input. The results obtained in the long-term experiment at Ghețari confirm the trends reported in recent literature, according to which *Agrostis capillaris* is one of the most sensitive and reliable indicator species of intense mineral fertilization (Gârda et. al., 2009; Gheţe et. al., 2025). The ecological trend of this species, also identified in other studies, confirms that *Agrostis capillaris* is adapted to nitrophilic conditions, responding favorably to increased nitrogen availability and effectively competing with other species in ecosystems with high nutrient inputs. By integrating these results, the experiment demonstrates that long-term mineral fertilization causes a functional redistribution of species in the plant community: *Agrostis capillaris* emerges as an indicator species of high fertilization intensity, while *Trisetum flavescens* (Gârda et. al., 2010) and other mesotrophic species remain characteristic of low-input variants. This differentiation is essential for understanding the adaptation mechanisms of mountain grasslands to different management regimes.

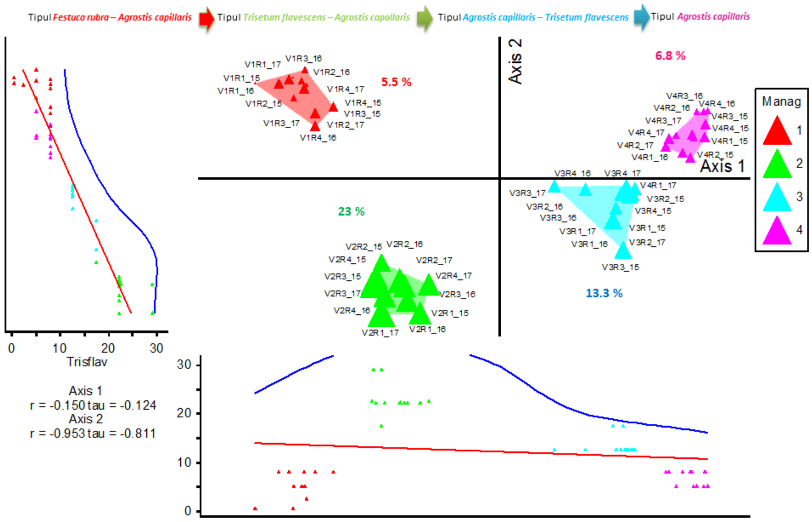


1 – V1 (control); **2** – V2 (50N25P25K); **3** – V3 (100N50P50K); **4** – V4 (150N75P75K); r-correlation coefficient

Fig. 3 The influence of *Agrostis capillaris* species on dry matter

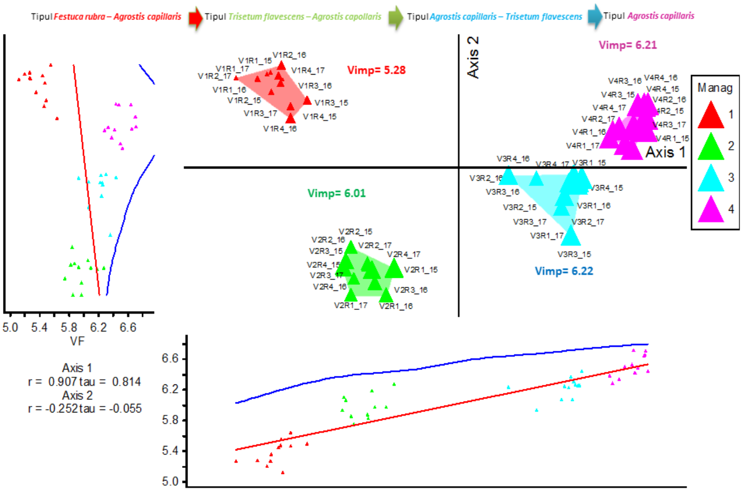
The species *Trisetum flavescens* is influenced by the treatments applied and has the highest proportion in the treatments with 50N25P25K and 100N50P50K (Fig. 4). The species increases its share from 5.5% (control) to 23% in the 50N25P25K treatment, 13.3% in the 100N50P50K treatment, after which it records a decrease in share (6.8%) in the 150N75P75K fertilized variant. Our results are also confirmed by SCHNEIDER in 2011, when he identified the species *Trisetum flavescens* on high-yield grasslands. Feed value is a complex concept that takes into account the following aspects (Vîntu, 2004; Rotar and Carlier, 2010): chemical composition; degree of consumability; palatability (acceptance by animals); degree of toxicity; percentage of leaves and stems; porosity of plant organs and their type; digestibility.

The application of mineral fertilization led to an improvement in forage quality. The phytocoenosis of the control (*Festuca rubra* – *Agrostis capillaris*) falls into class V (Fig. 5), the average category, being a meadow dominated by species with average forage value, supporting 0.81–1.00 UVM/ha, and following mineral fertilization, it falls into class VI quality, good category (V4 – 150N75P75K; *Agrostis capillaris* type), where species with good forage value predominate, supporting 1.01 – 1.20 UVM/ha. This increase in quality can be explained by the installation of new types of pasture as a result of the increased intensity of the system.



1 – V1 (control); **2** – V2 (50N25P25K); **3** – V3 (100N50P50K); **4** – V4 (150N75P75K); r-correlation coefficient

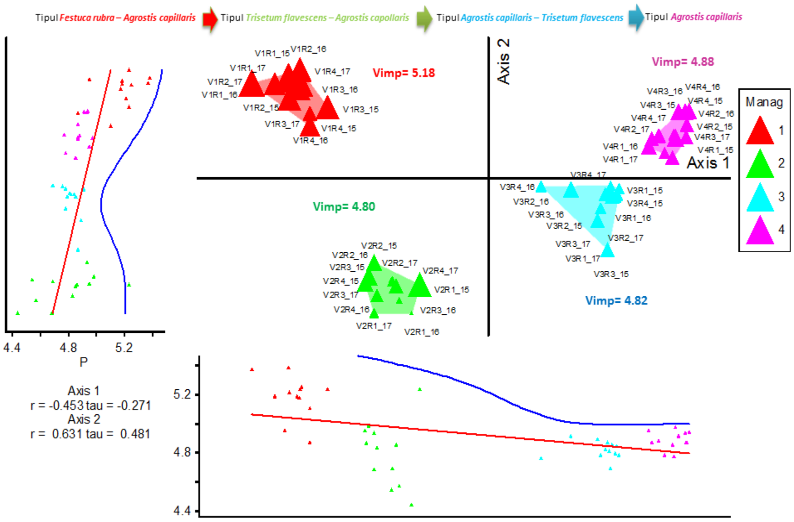
Fig. 4 The influence of *Trisetum flavescens* species on dry matter



1 – V1 (control); **2** – V2 (50N25P25K); **3** – V3 (100N50P50K); **4** – V4 (150N75P75K); r-correlation coefficient; VF – feed value

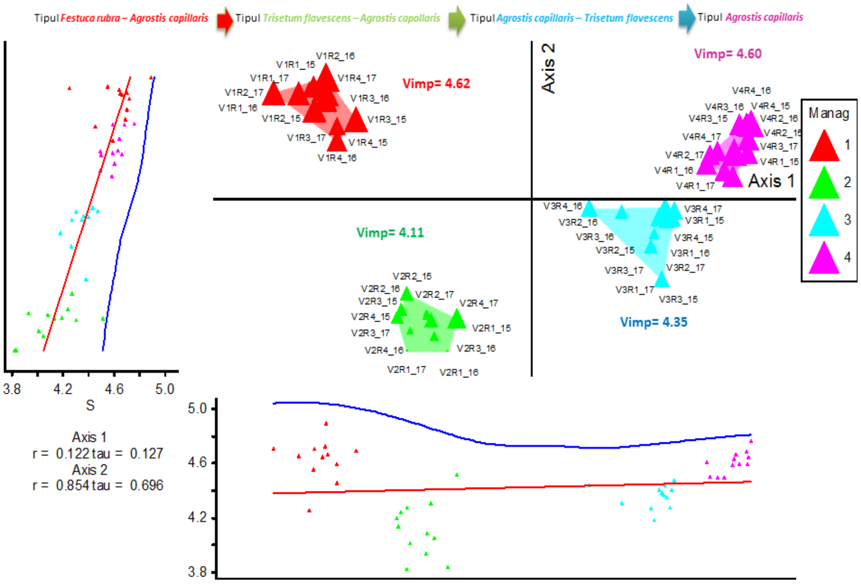
Fig. 5 Influence of mineral fertilization on fodder value

The tolerance of phytocenosis to grazing is inversely proportional to mineral fertilization (Fig. 6). The representative phytocenosis of the control is moderately tolerant to grazing (P=5.18) and is reduced to moderately tolerant to treatment with 150N75P75K (P=4.88). This situation can be explained by the new species (*Agrostis capillaris*) that have been introduced, which are medium to tall in height and have a lower tolerance to grazing compared to the species in the control phytocenosis (*Festuca rubra*).



1 – V1 (control); **2** – V2 (50N25P25K); **3** – V3 (100N50P50K); **4** – V4 (150N75P75K); r - correlation coefficient; P - grazing

Fig. 6 Influence of mineral fertilization on the tolerance of phytocenoses in grazing



1 – V1 (control); **2** – V2 (50N25P25K); **3** – V3 (100N50P50K); **4** – V4 (150N75P75K); r-correlation coefficient; S – crushed

Fig. 7 Influence of mineral fertilization on the tolerance of phytocenoses in crushed

Tolerance to crushing is inversely proportional to mineral fertilization, with a decrease in the tolerance to crushing of phytocenoses (Fig. 7). While in the control sample the tolerance to crushing is 4.62, following mineral fertilization and the installation of new types of grassland, it is reduced to 4.11 (V2 – *Trisetum flavescens* – *Agrostis capillaris* type), 4.35 in the treatment with 100N50P50K (*Agrostis capillaris* - *Trisetum flavescens type*), there is no change in the agronomic category, all being moderately tolerant to crushing.

CONCLUSIONS

The application of mineral fertilizers increases the fodder value of the vegetation cover, due to the establishment of new types of pasture with superior qualities;

Mineral fertilization causes a slight decrease in the grazing tolerance of phytocenoses;

Overlaying the results regarding the evolution of agronomic, ecological, and natural factors over those specific to vegetation changes leads to a clearer picture of the behavior of newly established pasture types as a result of fertilizer application.

REFERENCES

1. Apahidean, A. S., Apahidean, M., & Pacurar, F. (2004). Experimental results on the possibilities of vegetable growing in the area of western Carpathian Mountains from Romania. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 32, 30.
2. Apahidean, A. S., Apahidean, M., & Păcurar, F. (2005). Experimental results on the possibilities of vegetable growing in the area of Western Carpathian Mountains from Romania.
3. Auch E., F. Păcurar, A. Goia, 2001, Economic and Technological Aspects of the Agricultural Systems in Ţara moţilor (Gheţar, Gârda de Sus), în Buletinul USAMV, Seria Agricultura, vol. 55-56: 215.
4. Balázsi, Á., Pacurar, F., Mihu-Pintilie, A., & Konold, W. (2018). How do public institutions on nature conservation and agriculture contribute to the conservation of species-rich hay meadows? *International Journal of Conservation Science, 9*, 549–564.
5. Balázsi, Á., Păcurar, F., Rotar, I., & Vidican, R. (2016). Alternative management for oligotrophic grassland conservation in the Apuseni Mountains.

6. Barbara, M., Rotar, I., & Pacurar, F. (2006). Biodiversity and conservation of medicinal plants: A case study in the Apuseni Mountains in Romania. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, 62.
7. Barbara, M., Wolfgang, K., Susanne, S., Ioan, R., & Florin, P. (2006). Conservation of eastern European medicinal plants: Arnica montana in Romania.
8. Brinkmann, K., Pacurar, F., & Reif, A. (2009). Secondary succession and fluctuations in meadows of the Apuseni Mountains (Transylvania, Romania) under different fertilisation regimes. Transylvanian Review of Systematical and Ecological Research, (7), 41.
9. Brinkmann, K., Păcurar, F., Rotar, I., Rușdea, E., Auch, E., & Reif, A. (2009). The grasslands of the Apuseni Mountains, Romania, în Grasslands in Europe of high nature value, Print ISBN 978 90 5011 31 68.
10. Dale, L. M., Thewis, A., Boudry, C., Rotar, I., Păcurar, F. S., Abbas, O., Dardenne, P., Baeten, V., Pfister, J., & Fernández Pierna, J. A. (2013). Discrimination of grassland species and their classification in botanical families by laboratory scale NIR hyperspectral imaging: Preliminary results. *Talanta*, *116*, 149–154.
11. Dale, L., Thewis, A., Rotar, I., Boudry, C., Păcurar, F. S., Lecler, B., Agneessens, R., Dardenne, P., & Baeten, V. (2013). Fertilization effects on the chemical composition and in vitro organic matter digestibility of semi-natural meadows as predicted by NIR spectrometry. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *41*, 58–64.
12. Gaga, I., Pacurar, F., Vaida, I., Plesa, A., & Rotar, I. (2022). Responses of Diversity and Productivity to Organo-Mineral Fertilizer Inputs in a High-Natural-Value Grassland, Transylvanian Plain, Romania. Plants, 11(15), 1975.
13. Gârda, N. T., Păcurar, F., Rotar, I., & Bogdan, A. (2010). The floristic and stational characterisation of the grassland subtype *Agrostis capillaris + Trisetum flavescens* from Apuseni Mountains, Romania. *Research Journal of Agricultural Science, 42,* 454–457.
14. Gaga, I., Rotar, I., Păcurar, F., Vaida, I., & Pleşa, A. (2022). The influence of organic and mineral fertilization on the production of Festuca rupicola grasslands in the Transylvian Plain. *Rom. J. Grassl. Forage Crops, 25,* 25-30.
15. Gârda, N., Rotar, I., Păcurar, F., & Vidican, R. (2009). The role of pastoral landscape in defining the mountainous space in Apuseni Mountains. *Lucrări Științifice vol. 52. Seria Agronomie*.
16. Gheței, I., Rotar, I., Pleșa, A., Gheței, A., Șerban, C., & Stoian, V. (2025). Effect of mineral fertilization on vegetation of HNV pastures in the Apuseni Mountains (Romania). *Plants, 14,* 3564.

17.Gliga, A., Rotar, I., Vidican, R., Păcurar, F., Balazsi, A., & Deak, D. (2013). Evolution of semi-natural grasslands in Europe (bibliographical paper). (2013): 17-22.
18.Mălinas, A., Rotar, I., Vidican, R., Iuga, V., Păcurar, F., Mălinas, C., & Moldovan, C. (2020). Designing a sustainable temporary grassland system by monitoring nitrogen use efficiency. *Agronomy, 10,* 149.
19.Marușca, T., Păcurar, F. S., Scrob, N., Vaida, I., Nicola, N., Taulescu, E.,& Lukács, Z. (2021). Contributions to the assessment of grasslands productivity of the apuseni natural park (rosci 0002). Romanian Journal of Grassland and Forage Crops, 24, 23.
20.Maruşca, T., Păcurar, F. S., Taulescu, E., Vaida, I., Nicola, N., Scrob, N., & Dragoș, M. M. (2022). Indicative species for the agrochemical properties of mountain grasslands soil from the apuseni natural park (rosci 0002). Romanian Journal of Grasslands and Forage Crops, 25(22), 31.
21.Marușca, T., Păcurar, F., Memedemin, D., Oprea, A., Vaida, I., Taulescu, E., & Nicola, N. (2022). Ecological, Agronomic and Anthropogenic Characterization of the Habitat 62C0* Ponto-Sarmatian Steppes in the North of Dobrogea (Romania). Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, 79(2), 42-53.
22.Michler, B., Rotar, I., Pacurar, F., & Stoie, A. (2005). *Arnica montana*, an endangered species and a traditional medicinal plant: the biodiversity and productivity of its typical grasslands habitats. Grassland Science in Europe, 10, 336-339.
23.Milberg, P., Bergman, K. O., Glimskär, A., Nilsson, S., & Tälle, M. (2020). Site factors are more important than management for indicator species in semi-natural grasslands in southern Sweden. Plant Ecology, 221(7), 577-594.
24.Morea, A., Rotar, I., & Păcurar, F. (2008). Drying possibilities of Arnica montana flower heads using local resources.
25.Morea, A., Rotar, I., Vidican, R., & Păcurar, F. (2013). The influence of different types of management upon the floristic structure of grassland systems, with special attention on *Arnica montana* L. *Bulletin UASVM Agriculture, 70*(1).
26.Morea, A., Rotar, I., Vidican, R., Păcurar, F., & Stoian, V. (2014). Changes in vegetation in a Festuca rubra meadow in Apuseni Mountains due to organic fertilization.
27.Păcurar, F. (2005). *Cercetări privind dezvoltarea durabilă a satului Ghețari, comuna Gârda, prin îmbunătățirea pajiștilor naturale și a unor culturi agricole* (Teză de doctorat). USAMV Cluj-Napoca.
28.Păcurar, F. (2020). Specii indicator pentru evaluarea şi elaborarea managementului sistemelor de pajişti cu înaltă valoare naturală-HNV. Casa Cărţii de Ştiinţă.
29.Păcurar, F. S., Rotar, I., & Vaida, I. (2019). The effects of wild boar disturbances on the agronomical value of semi-natural grasslands. Romanian J. Grassl. Forage Crops, 20, 27.

30.Păcurar, F. S., Rotar, I., Michler, B., & Vidican, R. (2008). Traditional management of Arnica montana grasslands. Grassland Science in Europe, 13.
31.Păcurar, F. S., Rotar, I., Vaida, I., Gaga, I., & Costantea, D. (2020). Ecological and agronomical value of *Agrostis capillaris-Festuca rupicola* grasslands. Romanian Journal of Grasslands and Forage Crops, 22, 55.
32.Păcurar, F., & Rotar, I. (2004). Maintaining biodiversity and increasing the production of dry matter on mountain meadows.
33.Pacurar, F., and I. Rotar. "The evolution of biodiversity on *Festuca rubra* meadow following to some specifical technologies inputs to sustainable agriculture." (2006): 124-127.
34.Păcurar, F., Balazsi, Á., Rotar, I., Vaida, I., Reif, A., Vidican, R., & Sângeorzan, D. D. (2020). Technologies used for maintaining oligotrophic grasslands and their biodiversity in a mountain landscape.
35.Păcurar, F., Marușca, T., Scrob, N., Vaida, I., & Nicola, N. (2023). The ecological and agronomic study of some grasslands phytocenoses from the site Natura 2000 ROSCI0002 Apuseni. Rom. J. Grassl. Forage Crops, 28, 31-54.
36.Păcurar, F., Morea, A., & Gârda, N. (2008). Productivity and biodiversity evolution of *Festuca rubra* grasslands during a seven-year period. *Bulletin UASVM Agriculture, 65,* 5.
37.Păcurar, F., Reif, A., & Rusḍea, E. (2023). Conservation of oligotrophic grassland of high nature value (HNV) through sustainable use of Arnica montana in the Apuseni Mountains, Romania. In Medicinal Agroecology. Taylor & Francis.
38.Păcurar, F., Rotar, I., Balazsi, A., & Vidican, R. (2014). Influence of long-term organic and mineral fertilization on Festuca rubra L. grassland. The Future of European Grasslands, 294.
39.Păcurar, F., Rotar, I., Bogdan, A. D., Vidican, R. M., & Dale, L. (2012). The influence of mineral and organic long-term fertilization upon the floristic composition of *Festuca rubra* L.–*Agrostis capillaris* L. grassland in Apuseni Mountains, Romania. *Journal of Food, Agriculture & Environment, 10*(1).
40.Pacurar, F., Rotar, I., Gârda, N., & Morea, A. (2009). The Management of Oligotrophic Grasslands and the Approach of New Improvement Methods. Transylvanian Review of Systematical and Ecological Research, (7), 59.
41.Păcurar, F., Rotar, I., Gârda, N., & Morea, A. (2010). The organic-mineral fertilization of a Festuca rubra L. grassland for eight years.
42.Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New directions in the study of oligotrophic grasslands in the mountain area. *Lucrări Științifice – Seria Agronomie* (Iași).
43.Păcurar, F., Rotar, I., Gârda, N., & Vidican, R. (2009). New possibilities for sustainable use of oligotrophic grasslands in Apuseni Mountains. *Bulletin UASVM Agriculture, 66.*

44.Păcurar, F., Rotar, I., Pleșa, A., Balázsi, Á., & Vidican, R. (2015). Study of the floristic composition of certain secondary grasslands in different successional stages as a result of abandonment. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, 72,* doi:10.15835/buasvmcn-agr:11165.

45.Păcurar, F., Rotar, I., Vaida, I., Vidican, R., & Mălinaş, A. (2017). Indicator species of fertilization intensity in mountain grasslands. Grassl. Resour. Extensive Farming Syst. Marg. Lands Major Driv. Future Scenar, 22, 378.

46.Păcurar, F., Rotar, I., Vidican, R., & Gârda, N. (2007). Organic fertilization and biodiversity of *Festuca rubra* grasslands. In *Permanent and Temporary Grassland: Plant, Environment and Economy* (EGF Proceedings, Vol. 12, pp. 363–366).

47.Păcurar, F., Rotar, I., Vidican, R., & Vaida, I. (2023). The ecological and agronomic study of some grasslands phytocenoses from the Site Natura 2000 Rosci 0238 Suatu-Cojocna-Crairît. Rom. J. Grassl. Forage Crops, 27, 9-28.

48.Păcurar, F., Rotar, I., Vidican, R., Vaida, I., Pleșa, A., Stoian, V., Tomoș, L., & Ghețe, A. (2025). Density-based assessment of *Adonis vernalis* abundance in native habitats. *Scientific Papers Series A. Agronomy*, *68*(1).

49.Reif, A., Auch, E., Bühler, J., Brinkmann, K., Goia, A. I., Pacurar, F., & Rusdea, E. (2005). Landschaft und landnutzung im Apusenigebirge Rumäniens. Carinthia II, 195(115), 161-201.

50.Reif, A., Ruşdea, E., Păcurar, F., Rotar, I., Brinkmann, K., Auch, E.,& Bühler, J. (2008). A traditional cultural landscape in transformation. Mountain Research and Development, 28(1), 18-22.

51.Rotar, I., Gârda, N., Păcurar, F., & Vidican, R. (2009). Study of mountain landscape elements in Apuseni Mountains (Gârda de Sus Community).

52.Rotar, I., Huygens, D., Vidican, R., Carlier, L., Pacurar, F., & Malinas, A. (2013). The Effect of Low-input Grassland Management on *Arnica montana* L. Species in Apuseni Mountains, Romania. ProEnvironment Promediu, 6(13).

53.Rotar, I., Păcurar, F., & Vidican, R. (2006). The influence of organic fertilisers on the biodiversity of a *Festuca rubra* meadow. Grassland Productivity.

54.Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2014). Effects of low-input treatments on *Agrostis capillaris L.–Festuca rubra* L. grasslands. In *The Future of European Grasslands* (EGF Proceedings, 17th Meeting, Ghent).

55.Rotar, I., Păcurar, F., Balázsi, Á., Vidican, R., & Mălinaș, A. (2013). The influence of limestone upon the vegetation of *Festuca rubra–Agrostis capillaris* semi-natural grassland type in the mountain regions and on dry matter yield. *Romanian Journal of Grasslands and Forage Crops, 15,* 31–36.

56.Rotar, I., Păcurar, F., Stoie, A., Gârda, N., & Dale, L. M. (2010). The evolution of *Arnica montana* L. grasslands depending on the performed management (Apuseni Mountains, Romania).
57.Rotar, I., Pacurar, F., Vidican, R., & Sima, N. (2003). Effects of manure/sawdust fertilisation on *Festuca rubra* type meadows at Ghetari (Apuseni Mountains).
58.Rotar, I., Păcurar, F., Vidican, R., & Sima, N. (2005, November). Impact of the agricultural use on the biodiversity of a *Festuca rubra* meadow. In XX International Grassland Conference: Offered papers (pp. 616-616). Wageningen Academic.
59.Rotar, I., Vaida, I., & Păcurar, F. (2020). Species with indicative values for the management of the mountain grasslands. Romanian Agricultural Research, (37).
60.Rotar, I., Vidican, R., Păcurar, F., Mălinaş, A., & Gliga, A. (2013). Research on the behaviour of Medicago sativa and Dactylis glomerata simple mixture in Odorheiu Secuiesc basin. Romanian Journal of Grassland and Forage Crops, (7), 41-49.
61.Rușdea, E., Reif, A., Höchtl, F., Păcurar, F., Rotar, I., Stoie, A., & Aronsson, M. (2011). Grassland vegetation and management-on the interface between science and education. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca: Agriculture, 68(1).
62.Rotar, I., Păcurar, F., Vaida, I., Nicola, N., & Pleșa, A. (2020). The Effect of Mulching on a Grasslands in the Apuseni Mountains. *Rom. J. Grassl. Forage Crops*, *25*, 1128-1135.
63.Samuil, C., Nazare, A. I., Sîrbu, C., Grigoraş, B., & Vîntu, V. (2025). The Impact of Fertilizer Gradient on High Nature Value Mountain Grassland. Plants, 14(21), 3397.
64.Samuil, C., Vintu, V., Popovici, C. I., & Stavarache, M. (2014). Influence of fertilization on the biodiversity of Festuca rubra L. and Agrostis capillaris L. grassland. The Future of European Grasslands, 302.
65.Sângeorzan, D. D., Păcurar, F., Reif, A., Weinacker, H., Rușdea, E., Vaida, I., & Rotar, I. (2024). Detection and quantification of arnica montana l. inflorescences in grassland ecosystems using convolutional neural networks and drone-based remote sensing. Remote Sensing, 16(11), 2012.
66.Sângeorzan, D., Rotar, I., Păcurar, F., Vaida, I., Suteu, A., & Deac, V. (2018). The definition of oligotrophic grasslands. Rom. J. Grassl. Forage Crops, 2018, 17.
67.Sângeorzan, D. D., Rotar, I., Vidican, R., Păcurar, F., & Ranta, O. (2018). Romania's diet footprints: minimum arable land and ecological footprint of consumption, from 1961 to.
68.Sima, N., & Păcurar, F. (2002). Quality of forage obtained from a mountain pasture as influenced by harvesting phenophase and management.

69.Sima, N., Rotar, I., Vidican, R., Păcurar, F., & Rusu, M. (2005). The effect of some technological inputs on canopy sward biodiversity in a Festuca rubra mountain pasture.
70.Stoie, A., Păcurar, F., & Rotar, I. (2007). Studies regarding the Arnica montana meadows from the central part of the Apuseni Mountains. Research Journal of Agricultural Science, 39(1), 265-270
71.Vaida, I., Păcurar, F., Rotar, I., Tomoș, L., & Stoian, V. (2021). Changes in diversity due to long-term management in a high natural value grassland. Plants, 10(4), 739.
72.Vaida, I., Rotar, I., & Pacurar, F. (2017). The Cumulative Effect of Manure on a Festuca Rubra Grasslands for 15 Years. Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca. Agriculture, 74(2).
73.Vârban, R., Vârban, D. I., Mihăiescu, T., & Păcurar, F. (2014). Research on the optimisation of *Arnica montana* L seedling production.
74.Vintu, V., Chidovet, S., Samuil, C., & Stavarache, M. (2014). The effect of organic fertilization on *Agrostis capillaris* L. and *Festuca rubra* L. grasslands from the Romanian Eastern Carpathians. The Future of European Grasslands, 306.
75.Vîntu, V., Zaiț Grapan, T., Samuil, C., & Nazare, A. I. (2024). The Influence of Competition Between *Festuca arundinacea* Schreb. and *Trifolium pratense* L., Grown in Simple Mixtures, on the Quality of the Fodder. Agronomy, 14(12), 2934.
76.Vîntu, V., Samuil, C., Stavarache, M., & Nazarie, A. (2017). Influence of management on *Festuca valesiaca* grasslands from Romania's forest steppe.
77.Wittig, B., & Zacharias, D. (2006). An indicator species approach for result-orientated subsidies of ecological services in grasslands–A study in Northwestern Germany. Biological Conservation, 133(2), 186-197.

THE ROMANIAN SOCIETY FOR GRASSLANDS

The Bureau of the Romanian Society for Grasslands

President: Costel SAMUIL
Vice - President: Florin Simion PĂCURAR
Vice - President: Veronica SĂRĂȚEANU
General Secretary: Adrian Vasile BLAJ
Member - Teodor MARUŞCA
Member - Ioan ROTAR
Member - Vasile VÎNTU
Censor: Gabriela IGNAT

Committee of Founding Members of the Romanian Society for Grasslands

Neculai DRAGOMIR
Teodor MARUŞCA
Alexandru Pavel MOISUC
Iosif RAZEC
Ioan ROTAR
Costel SAMUIL
Mirela-Roxana VIDICAN
Vasile VÎNTU

Adhesion to The Romanian Society for Grasslands

Contact Address of the Romanian Society for Grasslands:
CLUJ-NAPOCA, MĂNĂŞTUR Street, No. 3 - 5, Room no: 46, 400372,
District CLUJ, e-mail: sropaj@yahoo.com
www.sropaj.ro

RJGFC

The Romanian Society for Grassland

Contact Adress:

Mănăştur Street, No. 3 - 5,
Chamber 46, Postal cod 400372
CLUJ-NAPOCA, ROMANIA

e-mail: sropaj@yahoo.com
https://sropaj.ro

ISSN 2068-3065