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Master Thesis

ASSESSMENT OF CATTLE GRAZING ON PLANT BIODIVERSITY IN THE PAGILUTE WETLAND COMPLEX

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CONTENT

SUMMARY

In September 2024, vegetation surveys were conducted in the Pagilutė wetland complex (a Natura 2000 site in northeastern Lithuania) to assess the impact of cattle grazing on wet meadow vegetation. The aim was to evaluate changes in plant biodiversity and functional community composition under grazing. Vegetation surveys employed the Braun–Blanquet method along two transects (ten 1 m^2 quadrats each) comparing a meadow grazed by cattle for one year and an adjacent ungrazed meadow. Species richness and diversity indices (Shannon–Wiener H' and Pielou's J') were calculated, and plant functional groups were analyzed by CSR strategy and Raunkiaer life-form categories.

Grazing markedly enhanced biodiversity: 44 vascular plant species were recorded in the grazed plot versus only 9 in the ungrazed plot. Species diversity was significantly higher under grazing (mean $H' = 3.25 \pm 0.14$) than without grazing ($H' = 1.08 \pm 0.26$), and community evenness also increased ($J' = 0.78$ vs 0.64). Grazing suppressed the dominance of tall competitive reeds (*Phragmites australis*, *Typha latifolia*), resulting in a more balanced, forb-rich community. Functional composition shifted with grazing: stress-tolerant species comprised ~54% of total cover and ruderals ~16%, whereas ungrazed vegetation was dominated by competitor strategists (~42% cover) with minimal ruderals or stress-tolerators. Likewise, life-form spectra changed under grazing: hemicryptophyte cover increased from 66% (ungrazed) to 79% (grazed), therophytes rose from 1% to 13%, and geophytes dropped from 32% to 3%. These results demonstrate that moderate cattle grazing can significantly enhance plant species richness and diversity in wet meadows and alter community functional structure, leading to a more heterogeneous plant community. Overall, the findings support controlled grazing as a beneficial management practice for conserving species-rich wet meadow vegetation in protected Natura 2000 sites.

INTRODUCTION

Meadows and semi-natural grasslands are among the most ecologically valuable ecosystems in Europe, providing a wide range of ecosystem services such as carbon storage, water regulation, and support for biodiversity (Bakker & Berendse, 1999; Glimskär et al., 2023). However, throughout the last century, these ecosystems have undergone rapid transformation. The intensification of agriculture, land-use change, and the abandonment of traditional management practices such as extensive grazing and mowing have led to significant degradation in both the area and ecological quality of semi-natural grasslands, particularly wet meadows (Deschutes Land Trust, 2024; Feather River Land Trust, 2024).

According to national statistics, the total area of meadows and natural pastures in Lithuania has decreased by more than 135,000 hectares between 2003 and 2023, representing a 27% reduction (Glimskär et al., 2023). Wet meadows - unique habitats supporting rare and protected species of plants, amphibians, birds, and insects are especially vulnerable. In the absence of disturbance, these habitats tend to undergo rapid ecological succession, becoming overgrown with shrubs and trees and gradually losing their characteristic flora and fauna (Tälle et al., 2016; Peco et al., 2006).

Grazing, when appropriately managed, plays an important ecological role by reducing plant biomass, limiting the dominance for most of competitive species, and maintaining structural heterogeneity. Reintroducing managed grazing is increasingly recognized as a tool to restore ecological balance and improve biodiversity in semi-natural meadows (Furman et al., 2018; Vernon et al., 2022). However, grazing can also lead to negative consequences when poorly regulated, particularly in sensitive wetland environments (Zhang et al., 2022). Therefore, there is a need for further research on the functional and structural vegetation responses to grazing in temperate wetland meadows.

This research was conducted in the Pagilutė wetland complex in northeastern Lithuania, a Natura 2000 protected area characterized by a mosaic of sedge-dominated wet meadows, transition mires, and deciduous woodland, in September 2024. In recent years, low-intensity cattle grazing has been reintroduced in parts of the wetland to help maintain open habitat structures (Lithuanian Ornithological Society (LOD), 2023). Two comparative transects,100 metres long each with 10 descriptive square metre squares, with vegetation under comparable edaphic conditions were created: one located within a grazed area and the other in an adjacent ungrazed area. Comparative data were collected on vascular plant species composition, relative cover, and functional types to assess the ecological impact of grazing.

The aim of this study is to evaluate the ecological effects of extensive cattle grazing on plant species diversity, taxonomic composition, and functional vegetation structure in wet meadow habitats of the Pagilutė complex..

Objectives:

1. To compare plant species richness, diversity and evenness between grazed and ungrazed plots using Shannon and Pielou indices.
2. To assess the influence of grazing on functional plant groups using CSR (Competitor–Stress–Ruderal) strategies and Raunkaer life form classifications.
3. To assess the effects of grazing on functional vegetation structure, including life-form composition, plant height distribution, and species dominance patterns, based on Braun–Blanquet cover–abundance data..
4. To interpret the role of low-intensity grazing as a management tool for maintaining biodiversity in Natura 2000 wetland habitats.

It is hypothesized that moderate cattle grazing in wet meadow habitats promotes higher species evenness and favors the establishment of ruderal and hemicryptophytic species. In contrast, ungrazed areas are expected to be dominated by tall, competitive species forming more homogeneous vegetation stands. This prediction is rooted in Grime's CSR theory, which postulates that disturbance (such as grazing) selects for ruderal and stress-tolerant strategies by suppressing competitive dominants (Grime, 1977). Furthermore, Raunkiaer's life-form classification suggests that hemicryptophytes, with protected buds at ground level, are more resilient to moderate grazing pressure (Tälle et al., 2016), contributing to their persistence in grazed plots. Previous studies on European wet meadows have demonstrated that grazing increases both species richness and evenness (Kulik et al., 2023; Rysiak et al., 2021), supporting the general expectation that moderate grazing maintains functional and structural diversity in meadow ecosystems.

This topic is relevant in the context of European biodiversity policy and adaptive conservation strategies. The findings of this study contribute to the understanding of how low-intensity grazing shapes plant community structure and supports biodiversity in threatened wetland habitats. The results may inform practical decision-making for protected area management.

Special thanks are extended to Andrius Gaidamavičius for introducing the study area and providing valuable initial guidance during the early stages of this research.

1. THE SCIENTIFIC LITERATURE ANALYSIS

1.1. Typology and classification of grasslands and meadows

Grasslands are terrestrial ecosystems characterized by the predominance of herbaceous vegetation, in particular by species of the *Grasses* family (*Poaceae*), which form the structural and functional core of these communities (Gibson, 2009). A universally accepted ecological criterion for defining grasslands and meadows is the limited presence of trees and shrubs, typically constituting less than 10% canopy cover (Wesche et al., 2016; Scholes & Hall, 1996). This low woody cover ensures high light availability, which allows for dense ground-level plant communities and supports a wide range of biodiversity.Meadows represent a distinct subtype within the broader grassland classification. They are typically associated with elevated soil moisture, seasonal flooding, and high species richness. Despite hydrological and floristic differences, ecological and functional parallels exist across all grassland types, particularly in their response to disturbance and management regimes (Gibson, 2009; Wesche et al., 2016; Scholes & Hall, 1996).

Ecologists commonly divide grasslands into major categories based on climate, hydrology, elevation, and vegetation structure (White et al.,2000):

1) Temperate grasslands - such as the prairies of North America, the pampas of South America, and the steppes of Eurasia;
2) Tropical and subtropical grasslands - including savannas and open woodlands, found in regions with seasonal rainfall;
3) Montane and alpine grasslands - occurring at higher elevations, with short growing seasons and cold-adapted flora;
4) Wet meadows - located in riparian zones, floodplains, peatlands, and lowlands with poor drainage, often transitional to wetlands.

Wet meadows are especially important for conservation due to their habitat specificity, floristic uniqueness, and the presence of species adapted to fluctuating water levels. These ecosystems host rare hydrophilic plant species, specialized invertebrates, and ground-nesting birds, and often serve as refugia in intensively managed agricultural landscapes. Despite their apparent simplicity, grasslands and meadows are disturbance-dependent ecosystems. Fires remove dead cover and stimulate seed germination of light-loving species, including those whose regeneration depends on heat or smoke (Gibson 2009). Wild ungulates - bison, deer, horses - have historically provided grazing, trampling, and mosaic vegetation dynamics, supporting openness and species diversity. With the development of agrarian societies, their role was partially replaced by moving or by the practice of controlled grazing - domestic herbivores such as sheep, goats, and cows became the managed analog of natural grazing. Under moderate pressure, this approach effectively maintains grassland structure. Without such disturbance, succession tends to favor shrub and tree encroachment, leading to significant changes in community composition and ecological function (Gibson, 2009; Wesche et al., 2016; Sandom, 2014).

Additionally, it is important to recognize that grasslands are not always defined ecologically. As Scholes and Hall (1996) emphasize, land-use-based classifications frequently dominate: in many cases, any open land used primarily for grazing or forage production is labeled as grassland, regardless of its original vegetation or ecological characteristics. This duality of classification, ecological versus functional, remains a persistent challenge in conservation planning and landscape assessment.

1.2. Global extent and distribution of grasslands and meadows

Grasslands (including savannas, shrublands, and tundra) are one of the most extensive terrestrial biomes, covering roughly 30-40% of the Earth’s land surface (Bardgett et al., 2021; O’Mara, 2012). Within this broad category, about 3.2-3.4 billion hectares of land are used as permanent meadows and pastures for livestock, which is approximately one-quarter of Earth’s land area and ~70% of agricultural land (FAO, 2020; O’Mara, 2012). Regionally, Asia and Africa hold the largest grassland and pasture areas (around 1.08 and 0.84 billion ha respectively, together over half the global total), followed by South America (~0.44 billion ha) and Oceania (~0.34 billion ha), with relatively smaller extents in North America (~0.27 billion ha) and Europe (~0.17 billion ha) (FAO, 2020). These figures reflect both natural/semi-natural grasslands and intensively managed pastures. Major grassland subtypes span all continents: for example, the tropical savannas of sub-Saharan Africa (such as the East African grasslands and southern African veld), the temperate steppes of Eurasia (stretching from Eastern Europe through Central Asia, including the Mongolian and Tibetan plateaus), the prairies of North America’s Great Plains, and the pampas and campos of South America (White et al., 2000; Suttie et al., 2005). In Europe, remaining grasslands are largely semi-natural meadows and pastures often maintained by traditional grazing or mowing (Peeters, 2004)

Globally, the majority of grassland area consists of natural or semi-natural rangelands, with a subset being improved pastures that are regularly cultivated or fertilized in high-productivity regions (Herrero et al., 2013). In recent decades the total extent of grasslands and grazed pastures has been relatively stable or even slightly declining: FAO records indicate a modest decrease (on the order of 2% globally between 1990 and 2018), with evidence that global pasture area peaked around the year 2000 and has since contracted by tens of millions of hectares (Poore, 2016; Ramankutty et al., 2018). These vast ecosystems remain critical for agriculture, carbon storage, and biodiversity, and their distribution is global (Figure 1), concentrated in the above-mentioned regions and grassland types.

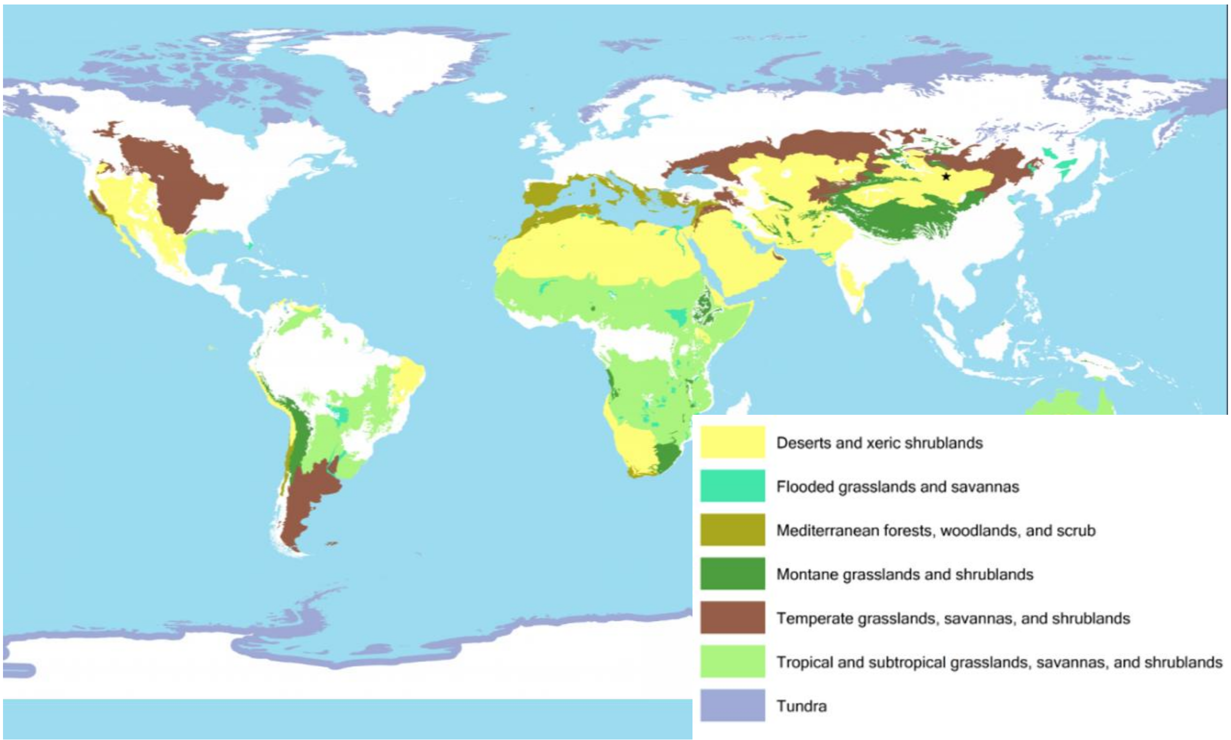

Figure 1. Global distribution of grasslands (World Wildlife Fund’s, 2025).

Tropical and subtropical grasslands/savannas dominate in sub-Saharan Africa, South America, and northern Australia, while temperate grasslands/steppes span central Asia (Eurasian Steppe) and the North American Great Plains. Montane grasslands occur in high elevations (e.g. Tibet), and extensive shrubland and tundra rangelands cover parts of Australia, southern Africa, and the Arctic. (Rangelands Atlas, 2021).

1.3. Ecosystem services and ecological functions of meadows

Meadows - provide a wide array of ecosystem services that benefit both humans and the environment. According to the Common International Classification of Ecosystem Services (CICES V5.1) (Haines-Young & Potschin, 2018), these services are categorized into three main groups: Provisioning services, regulation with maintenance service, cultural services.

Provisioning services include the supply of biomass for nutrition and materials, such as fodder for livestock, hay, honey, and medicinal plants. Meadows also serve as reservoirs of genetic resources, offering a diverse array of plant and animal species valuable for agriculture and medicine.

Regulating and maintenance services encompass climate regulation through carbon sequestration, water regulation by enhancing infiltration and reducing runoff, soil protection via root systems that prevent erosion, and support for biodiversity by providing habitats for various species, including pollinators.

Cultural services involve recreation and tourism opportunities afforded by the natural beauty of meadows, educational and scientific research facilitated by their ecological richness, and the preservation of cultural heritage through traditional practices like haymaking and grazing.

Together, these services underscore the multifunctionality of meadow ecosystems and their importance to both ecological integrity and human well-being. An integrated overview of the ecosystem goods and services provided by grasslands is presented in Figure 2.

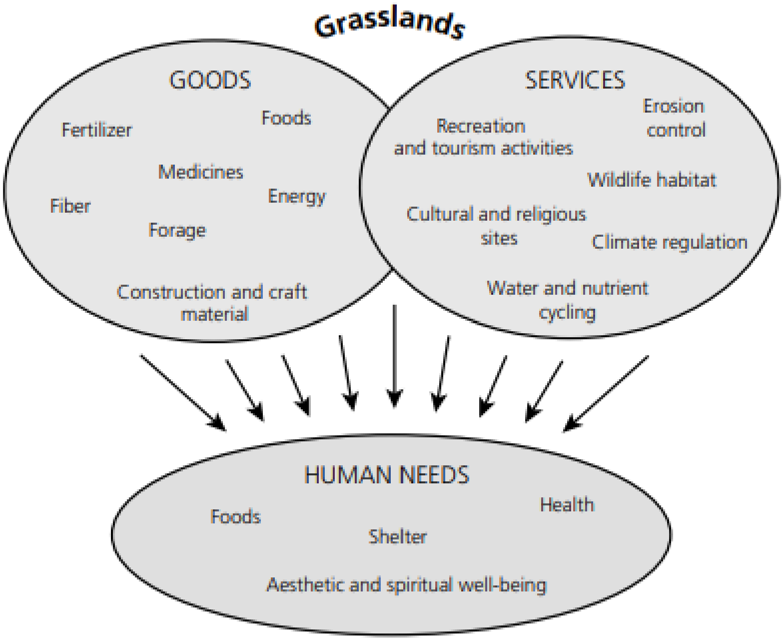

Figure 2. Goods and services provided by grasslands (White, 2000)

In Lithuania and across Europe, the importance of preserving meadows is increasingly recognized for climate change mitigation, biodiversity conservation, and cultural heritage (Ivavičiūtė, 2024; Bengtsson et al., 2019). These semi-natural ecosystems are integral to green infrastructure, supporting ecological connectivity and resilience. In Lithuania, national parks and protected areas play a vital role in safeguarding meadows, which are essential for maintaining biodiversity and cultural landscapes. The National Environmental Protection Strategy emphasizes the conservation and sustainable use of biodiversity, highlighting the significance of meadows in ecological stability (Ministry of Environment of the Republic of Lithuania, 2015).

One of the most fundamental services of meadows is biodiversity support, as these species-rich habitats are among the most diverse plant communities in temperate regions (Dengler et al., 2014; Bengtsson et al., 2019). Botanical richness creates habitat and food for numerous species, including pollinators and threatened fauna. This diversity also enhances ecosystem resilience, ensuring that critical functions persist under environmental stress (Wilson et al., 2012). In fragmented landscapes, meadows serve as ecological corridors that facilitate species dispersal and gene flow (Habel et al., 2013; Korpela et al., 2013).

Grasslands play a major role in carbon sequestration and climate regulation. Soils in meadows contain roughly 20-30% of the Earth’s terrestrial soil carbon (Conant et al., 2017), due to deep root systems that accumulate and stabilize organic matter (Poeplau & Don, 2013). In certain landscapes, such as the Sierra Nevada, meadows cover only ~2% of land area yet store about one-third of the region’s soil carbon (Reed et al., 2020). If degraded, however, meadows may shift from carbon sinks to sources, reinforcing the importance of conservation and restoration for maintaining their climate-regulating function (Nusslé et al., 2021).

Water regulation is another essential service of meadows. Wet and floodplain meadows absorb rainfall and snowmelt, reducing flood peaks and maintaining stream baseflows during droughts (Wolf et al., 2020; Huntington & Viers, 2016). These systems also improve water quality by filtering runoff: sediments are captured, and nutrients are absorbed by vegetation and microbes. In California, for example, ~60% of developed water flows through meadow–wetland complexes that naturally purify contaminants (Sheehan, 2019).

Soil protection and nutrient cycling are also supported by meadow ecosystems. Dense root systems prevent erosion and maintain soil structure, especially on vulnerable slopes (Gyssels et al., 2005). Meadows recycle organic matter efficiently: annual plant growth, decay, and decomposition maintain soil fertility. Legumes fix atmospheric nitrogen, while grazing animals redistribute nutrients via dung and urine, enhancing nutrient turnover (Soussana & Lemaire, 2014; USDA Forest Service, 2011).

Pollination is a key ecosystem function provided by flower-rich meadows. Their continuous bloom supports diverse pollinator communities that enhance crop yields in nearby agricultural fields (Kremen & M’Gonigle, 2015). Loss of meadows reduces pollinator abundance, threatening both wild plant reproduction and agricultural productivity (Ollerton et al., 2014). By preserving pollinator habitats, meadows play an essential role in food security and ecological resilience.

Collectively, the biodiversity conservation, climate regulation, water retention, soil stability, and pollination functions offered by meadows underscore their vital role in sustaining both ecosystem health and human well-being.

1.4. Lithuanian and European meadows in nowadays context

Semi-natural meadows in Europe have undergone drastic declines in extent over the past century, which has heightened awareness of their ecosystem services. It is estimated that over 90% of Europe’s traditional species-rich meadows have been lost or degraded due to conversion to intensive agriculture, afforestation, or urban development (Walker et al., 2018). This widespread degradation has led to the reduction of key ecosystem functions, such as pollination, flood control, and biodiversity support. Recognizing their multifunctionality, European conservation frameworks, including the EU Habitats Directive and various agri-environmental schemes, now prioritize the protection, restoration, and sustainable use of meadow habitats.

In Lithuania, wet meadows are considered unique ecosystems that provide critical habitat for numerous rare and protected species, including plants such as *Campanula bononiensis* and *Orchis militaris*; insects such as *Euphydryas aurinia*; amphibians like *Bombina variegata*; and birds such as *Crex crex* (Tanneberger & Wichtmann, 2011). In addition to their positive impact on biodiversity, wet meadows in Lithuania offer substantial ecosystem services, including carbon storage, water regulation, and cultural value (Sulcienė et al., 2021).

Despite these benefits, the area of meadows and natural pastures in Lithuania has shrunk significantly. According to Sulcienė et al. (2021), from 2003 to 2023, their total area decreased by 135,439.55 hectares, equating to a 27.21% reduction, with the most severe losses observed in Šiauliai County, where meadow area declined by 59.02%. This decline is primarily attributed to the conversion of grasslands to cropland, encroachment of shrubs and trees due to abandonment of traditional land management, and nutrient pollution. In this context, “traditional use” refers to low-intensity grazing and mowing, practices that historically maintained open grassland structure and species composition.

The reduction in grazing pressure is particularly notable. Between 2010 and 2020, livestock density in Lithuania decreased by 22.9%, one of the steepest declines in the European Union (Eurostat, 2023). This reduction in grazing intensity has contributed to the degradation of meadow ecosystems, especially in areas previously maintained through Soviet-era reclamation or grazing systems. Without herbivore pressure, many pastures have become overgrown, losing their characteristic plant and habitat diversity (CBD, 2023).

Currently, 17.1% of Lithuania's terrestrial area is designated as protected, falling short of the EU average of 26.4% and the EU Biodiversity Strategy target of 30% by 2030 (BISE, 2024). Nonetheless, Lithuania exceeds the EU average in marine protection, covering 22.81% compared to the EU's 12.1% (BISE, 2024). Under the EU Habitats Directive, Lithuania hosts 54 protected habitat types, which is approximately 23.2% of all habitat types protected by this directive (BISE, 2024). Grasslands constitute a significant share (16.6%) of these protected habitats, although their conservation status remains concerning: 22.22% are classified as “Poor,” and the remaining 77.78% as “Bad” (BISE, 2024). This underlines the critical condition of Lithuanian grasslands and emphasizes the urgency of improving their management and conservation practices.

Despite these challenges, there is a clear opportunity for positive change. Lithuanian wet meadows, owing to their ecological uniqueness and multifunctionality, present a strong case for conservation-based land management. Preserving and expanding these ecosystems could deliver multiple benefits for biodiversity, water security, and rural sustainability. As Ivavičiūtė (2024) notes, supporting agricultural activities aligned with ecological goals, such as traditional cattle grazing, may be key to resolving the conflict between conservation and rural development. Restoration efforts under EU-funded LIFE projects and national biodiversity strategies increasingly reflect this integrated vision.

In sum, Lithuania’s wet meadows are not only a natural heritage but also a living infrastructure delivering tangible ecosystem services. Safeguarding them requires policy alignment, financial incentives for sustainable grazing, and continued ecological monitoring. Their future depends not only on protection but also on active management that maintains their open structure and biodiversity-rich character.

1.5. Flora of Lithuanian wet meadows in a Baltic-Eastern European context

Wet meadows in Lithuania and the broader Baltic–Eastern European region are species-rich grassland habitats characterized by seasonally high soil moisture and occasional flooding. These semi-natural meadows, historically maintained by hay-making or grazing, can support dozens of plant species in a single site (Nekrošienė & Skuodienė, 2012). The flora is dominated by herbaceous species, chiefly grasses (Poaceae) and sedges, alongside a profusion of broadleaf forbs adapted to saturated soils (Nekrošienė & Skuodienė, 2012). This diverse plant assemblage is adapted to the humid temperate climate and hydrological regime of the region, and it contributes to the high conservation value of wet meadows as reservoirs of biodiversity.

In these meadows, a few dominant species often define the community structure and physiognomy. Robust perennial grasses and sedges thrive in the moist, nutrient-rich soils and form the structural matrix of the vegetation. For instance, tufted hairgrass (*Deschampsia cespitosa*), meadow foxtail (*Alopecurus pratensis*), and meadow fescue (*Festuca pratensis*) commonly co-occur, creating a tall, dense sward in lowland wet meadows. Large wet-tolerant sedges such as *Carex* spp. (e.g., *Carex disticha*) can prevail in the wetter depressions and floodplain zones. These graminoids (grass-like plants) produce the bulk of the above-ground biomass and essentially scaffold the habitat, providing support and microhabitats for numerous smaller plants. Another noteworthy dominant is purple moor-grass (*Molinia caerulea*), which forms tussocky clumps on peaty or acidic soils; *Molinia* meadows are widespread in western Lithuania and are recognized as important habitats under the EU Habitats Directive. While graminoids typically dominate, in certain conditions tall broadleaf forbs can assume co-dominance. For example, meadowsweet (*Filipendula ulmaria*) often proliferates in wetter, lightly shaded spots, forming nearly monospecific stands, and other tall herbs like wild angelica (*Angelica sylvestris*) can become locally abundant in nutrient-rich patches. Overall, the dominant plant species of Lithuanian wet meadows tend to be sun-loving perennials with adaptations to waterlogged substrates (such as tolerance to low oxygen in the root zone) that allow them to withstand periodic inundation.

Beneath and between these dominants exists a rich understory of associated species that elevates the biodiversity and ecological function of wet meadows. A variety of wildflowers, low sedges, and rushes flourish in the gaps, many of them less abundant individually but collectively forming a colorful and species-rich carpet. Seasonal succession of blooms is characteristic: early in spring, marsh marigold (*Caltha palustris*) punctuates wet hollows with bright yellow flowers, signaling areas of spring inundation, while as the soils warm and dry slightly, other forbs characteristic of these meadows appear. Ragged robin (*Lychnis flos-cuculi*) with its pink, fringed petals and devil’s-bit scabious (*Succisa pratensis*) with purple-blue flower heads are typical mid-season wildflowers thriving on the damp (but not permanently flooded) soils. These and numerous other wildflowers (including members of the daisy family such as *Leucanthemum vulgare* and *Senecio aquaticus*) intermingle with medium-height grasses (e.g., *Poa pratensis*, *Agrostis capillaris*) and clovers to create a diverse sward. Many legumes (Fabaceae) are important contributors in this layer: for instance, tufted vetch (*Vicia cracca*) and meadow vetchling (*Lathyrus pratensis*) weave through the grasses, while red clover (*Trifolium pratense*) and greater bird’s-foot trefoil (*Lotus pedunculatus*) pepper the sward with purple and yellow blooms. These legumes not only enhance floral diversity but also enrich the soil by fixing atmospheric nitrogen in their root nodules, improving nutrient availability over time (Silveira & Vendramini, 2024). The associated forbs and small grasses play key ecological roles by providing nectar, pollen, and habitat structure for a variety of meadow invertebrates. Notably, studies in Lithuanian wet meadows have found that certain common meadow herbs (e.g., yarrow *Achillea millefolium* or oxeye daisy *Leucanthemum vulgare*) tend to persist under regular mowing or light grazing, indicating a resilient “background” plant community that underpins overall diversity (Nekrošienė & Skuodienė, 2012). This suite of supporting species is thus integral to wet meadows, sustaining pollinators and other fauna and maintaining ecosystem functions alongside the dominants.

Wet meadows of this region also serve as important refugia for rare and protected plant species, several of which are of high conservation concern. These specialist plants often have strict habitat requirements and are sensitive to changes in land use or hydrology, making them indicators of well-preserved, long-continuity meadows. A prominent example is *Iris sibirica* (Siberian iris), a striking iris of floodplain meadows and fens that has become rare throughout Eastern Europe. Owing to wetland drainage and conversion of meadows to agriculture, *I. sibirica* has experienced marked declines and is now strictly protected and listed in national Red Data Books (Lithuanian Red Data Book, 2021). Another characteristic species is the wild gladiolus *Gladiolus imbricatus*, which bears tall spikes of purple-pink flowers in summer. *G. imbricatus* was once more widespread in Eastern European wet grasslands but is now endangered across much of its range due to habitat loss and alteration; for example, the drainage and abandonment of traditionally managed meadows have led to severe population declines of this species (Kostrakiewicz-Gierałt et al., 2018). Conservation research indicates that *G. imbricatus* is highly sensitive to successional changes, the cessation of mowing or grazing allows coarse grasses and shrubs to overgrow its habitat, effectively shading it out, and thus its survival is tightly linked to continued low-intensity management (Kostrakiewicz-Gierałt et al., 2018). In addition to these flagship species, a variety of orchids and other fen or wet-grassland specialists occur sparingly in Lithuanian wet meadows, underscoring their ecological value. For instance, marsh orchids (*Dactylorhiza* spp.) and fragrant orchid (*Gymnadenia conopsea*) can be found in some intact wet meadows, and plants like marsh gentian (*Gentiana pneumonanthe*) or grass-of-Parnassus (*Parnassia palustris*) appear where conditions are favorable. These species typically require undisturbed soils, specific hydrological conditions, and often specialized mutualisms (such as fungal symbionts or pollinators), making them vulnerable to habitat degradation. Their presence in a meadow is often a sign of long-term ecological stability and low-intensity land use. Accordingly, many of these plants are legally protected, and their populations are monitored as indicators of habitat quality. The persistence of rare species like *Iris sibirica* and *Gladiolus imbricatus* in wet meadows is strongly dependent on maintaining the traditional management practices, notably annual mowing or light grazing, that prevent successional overgrowth and preserve the open, species-rich conditions of the habitat (Kostrakiewicz-Gierałt et al., 2018).

Despite their high ecological value, Lithuanian wet meadows (and their Baltic–Eastern European counterparts) face serious threats from invasive and encroaching plant species that can disrupt native plant communities. Among the most problematic are invasive alien species introduced from other continents that readily colonize moist meadows and wetlands. Notably, North American goldenrods (*Solidago canadensis* and *S. gigantea*) have become widespread invaders in the region. Originally introduced as ornamentals, these tall goldenrods have escaped cultivation and are now pervasive in abandoned or poorly managed meadows, where they form dense, monospecific stands that outcompete native flora. In Lithuania, both *S. canadensis* and *S. gigantea* are established across large areas (Karpavičienė et al., 2015), and their invasion has been shown to cause significant declines in native plant species richness and even alter ecosystem processes in wet meadow habitats (Kundel et al., 2024).

Other invasive herbs pose additional challenges: Himalayan balsam (*Impatiens glandulifera*), for example, thrives in wet riparian meadows and can create impenetrable thickets that suppress smaller native plants, while Sosnowsky’s hogweed (*Heracleum sosnowskyi*), a giant cow-parsnip introduced in the 20th century, occasionally invades damp grasslands and riverbanks, threatening both ecology (through competitive exclusion of natives) and public safety (due to its caustic sap). Alongside these exotics, native woody encroachment is a pervasive issue in wet meadows whenever traditional management ceases. In the absence of regular mowing or grazing, pioneer trees and shrubs quickly establish in the fertile, moist soils. Species like downy birch (*Betula pubescens*), willows (*Salix* spp.), and alder (*Alnus glutinosa*) readily colonize open meadows, leading to a gradual succession from herbaceous vegetation to scrub and eventually wet woodland. This transition dramatically reduces light availability at ground level and fundamentally alters soil moisture and nutrient dynamics, resulting in the loss of many meadow-specialist herbs. Empirical observations in the region show how rapid this change can be: for instance, in a protected Polish wet meadow where mowing was halted in the 1970s, *B. pubescens* spread so aggressively that within about three decades it covered roughly half of the meadow area, converting species-rich grassland into young birch thicket (Kamocki et al., 2017). Such woody overgrowth can eliminate the very plant diversity that makes wet meadows valuable. Consequently, active measures (periodic shrub removal, tree cutting, or reintroduction of grazing) are often necessary to combat both invasive herbs and native scrub encroachment. The continued coexistence of the rich native flora, from the dominant grasses to the rare orchids, thus hinges on ongoing management interventions. Overall, the flora of Lithuanian wet meadows in the Baltic-Eastern

European context represents a dynamic equilibrium: a unique assemblage of plant species adapted to wet conditions and traditional land use, which flourishes under low-intensity management but is quick to diminish if that balance is disturbed by neglect or invasive species pressures.

1.6. Functional roles and ecological significance of key species

Plant species in wet meadows, beyond being dominant or rare, fulfill essential functional roles such as nutrient cycling, habitat structuring, and supporting food webs. Maintaining a diverse flora is crucial for ecosystem health and resilience (Bakker & Berendse, 1999; Odum, 1971).

Legumes such as *Vicia cracca*, *Trifolium spp.*, and *Lotus pedunculatus* enrich nutrient-poor soils through symbiotic nitrogen fixation, reducing the need for fertilizers (Silveira & Vendramini, 2024). This fosters plant diversity, though excess nutrients can shift the competitive balance toward aggressive species like *Urtica dioica*. Other species, including sedges and reeds (*Carex spp.*, *Phragmites australis*), sequester nitrogen and phosphorus from floodwaters, acting as natural nutrient buffers that prevent leaching and eutrophication (Kulik et al., 2023).

Tussock-forming species like *Deschampsia cespitosa* and *Carex elata* shape microtopography, offering dry refuges and increased structural complexity. This promotes microclimatic heterogeneity, supports invertebrate diversity, and buffers soil moisture and temperature (Vermeersch & Van Kerckvoorde, 2016). However, overdominance by monocultures such as *Molinia caerulea* or *Solidago gigantea* can simplify vegetation structure and reduce habitat quality (Glimskär et al., 2023). Standing dead biomass, left by robust grasses and sedges, also plays a role by offering overwintering shelters for insects and nesting structures for small birds.

Key species in wet meadows perform essential ecological functions. For instance, Succisa pratensis not only provides late-season nectar but also sustains the full larval development of the marsh fritillary butterfly (Euphydryas aurinia), linking plant phenology to insect population dynamics and long-term persistence of pollinators (van Swaay et al., 2002). Similarly, Sanguisorba officinalis serves as a vital host for Phengaris teleius, a butterfly with a complex life cycle involving both the plant and ant colonies (Myrmica spp.), thus playing a unique role in maintaining trophic and symbiotic interactions within the meadow community (Warming & Grubb, 2018). These species exemplify how individual plants can shape entire ecological networks. Orchids like Dactylorhiza spp., highly specialized in both habitat and pollination, contribute to biodiversity and structural complexity but are vulnerable to shifts in vegetation or pollinator availability, making them sensitive indicators of habitat degradation

Certain species also serve as environmental indicators. For example, *Molinia caerulea* indicates acidic, nutrient-poor conditions, while the presence of *Caltha palustris* and *Lotus* *pedunculatus* suggests stable hydrological regimes (Tanneberger & Wichtmann, 2011). Wet meadow vegetation helps regulate water retention: dense mats of *Carex elata* and *C. acutiformis* slow floodwaters, reduce evaporation, and help maintain moist microhabitats. Invasive species such as *Solidago gigantea* undermine these functions by displacing native root systems and increasing winter soil exposure (Zhang et al., 2022).

Wet meadow flora in Lithuania and Eastern Europe thus plays a multifaceted ecological role. From nutrient regulation and habitat provision to pollinator support and hydrological buffering, these ecosystems depend on a functionally diverse plant community. To preserve their integrity, management must promote native species and limit the spread of invasive or successional dominants such as *Betula pubescens* and *Rubus idaeus* (Meehan et al., 2011).

1.7. Ecological strategies of plants – CSR

One of the most widely accepted ecological classifications of plant species is the CSR strategy theory, developed by J.P. Grime (1977). This framework categorizes plants according to their adaptive responses to environmental conditions into three primary strategies: Competitors (C), Stress-tolerators (S), and Ruderals (R). Each group reflects distinct ecological trade-offs concerning growth rates, reproduction, and resource use.

Competitor (C) species thrive in stable, productive, and relatively undisturbed environments. These plants prioritize rapid growth and efficient resource acquisition, often outcompeting other species for light, water, and nutrients. Typical morphological and physiological traits include tall stature, large leaf area, and extensive root systems (Grime, 2001). In wet meadow ecosystems, representative competitor species are tall grasses or emergent plants such as *Phragmites australis* and *Typha latifolia*, which form dense, robust stands under stable hydrological conditions.

Stress-tolerator (S) species dominate harsh, resource-limited environments, such as waterlogged soils or nutrient-poor substrates. These species exhibit slow growth, high resource conservation, and longevity, prioritizing survival rather than aggressive competition (Pierce et al., 2017). Wet meadow habitats frequently host stress-tolerant species like *Equisetum palustre* and *Parnassia palustris*, which have specific physiological adaptations enabling them to withstand prolonged water saturation and low oxygen conditions in soil.

Ruderals (R) are adapted to highly disturbed conditions characterized by frequent disturbances such as mowing, grazing, or flooding events. They have rapid growth rates, early reproduction, prolific seed production, and high dispersal ability (Grime, 2001; Hodgson et al., 1999). In wet meadows subject to regular grazing or flooding, ruderal species such as *Bidens* *tripartita* and *Rorippa palustris* quickly colonize exposed soils and newly opened habitats, playing a critical role in initial community recovery and succession. However, many plant species exhibit intermediate strategies reflecting combined adaptations to multiple ecological pressures:

Competitor-Stress-tolerator (CS) species possess traits enabling both competitive dominance and tolerance of environmental stress. These species commonly occur in habitats that are marginally productive and occasionally subject to moderate stressors. In wet meadows, characteristic CS species include sedges like *Carex acuta* and young woody species such as *Betula pubescens,* capable of tolerating moderate waterlogging and nutrient fluctuations while still efficiently competing for available resources.

Competitor-Ruderal (CR) species are adapted to stable yet periodically disturbed habitats, combining rapid post-disturbance recovery with robust growth under more stable conditions. Typical CR species in wet meadows include the fast-growing grass *Agrostis stolonifera* and nutrient-demanding herbs such as *Urtica dioica*, which quickly regenerate after disturbance events like mowing or grazing, rapidly regaining their dominant position within plant communities.

Stress-tolerator-Ruderal (SR) species represent a rare group adapted to stressful conditions but dependent on periodic disturbances for reproduction and persistence. In wet meadow ecosystems, an example of an SR species is *Lycopus europaeus*, often found in moderately grazed, saturated soils, utilizing occasional habitat openings created by grazing or water fluctuation events to reproduce and spread.

Incorporating these mixed strategies (CS, CR, SR) into the traditional CSR framework allows for a nuanced understanding of plant community dynamics, particularly in ecosystems such as wet meadows, where gradients of stress (e.g., waterlogging, nutrient availability) and disturbance (e.g., grazing, mowing) intersect. Assessing the distribution of CSR strategies within plant communities provides valuable insights into their resilience, stability, and likely responses to future land-use changes or climate fluctuations (Caccianiga et al., 2006).

1.8. Raunkiaer life form classification

In the early 20th century, Danish botanist Christen C. Raunkiaer (1860-1938) developed a system to group vascular plants based on the position of their perennating buds during adverse seasons (Raunkiaer, 1934). He first presented this classification in 1904 and elaborated it further in his later publications. Raunkiaer's goal was to create a method for ecologically meaningful comparison of different floras by classifying species according to survival strategies (Raunkiaer, 1934; Box, 1996). By analyzing vegetation through life-form spectra, he provided an objective framework to compare plant communities across regions.

Raunkiaer's life-form spectrum remains a foundational tool in plant ecology and vegetation science (Mueller-Dombois & Ellenberg, 1974; Díaz et al., 2016). Because it is based on a simple and universally applicable criterion (the location of buds relative to the soil surface) the system allows functional grouping of species across climates and ecosystems. Life-form categories also reflect species’ tolerance to climatic extremes and disturbance regimes, making Raunkiaer's system a highly practical tool for ecological classification and habitat analysis (Woodward, 1987; Díaz et al., 2016).

Raunkiaer distinguished five principal life-form groups (Raunkiaer, 1934):

1) Phanerophytes are trees and large shrubs whose resting buds are located well above ground level (>50 cm).
2) Chamaephytes are small shrubs or perennial herbs with buds located close to the ground surface (typically up to 25 cm).
3) Hemicryptophytes are herbaceous perennials with overwintering buds at or just below ground level.
4) Cryptophytes (including geophytes and hydrophytes) bear protected buds below the soil surface or underwater, such as bulbs and rhizomes.
5) Therophytes are annual plants that complete their life cycle within a single growing season and survive unfavorable periods as seeds.

Each of these groups represents distinct adaptations to climate, seasonality, and disturbance, and they remain essential categories in modern functional ecology.

The distribution of life forms is closely related to climate zones. Tropical regions are dominated by phanerophytes (tall trees), while hot deserts are characterized by the dominance of therophytes (annuals) (Woodward, 1987). In contrast, cool-temperate and boreal zones exhibit a prevalence of hemicryptophytes and cryptophytes (Box, 1996; Díaz et al., 2016). Raunkiaer himself noted that "each climatic zone has its own life-form spectrum" (Raunkiaer, 1934). Empirical studies confirm that in humid temperate climates, such as that of Lithuania, hemicryptophytes form the dominant life form, reflecting adaptations to cold winters and regular seasonal disturbance (Ellenberg, 1988). Thus, the Lithuanian flora is primarily composed of perennial herbs with buds protected at the soil surface, ensuring resilience against harsh winters and mechanical disturbances like grazing.

Raunkiaer's life-form classification is also valuable for understanding plant responses to herbivory and grazing pressures. Since bud position and perennating organ location are fundamental to plant survival strategies, life forms predict how species cope with grazing (Grime, 1977; Díaz et al., 2016). Hemicryptophytes and cryptophytes, with their buds at or below ground level, are generally more tolerant of grazing because the vital regenerative structures remain protected when shoots are removed. Moderate grazing thus primarily removes aboveground biomass but spares the resprouting potential of these plants (Tälle et al., 2016). In contrast, plants with exposed buds, such as many phanerophytes and annual therophytes, are more vulnerable to complete removal.

Therefore, grasslands and wet meadows dominated by hemicryptophytes and cryptophytes are likely to be resilient to well-managed, low- to moderate-intensity grazing, while heavy grazing may shift communities toward grazing-tolerant annuals or disturbance specialists (Houessou et al., 2012; Li et al., 2024). This insight reinforces the value of life-form analysis for interpreting grazing impacts in ecological research and conservation management.

Raunkiaer's century-old life-form system remains a robust, quantitative framework for analyzing plant strategies globally (Raunkiaer, 1934; Díaz et al., 2016). It effectively links plant morphology to climate, seasonality, and disturbance regimes. In Lithuania’s cool-temperate context, the dominance of hemicryptophytes explains the high resilience of wet meadow communities to controlled grazing, providing practical insights for maintaining species-rich, semi-natural grasslands.

1.9. Pleistocene megafauna as a factor of grassland ecosystem formation

To fully understand the ecological dynamics of modern grasslands and the rationale behind conservation grazing, it is necessary to consider their evolutionary origins. Historical disturbance regimes, especially grazing by wild megafauna, played a fundamental role in shaping the structure and species composition of open habitats long before agricultural activity. This chapter provides the ecological background behind meadow formation, contextualizing the role of grazing as an ancient and natural force.

Such phenomenon as meadows appeared due to the process of grazing, and this process began long before the domestication of grass animals by humans. The Pleistocene (2.6 million - 11.7 thousand years ago) was characterized by the widespread distribution of large herbivorous animals - megafauna, which included such species as: *Mammuthus primigenius, Coelodonta antiquitatis, Bison priscus, Megaloceros giganteus, Elasmotherium sibiricum* and many others. These species actively shaped landscapes: by eating herbaceous and shrub vegetation, trampling the soil, creating open spaces, they inhibited overgrowth of territories with trees. The activities of megafauna led to the creation of a mosaic structure of vegetation and to the maintenance and increase of biodiversity (Johnson, 2009).

The resulting conditions were favorable for both animals and plants, and regular grazing began to have such an impact on plants that they began to develop adaptive mechanisms. Plant seeds became resistant to digestion, some seeds developed a shape that allowed them to cling to animal hairs for dispersal, a rapid regeneration cycle developed, and dense root rosettes protecting growth points began to form. Coevolution between large herbivores and plants - animals have more food resources, plants have more dispersal and nutrients (Toit, 2019). Moreover, the fleshy fruits that we enjoy today at the base are also the result of coevolution of plants with herbivores, because the nutritious and flavorful qualities of the fruits were necessary for animals to eat them more actively and thus, again, to promote the spread of seeds (Barlow, 2000).

By the end of the last ice age (~11 — 9 thousand years ago), much of the megafauna of Eurasia, North and South America, Australia, and other regions had disappeared, two main hypotheses suggest that climatic changes (Guthrie, 2006) and hunting pressure from the emerging *Homo sapiens* were the causes (Martin, 1984). And in general, these two factors probably together caused the extinction of megafauna, when climate change negatively affected populations, active hunting was the last straw for the extinct species (Koch & Barnosky, 2006). However, the ecological role of large herbivores did not entirely disappear with the end of the Pleistocene.

During the Holocene epoch (~11,700 years ago to present), several large grazers continued to influence European landscapes. Species such as the European bison (*Bison bonasus*), aurochs (*Bos primigenius*), wild horses (*Equus ferus*), elk (*Alces alces*), and red deer (*Cervus elaphus*) maintained grazing pressure, slowed forest encroachment, and supported habitat diversity. These animals favored open or semi-open habitats, prevented succession, and sustained mosaic structures through grazing, browsing, trampling, and seed dispersal (Pucek et al., 2004; Vera, 2000). Their gradual disappearance due to anthropogenic pressure led to increased forest expansion and reduction of traditional grasslands. Recognizing their historical role underlines the value of reintroducing or simulating herbivore dynamics through conservation grazing or rewilding programs (e.g., Rewilding Europe). As a result of forest succession, meadows began to overgrow with trees and shrubs, lack of mechanical and biological impact on the grass cover, reduced mosaic environment, which led to a decline in flora species, especially specialized meadow and wetland plants (Johnson, 2009).

The disappearance of megafauna caused profound changes in temperate ecosystems, including reduced biodiversity and a collapse of the mosaic vegetation patterns that supported it (Johnson, 2009; Sandom et al., 2014). In this context, conservation grazing , such as the one studied in the Pagilutė wetland, is not merely a land management tool but a form of ecological continuity. By mimicking ancient disturbance regimes, modern grazing restores structural and functional diversity in open habitats, helping to reverse the long-term consequences of megafaunal extinction (Cromsigt et al., 2012).

1.10. Grazing as ecological mechanism of management

Agricultural grazing should not be viewed solely as a form of land use, but as a complex ecological process that exerts substantial pressure on ecosystems. Livestock now make up the majority of mammalian biomass on Earth, far surpassing wild mammals (Bar-On et al., 2018). When applied with appropriate management, grazing helps prevent ecological succession, supports rare and specialist species, and maintains the structural and compositional distinctiveness of meadow ecosystems.

Succession refers to the natural, directional process through which ecosystems change in species composition and structure over time, typically progressing from early-colonizing communities to more stable, long-lived vegetation. In classical ecological theory, Frederic Clements (1916) proposed that plant communities follow a predictable series of stages, culminating in a stable climax community often a closed-canopy forest in temperate zones. However, this deterministic view was later challenged by Henry Gleason (1926), who argued for an individualistic concept of community development shaped by environmental variability and species-specific responses to disturbance.

In grasslands and wet meadows, the climax concept is often not applicable. These systems depend on recurring disturbances, such as grazing, fire, or flooding, to prevent encroachment by woody species and to sustain their open structure and biodiversity (Laycock, 1991). In such contexts, grazing acts as a resetting force, maintaining the system in a non-equilibrium state that supports high habitat heterogeneity and plant species richness.

Many semi-natural meadows can thus be described as disclimax communities, where succession is regularly interrupted by external factors, particularly herbivory (White & Jentsch, 2001). Additionally, some ecologists advocate for a polyclimax perspective, recognizing that multiple stable vegetation states may occur depending on local disturbance regimes, edaphic conditions, and land-use history (Whittaker, 1975). This view is particularly relevant to managed grasslands, where different disturbance histories can maintain alternative yet equally stable meadow assemblages.

However, grazing can also have negative ecological consequences if poorly managed. In most cases, negative outcomes are associated with overgrazing, when grazing intensity exceeds the regenerative capacity of vegetation and soil. Overgrazing may lead to soil compaction, which reduces infiltration and aeration (Zhang et al., 2022), and may also cause a decline in plant diversity, emergence of bare patches, and increased erosion. Additionally, such disturbed sites may provide a "window of opportunity" for invasive species to establish (Vernon et al., 2022). These effects are especially pronounced in wet meadows and riparian zones. Intensive grazing near water bodies can degrade riparian vegetation and cause nutrient runoff (e.g., nitrogen, phosphorus), which can lead to eutrophication and negatively affect aquatic habitats (Meehan et al., 2011).

Effective restoration of species-rich grasslands therefore requires careful regulation of grazing intensity. To better understand this, grazing regimes are typically categorized based on livestock density and ecological impact and measured in Livestock Units per hectare. LU (Livestock Unit) is a standardized metric used to quantify grazing pressure, where 1 LU is equivalent to the grazing impact of a mature 500-600 kg cow per year. This allows for consistent comparison across different species and grazing systems. Detailed shown in the Table 1:

Table 1. **Grazing intensity rate classification adapted from Peeters (2004)**

Grazing Intensity	**Stocking Rate (approx.)**	**Ecological Characteristics**
Very Light Grazing	< 0.2 LU/ha	Little or no noticeable impact on vegetation. Minor biomass removal; tall grasses dominate; risk of succession towards shrubs and trees.
Light Grazing	0.2–0.5 LU/ha	Reduction of dominant tall grasses; increased species richness; creation of microsites for small herbs; improved structural heterogeneity.
Moderate Grazing	0.5–1.0 LU/ha	Highest plant species diversity; limited competitive exclusion; greater abundance of forbs; maintenance of open and diverse meadows.
Heavy Grazing	1.0–2.0 LU/ha	Significant biomass removal; exposed soil patches; increased dominance of grazing-tolerant or disturbance-adapted species; partial biodiversity decline.
Overgrazing (Degradation)	>2.0 LU/ha	Severe biomass removal; soil compaction and erosion; loss of palatable species; dominance of unpalatable, stress-tolerant flora; marked biodiversity collapse.

In general, moderate grazing is considered most beneficial for biodiversity, as it prevents succession without causing degradation (Tälle et al., 2016). Empirical studies suggest that an average stocking rate of 0.3 to 1.0 LU/ha is suitable for maintaining most temperate grasslands (Peco et al., 2006; EuroGrazing, 2012). Grazing intensity also needs to consider temporal dynamics. Continuous year-round grazing may lead to overutilization, while rotational or seasonal grazing, especially during late spring or summer, allows for vegetation recovery and flowering, supporting insects and seed production.

Grazing affects ecosystems through several interconnected ecological mechanisms that influence soil, vegetation, nutrient cycling, and biodiversity. As explained by Tonneijck et al. (2023), nutrient cycling is significantly accelerated by grazing: herbivores consume vegetation and return nutrients to the soil via dung and urine, thereby increasing the availability of essential elements such as nitrogen and phosphorus. This enhances plant productivity and supports dynamic vegetation turnover. Grazing also alters energy flow in ecosystems by facilitating rapid biomass turnover. Frequent regrowth after herbivore grazing increases photosynthetic activity and supports higher trophic levels, including pollinators and herbivorous insects (Tälle et al., 2016). Another critical effect of grazing is its role in preventing ecological succession. According to USGS (2021), grazing suppresses tall grasses and woody vegetation, maintaining open habitats. This grazing-induced disturbance creates niches for a wide variety of plant species, many of which are adapted to periodic grazing and trampling.

As noted by Kulik et al. (2023), grazing limits dominance of aggressive competitors (such as *Urtica dioica*), which otherwise monopolize resources like light and nutrients. By maintaining a relatively uniform vegetation height, herbivores reduce competitive exclusion and promote the coexistence of multiple species. This fosters rich plant diversity, which in turn supports diverse bird and insect communities. Importantly, grazing promotes spatial heterogeneity, grazers rarely feed evenly across the entire landscape. This leads to patches of varying vegetation height and structure, which support a broader range of species with different ecological requirements (Peco et al., 2017). Moderate trampling, while sometimes seen as damaging, can actually benefit biodiversity by breaking dense swards, exposing soil, and creating microhabitats for seed germination and invertebrates (Tälle et al., 2016). In wet meadows, these effects are particularly valuable for maintaining floristic diversity.

In conclusion, moderate, targeted, and flexible grazing, ideally informed by prior vegetation assessment and adaptive management, is recommended for effective grassland restoration and conservation outcomes.

1.11. Comparison of European grazing studies in meadow restoration

Several recent studies confirm that low-intensity cattle grazing can enhance species diversity and vegetation structure in temperate grasslands.

Chabuz et al. (2019) investigated the long-term effects of cattle and sheep grazing on plant communities in the Magura National Park, southern Poland. Vegetation surveys were conducted using the Braun–Blanquet method within 25 m² plots, and plant diversity was assessed using the Shannon–Wiener diversity index (H). The grazed pastures exhibited a significantly higher Shannon diversity ($H = 2.69 \pm 0.19$) compared to the adjacent abandoned (ungrazed) grassland ($H = 1.98 \pm 0.22$), with a p-value < 0.01. Moreover, grazed plots showed a greater number of herbaceous species and a more balanced species distribution, resulting in lower dominance by a few competitive taxa. Similarly, Bochniak et al. (2023) studied cattle grazing impacts on Polish wet meadows area of 48 hectares over a four-year period (2016–2019), using repeated Braun–Blanquet relevés (13 × 25 m² plots) under management by White-Backed Polish cattle in amount 0.12 to 1.12 conventional head of livestock (UGS) per hectare. Their findings demonstrated that continuous moderate grazing reduced the cover of dominant sedges (Carex spp.) and reed species (Phragmites australis), thereby creating open microsites that were rapidly colonized by a broader range of meadow species. The median Shannon diversity index (H) in grazed plots increased from 1.52 in 2016 to 2.13 in 2019, while Pielou's evenness index (J) rose from 0.57 to 0.72 over the same period.

These outcomes align closely with the results of this study. In both Chabuz et al. (2019) and Bochniak et al. (2023), grazing by cattle led to a measurable increase in species diversity (higher Shannon H values) and improved species evenness (higher Pielou J values) compared to ungrazed or abandoned plots. Similarly, this thesis observed that cattle grazing promotes species richness and evenness while reducing dominance by a few tall or competitive species. The consistency between these independent studies strengthens the evidence that moderate grazing pressure can positively influence plant community structure and biodiversity in temperate wet grasslands.

A recent Lithuanian study by Živatkauskienė et al. (2024) reinforces these findings. The authors compared floral composition and species richness across different types of grasslands and found that semi-natural pastures subjected to low-intensity traditional use (grazing and/or mowing) hosted approximately 120 vascular plant species, in contrast to only ~20 species in intensively sown leys. While the biodiversity of these permanent meadows was substantially higher, their productivity was 2–3 times lower, highlighting a trade-off between yield and ecological value.

These findings from Lithuania confirm that continuous, extensive grazing supports higher plant diversity and aligns with conservation goals in temperate meadow systems.

The consistency between these independent studies strengthens the evidence that moderate grazing pressure can positively influence plant community structure and biodiversity in temperate wet grasslands.

2. OBJECTS AND METHODS

2.1. Object of research

The object of this research is the plant community of the Pagilutė wetland complex, and the primary focus is to assess the effects of cattle grazing on species composition and plant diversity within this ecosystem.

The fieldwork was conducted in Pagilutė wet meadows, located in the western part of Aukštaitija National Park, northeast Lithuania, north of Lake Gilūtas, near the Ignalina–Molėtai road (approx. 55.26° N, 25.95° E). According to the European Nature Information System (EUNIS, 2024), the study area corresponds to habitat type E3.4 (Moist or wet eutrophic and mesotrophic grassland). This habitat is characterized by periodic flooding, moderate nutrient availability, and high biodiversity, which underscores its ecological significance within the European Union's Natura 2000 conservation network. So part of the Pagilutė wetland complex, in a Special Protection Area (SPA) borders, under the EU Birds Directive (2009/147/EC) and included in the Natura 2000 network. Specifically, it falls within the territory of the Aukštaitija National Park SPA (LTIGNB003), established for the conservation of protected bird species such as the Corncrake (*Crex crex*), Black Kite (*Milvus milvus*), Osprey (*Pandion haliaetus*), and others (LIFE Farms for Birds Project, 2023).

As part of a habitat restoration project co-funded by the LIFE Programme, 92 hectares of these wet meadows were fenced in September 2023, and a herd of 33 Aberdeen Angus cattle was introduced as a nature-based management measure (Fig. 3), it is equal to 0.36 LU/ha (light grazing). Aberdeen Angus is a traditional Scottish beef breed known for its hardiness, docile temperament and efficient use of forage. Naturally comely and compact, adult cows typically weigh 500-600kg and bulls 800-1000kg (FAO, 2014), making them significantly lighter than intensive beef breeds such as Charolais or Limousin. This moderate body weight reduces the risk of soil compaction, a critical factor in sensitive wet grassland ecosystems.

The aim of cows intervention was to restore open meadow conditions by suppressing the overgrowth of tall grasses, shrubs, and early-successional trees, thereby enhancing breeding habitats for meadow-dependent bird species, particularly *Crex crex.*

Figure 3. Aberdeen Angus cows are grazing on territory of Pagilute wetland complex.

Prior to the introduction of cattle, the area underwent mechanical removal of woody vegetation, including extensive clearing of *Betula pubescens* and various shrubs, in order to prepare the site for effective grazing management. Although no precise records of this intervention are were available for this work, visual evidence and project documentation confirm that such preparatory measures were implemented as part of the restoration strategy.

A detailed map (Fig. 4) provided by the Lithuanian Ornithological Society marks the SPA boundaries, areas allocated for hydrological restoration, and by red line the zones currently used for restoration by grazing and sustainable farming within the Pagilutė meadows, which corresponds to the research site where vegetation monitoring was conducted.

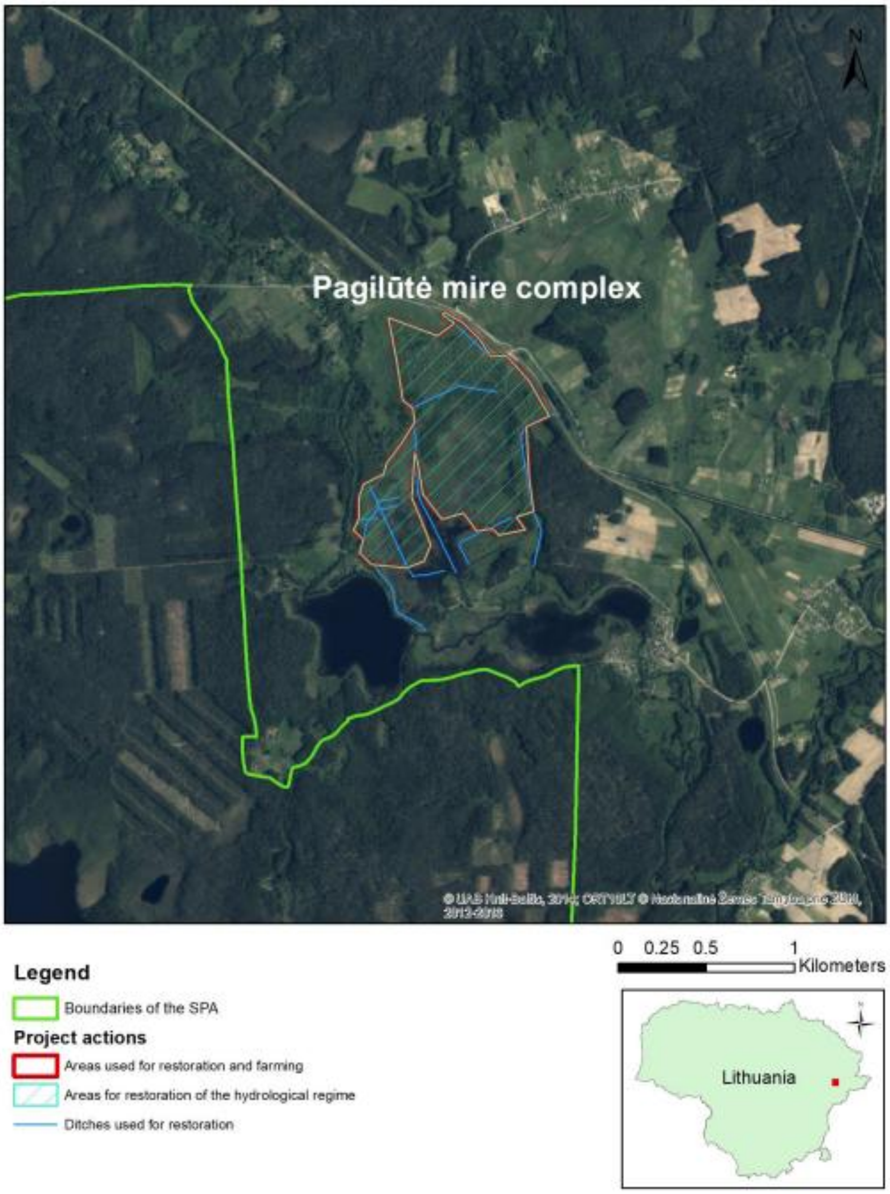

Figure 4. Areas used for restoration and farming, areas for restoration of the hydrological regime and ditches used for restoration in Western part of Aukstaitija national park SPA (LTIGNB003), Pagilutė meadows. (LIFE Farms for Birds, 2025).

2.2 Vegetation sampling design

To evaluate grazing impacts, a comparative field survey was implemented between a grazed area and an ungrazed control area within the wetland. Two parallel transects of 100 m length were established: one in the cattle-grazed zone and a second in a nearby similar habitat with no grazing (control). The transects were placed in representative wet meadow vegetation, with the grazed transect located inside the cattle enclosure and the control transect just outside. Along each 100 m transect, 10 sample plots (quadrats) of 1 m² each were systematically marked for vegetation assessment. Plots were spaced at regular intervals (every 10 m) to cover the length of the transect and capture variation along environmental gradients. Each 1 m² plot was delimited in the field using a portable square frame constructed from taut garden string and four plastic stakes at the corners, ensuring consistent plot size and shape across all samples. Geographic coordinates were recorded for the endpoints of each transect using a phone GPS to document precise location of the study plots (e.g., the grazed transect spanned ~55.26379° N, 25.95477° E to 55.26345° N, 25.95601° E, while the control transect spanned ~55.26120° N, 25.95836° E to 55.26079° N, 25.95686° E). These transects (Fig. 5) were positioned in similar wet meadow conditions to allow a direct comparison of vegetation under grazing vs. no grazing treatments.

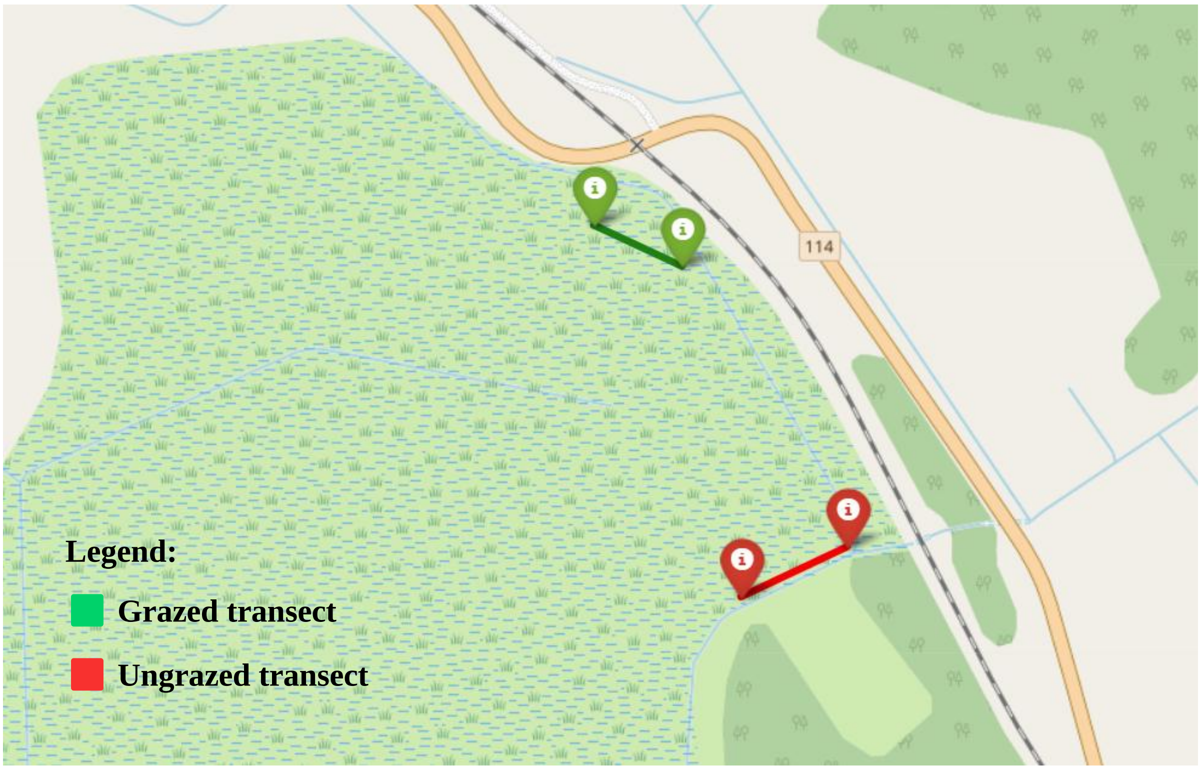

Figure 5. Location of transects on territory of Pagilute wetland complex. Map created using uMap based on OpenStreetMap data.

While minor spatial inaccuracies may exist due to the use of mobile GPS and manual quadrat placement, the documented coordinates and mapped transect layout ensure that the same sites can be relocated in the future. This provides opportunities for repeated sampling and long-term monitoring of vegetation dynamics under continued grazing management.

2.3 Vegetation assessment and identification

Within each 1 m² plot (quadrat), vegetation composition and cover were surveyed using the Braun-Blanquet cover–abundance method (Braun-Blanquet, 1932; Braun-Blanquet 1964). All vascular plant species present in the examinate plots were listed, and each species was assigned a cover-abundance score based on visual estimation. A modified Braun-Blanquet scale with numerical codes was used for consistency in data analysis, following the approach of Furman et al. (2018). This cover-abundance scale (Table 2) provided a semi-quantitative measure of each species' dominance in the community without requiring exact percent cover estimates, which is practical given the dense and intermingled vegetation of wetlands.

Table 2. **Braun-Blanquet Density Score (Furman et al., 2018)**

Score	**Cover**
0	Taxa absent from quadrat
0.1	Taxa represented by a solitary shoot, <5% cover
0.5	Taxa represented by a few (<5) shoots, >5% cover
1	Taxa represented by many (>5) shoots, <5% cover
2	Taxa represented by many (>5) shoots, 5 - 25% cover
3	Taxa represented by many (>5) shoots, 25 - 50% cover
4	Taxa represented by many (>5) shoots, 50 - 75% cover
5	Taxa represented by many (>5) shoots, 75 - 100% cover

In total using this method, 20 quadrats were described, 10 quadrats from area with cows and 10 quadrats from area without cows. Based on the collected data, a common Brown Blanket cover-abundance scale table (Table 4) was compiled with average scales to represent common area situation.

The CSR classification of species was performed using the PLADIAS (Plant Diversity Analysis and Synthesis; Chytrý et al., 2021) database, which provides functional traits of plants, including strategies according to Grime (2001). For species not listed in the PLADIAS database, CSR strategies were determined using key morphological traits - leaf area (LA), specific leaf area

(SLA), and leaf dry matter content (LDMC) - extracted from the TRY database (Kattge et al., 2011) and processed via the StrateFy tool developed by Pierce et al. (2017).

Table 3. **Assessment abbreviations of CSR strategies according to Grime (2001).**

CSR	**Name**	**Description**	**Example species from the study**
C	Competitor	Species with high resource acquisition (light, nutrients) in stable conditions. Dominant in the absence of disturbances.	*Phragmites australis*, *Typha latifolia*
S	Stress-tolerator	Species adapted to extreme conditions (waterlogging, low soil fertility). Slow growth, high survivability.	*Equisetum palustre*, *Parnassia palustris*
R	Ruderal	Pioneer species colonizing disturbed areas. Fast life cycle, high seed production.	*Bidens tripartita*, *Rorippa palustris*
CS	Competitor-Stress-tolerator	Species combining competitive traits with stress tolerance. Common in marginal habitats.	*Carex acuta*, *Betula pubescens* (young specimens)
CR	Competitor-Ruderal	Species competitive in stable conditions but capable of rapid recovery after disturbances.	*Urtica dioica*, *Agrostis stolonifera*
SR	Stress-tolerator-Ruderal	Stress-resistant species dependent on disturbances for reproduction. Rare in wet meadows.	*Lycopus europaeus* (under moderate grazing)

In parallel with CSR classification, all identified vascular plants were categorized according to Raunkiaer's life-form system (Raunkiaer, 1934), which classifies species based on the location of their perennating buds during the unfavorable season. This trait is closely linked to species' ecological strategies, resilience, and tolerance to disturbances such as grazing and trampling. Five principal categories were used in this study:

– Therophytes, annual species that complete their life cycle within a single season;

– Geophytes, with buds located underground (e.g. in rhizomes or bulbs);

– Hemicryptophytes, with buds at soil level, often protected by leaf rosettes or litter;

– Chamaephytes, with perennating buds located just above ground level;

– Phanerophytes, woody species with buds exposed well above the ground.

Species were assigned to life-form types manually based on morphological traits described in regional floras (Gudžinskas, 1999) and consistent with field observations. Life-form distribution data were later used to analyze structural composition differences between grazed and ungrazed plots, and to interpret functional vegetation shifts under grazing pressure.

All plant species were identified in the field to the lowest taxonomic level possible. Species that could not be reliably identified in the field were photographed and later verified using the Pl@ntNet application (Affouard et al., 2017). This app was selected for its extensive global database, high-quality reference images, and peer-reviewed identification algorithm. Compared to alternative tools, Pl@ntNet offers one of the most comprehensive datasets for vascular plants, is continuously updated, and integrates both expert and community feedback. Its performance in European floristic contexts, including wetlands, has been positively evaluated in multiple field studiesTo ensure scientific accuracy, each species identification was subsequently verified using authoritative botanical sources. In particular, diagnostic features of uncertain taxa (e.g., floral structure, leaf morphology, habitat preferences) were cross-checked against descriptions and dichotomous keys in the comprehensive reference *Flora Europaea* (Tutin et al., 1964–1980). Morphological and ecological trait data were also consulted in trait databases such as the LEDA Traitbase (Kleyer et al., 2008) and the TRY Plant Trait Database (Kattge et al., 2020)

2.4 Data analysis and statistical methods

Shannon and Pielou’s Evenness indices were applied to the described data to assess community diversity metrics between grazed and ungrazed areas (Magurran, 2004; Pielou, 1966). These calculations were first performed manually and cross-checked using Microsoft Excel. For each transect, the set of 10 plots was treated collectively to produce one overall Shannon index and evenness value. Given the limited number of transects (one per treatment), formal statistical significance testing was not feasible; instead, the comparison is descriptive. Simpler metrics such as total species richness (number of observed species) were also included (Vermeersch & Van Kerckvoorde, 2016).

Formula 1. Shannon index Formula (Magurran, 2004)

$$H' = -\sum_{\{i=1\}_{i}^{\{S\}p}\backslash ln} p_i$$

H': Shannon diversity index

S: The total number of species observed

ln(p_i): The natural logarithm of the proportion **p_i**

p_i: The proportion of individuals or coverage of species i relative to the total in the sample. Because individual plants cannot be reliably counted in dense meadow vegetation, Braun–Blanquet cover-abundance scores were used as a proxy for species abundance. For each plot, the cover score of each species was divided by the total cover score of all species in that plot to obtain its relative abundance. These relative abundances (p_i) were then entered in the Shannon index formula. Using cover instead of individual counts is a standard procedure in vegetation ecology when discrete individuals cannot be enumerated (Vermeersch & Van Kerckvoorde, 2016)

The Shannon Index quantifies the diversity of a community by considering both species richness (number of species) and evenness (distribution of individuals among species). It is particularly useful for comparing ecosystems with varying species compositions. A higher H′ value indicates greater diversity, meaning the community has a more balanced distribution of species and is less dominated by any single species.

Formula 2. Pielou's Evenness index Formula (Pielou, 1966)

$$J' = \frac{H'}{\ln(S)}$$

J′: Pielou's Evenness index

H′: Shannon diversity index

S : Total number of species

Pielou’s Evenness Index (J′) quantifies how evenly species abundances are distributed within a community. It is obtained by dividing the observed Shannon diversity (H′) by the natural logarithm of the total number of species (S), since ln(S) represents the maximum possible value of H′ when all species are equally abundant. Consequently, J′ ranges from 0 to 1: values near 1 indicate that species are present in almost equal proportions, whereas lower values reflect dominance by one or a few species

To complement manual calculations and enhance analytical reliability, all diversity indices were recalculated in R (version 4.x; R Core Team, 2024) using the vegan, stats, and effectsize packages. Diversity values were analyzed at the level of individual quadrats (n = 20). The normality of Shannon index distributions within each treatment group was tested using the Shapiro–Wilk test (Field, 2013), and no significant deviations were detected ($p > 0.05$). Accordingly, a two-sample Student's t-test was applied to assess statistical differences in diversity between grazed and ungrazed plots. To further quantify the magnitude of this difference, Cohen's d was computed along with a 95% confidence interval using the effectsize package (Ben-Shachar et al., 2020). Effect size interpretation followed the conventional thresholds proposed by Cohen (1988), where values above 0.8 are considered large. All R scripts and data processing steps are documented and reproducible.

2.5 Assignment of species grazing response categories

To evaluate how individual species respond to grazing pressure, each recorded plant was assigned a grazing response score based on its ecological traits. This classification integrated three criteria: Raunkiaer life form, CSR strategy (Grime, 2001), and relative cover values derived from Braun–Blanquet scores. The assignment reflects whether a species is typically promoted, tolerated, or disadvantaged under grazing. This trait-based approach is commonly used in grazing impact assessments (e.g., Pakeman, 2004) and allows for linking changes in species composition to underlying functional adaptations.

Each species was assigned to one of the following response categories:

1) Positive response (+1): Ruderal species (R, CR) and therophytes (annuals), which tend to benefit from disturbance and rapidly colonize grazed habitats (Grime, 1977; Díaz et al., 2016).
2) Neutral response (0): Stress-tolerant (S) and intermediate (CS) strategists, as well as hemicryptophytes with protected buds at or below ground level, which can persist under grazing without being specifically promoted (Grime, 1977; Tälle et al., 2016).
3) Negative response (–1): Competitive species (C), tall hemicryptophytes, and phanerophytes, which typically decline under grazing due to biomass removal and loss of competitive advantage (Grime, 1977; Díaz et al., 2016).

2.6 Field conditions and limitations

Field data were collected at the end of September 2024 under challenging wetland conditions. The soil was water-saturated throughout the site, making ground traversal difficult. In the grazed area, numerous cattle hoofprints (up to ~20 cm deep) and standing water puddles were present, reflecting both the wetness of the habitat and the physical disturbance from the introduced cattle. High rubber boots was a must, and soft wet soil demanded careful navigation to avoid trampling vegetation outside the quadrats. The saturated substrate sometimes caused the quadrat frame stakes to sink or lean, but care was taken to place them firmly and record data quickly to minimize disturbance. These conditions potentially influenced plant detectability.

Several limitations of the study should be acknowledged. The experimental design involved only a single transect in each treatment, which limits spatial replication. The study represents a short-term snapshot after the introduction of grazing, since cows were brought to wetland complex in September 2023, and data of this research were collected in September 2024, so it may not reflect longer-term successional changes. The Braun-Blanquet method involves subjective visual estimates of cover, and while this is standard practice, some observer bias may have occurred. Although the Pl@ntNet app facilitated identification, it has limitations, and efforts were made to verify results. The application occasionally misidentified species, especially under variable lighting conditions or when plant morphology was unclear, for example too young plants or deformed. For every unfamiliar or uncertain identification suggested by the app, a manual verification process was applied. This included re-examining morphological features and, if necessary, photographing the plant again from different angles to improve recognition or consulting printed field guides. This process helped minimize misidentifications but added time and complexity to the fieldwork. Environmental factors also prevented sampling in some portions of the wetland. These limitations suggest caution in generalizing results, though the study provides valuable initial insights into grazing effects in this wetland and can guide more extensive future research.

3. RESULTS AND DISCUSSION

3.1 Species composition and average cover in grazed and ungrazed plots based on Braun–Blanquet data

After passing the two transects, the collected data from each quadrat was recorded in two Brown-Blanket tables for each of the transects, for area with cows (Appendix 1) and for area without cows (Appendix 2). This raw data became fundamental point of this work, out of which came out all further results and insights.

Each transect data were processed, described species was assigned a density score corresponding to scale of its coverage. During data collection were identified 44 plant species, transect on territory with cows had all 44 plants, in transect on territory without cows were not identified any plants which were not observed at area with cows. For each transect, average of their 10 quadrats displayed a general situation. Totals can be seen in Table 5.

Table 4 **Modal Braun–Blanquet scores for grazed and ungrazed plots; bottom rows: Shannon diversity (H′) and Pielou's evenness (J′).**

Plant name	**Modal score (with cows area)**	**Modal score (without cows area)**
Agrostis stolonifera	0.1	0.1
Angelica sylvestris	0.1	0
Betula pubescens	0.1	0
Bidens cernua	0.1	0
Bidens tripartita	0.1	0
Carduus crispus	0.1	0
Carex acuta	0.1	2
Chrysosplenium alternifolium	0.1	0
Cerastium holosteoides	0.1	0
Cicuta virosa	0.1	0
Cirsium oleraceum	0.1	0
Cirsium vulgare	0.1	0
Conium maculatum	0.1	0.1
Epilobium hirsutum	0.1	0
Equisetum palustre	0.1	0.1

Festuca rubra	0.1	0.1
Filipendula ulmaria	0.1	0
Galium mollugo	0.1	0
Galium uliginosum	0.1	0
Geranium molle	0.1	0
Geum rivale	2	0
Lysimachia vulgaris	0.1	0
Juncus effusus	0.1	0
Juncus articulatus	0.1	0
Lycopus europaeus	0.1	0
Mentha aquatica	0.1	0
Mentha arvensis	0.1	0
Parnassia palustris	0.1	0
Phragmites australis	0.1	4
Ranunculus flammula	0.1	0
Ranunculus lanuginosus	0.1	0
Ranunculus repens	0.1	0
Rorippa palustris	0.1	0
Rubus idaeus	0.1	0
Rumex acetosa	0.1	0.1
Rumex crispus	0.1	0
Salix cinerea	0.1	0.1
Scutellaria galericulata	0.1	0
Succisa pratensis	0.1	0
Thalictrum minus	0.1	0
Trifolium repens	0.1	0
Typha latifolia	0.1	3
Urtica dioica	0.1	0
Valeriana officinalis	0.1	0
Shannon index	**3.19**	**1.34**
Pielou's Evenness index	**0.78**	**0.64**

In the ungrazed meadow, *Carex acuta* (modal cover score 2) and *Phragmites australis* (modal cover score 4) together accounted for the vast majority of plant cover, while most other species were nearly absent. By contrast, the grazed meadow supported many forbs and small grasses, each at low cover: for example, a suite of annuals and short-lived perennials (e.g. *Bidens*, *Carduus*, *Cerastium*, *Conium*, *Rumex*, *Thalictrum*, etc.) were present only in the grazed area.

These compositional differences suggest that grazing prevents competitive exclusion by tall vegetation. Without grazing, the tall sedges and grasses (C- and CS-strategists) grow unchecked, shading out lower herbs (Grime 1977). Consequently, the community becomes impoverished and dominated by a few highly competitive graminoid species, reflecting succession toward reed-swamp or tall-sedge meadow communities. Under grazing, repeated defoliation and trampling suppress such dominants, opening space and light for many herbs and short grasses. This promotes a floristically rich community (Bolton et al. 2009). In fact, the higher Pielou evenness in grazed plots reflects exactly this pattern: no single species could monopolize resources. These findings agree with studies showing that cessation of grazing in wet meadows often leads to tall sedge and grass dominance and loss of herbs (Wesche et al. 2016; Kulik et al. 2021). In summary, the Braun–Blanquet data indicate that moderate grazing maintains a heterogeneous, herb-dominated meadow, whereas passive management allows succession toward grass- and rush-dominated stands.

The Shannon diversity index was significantly higher in the grazed site (H′ = 3.19) than in the ungrazed site (H′ = 1.34). This difference probably caused by grazing, but further it will be tested. Pielou’s evenness index followed a similar pattern: J′ = 0.78 in the grazed area versus J′ = 0.64 in the ungrazed area.

The identified woody plants such as *Betula pubescens*, *Salix cinerea*, and *Rubus idaeus* was present in forms of vegetative shoots (under 15-20 cm) in the grazed transect. This finding indicates the beginning of the succession process, if these shoots are not subjected to stress (in case of Pagilute – mowing) they will develop into full-fledged trees and shrubs.

3.2 Analysis of plant diversity using Shannon index

The results were clear and consistent, the data met the assumptions of normality: quadrats located in the grazed area exhibited significantly higher Shannon diversity, with a mean H′ = 3.25 (± 0.14), compared to just 1.08 (± 0.26) in the ungrazed area. This pattern reflects a notable shift in community structure under the influence of grazing and also illustrated in Figure 6, where Shannon index values are compared visually using a boxplot.

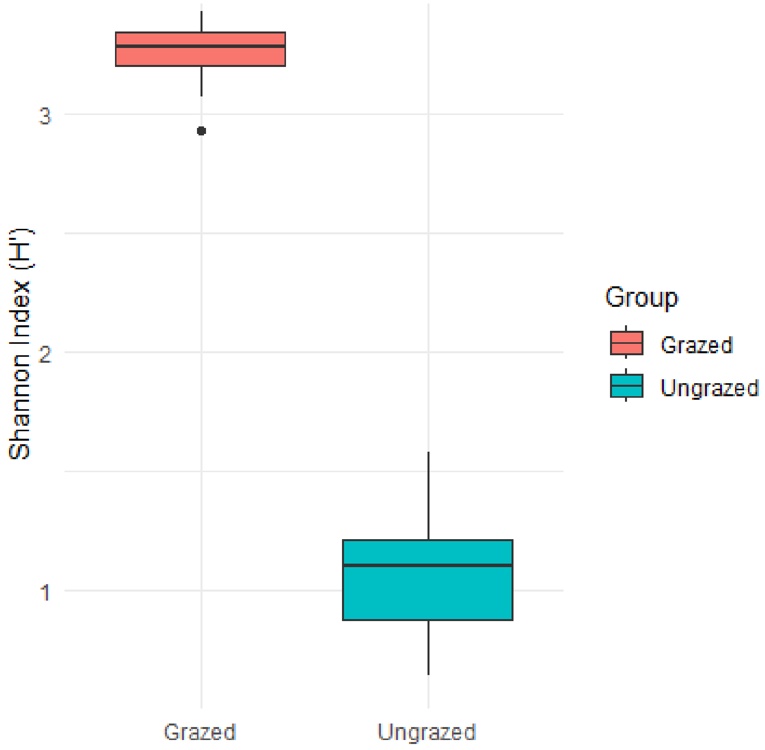

Figure 6. Boxplot comparison of Shannon diversity index (H′) values between grazed and ungrazed plots

To statistically test this observation, a two-sample t-test was conducted, which yielded a test statistic of $t = 21.46$ and a p-value < 0.001, strongly rejecting the null hypothesis of no difference. This confirms that the observed pattern is not the result of random variation but a statistically robust consequence of grazing.

To further assess the strength of this effect, the Cohen's d effect size was calculated, yielding a value of 9.60 with a 95% confidence interval of [6.36, 12.81]. According to established interpretation thresholds (Cohen, 1988), a value of 0.2 indicates a small effect, 0.5 moderate, and 0.8 large. The value observed in this study is an order of magnitude greater than the threshold for a "large" effect, indicating an exceptionally strong and biologically meaningful impact of cattle grazing on species diversity in this habitat.

This result aligns with the predictions of the intermediate disturbance hypothesis, which posits that moderate levels of disturbance maximize species diversity by preventing competitive exclusion (Connell, 1978). Supporting this theory, empirical studies and meta-analyses have shown that moderate grazing tends to enhance species richness and evenness in semi-natural grasslands (Tälle et al., 2016; Pulungan et al., 2019). Findings thus confirm that grazing-driven disturbance significantly increased both richness and evenness in the Pagilute wet meadow system, supporting its role as a biodiversity-promoting management tool.

3.3 CSR strategies of identified plants of Pagilute wetland complex

Grazing markedly shifted the community's functional makeup (Table 6). In the grazed plots, mixed strategies (C–S and C–R) and disturbance-adapted ruderals together predominated, whereas the ungrazed area was largely dominated by pure competitors (C), with stress-tolerators (S) as the next most abundant group.

Table 5. **Plant species classified according to CSR strategies in the Pagilutė wetland complex**

CSR strategy	**Number of species**	**Species list**
C	6	*Angelica sylvestris, Cirsium oleraceum, Filipendula ulmaria, Phragmites australis, Rubus idaeus, Typha latifolia*
S	15	*Chrysosplenium alternifolium, Cicuta virosa, Equisetum palustre, Galium uliginosum, Geum rivale, Juncus effusus, Juncus articulatus, Lycopus europaeus, Parnassia palustris, Ranunculus flammula, Ranunculus lanuginosus, Scutellaria galericulata, Succisa pratensis, Thalictrum minus, Valeriana officinalis*
R	10	*Bidens cernua, Bidens tripartita, Carduus crispus, Cerastium holosteoides, Cirsium vulgare, Conium maculatum, Geranium molle, Rorippa palustris, Rumex crispus, Trifolium repens*
CR	7	*Agrostis stolonifera, Epilobium hirsutum, Galium mollugo, Mentha arvensis, Ranunculus repens, Rumex acetosa, Urtica dioica*
CS	6	*Betula pubescens, Carex acuta, Festuca rubra, Lysimachia vulgaris, Mentha aquatica, Salix cinerea*

Stress-tolerant species (S) formed the largest group, comprising 15 species adapted to wet, nutrient-poor, and periodically waterlogged soils. Ruderals (R), represented by 10 species, indicate adaptation to disturbance and frequent biomass turnover - typical of grazed meadows. Competitors (C) included 6 species that thrive in undisturbed and productive sites. Mixed strategies, such as

CR (7 species) and CS (6 species), suggest functional plasticity and dominance in transitional environments

Figure 7 displays the number of species in each CSR category for grazed and ungrazed plots. It demonstrates that grazed areas host substantially more species across all strategy types, especially stress-tolerators (S) and ruderals (R) - whereas ungrazed plots exhibit very low richness, with only a few competitor (C) species remaining.

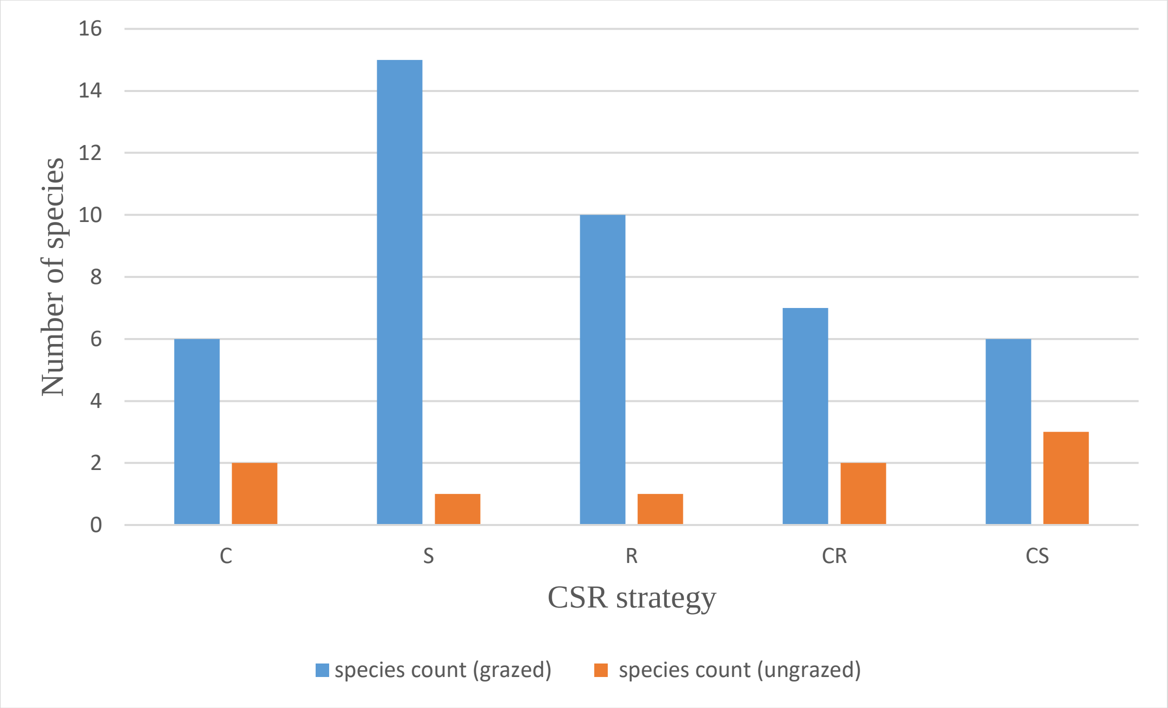

Figure 7. Species richness per CSR (C – Competitors; S – Stress-tolerators; R – Ruderals) strategy in grazed vs. ungrazed plots.

Chart below (Fig. 8) illustrates the proportional cover of different plant CSR strategies, Competitors (C), Stress-tolerators (S), Ruderals (R), and their combinations (CR, CS), on grazed and ungrazed wet meadow plots. The data is based on average Braun-Blanquet cover score.

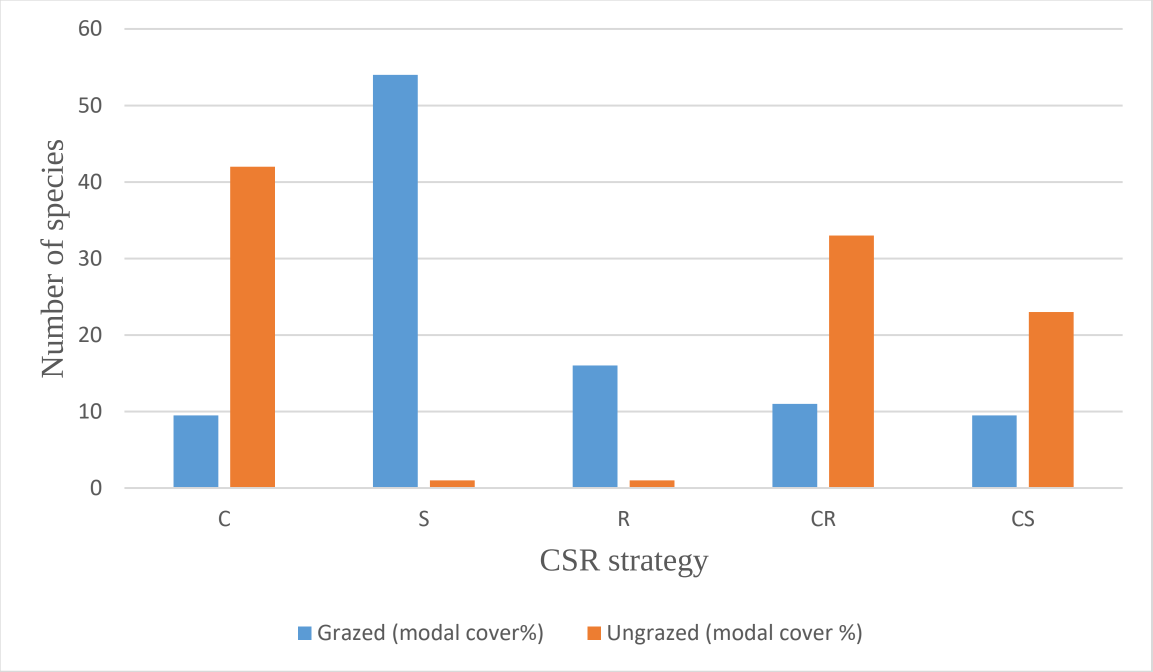

Figure 8. Proportional plant cover by CSR (C – Competitors; S – Stress-tolerators; R – Ruderals) strategy in grazed and ungrazed areas of the Pagilutė wetland complex

In the grazed meadow, stress-tolerators (S-strategists) accounted for the largest fraction of vegetation cover, comprising approximately 54% of total abundance, followed by ruderals (R-strategists, ~16%), competitive–ruderals (CR, ~11%), and smaller contributions from pure competitors (C) and competitive–stress (CS) strategists (each ~9.5%). In contrast, the ungrazed meadow was overwhelmingly dominated by competitors, with C-species covering around 42% of the area, CR-types 33%, and CS-types 23%, while pure ruderals and stress-tolerators were nearly absent, each representing only about 1% of the community.

This pattern is readily explained within the framework of disturbance ecology. As originally proposed by Grime (1977), grazing acts as a recurrent disturbance that favors plants possessing traits adapted to biomass loss, fluctuating resource availability, and spatial heterogeneity. Ruderal species, typically fast-growing annuals and short-lived perennials, can quickly colonize disturbed patches and complete their life cycles before competitive regrowth occurs (Grime, 1977; Díaz et al., 2016). Similarly, stress-tolerant species, often specialized for survival in nutrient-poor and periodically inundated soils, maintained a substantial role in the grazed meadow. Their persistence aligns with the prevailing edaphic conditions of the wetland environment (Díaz et al., 2016).

In contrast, tall competitors—such as *Carex acuta* and *Phragmites australis*—thrived in the absence of disturbance in the ungrazed plot, consistent with Grime’s (1977) predictions that

C-strategists dominate under conditions of low disturbance and high resource availability. The CSR analysis therefore underscores that grazing promotes functional diversity by maintaining a coexistence of C-, S-, and R-strategists, preventing competitive exclusion by dominant perennial species (Grime, 1977; Díaz et al., 2016).

These findings mirror broader patterns observed in European grasslands, where regular disturbance through grazing or mowing shifts functional composition toward a higher representation of R- and S-strategists, while abandonment typically leads to dominance by C- and CS-types (Tälle et al., 2016; Díaz et al., 2016). Overall, the CSR profiles in this study support the interpretation that moderate grazing acts as an ecological regulator, delaying successional closure and preserving a dynamic, heterogeneous community structure in wet meadow ecosystems.

3.4 Morpho-functional groups of identified plant species

All 44 identified vascular plant species were assigned to morpho-functional groups based on growth form, woodiness, and ecological role, following the classification criteria proposed by Pérez-Harguindeguy et al. (2013). The four groups used in this study were: grasses, herbs, other (e.g., sedges, rushes, horsetails), and Shrubs/Trees.

Table 6. **List of identified plant species of Pagilute wetland complex grouped by morpho-functional type (Cornelissen et al., 2003)**

Morpho-functional group	Number of species	Species list
Grass	3	*Agrostis stolonifera, Festuca rubra, Phragmites australis*
Herb	33	*Angelica sylvestris, Bidens cernua, Bidens tripartita, Carduus crispus, Cerastium holosteoides, Chrysosplenium alternifolium, Cicuta virosa, Cirsium oleraceum, Cirsium vulgare, Conium maculatum, Epilobium hirsutum, Filipendula ulmaria, Galium mollugo, Galium uliginosum, Geranium molle, Geum rivale, Lycopus europaeus, Lysimachia vulgaris, Mentha aquatica, Mentha arvensis, Parnassia palustris, Ranunculus flammula, Ranunculus lanuginosus,*

		Ranunculus repens, Rorippa palustris, Rumex acetosa, Rumex crispus, Scutellaria galericulata, Succisa pratensis, Thalictrum minus, Trifolium repens, Urtica dioica, Valeriana officinalis
Other	5	*Carex acuta, Equisetum palustre, Juncus articulatus, Juncus effusus, Typha latifolia*
Shrub/Tree	3	*Betula pubescens, Rubus idaeus, Salix cinerea*

As summarized in Table 6, the largest category was Herbs, comprising 33 species (75%). The Other group included 5 species (11.4%), typically associated with water-saturated or semi-aquatic environments. Grasses were represented by 3 species (6.8%), while Shrubs and Trees also accounted for 3 species (6.8%), including Rubus idaeus, Salix cinerea, and Betula pubescens, which are indicative of successional encroachment in the absence of regular management interventions.

We can get acquainted with an approximate picture, however, in order to talk about the dominance of something, we need to look at the percentage of coverage, which is why cart below (Fig. 9) was created.

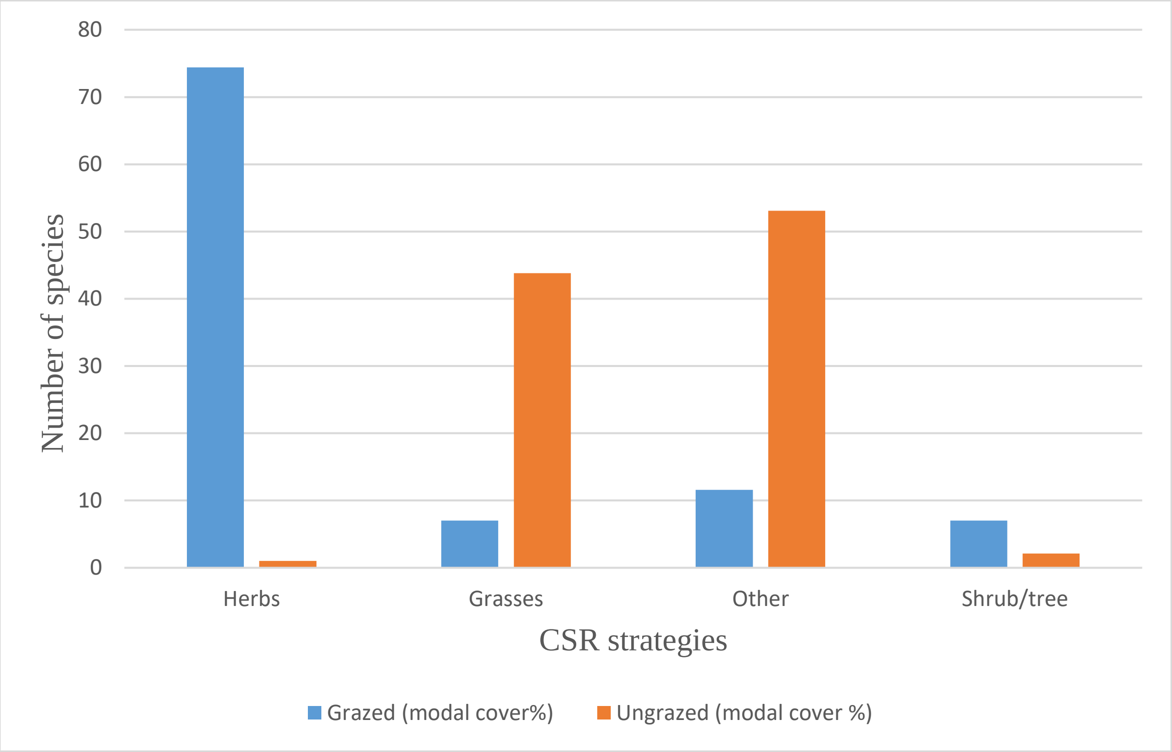

Figure 9. Total cover of morpho-functional plant groups in grazed and ungrazed areas based on average Braun-Blanquet scores

In the grazed meadow, broadleaf herbs overwhelmingly dominated cover (74.4%), while grasses contributed only 7.0% and sedges/rushes ("Other") 11.6%. Shrubs and tree-seedlings made up about 7.0% of cover. By contrast, in the ungrazed meadow sedges and rushes (the "Other" category) and grasses together dominated (53.1% and 43.8% cover, respectively), with forbs only 1.0% and woody species ~2.1%. These data show that grazing effectively suppresses tall graminoids and opens space for forb-rich vegetation. Cattle in wet meadows often consume or trample vigorous grasses, preventing them from shading out smaller species (Firbank et al. 2003). As a result, short-statured forbs proliferate under grazing. In ungrazed conditions, however, the robust sedges (*Carex*) and rushes (*Equisetum*, *Juncus*, *Typha*) can grow unchecked, forming a dense canopy and reducing forb cover. This research observations are in line with previous studies on managed meadows: for example, grazing tends to increase forb biomass and diversity by controlling competitive monocots (Diaz et al. 2016; Morris 2008), whereas abandonment or low disturbance leads to grass/sedge monocultures. The relative increase of shrubs/trees under grazing (noted in the cover percentages) is surprising at first glance, but it likely reflects the fact that many woody seedlings (e.g. *Betula pubescens, Salix cinerea*, *Rubus idaeus*) were only found in the grazed transect (albeit at low height). In reality, regular mowing was needed to prevent their full establishment. Nonetheless, both treatments had very low woody cover, indicating that even without grazing the wet meadow had not yet progressed to a shrub-dominated stage during this study.

3.5 Life forms of plant species in the Pagilutė wetland by Raunkiaer's system

To gain further ecological insight into the structural composition of plant communities, all recorded species were classified according to the Raunkiaer life form system. This classification reflects the adaptive strategies of plants in relation to disturbance, seasonality, and growth form. The majority of species were identified as hemicryptophytes, a common life form in temperate grasslands and wetlands. Other life forms included therophytes, geophytes, chamaephytes, and phanerophytes, indicating a moderate level of functional diversity across the study plots (Table 7).

Table 7. **Raunkiaer classification of identified plant species**

Raunkiaer life form	**Species (Latin names)**
Chamaephyte	*Rubus idaeus*
Geophyte	*Equisetum palustre, Typha latifolia*

Hemicryptophyte	*Agrostis stolonifera, Angelica sylvestris, Carex acuta, Chrysosplenium alternifolium, Cicuta virosa, Cirsium oleraceum, Epilobium hirsutum, Festuca rubra, Filipendula ulmaria, Galium mollugo, Galium uliginosum, Geum rivale, Juncus articulatus, Juncus effusus, Lycopus europaeus, Lysimachia vulgaris, Mentha aquatica, Mentha arvensis, Parnassia palustris, Phragmites australis, Ranunculus flammula, Ranunculus lanuginosus, Ranunculus repens, Rumex acetosa, Rumex crispus, Scutellaria galericulata, Succisa pratensis, Thalictrum minus, Trifolium repens, Urtica dioica, Valeriana officinalis*
Phanerophyte	*Betula pubescens, Salix cinerea*
Therophyte	*Bidens cernua, Bidens tripartita, Carduus crispus, Cerastium holosteoides, Cirsium vulgare, Conium maculatum, Geranium molle, Rorippa palustris*

The definition of life forms allows us to look deeper into why there is a difference between grazed and ungrazed areas, allows us to look in more detail at the rationale behind the induction of certain species, their absence or their dominance in certain conditions.

The chart below (Fig. 10) illustrates plant cover classified by Raunkiaer life forms, based on average Braun–Blanquet scores in grazed and ungrazed plots. This allows for deeper insight into how grazing influences the abundance of different structural life forms.

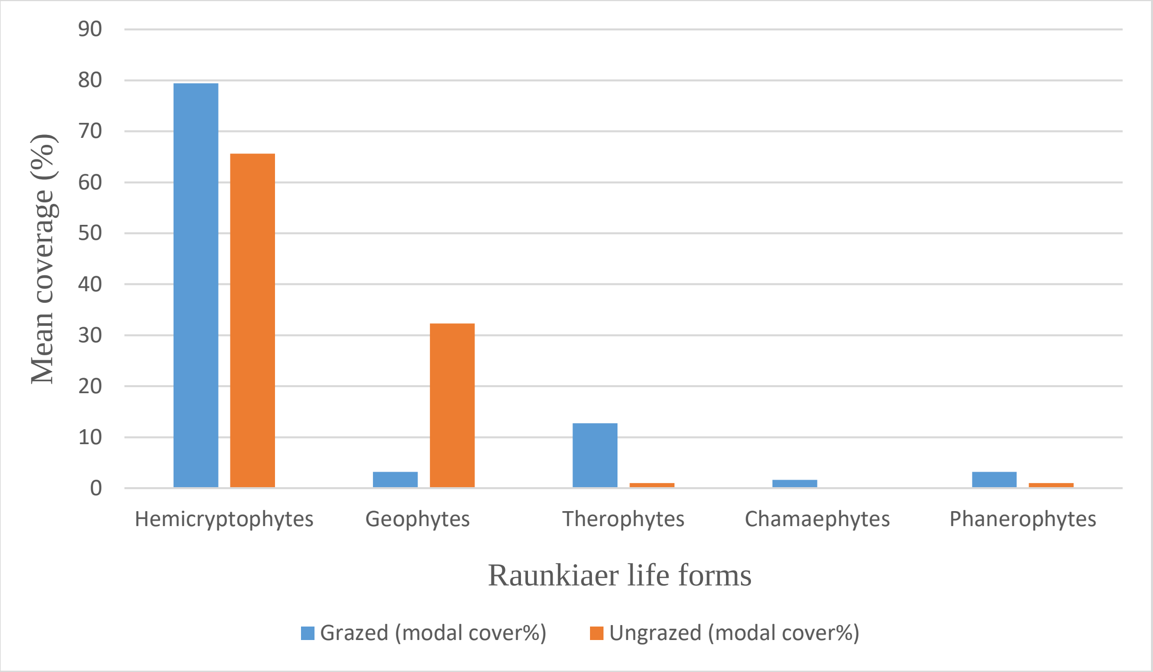

Figure 10. Raunkaer life forms coverage based on average Braun-Blanquet cover scores

The analysis of Raunkiaer life-form cover revealed clear differences between grazed and ungrazed plots in a wet meadow ecosystem in Lithuania. Hemicryptophytes were the dominant life form in both conditions, comprising 79.4% of total cover in grazed plots and 65.6% in ungrazed plots. Geophytes exhibited a marked increase in the absence of grazing, accounting for 32.3% of total cover in ungrazed areas compared to only 3.2% in grazed ones. Conversely, therophytes were more abundant in grazed plots (12.7%) and nearly absent in ungrazed plots (1.0%). Chamaephytes and phanerophytes were minimally represented in both conditions. Chamaephytes showed a slight presence only in grazed areas (1.6%), while phanerophytes accounted for a small fraction in both scenarios (3.2% with grazing; 1.0% without).

These differences make ecological sense - the surge of therophytes under grazing likely reflects their ability to complete life cycles before or after grazing events; annuals can “escape” grazing by living as seeds during intensive defoliation, and they exploit open niches created by disturbance (Grime 1977; Tälle et al. 2016). In contrast, geophytes with extensive rhizomes (e.g. Phragmites, Equisetum) tend to dominate when disturbance is low, as they gradually spread clonally. Thus in the ungrazed meadow, these clonal perennials accumulated and occupied much of the biomass. The high overall dominance of hemicryptophytes in both plots is typical of temperate grassland/wetland communities, but grazing increased the proportional cover of small rosette herbs and grasses relative to the taller hemicryptophytes. In sum, the life-form spectrum confirms that grazing promoted annuals and low-growing perennials at the expense of tall clonal plants. Such shifts have been reported in other grassland studies (e.g. increased annuals under higher grazing pressure; Grime 1977; Díaz et al. 2016), again illustrating that herbivory creates conditions favoring species with protected buds or rapid life cycles.

3.6 Plant community response to grazing pressure

Plant species vary in their response to grazing depending on their life form,morphological traits, and ecological strategies. In order to assess the relationship between increased biodiversity and the presence of species positively responding to grazing, each recorded species was classified as having a positive, neutral, or negative response to grazing pressure. This classification was based on Raunkiaer life form, CSR strategy, and its relative cover (in percentage, derived from Braun–Blanquet scores), indicating whether the species benefits from, tolerates, or is suppressed by grazing.

A table with grazing response for each plant has been added to the appendix as Appendix 4, the processed data are presented as chart (Fig. 11). Important to note that the grazing effect in the Pagilute area appeared in September 2023, and field data for this work (Brown-Blanket coverage) were collected in September 2024, both transects located in the same wet meadow under relatively similar natural conditions.

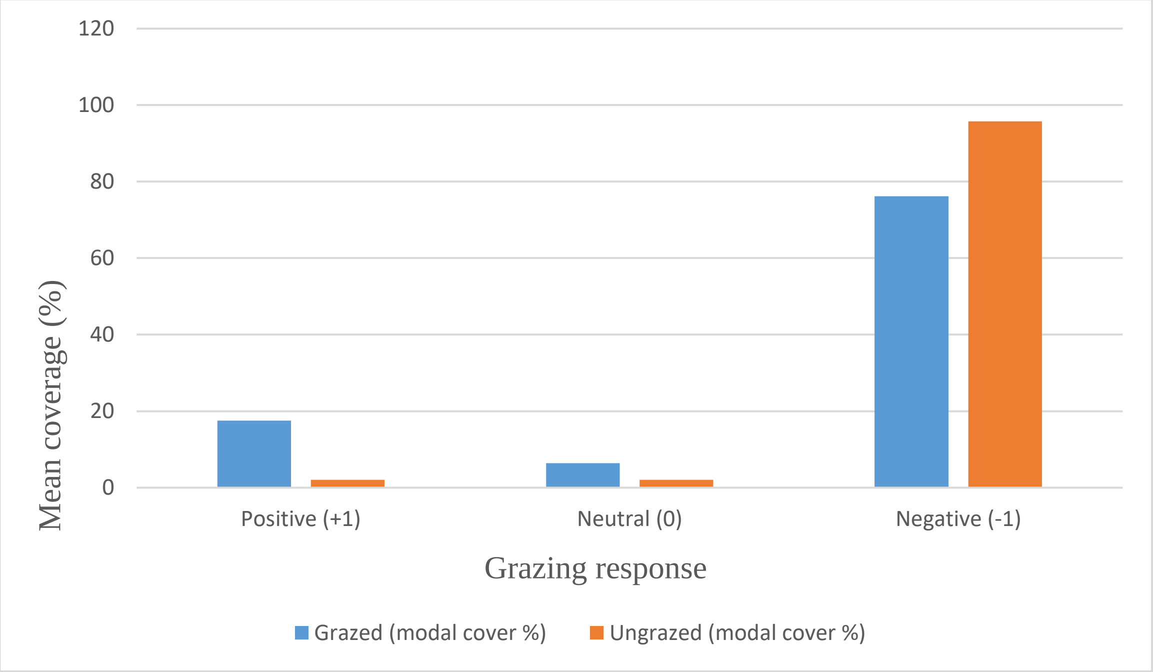

Figure 11. Plant cover by response to grazing species

Analysis revealed that in grazed plots, positive-response species accounted for 17.5% of total cover, compared to only 2.1% in ungrazed plots. Conversely, negatively responding species dominated overall vegetation in both treatments but were far more prevalent in the ungrazed site (95.8%) than in the grazed site (76.2%). Neutral species formed a minor component in both cases (6.4% grazed, 2.1% ungrazed).

These trends are consistent with findings from other European wet meadow systems (Bochniak et al., 2023; Kulik et al., 2023), where grazing disturbance suppressed dominant tall perennials and promoted a greater abundance of ruderal and stress-tolerant species. As outlined by Díaz et al. (2016), moderate grazing alters competitive hierarchies by removing aboveground biomass, thereby allowing disturbance-adapted species to establish. Results confirm this mechanism: grazing shifted the community composition toward a greater proportion of species that thrive under disturbance, validating predictions made by Grime’s CSR framework (Grime, 1977).

In line with previous studies (Tälle et al., 2016; Pulungan et al., 2019), the observed increase in positively responding species and overall diversity under grazing highlights the importance of managed herbivory for maintaining species-rich wet meadow ecosystems. Thus, the significantly higher Shannon index values and altered species response profiles both demonstrate the critical role of moderate cattle grazing in sustaining biodiversity in the Pagilutė wetland.

3.7 Discussion

Moderate cattle grazing significantly increased plant biodiversity in the Pagilutė wetland complex, as evidenced by multiple quantitative indicators. Grazed plots supported a much richer flora (all 44 recorded species were present with grazing, whereas ungrazed plots contained only a small subset of these), resulting in a Shannon–Wiener diversity index (H′) more than doubling from ~1.1 in ungrazed conditions to ~3.2 under grazing (mean quadrat H′ 1.08 ± 0.26 vs 3.25 ± 0.14; $p < 0.001$). Species evenness likewise improved markedly, with Pielou’s J′ rising from ~0.64 without grazing to ~0.78 with grazing, reflecting a more equitable distribution of abundances. These changes correspond to a dramatic reduction in dominance by a few tall clonal plants and an expansion of niche opportunities for smaller herbs. For instance, in ungrazed stands two graminoids, *Phragmites australis* and *Carex acuta*, monopolized most of the cover (Braun-Blanquet cover scores 4 and 2, respectively, indicating well over 50% combined cover), while many other species were nearly absent. Grazing curtailed these dominants (e.g. *Phragmites* cover dropped from score 4 in ungrazed plots to negligible levels in grazed plots, and *Typha latifolia* fell from score 3 (~25% cover) to a trace) and created open patches that were quickly colonized by a variety of subordinate forbs and grasses. As a result, the grazed meadow exhibited a far more heterogeneous vegetation structure with numerous low-growing herbs (including annuals such as *Bidens cernua, Carduus crispus, Cerastium holosteoides,* etc.) that were absent in ungrazed control areas. The Raunkiaer life-form spectrum shifted accordingly: grazing favored hemicryptophytes and therophytes, while greatly reducing the prevalence of tall perennials (geophytes) and woody plants. Hemicryptophytes (perennial herbs with ground-level buds) remained the dominant life form in both treatments but constituted an even larger share of community cover under grazing (≈79% of total cover, up from 66% without grazing) due to the suppression of tall competitors. Therophytes (annuals) flourished under grazing, expanding to ~13% of plant cover (versus only ~1% in ungrazed plots), whereas geophytes (rhizomatous clonal species like *Phragmites* and *Equisetum*) dropped from about 32% cover in the ungrazed meadow to only ~3% with grazing. Chamaephytes (low subshrubs) and phanerophytes (tall woody plants) remained minor components in both conditions (<5% cover each), though grazing kept phanerophytes (e.g. regenerating *Salix* and *Betula* shoots) at a very low coverage (≈3% vs 1% without grazing) by browsing and trampling. Consistent with these life-form changes, an analysis of Grime's CSR strategies shows that disturbance from grazing shifted the functional composition toward stress-tolerant and ruderal plants at the expense of competitive strategies. In grazed plots, stress-tolerators (S-strategists) accounted for roughly 54% of total plant cover and ruderals (R-strategists) ~16%, whereas the ungrazed vegetation was overwhelmingly dominated by competitor-associated strategies (C-strategists alone ~42% cover, with an additional ~56% combined from mixed C/R and C/S types) and virtually lacked pure R or S strategists (<2% cover combined). All lines of evidence – higher species counts, diversity indices, evenness, cover structure, life-form distribution, and CSR profiles – converge to confirm that moderate cattle grazing promoted greater plant species diversity and a more heterogeneous community structure in this wet meadow ecosystem. These patterns align closely with findings from other European grassland studies. For example, Kulik *et al.* (2023) reported significant upward trends in species richness and Shannon diversity over four years of cattle grazing in Polish wet meadows, as grazing reduced dominant rush and reed cover and facilitated colonization by diverse meadow species. Similarly, Rysiak *et al.* (2021) observed that reintroducing grazing to formerly abandoned meadows nearly doubled plant species number within two years and effectively halted encroachment by shrubs and young trees, maintaining an open habitat. A broader meta-analysis by Tälle *et al.* (2016) likewise emphasizes that continuous low-intensity management (through grazing or mowing) is usually required to sustain high biodiversity in grasslands. Taken together, the quantitative outcomes of this study substantiate the positive ecological role of controlled moderate grazing, corroborating the notion that properly managed herbivory can enhance plant species diversity, inhibit competitive exclusion by dominant tall vegetation, and thus help conserve the open, species-rich character of wet meadow habitats.

4. CONCLUSIONS

1. Grazed plots of Pagilute wetland complex has higher diversity of plant species: a mean Shannon diversity index (H′) of 3.19, compared to 1.34 in ungrazed plots. Evenness (Pielou's J′) also increased under grazing (0.78 vs 0.64), reflecting both higher species richness and a more balanced distribution of cover among species.
2. Grazing shifted functional composition toward disturbance-adapted plant groups. In grazed plots, stress-tolerant (54%) and ruderal (16%) species dominated cover, while ungrazed plots were dominated by competitors (42%) with ruderal and stress-tolerant species each at 1%. Similarly, life-form spectra changed: therophyte cover rose to 12.7% in grazed plots vs 1% ungrazed, while geophytes dropped from 32.3% to 3.2%.
3. Grazing reduced dominance by tall graminoids (*Phragmites australis*, *Typha latifolia*, *Carex acuta*) and promoted a more structurally heterogeneous, forb-rich community. Cover of species negatively responding on grazing decreased from 95.8% to 76.2%, while positively responding species increased from 2.1% to 17.5%.
4. Low-intensity cattle grazing (≈ 0.36 LU/ha) maintained high plant diversity and prevented encroachment by shrubs or degradation of meadow structure. These results demonstrate grazing's effectiveness as a conservation tool for sustaining open, species-rich wetland vegetation under Natura 2000.

4.1 Recommendations

Based on the findings of this study, the following recommendations are proposed for the management of wet meadows in the Pagilutė complex and ecologically similar Natura 2000 sites:

1) Increase the number of transects and sampling locations to better capture spatial variability and improve the representativeness of plant community data. Given the natural heterogeneity of wet meadows and the patchy effects of grazing, a minimum of 3 transects per treatment, covering different microhabitats, with at least 30 quadrats per condition, would improve spatial resolution and reduce sampling bias.
2) Conduct repeated vegetation surveys across multiple seasons and years to account for both seasonal and interannual variation in species composition and grazing effects. Ideally, monitoring should be conducted at least twice per year (e.g., in early summer and early autumn) for a minimum of 3 consecutive years to capture phenological dynamics and long-term vegetation changes.
3) Include abiotic environmental data, such as soil chemistry, moisture levels, and hydrological dynamics, to better understand the underlying drivers of vegetation

responses. Hydrological dynamics refer to seasonal fluctuations in groundwater levels, surface water presence, and soil saturation, which strongly influence plant community structure in wet meadows. It is recommended to test relationships between vegetation parameters (e.g., species richness, functional group composition, CSR strategies) and abiotic factors, such as soil pH, nitrogen and phosphorus levels, and average soil moisture, to identify key environmental drivers of plant responses to grazing.

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APENDIX

Apendix 1. **Transect coordinates**

Transect	**1st quadrat**	**10th quadrat**
Area with cows	55.26379° N, 25.95477° E	55.26345° N, 25.95601° E

No cows area	55.26120° N, 25.95836° E	55.26079° N, 25.95686° E

Apendix 2. **Area with cows**

Plant name	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
Agrostis stolonifera	1		1	0,5	0,5					
Angelica sylvestris	0,5	1		1			2	0,5		
Betula pubescens		0,5			0,5	0,5	0,5	0,5		0,5
Bidens cernua		0,5		2		0,5			0,5	
Bidens tripartita	0,5	0,5	0,5			0,5				
Carduus crispus				1	0,1	1				
Carex acuta	0,5						0,5	1		4
Chrysosplenium alternifolium	0,5			0,5			1			
Cerastium holosteoides	1					0,5				
Cicuta virosa				2	0,5				0,1	
Cirsium oleraceum									1	
Cirsium vulgare		0,5	0,5							
Conium maculatum		0,1	0,5			2	0,5			
Epilobium hirsutum		1	1	0,5			2			
Equisetum palustre	1	0,5								0,5
Festuca rubra	0,5		0,5			1			2	
Filipendula ulmaria	0,1	1		0,5						0,1
Galium mollugo		0,5				0,5				
Galium uliginosum	0,1				0,5				0,5	
Geranium molle		0,5								
Geum rivale		0,5	0,5		4	2	2	1		
Lysimachia vulgaris		0,1								
Juncus effusus	0,1		0,5	0,5		0,5			0,5	
Juncus articulatus	2									
Lycopus europaeus	0,5		0,5			1				
Mentha aquatica		0,5	0,5		0,5		0,5			
Mentha arvensis	0,1		1		0,1	0,5		0,5		
Parnassia palustris		0,5								
Phragmites australis	0,5		0,1			0,5			1	2

Ranunculus flammula			0,5	1				0,5	0,5	
Ranunculus lanuginosus			0,5				1	2	0,5	
Ranunculus repens	0,5	2			0,5					
Rorippa palustris						0,5			0,5	
Rubus idaeus	0,5			0,5		0,5		1		
Rumex acetosa		0,5	1						2	0,5
Rumex crispus	0,5	0,5	0,5				0,5			
Salix cinerea						0,5		3	2	0,5
Scutellaria galericulata		0,5								
Succisa pratensis	0,5		2	1						
Thalictrum minus	1					0,5	0,5		0,5	
Trifolium repens	0,5	0,5				0,1	0,1	0,5	0,5	
Typha latifolia		0,5	0,5				0,5		0,5	0,5
Urtica dioica	0,5	0,5		0,5	0,5		1	0,5	0,5	
Valeriana officinalis		0,5	1	0,5	1	0,5				

Appendix 3. Area without cows

Plant name	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
Agrostis stolonifera	0,5									
Angelica sylvestris										
Betula pubescens										
Bidens cernua										
Bidens tripartita										
Carduus crispus										
Carex acuta	1	0,5	1	2	0,5	1	2	0,5	2	2
Chrysosplenium alternifolium										
Cerastium holosteoides										
Cicuta virosa										
Cirsium oleraceum										
Cirsium vulgare										
Conium maculatum	0,1		0,1					0,5		0,5
Epilobium hirsutum										
Equisetum palustre	0,5		0,5	0,1		0,5	0,5		0,1	0,5

Festuca rubra	1	0,5	0,1	0,5	0,5			0,1		
Filipendula ulmaria										
Galium mollugo										
Galium uliginosum										
Geranium molle										
Geum rivale										
Lysimachia vulgaris										
Juncus effusus										
Juncus articulatus										
Lycopus europaeus										
Mentha aquatica										
Mentha arvensis										
Parnassia palustris										
Phragmites australis	3	4	4	3	3	4	4	5	3	2
Ranunculus flammula										
Ranunculus lanuginosus										
Ranunculus repens										
Rorippa palustris										
Rubus idaeus										
Rumex acetosa			0,5	0,5						
Rumex crispus										
Salix cinerea	1	0,5								
Scutellaria galericulata										
Succisa pratensis										
Thalictrum minus										
Trifolium repens										
Typha latifolia	2	2	3	3	3	2	2	1	3	4
Urtica dioica										
Valeriana officinalis										

Appendix 4

Species	**Raunkiaer**	**CSR**	**Response**
Agrostis stolonifera	Hemicryptophyte	CR	1

Angelica sylvestris	Hemicryptophyte	C	0
Betula pubescens	Phanerophyte	CS	-1
Bidens cernua	Therophyte	R	1
Bidens tripartita	Therophyte	R	1
Carduus crispus	Therophyte	R	1
Carex acuta	Hemicryptophyte	CS	-1
Chrysosplenium alternifolium	Hemicryptophyte	S	-1
Cerastium holosteoides	Therophyte	R	1
Cicuta virosa	Hemicryptophyte	S	-1
Cirsium oleraceum	Hemicryptophyte	C	0
Cirsium vulgare	Therophyte	R	1
Conium maculatum	Therophyte	R	1
Epilobium hirsutum	Hemicryptophyte	CR	1
Equisetum palustre	Geophyte	S	-1
Festuca rubra	Hemicryptophyte	CS	-1
Filipendula ulmaria	Hemicryptophyte	C	0
Galium mollugo	Hemicryptophyte	CR	1
Galium uliginosum	Hemicryptophyte	S	-1
Geranium molle	Therophyte	R	1
Geum rivale	Hemicryptophyte	S	-1
Lysimachia vulgaris	Hemicryptophyte	CS	-1
Juncus effusus	Hemicryptophyte	S	-1
Juncus articulatus	Hemicryptophyte	S	-1
Lycopus europaeus	Hemicryptophyte	S	-1
Mentha aquatica	Hemicryptophyte	CS	-1
Mentha arvensis	Hemicryptophyte	CR	1
Parnassia palustris	Hemicryptophyte	S	-1
Phragmites australis	Hemicryptophyte	C	0
Ranunculus flammula	Hemicryptophyte	S	-1
Ranunculus lanuginosus	Hemicryptophyte	S	-1
Ranunculus repens	Hemicryptophyte	CR	1
Rorippa palustris	Therophyte	R	1
Rubus idaeus	Chamaephyte	C	-1

Rumex acetosa	Hemicryptophyte	CR	1
Rumex crispus	Hemicryptophyte	R	1
Salix cinerea	Phanerophyte	CS	-1
Scutellaria galericulata	Hemicryptophyte	S	-1
Succisa pratensis	Hemicryptophyte	S	-1
Thalictrum minus	Hemicryptophyte	S	-1
Trifolium repens	Hemicryptophyte	R	1
Typha latifolia	Geophyte	C	-1
Urtica dioica	Hemicryptophyte	CR	1