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

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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:

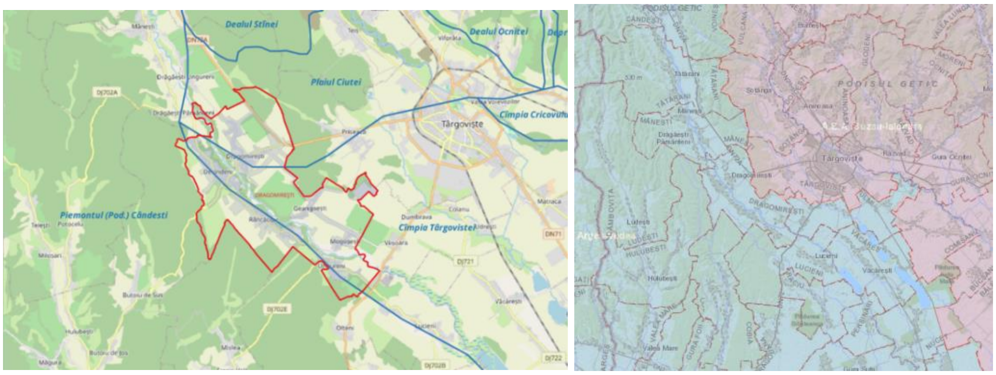
- *Festuca pratensis* (meadow fescue),
- *Poa pratensis* (Kentucky bluegrass),
- *Lolium* spp. (various ryegrass species),
- *Agrostis stolonifera* (creeping bentgrass)
- *Agrostis capillaris* (common bentgrass),

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).

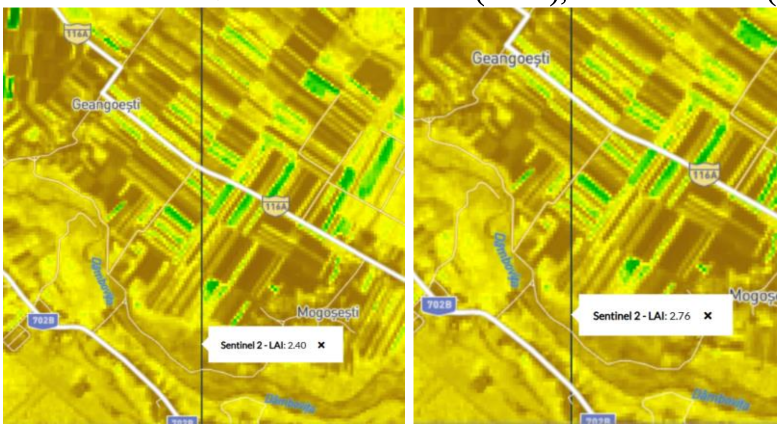


Fig. 3. LAI estimations in the Mogosesti grassland near the Dambovita River based on Sentinel-2 data extracted from Terrascope (Belgium's Earth Observation Data Space)

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

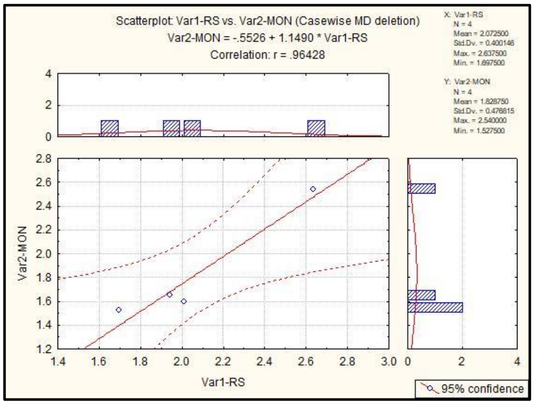


Fig. 4 Correlation between satellite-derived estimations and field measurements using multiannual averages (significant r = 0.96)

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.

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