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In Situ Conservation of Dry Meadows

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Abstract: Grassland ecosystems are increasingly vulnerable as they are threatened by both intensive agriculture and abandonment of land use, which leads to overgrowth with scrub vegetation and forest. Given that meadows are habitat types of very high biodiversity, their loss significantly reduces local biodiversity. That is why the University Botanic Gardens Ljubljana has been renting a 2 ha dry meadow at the edge of Ljubljana capital city since 2001, for the purpose of in situ conservation in the urban area. We have been observing the meadow since 1997. In 2023, in addition to the complete inventory of species, we also carried out an inventory and analysis of the community in the meadow using the Braun–Blanquet method in 25 relevés. We recorded 163 plant species in the meadow during the entire growing season, and a total of 82 were recorded in the relevés. Eighteen of the species recorded are on the red list of protected plant species in Slovenia. In the relevés, 15 species types were constant (occurring in 60%) and as many as 21 were unique. The species *Peucedanum oreoselinum* (L.) Moench was recorded in all relevés (25), followed by the species *Bromopsis erecta* (Huds.) Fourr. (24), *Galium verum* L. (24), *Briza media* L. (23), *Brachypodium pinnatum* (L.) PB. (22) and *Salvia pratensis* L. (21).

Keywords: grasslands; biodiversity; conservation; traditional management

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1. Introduction

Although Slovenia is mainly a forested country and meadows were created primarily due to human activity or natural sudden environmental changes (windfalls, ice damage, fires), meadows are much more diverse than forests in their old-growth stage. In Slovenia, permanent grassland comprises 60 percent of agricultural land [1]. Grasslands were once divided into pastures and commons, meadows and alpine meadows, and even artificial meadows [2]. In the past, farmers could distinguish between different types of meadows simply by observing nature. They knew their appearance in different seasons and knew which meadows help livestock produce more milk with better taste.

Today, there are different classifications of grasslands mainly based on their use in agriculture, either according to their location and environmental factors or based on the division into habitat types [3–7]. In terms of the number of species, dry grasslands on alkaline soil are the richest. Such meadows are home to many sensitive plant species, which quickly disappear when fertilised [8,9]. In the hilly regions of Slovenia, on Karst and in the lowland in wetter areas in some places, single-mowed meadows dominated until recently, and they were named differently across Slovenia: *senožeti*, *rovti*, *lazi*, *logi*. These areas were traditionally mown from mid-July onwards. These were mown, unfertilised areas. Only specific areas like those mown till 10th of July, with surfaces at lower altitudes and those on deep soil were used for livestock grazing in autumn [8–11]. Grass was traditionally dried in situ freestanding vertical drying racks peculiar to Slovenia and known as *kozolec*, *kazuc*, *stog* and *topla* [12]. In the interior of Slovenia, grass was left to dry for up to three days, but in the dry Karst, it could be dried for only one day [11,13]. Nowadays, meadows with such a rich plant diversity are rare, because the management of such areas has completely changed [10,11]. An important turning point in the management of meadows in Slovenia

was the beginning of fodder silage in the 1970s. This type of management was started primarily by larger farms, which started building tower silos. Later, bunker silos were introduced, and at the end of the 1990s, baling became widespread. Nowadays, baling is prevalent on almost all farms [10–12]. According to Verbič's data [14], only one-third of farms dries fodder, while the rest silage it in one way or another. However, premature mowing and ensilage prevent the renewal of the soil seed bank. At the beginning of May, most grassy areas are already mown for the first time. Then the meadows are fertilised and mowed until October. If there is no drought, there is significantly more mowing than in the past. The changed management method is present both on large and small farms. Due to frequent mowing, flowering and seeding of plant species almost never occurs, causing a decrease in species diversity. Abandoning the traditional management of meadows therefore leads to a decrease in the biodiversity of the environment [10,15].

In traditional meadow management, the meadows were mown for the first time only when the grasses could be 'stripped' (i.e., when the spikes of grass were so mature that the seeds could be pulled from the spikes with fingers) [2,16,17]. At that time, the mowing of large areas, especially alpine meadows, was a major burden for the farm, both in terms of organisation of labour and food. The work was performed by hand, which required a large number of mowers and rakers. Thus, the difficulty of the work led to a decline in mown areas [18–22]. Of course, mowing in the hilly areas was different and much more difficult than in the lowlands [23,24]. Despite today's mechanisation and thus the simplification of work, single-mowed areas, alpine meadows or meadows on shallow or Karst soils are mostly overgrown nowadays due to the abandonment of the use of space [11]. In addition to modern management, this is the second cause of the disappearance of biodiverse-rich meadows. Grazing is therefore often the only way to preserve the cultural landscape and biodiverse grasslands today [10,11,25–27].

Despite the causes threatening the biodiversity of meadows, Slovenia can still boast a considerable area of biodiverse meadows. Compared to several much larger EU countries such as Hungary, Poland and the Czech Republic, Slovenia has a far greater area of semi-natural dry grasslands in the Natura 2000 protected areas network at 7970 hectares, exceeding the aforementioned countries by 1000 to 4000 hectares [3]. The reasons for the rich biodiversity of Slovenian territory are also to be found in its specific geographical location. It is located at the junction of different geographical regions: the Alps, the Dinaric, the Mediterranean and the Pannonian Basin [28]. And each region influences the flora and fauna with its characteristic climatic factors and soil. The consequence of the mix of different climatic influences in such a small area as Slovenia causes the rich plant biodiversity compared to some much larger countries. Dry meadows are found in all these regions, located at different altitudes and different exposures. Dry meadows are usually very rich in biodiversity, which is also typical for Slovenia [8,11,29–32] and is also observed elsewhere in Europe and the world [3,33–36]. Due to insufficient biomass production, however, these types of meadows are being abandoned, resulting in overgrowth by scrub [11]. In flat areas, on former river terraces, they are often ploughed into fields, which are then irrigated. This results in loss of biodiversity. A similar thing is happening to pastures. With traditional management methods (sufficiently large pasture divisions, crop rotation), there are high-quality and biodiversity-rich areas, which we observed in our own field work in Slovenia and confirmed by extensive research in Europe X [3,33–38].

Dry and semi-dry meadows were once widespread. Due to changed management methods, they now represent highly threatened habitats, which is observed both in Slovenia [8,10,11,13,15,29,30,39] and abroad [3,35,40–43]. Every meadow recognised as rich in biodiversity should therefore be properly studied and properly managed, as it can represent an important island of biodiversity that can, if necessary, be utilised as a source for natural or planned regeneration of biodiversity-poor meadows.

For these reasons, since 2001, the University Botanic Gardens Ljubljana have been leasing a 2-hectare dry meadow for the purpose of studying and preserving the biodiversity of meadows. It is located on the terraces on the edge of the city of Ljubljana (Slovenia),

which were formed in the past by the Sava River. These meadows were already studied in the past by the former head of the Botanic Gardens [44,45], which indicates that the University Botanic Gardens Ljubljana have been active in in situ protection of plant species, and consequently also of endangered habitats, for a very long time. By leasing the said meadow, the University Botanic Gardens Ljubljana have a model area for observing the impact of traditional meadow management on biodiversity. Considering that the meadow is surrounded by urban land, fields and intensive meadows, it can represent a hotspot of biodiversity and act as a donor site for the spread of plant species to intensively maintained areas. In the past, recording the presence of specific plant species on this meadow was random and ad hoc, which made the definition of the plant community on the meadow more inconclusive. Therefore, the goal of our study was a floristic examination of the plant community on the meadow from the point of view of species composition. An accurate inventory of plant species and the size of their populations will thus provide us with a baseline for evaluating the studied meadow from the point of view of biodiversity, the adequacy of its management, and the source of plant species for spill-over into surrounding intensive meadows. The first step in the protection of habitat types (like meadows) is the precise inventory of plant species in specific habitats, because only with an inventory can we determine the actual state of species diversity and define the plant community and habitat type. Habitat determination is then key to further management of the habitat type and in situ protection. If the inventory of plant species also reveals the presence of threatened and protected plant species, this type of data can help classify the relevant habitat type as a protected area, which can then be used to determine its further management. Namely, due to the presence of protected plant species, the examined meadow in Ljubljana was also included in the Natura 2000 area.

2. Materials and Methods

2.1. Site Description

Plant species were inventoried on the meadow in Roje on the edge of the capital city of Ljubljana, Slovenia (Figure 1). The meadow is located in the pre-Alpine region of Slovenia or in the Alpine macroregion. Slovenia lies at the crossroads of the Alpine, Dinaric, Pannonian and Mediterranean regions. This is reflected in the climate and plant life in the country, which differs depending on the geographical region. Due to its location at the junction of regions, it has a transitional climate—Alpine, continental and Mediterranean climates intertwine, whereby most of Slovenia—including the meadow where we inventoried the species—is otherwise characterised by a moderate continental climate [46]. The continental climate is characterised by average January temperatures ranging from 0 to −3 °C and average July temperatures ranging from 15 to 20 °C. In the area where the meadow is located, average annual temperatures can range from 12 to 14 °C [47], with average annual precipitation from 1201 to 1300 mm [48]. In 2023, the amount of precipitation and the average summer temperatures for the area where the meadow is located were not usual. Namely, the amount of precipitation ranged, in summer months, from 40% to 60% above average and the temperature was 1 °C below average. As can be seen in the graph (Figure S1 from Supplementary Materials), highest precipitation was in July and August, although it is usually highest in spring and autumn months. The average temperature during these two months was at least 3 °C lower than normal (Figure S2).

The studied flat meadow is located at 297.51 metres above sea level (46°06′37.0″ N, 14°29′05.7″ E). It spans 2 hectares and is classified as a dry meadow [49]. It is oriented from north to south, in the shape of a long rectangle. It is 28 metres wide at its widest point. In some parts, there are also small communities of shrubs (Figure 2). The bedrock of the researched meadow is limestone, on which undeveloped riparian soil was formed due to deposits of gravel from the nearby Sava River [50]. The soil pH ranges from 7.5 to 8. At its edges, the meadow is bordered by a small deciduous forest and agricultural areas. These are intensively cultivated meadows and grain fields. On one of the neighbouring abandoned fields, there is also a large stand of invasive plant species *Solidago canadensis* L. and *Erigeron*

annuus (L.) Pers. According to our observation of grazed plants, animal sleeping places and animal faeces, it is obvious that wild animals are also using this meadow as their living space.

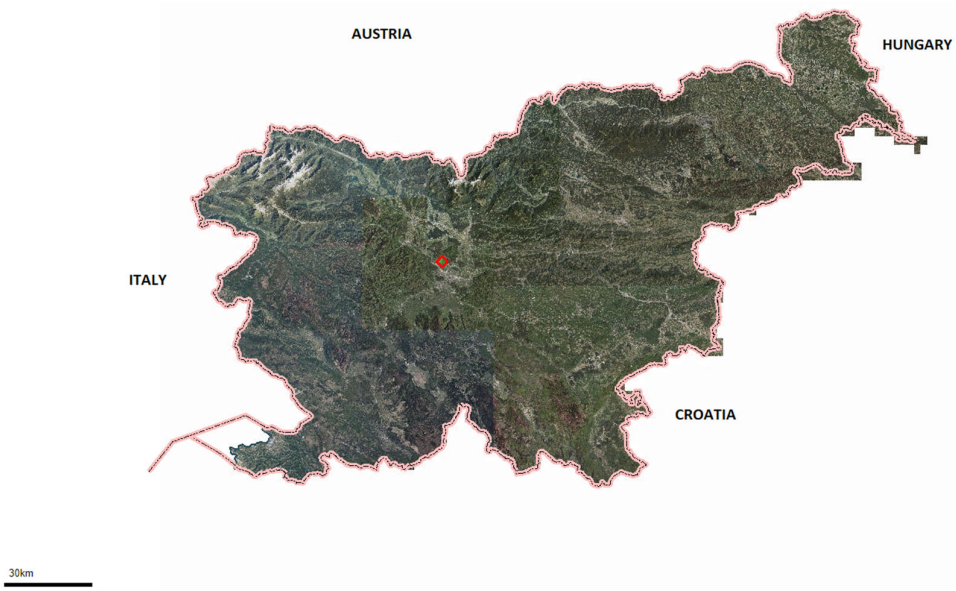

Figure 1. Map of Slovenia where with the red square the location of research meadow in Roje is marked (source: Atlas okolja (gov.si)).

Figure 2. Orthophoto of dry meadow in Roje—Ljubljana. The meadow is marked with red rectangle. (source: Atlas okolja (gov.si)).

University Botanic Gardens Ljubljana began monitoring the meadow in Roje in 1997, when locals informed us about the meadow where wild gladioli supposedly grew in a small area. Unfortunately, before we took over the management of the meadow, it had not been mowed for a number of years, which was evident from the tufted growth of grass. In 2001, the meadow was officially leased. The very first basic inventory in 2001 showed approximately 56 species growing there. In 2002, we burned the meadow in the beginning of March in order to prevent the growth of tufted grasses. Since then, we mow the meadow regularly once a year, specifically in the end of July or the beginning of August. For the first 10 years, we used a shear mower, but now we use a rotary mower.

2.2. Inventory of Plant Species on the Meadow

We have been carrying out random observation of the plant species on the meadow since 1998. More detailed data of plant species presence/absence was performed in years 2001, 2002, 2003, 2016 and 2018, but the first systematic inventory of species of the entire meadow was conducted in 2023. Species were inventoried from early spring to autumn, with two surveys per season. In these surveys, we recorded only the presence or observation of specific plant species on the meadow. Based on the presence/absence of plant species inventory in years 2001, 2002, 2003, 2016, 2018 and 2023, the Jaccard and Sørensen indices were calculated in the JUICE 7.0 program between the years of inventory. In 2023, on 17 June, for more accurate statistical data processing, we also conducted a phytocenological inventory of the meadow using the Braun–Blanquet method [51]. On the meadow, we assessed cover according to the Braun–Blanquet method for each species in 25 3 × 3-metre relevés (Figure 3). The relevés were randomly selected on the surface of the meadow.

Figure 3. Photo of a phytocenological inventory of the meadow using the Braun–Blanquet method.

2.3. Analysis of Species Composition

Using data on chorotypes according to Pignati et al. [52], we performed an analysis of the distribution type for the recorded species on the meadow. Using the JUICE 7.0 software [53], we then conducted some basic analyses of plant species composition in relevés. We calculated the minimum, maximum and average cover of each species in each reléve, as well as the frequency of their occurrence. For the meadow, we recorded the presence of one-time species, as well as diagnostic, constant and dominant plant species. For the fidelity threshold of diagnostic species, we chose the occurrence of the species in at least 50% of the relevés. A species was constant if it occurred in at least 60% of relevés, and dominant when it had a cover of more than 30% in each subplot. Rare species were those that were present in only one relevé [53]. With the same program (JUICE 7.0), we analysed interspecies associations for the following chosen species: *Gladiolus illyricus* Koch., *Anthericum ramosum* L., *Linum viscosum* L., *Veronica berrelieri* Schott ex Roem. & Schult. subsp. *nitens* Host and *Chamaecytisus purpureus* Scop. We chose the species *Gladiolus iliyricus* because it is a protected species and we have been monitoring the state of its population in the meadow since the beginning of our management of the meadow. The rest of the species were chosen because they are typical representatives of dry meadows. We analysed the co-occurrence of the mentioned species with other species present in the meadow. In the results, we considered as co-occurring species only those species that had a fidelity measure value above 40 with the selected species.

3. Results

3.1. Species Diversity

So far, we recorded a total of 163 plant species on the dry meadow in Roje on the outskirts of Ljubljana (Table 1). Of the recorded species, as many as 18 are on the list of protected plant species in Slovenia [54]. Among them are *Galanthus nivalis* L., *Gladiolus illyricus* and *Lilium bulbiferum* L., and 15 species of orchids. Among the species present are the species typical of dry meadows with shallow soils (*Anthericum ramosum*, *Veronica barrelieri* subsp. *nitens*, etc.) and species typical of wetter soils (*Astrantia major* L., *Epipactis palustris* (L.) Crantz, *Calluna vulgaris* (L.) Hull, etc.). Primarily moisture-loving plant species appear on the meadow in small patches. *Peucedanum oreoselinum* (L.) Moench and *Cirsium pannonicum* (L. f.) Link are uniformly present in the central part of the meadow, *Anthericum ramosum* and *Veronica barrelieri* subsp. *nitens* primarily in the southern part, and *Allium carinatum* subsp. *carinatum* L. and *Cichorium intybus* L. primarily near the field path that crosses the meadow. There is also a larger population of *Gladiolus illyricus* in the eastern central and southern parts. *Solidago canadensis* and *Erigeron annuus* can also be found, especially on the eastern edge of the meadow, posing a risk of spreading from the nearby abandoned field. Most of the species present on the meadow have Eurasiatic distribution (19%), slightly lesser (14%) European Caucasian and paleotemperate distribution (10%). Species with a eurimediterranean, southern European–southern Siberian, circumboreal and Eurosiberian distribution are also represented with 8%. Species with other distribution types represent less than 4% (Figure 4). Within the meadow, there are also islands of scrub vegetation *Prunus spinosa* L., *Cornus sanguinea* L., *Corylus avellana* L., *Crataegus monogyna* Jacq., *Euonymus europaeus* L., *Frangula alnus* Mill., *Ligustrum vulgare* L., *Sambucus nigra* L. and *Viburnum opulus* L.

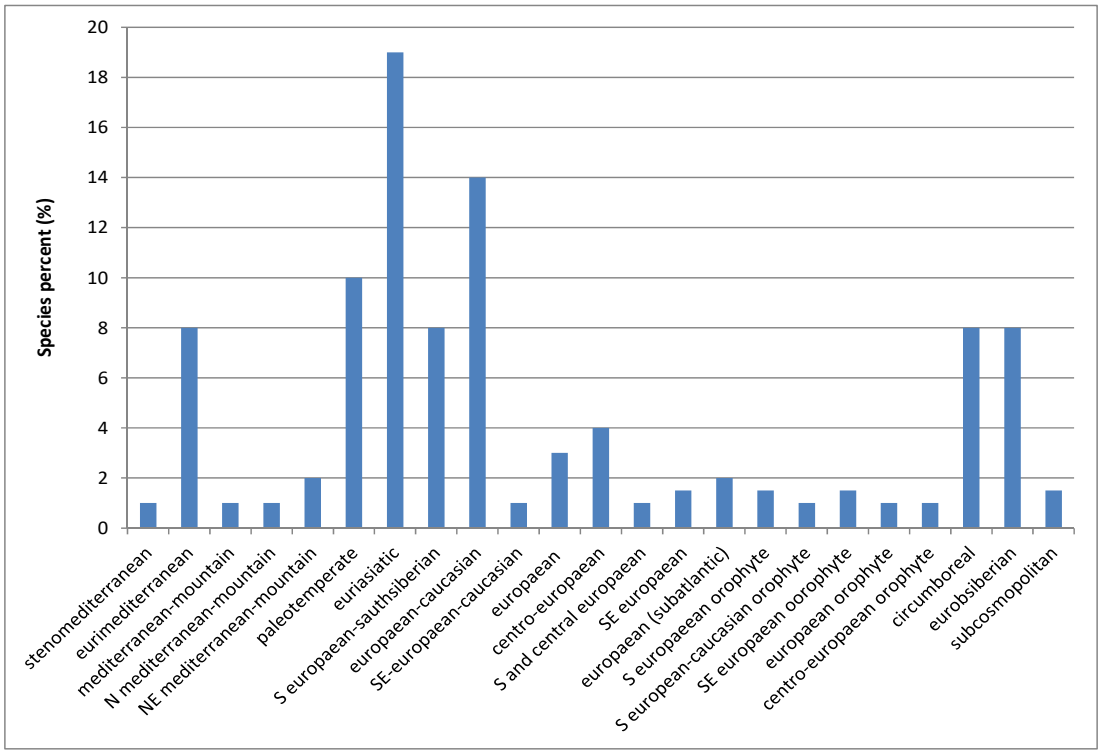

Figure 4. The proportion of recorded plant groups on the meadow with a specific type of distribution (type of distribution is summarised according to Pignatti et al. [52]).

Table 1. List of recorded species on the dry meadow in Roje (Ljubljana) (*—species recorded in subplots; ⧫—species recorded throughout the meadow).

	Species Present in Relevé	**Species Detected in Whole Meadow**
Achillea millefolium L.	*	⧫
Ajuga reptans L.		⧫
Allium carinatum subsp. *carinatum* L.	*	⧫
Anacamptis pyramidalis (L.) Rich.		⧫
Anthericum ramosum L.	*	⧫
Anthoxanthum odoratum L.		⧫
Anthyllis vulneraria L. subsp. *Vulneraria*		⧫
Arrhenatherum elatius (L.) P. Beauv. ex J. & C. Presl	*	⧫
Asperula cynanchica L.	*	⧫
Astrantia major L. subsp. *Major*	*	⧫
Bellis perennis L.		⧫
Betonica officinalis L.	*	⧫
Biscutella laevigata L.	*	⧫
Brachypodium rupestre (Host) Roem. & Schult.		⧫
Brachypodium pinnatum (L.) PB.	*	⧫
Briza media L.	*	⧫
Bromopsis erecta (Huds.) Fourr.	*	⧫
Bromus hordeaceus L. em. Hyl. subsp. *hordeaceus*		⧫
Buphthalmum salicifolium L.	*	⧫
Calluna vulgaris (L.) Hull		⧫
Campanula glomerata L.	*	⧫
Campanula patula L.		⧫
Carex caryophyllea Latourr.	*	⧫
Carex flacca Schreb.	*	⧫
Carex humilis Leyss.	*	⧫
Carex tomentosa L.		⧫
Carlina acaulis L.	*	⧫
Centaurium erythraea Rafn		⧫
Centaurea scabiosa L.	*	⧫
Centaurea haynaldii Borbás ex Vuk.	*	⧫
Centaurea jacea L.	*	⧫
Cerastium sp.	*	⧫
Chamaecytisus purpureus Scop.	*	⧫
Chrysopogon gryllus (L.) Trin.		⧫
Cichorium intybus L.	*	⧫
Cirsium erisithales (Jacq.) Scop.		⧫
Cirsium oleraceum (L.) Scop.		⧫
Cirsium pannonicum (L. f.) Link	*	⧫

Table 1. *Cont.*

	Species Present in Relevé	Species Detected in Whole Meadow
Clematis vitalba L.		♦
Colchicum autumnale L.	*	♦
Crepis biennis L.		♦
Cruciata glabra (L.) Ehrend.		♦
Cynosurus cristatus L.	*	♦
Cuscuta sp.		♦
Dactylis glomerata L.	*	♦
Daucus carota L.		♦
Deschampsia cespitosa (L.) P. Beauv.		♦
Dorycnium germanicum (Gremli) Rikli	*	♦
Epipactis palustris (L.) Crantz		♦
Euphorbia cyparissias L.	*	♦
Euphorbia verrucosa L.	*	♦
Euphrasia rostkoviana Hayne		♦
Festuca pratensis Huds.	*	♦
Festuca valesiaca agg.	*	♦
Filipendula vulgaris Moench	*	♦
Fragaria vesca L.		♦
Galanthus nivalis L.		♦
Galium mollugo L.		♦
Galium verum L.	*	♦
Genista tinctoria L.	*	♦
Gentianella ciliata (L.) Borkh.		♦
Gladiolus illyricus Koch	*	♦
Glechoma hederacea L.		♦
Globularia punctata Lapeyr.	*	♦
Gymnadenia conopsea subsp. *densiflora* (Wahlenb.) K. Richt.		♦
Helianthemum nummularium (L.) Mill.	*	♦
Helictotrichon pubescens (Huds.) Pilger	*	♦
Helictotrichon sp.	*	♦
Heracleum sphondylium L.	*	♦
Hippocrepis comosa L.		♦
Holcus lanatus L.	*	♦
Hypericum perforatum L.		♦
Hypochoeris maculata L.	*	♦
Inula hirta L.		♦
Juncus compresus Jacq.		♦
Knautia arvensis (L.) Coulter	*	♦

Table 1. *Cont.*

	Species Present in Relevé	Species Detected in Whole Meadow
Knautia drymeia Heuffel subsp. *drymeia*		♦
Koeleria pyramidata (Lam.) PB.	*	♦
Lathyrus vernus (L.) Bernh.	*	♦
Leontodon hispidus L.		♦
Lathyrus pratensis L.		♦
Leucanthemum ircutianum (Turcz.) DC.		♦
Lilium bulbiferum L.	*	♦
Linum catharticum L.		♦
Linum tenuifolium L.		♦
Linum viscosum L.	*	♦
Lolium perenne L.		♦
Lonicera caprifolium L.		♦
Lotus corniculatus L.	*	♦
Lotus corniculatus L. subsp. *hirsutus* Rothm.	*	♦
Luzula campestris (L.) DC.	*	♦
Lychnis flos-cuculi L.		♦
Medicago lupulina L.	*	♦
Melilotus officinalis (L.) Lam.		♦
Molinia caerulea (L.) Moench subsp. *caerulea*		♦
Onobrychis viciifolia Scop.	*	♦
Ononis spinosa L.	*	♦
Ophrys holosericea (Burm. f.) Greuter	*	♦
Anacamptis coriophora (L.) R. M. Bateman, Pridgeon & M. W. Chase	*	♦
Orchis militaris L.		♦
Anacamptis morio (L.) R. M. Bateman, Pridgeon & M. W. Chase		♦
Neotinea tridentata (Scop.) R. M. Bateman, Pridgeon & M. W. Chase	*	♦
Neotinea ustulata (L.) R. M. Bateman, Pridgeon & M. W. Chase		♦
Neotinea x dietrichiana (Bogenh.) H. Kretzschmar, Eccarius & Dietr.		♦
Neottia ovata (L.) Hartm.		♦
Ornithogalum pyrenaicum L.	*	♦
Orobanche gracilis Sm.		♦
Orobanche sp.	*	♦
Pastinaca sativa L.		♦
Petrorhargia saxifraga (L.) Link		♦
Peucedanum oreoselinum (L.) Moench	*	♦

Table 1. *Cont.*

	Species Present in Relevé	Species Detected in Whole Meadow
Phleum pratense L.		♦
Pimpinella major (L.) Huds.	*	♦
Pimpinella saxifraga L.		♦
Plantago lanceolata L.	*	♦
Plantago major L.		♦
Plantago media L.	*	♦
Platanthera bifolia (L.) Rich.		♦
Poa pratensis L.	*	♦
Polygala amara L.		♦
Polygala vulgaris L.		♦
Polygonatum multiflorum (L.) All.		♦
Potentilla erecta (L.) Raeusch.	*	♦
Primula vulgaris Hudson		♦
Prunella grandiflora (L.) Scholler		♦
Prunella laciniata (L.) L.		♦
Prunella vulgaris L.		♦
Prunus spinosa L.	*	♦
Ranunculus acris L.	*	♦
Ranunculus bulbosus L.		♦
Reseda lutea L.		♦
Rhinanthus glacialis Personnat	*	♦
Rhinanthus minor L.		♦
Rubus sp.	*	♦
Rubus caesius L.		♦
Rumex acetosa L.		♦
Rumex obtusifolius L.		♦
Salvia pratensis L.	*	♦
Sanguisorba minor Scop.		♦
Scabiosa triandra L.		♦
Sedum acre L.	*	♦
Sedum sexangulare L.		♦
Silene noctiflora L.		♦
Silene vulgaris (Moench) Garcke	*	♦
Seseli annuum L.	*	♦
Spiranthes spiralis (L.) Chevall.		♦
Succisella inflexa (Kluk) G. Beck		♦
Stachys recta L.		♦
Taraxacum officinale Weber in Wiggers		♦

Table 1. *Cont.*

	Species Present in Relevé	Species Detected in Whole Meadow
Teucrium montanum L.		♦
Thalictrum aquilegiifolium L.		♦
Thalictrum minus L.	*	♦
Thlaspi praecox Wulfen		♦
Thymus vulgaris L.	*	♦
Tragopogon pratensis L.	*	♦
Trifolium montanum L.	*	♦
Trifolium pratense L.		♦
Trifolium repens L.		♦
Trisetum flavescens (L.) PB.	*	♦
Veronica chamaedrys L.		♦
Veronica barrelieri Schott ex Roem. & Schult. subsp. *nitens* Host	*	♦
Viola hirta L.	*	♦
Vicia cracca L.	*	♦
SUM	163	

In a comparison of plant species inventory between the years 2001, 2002, 2003, 2016, 2018 and 2023, the highest number of species was recorded in 2003 (113 species) and 2023 (105 species), and the lowest in 2001 (48 species) (Table S1). From the point of view of the Jaccard and Sørensen similarity coefficients between individual inventories, the states of the recorded plant species were most similar in 2003 and 2023, and in 2003 and 2016 (Tables 2 and 3).

Table 2. Jaccard similarity coefficients of species inventory between the years 2001, 2002, 2203, 2016, 2018 and 2023.

	2001	2002	2003	2016	2018	2023
2001	1					
2002	0.385	1				
2003	0.387	0.513	1			
2016	0.301	0.443	0.554	1		
2018	0.267	0.430	0.350	0.419	1	
2023	0.354	0.495	0.603	0.504	0.434	1

Table 3. Sørensen similarity coefficients of species inventory between the years 2001, 2002, 2203, 2016, 2018 and 2023.

	2001	2002	2003	2016	2018	2023
2001	1					
2002	0.574	1				
2003	0.559	0.678	1			
2016	0.507	0.601	0.714	1		
2018	0.438	0.408	0.508	0.614	1	
2023	0.51	0.651	0.734	0.650	0.627	1

3.2. Analysis of Species Composition

A total of 82 plant species were recorded during the inventory of plant species within 25 relevés (Tables 1 and S2). The highest number of species per individual subplot was 28 and the lowest was 15. The average number of plant species per individual relevé was 21. According to the species accumulation curve, we have not yet reached the plateau of the number of species in the studied meadow with the 25 relevés surveyed (Figure 5), which is also shown by the upper limit of the 95% confidence interval. The estimated upper limit of the confidence interval is 92 species. Among the recorded species, 18 belong to monocotyledons (Poaceae and Cyperaceae), while all the rest are dicotyledons. *Peucedanum oreoselinum* was most often present in relevés, as it was recorded in each relevé. In addition to this species, *Bromopsis erecta* (96%), *Galium verum* (96%), *Briza media* (92%), *Brachypodium pinnatum* (88%) and *Salvia pratensis* (84%) were also present in several of the 20 relevés (Table 4). As many as 23 species were present in only one relevé.

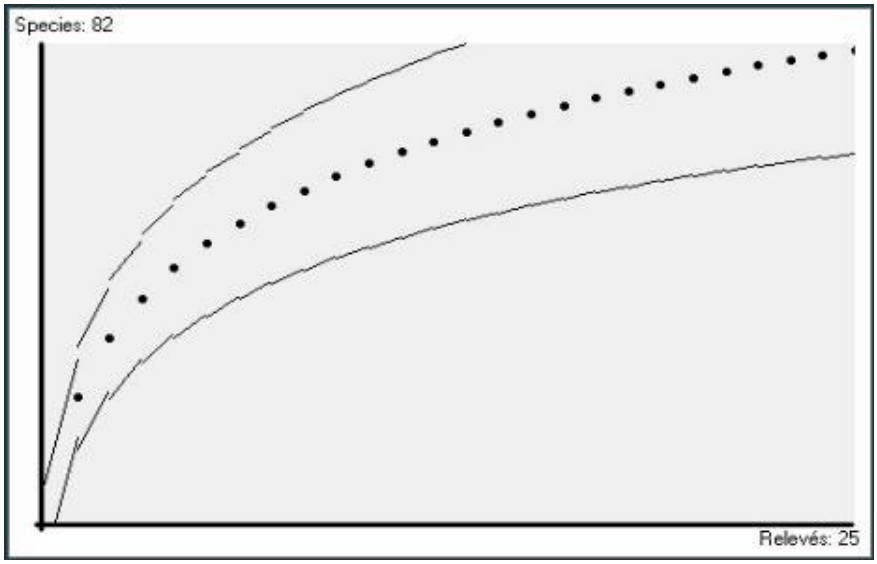

Figure 5. Species accumulation curve with associated 95% confidence interval limits for the dry meadow in Roje.

Species *Bromopsis erecta* (38.2%), *Cerastium* sp. (38%), *Euphorbia cyparissias* L. (38%), *Anthericum ramosum* (29.3%) and *Galium verum* (20.7%) had the highest average cover value in relevés. All other species had an average cover in relevés. under 20%, while as many as 67 species even under 10%. The maximum cover above 50% was reached in relevés by species *Brachypodium pinnatum* (63%), *Briza media* (63%), *Bromopsis erecta* (63%), *Galium verum* (63%), *Peucedanum oreoselinum* (63%) and *Rhinanthus glacialis* Personnat (63%).

While none of the recorded species were diagnostic, as many as 15 species were constant (*Betonica officinalis*, *Brachypodium pinnatum*, *Briza media*, *Bromopsis erecta*, *Campanula glomerata* L., *Centaurea scabiosa* L., *Cirsium pannonicum*, *Festuca pratensis* Huds., *Filipendula vulgaris Moench*, *Galium verum*, *Lotus corniculatus* L., *Peucedanum oreoselinum*, *Salvia pratensis*, *Trifolium montanum* Jacq.) and six species were dominant (*Brahypodium pinnatum*, *Briza media*, *Bromopsis erecta*, *Galium verum*, *Peucedanum oreoselinum*, *Rhinanthus glacialis*). As many as 21 species occurred only one time, which means that they were present in only one subplot. Among the constant species, species *Brahypodium pinnatum*, *Briza media*, *Bromopsis erecta*, *Galium verum*, *Peucedanum oreoselinum*, *Rhinathus glacialis* also had the highest maximum cover in subplots, which was 63%. Among the species recorded, 52 had a maximum cover in subplots between 2% and 15%, while 8 species (*Carlina acaulis*, *Gymnadenia conopsea*, *Helictotrichon pubescens*, *Lotus corniculatus* subsp. *hirsutus*., *Luzula campestris*, *Anacamptis coriophora*, *Neotinea tridentata*, *Seseli annuum*) had a cover of only 1%, which grants them the status of rare species in the inventory of the surveyed meadow.

Table 4. List of plant species with a percentage of frequency of occurrence in relevés above 50%.

	Frequency of Occurrence	Percentage of Frequency of Occurrence (%)
Betonica officinalis L.	18	72
Brachypodium pinnatum (L.) PB.	22	88
Briza media L.	23	92
Bromopsis erecta (Huds.) Fourr.	24	96
Campanula glomerata L.	13	52
Centaurea scabiosa L.	18	72
Cirsium pannonicum (L.f.) Link	16	64
Euphorbia verrucosa L.	18	72
Festuca pratensis Huds.	14	56
Filipendula vulgaris Moench	20	80
Galium verum L.	24	96
Lotus corniculatus L.	15	60
Peucedanum oreoselinum (L.) Moench	25	100
Salvia pratensis L.	21	84
Trifolium montanum L.	16	64

When analysing the co-occurrence of selected plant species with other plant species on the meadow, we found that the species *Gladiolus illyiricus* with a fidelity measure value above 50 occurs together with four other species (*Ranunculus acris*, *Cirsium pannonicum*, *Achillea millefolium*, *Genista tinctoria*). While the species *Anthericum ramosum*, *Veronica barelieri* and *Chamecytisus purpureus* mostly occur together (at fidelity measure values between 40 and 70), *n* also occurs together with the species *Anthericum ramosum* and *Veronica barelieri*. The species *Linum viscosum* occurs mainly together with the species *Festuca pratensis* and *Betonica officinalis*.

4. Discussion

As a result of traditional use of agricultural lands, which included mowing and grazing, species-rich dry meadows were formed in the past on carbonate soils. These are meadows without standing water with well-drained soils. Such meadows are rich in species, as up to 80 plant species can be present per square metre [55]. The results of our research indicate that the studied meadow in Roje on the edge of Ljubljana can also be classified among species-rich dry meadows. According to the Palearctic classification of habitat types, this meadow conforms to a habitat type of semi-dry meadows rich in orchids [4,56]. In terms of syntaxonomy, the meadow is classified in the *Festuco-Brometea* class, order *Brometalia erecti* and association *Bromion erecti* or into the *Onobrychion viciifolie-Brometum* community [29] (Figure 6. With 163 recorded species on two hectares and 82 species in 25 subplots (total area of 225 m^2), the meadow in Roje can be classified among meadows with high species diversity. The biodiversity of the surveyed meadow can also be compared with species-rich meadows elsewhere in Europe, such as semi-dry meadows in Eastern Europe. In a similar study, Roleček et al. [57] recorded 119 species on a subplot measuring 16 m^2 in Ukraine and 106 species on a subplot measuring 10 m^2 in Romania, but the inventory included mosses as well, whereas in our case it only includes flowering plants. These two locations are considered to be some of the most species-rich meadows in the Central Eastern European region [58]. In a similar study of the species diversity of meadows in Switzerland on the southern slopes above the village of Ausserberg [59], the average number of species on subplots measuring 10 m^2 was 26.8 species. A lower number of species than we inventoried on our studied meadow was recorded on dry meadows in the central part of the Czech

Republic [60], where the species diversity on investigated plots of 100 m^2 was only between 13 and 55 species. According to the species accumulation curve, the number of species present on the meadow in Roje has not yet peaked with the inventory on subplots, which means that with a larger number of surveyed subplots, the average number of species on the surface area of 9 m^2 would likely be higher. This is evidenced by the fact that during the general presence/absence record of plant species in all seasons, we noted almost as many species (81) outside the subplots as we inventoried within the subplots. With additional relevés, we could thus obtain additional information about the coverage of some species, which as of now we only recorded as present in the meadow.

Figure 6. Photo of dry meadow in Roje—Ljubljana.

When comparing the number of species present in the 2001 inventory and later inventories, a significant difference was observed. In 2001, almost half as many species were inventoried as in later years, among which the years 2003 and 2023 stood out. The reason for the greater number of inventoried species in these two years is primarily that a larger unit of effort was invested in the inventory. Namely, in 2003, for the first time in all seasons, we recorded the presence of plants due to the inclusion of the meadow survey in the project of preserving the biodiversity of diverse habitats of the Ljubljana Municipality. In 2023, however, as already mentioned, the inventory also took place during all seasons. The reason is that in 2001, we did not conduct a thorough inventory.

Despite the fact that not all inventories were carried out with the same unit of effort, it is worth paying attention to those species that appeared in the inventory between 2001 and 2003 and were no longer recorded after 2016, or to those species that we did not notice in the first years on the meadow, but we only found them in 2023. This could be either a rare species or a species turnover in twelve years, in which case an analysis of the population dynamics of these species would also be necessary to confirm the species turnover.

As expected, the studied meadow is predominantly covered by species with the Central to Southern and Eastern European chorotype. Slovenia lies at the transition between Central, Southern and Eastern Europe, and the studied meadow actually already lies in the pre-Alpine geographical region [46]. For this reason, the presence of some species characterised by one of the five Mediterranean types of distribution is definitely interesting [52]. For example, the subspecies *Veronica barrelieri*. subsp. *nitens* Host with a north-eastern Mediterranean-mountain chorotype is present in the part of the meadow with the shallowest and sandiest soil. The subspecies grows primarily on dry, sunny, sandy

and stony soils on calcareous grasslands in the sub-Mediterranean, Dinaric, sub-Pannonian and pre-Alpine regions [9,61,62]. This subspecies even has its *locus classicus* along the Sava River near Ljubljana, i.e., in the area where this meadow is located. The subspecies was described by N. T. Host in 1827 as *Veronica nitens*, namely on the basis of specimens sent to him by the then-head of the University Botanic Gardens Ljubljana, Franc Hladnik [63]. Hladnik collected the specimens on meadows by the Sava River. Considering that the subspecies is still present on this meadow, it indicates that traditional management has allowed for the preservation of the species from 1827 in at least some areas. In addition to subspecies *Veronica barrelieri* subsp. *nitens*, there is also the species *Chamaecytisus purpureus* with a similar type of distribution, also growing in shallow and dry locations. It represents a remnant of the association of pine forests *Pinetum-Genistetum januensis*, which once grew also on the terraces of the Sava River, where the studied meadow is located [44,45]. The flowers of *Chamaecytisus purpureus* appear in this meadow in shades of colour ranging from pinkish–white to dark pink, which indicates a large intra-species variability in the population present on the meadow. In 2013, we also found well-developed specimens with white flowers on the meadow for the first time [64,65] (Figure 7). Again, in the shallowest sandy southern section of the meadow, there are also three species of orchids (*Anacamptis coriofora*, *Anacamptis pyramidalis* (L.) Rich. and *Neotinea tridentata*) whose area is primarily in the Mediterranean region. *Anacamptis coriofora*, which is characteristic of higher altitudes in the Mediterranean [66], otherwise occurs in Slovenia mainly in southern and south-western Slovenia [67,68], while *A. pyramidalis* is predominantly a Western European-Mediterranean species [66]. Another plant that has its locus classicus in Slovenia (around Idrija) is *Neotinea tridentata* [69,70], with its area extending all the way from North Africa through the Mediterranean to England [66]. In the same part of the meadow where the previously mentioned species were present, we also observed the presence of species *Inula hirta* L. for the first time during the survey in 2023. The species is characteristic of dry meadows, sunny and rocky slopes with shallow soils [61,71] and has a locus classicus in Slovenia (Mt. Nanos) [69] on the border between the sub-Mediterranean and Dinaric regions. Similarly, *Onobrychis viciifolia* is also found here, but it has its locus classicus in dry meadows around Senožeče [69,70]. The next species with the locus classicus in Carniola in Slovenia, *Sanguisorba minor* [69], also originates from dry meadows.

Figure 7. Photo of white *Chamaecytisus purpureus* found in dry meadow in Roje—Ljubljana.

During the several years of our species diversity study in the meadow, we were particularly focused on monitoring the population dynamics of the species *Gladiolus illyricus* as a protected plant species, *Chamecytisus purpureus* as a species recorded on this site as early as 1940 [44] and the species *Epipactis palustris* and *Astrantia major*, which are otherwise

characteristic of moist soils. Monitoring the populations of the latter is interesting mainly because they confirm the existence of microhabitats with moist soil within the dry meadow. In the middle third of the meadow on the eastern side, there is a larger population of *Gladiolus illyricus*. When we began the monitoring project, *Gladiolus illyricus* was present with populations of up to 30 individuals on the extreme south of the meadow, next to the bushes in the middle of the meadow and on its northern third [15,29,30]. According to the latest surveys, the species has an extensive and contiguous population spreading from the northern third of the meadow to the middle, despite the fact that every year a considerable number of seeds is gathered from the population for the seed bank (Figure 8). We also monitored the multi-year growth dynamics in the meadow of *Chamaecytisus purpureus*, where we noticed better growth during drier years. During such years, grasses do not smother it and the species can grow without restriction. Its growth is also strengthened when no mowing occurs in the year by the occasional skipped mowing, which we noticed in 2013. In 2012, because of the severe drought, we skipped mowing the meadow, so in the wet spring of 2013, the purple broom grew strongly and bloomed profusely [64].

Figure 8. Population of *Gladiolus illyricus* in Roje—Ljubljana dry meadow.

Although the meadow in Roje with an area of 2 hectares does not represent a very large meadow from the point of view of grasslands, it is a hot spot of biodiversity within the intensively cultivated agricultural land. The reason for the rich species diversity can be found in the intertwining of the location itself and its proper management. According to oral testimonies of the owners, the meadow had not been intensively used since at least 1990, and according to the owners' knowledge, the meadow had never been fertilised. It was mown only occasionally, which prevented it from becoming overgrown with scrub vegetation. From this perspective, it was managed similarly to single-mowing alpine meadows, which were traditionally mown once in late summer and were never fertilised [11]. The owners also said that when they were still managing it, they had already noticed different types of plants which were typical for higher-lying single-mowed meadows. By leasing and taking over the meadow for potential in situ protection, we utilised even more careful management and increased the number of species and the population of certain species. From the perspective of protection of individual species, it is encouraging that the populations of protected plants, such as orchids and *Gladiolus illyricus*, have increased, which together represent as much as 11% of all meadow species in Roje [39]. Utilising traditional management methods, which include mowing no more than three times a year,

whereby the first mowing must be after the plants have finished flowering and seeding, and with the traditional harvesting of hay, we can therefore maintain and even increase the species diversity of meadows [9,11]. Traditional management of meadows was also cited by Roleček et al. [58] as the reason for rich species diversity. As already mentioned, the location of the meadow also affects the variety, since the meadow is located at the junction of two biogeographical regions: Alpine and Dinaric. Each biogeographical region, with its climate–geographical characteristics, influences the occurrence of certain plant species, resulting in higher species diversity of such junction areas. A similar finding was reached in the study of dry meadow communities in Bulgaria in the transition zone between the South-Eastern European region and the Mediterranean region [72].

5. Conclusions

Meadows are one of the fastest disappearing habitat types, and it is precisely meadows that can boast a great diversity of plant species. The species diversity of meadows is mainly threatened by overgrowth (abandonment of land use) and intensive agriculture with fertilisation, as well as early mowing and baling. It is for this reason that any meadow on which a rich diversity of species is recognised can represent an in situ possibility of protecting meadow plant species. At the same time, it can also be a donor site for the revitalisation of intensively cultivated areas or a source of seed material for other areas intended for the revitalisation of meadows. According to the latest data, we recorded a total of 163 species in the meadow, of which 82 were recorded in the relevés. Of the recorded species, as many as 18 are on the list of protected plant species in Slovenia. The protected plant species represent 11% of all species growing on the meadow. In the meadow, mainly species with a Eurasian distribution are present. The meadow is classified in the class *Festuco-Brometea*, order *Brometalia erecti* and association *Bromion erecti* or into the *Onobrychion viciifolie-Brometum* community. The meadow mainly contains plant species typical of dry meadows, while the occurrence of species such as *Epipactis palustris* and *Astrantia major* indicates the presence of moist microhabitats. Among the species recorded in the subplots, as many as 15 were constant and were more or less evenly distributed over the surface. Compared to similar meadows in Europe, the studied meadow belongs to species-rich meadows. Because of environmental pressures such as agricultural areas overgrown with invasive plant species, it is necessary to continue to monitor the presence of plant species on the meadow and monitor their populations. At the same time, of course, it is also ne33cessary to ensure proper management of the meadow.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13030315/s1, Figure S1: Average month precipitation graph for Ljubljana for year 2023 (source: https://meteo.arso.gov.si/ (3 November 2023)); Figure S2: Average month temperature graph for Ljubljana for year 2023 (source: https://meteo.arso.gov.si/ (15 November 2023)); Table S1: List of plant species present in inventory in years 2001, 2002, 2003, 2016, 2018 and 2023; Table S2: The presence and coverage of individual plant species in 25 relevé according to the Braun–Blanquet method.

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