Assessment of ex-arable land conversion in grassland restoration program using local or commercial seed mixtures in Gers (32 - France)

Three-year-old hay meadow sown with a local seed mixture in the Gers (France)

Master’s degree in Life Science

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Summary

This study evaluates the early trajectories of semi-natural grasslands in agricultural landscape by comparing three grassland conditions: restored with local seed mixtures, restored with commercial seed mixtures, and target reference grasslands. The main objective was to analyze the evolution of plant composition, functional diversity and patterns, as well as successional dynamics during the first three years post-restoration. Target grasslands displayed high species richness and a diverse syntaxonomic composition, encompassing three main syntaxons (*Agrostietea stoloniferae*, *Arrhenatheretea elatioris* and *Festuco-Brometea*) that collectively provided a broad functional spectrum. Commercial grasslands (restored with commercial seed mixtures) were dominated by perennial, tall, competitive grasses promoted by residual soil nutrient enrichment. These species-poor seed mixtures used for restoration, with a low occurrence of target species and a structural dominance of the resulting communities, constrained target species recruitment and overrode the expected annual-dominated stage, and are expected to slow progression toward later successional stages. These communities exhibited low functional diversity, most likely linked to strong competitive exclusion. In contrast, Local grasslands displayed higher species and functional diversity, resulting from the combined influence of local and commercial seed mixtures, the soil seed bank, and possibly dispersal inputs. A greater target species occurrence and trait functional similarity to Target grasslands was found. Finally, seed mixture composition used for restoration appeared as a major driver of early successional trajectories. Long term monitoring, integrating landscape-scale processes and soil historical legacies may help to better understand variability in grassland trajectories.

Key words : Grassland restoration • Local seed mixture • Commercial seed mixture • Ex-arable land conversion • Succession

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Table of Abbreviations

CBNPMP	Conservatoire Botanique National des Pyrénées et Midi-Pyrénées
CWMs	Community Weighted Means
DCA	Detrended Correspondence Analysis
FD	Functional diversity
FD$_Q$	Functional diversity - Quadratic entropy
DCA	Detrended Correspondence Analysis
NMDS	Non-metric Multidimensional Scaling
SD	Standard Deviation

1 . Introduction

Grasslands are usually considered as habitat dominated by grass species with infrequent or absence of woody species, they occupying 31 to 43% of the Earth's surfaces (**Gibson, 2009; Sala, Vivanco & Flombaum, 2013**) Grasslands are globally related to a wide and rich biodiversity also linked to many ecosystemic services—which are advantages for human societies (**Daily, 1997**)—and historical uses as agriculture or domestic livestock (**Gibson, 2009**), and are notably maintained through management practices as mowing or grazing (**Sollenberger et al., 2012**). Nevertheless, grasslands are subjected to numerous threats, as the intensification of the practices using inputs, introduction of productives species (**Mayel, Jarrah & Kuka, 2021**), repetitive pasture or mowing, negligence (**Gallagher & Wagenius, 2016**), as well as erosion of ecological connectivities within the landscape (**Aavik & Helm, 2018**). During the last decades, grasslands decreased due to agricultural exploitation (**Brouwer & van der Straaten, 2002**). To overcome these threats, initiatives emerged, such as the European LIFE funding program (established in 1992), which supports initiatives addressing climate, environmental, and nature conservation challenges. The LIFE Coteaux-Gascons project was initiated in 2020 through a collaborative effort between ADASEA Gers, SAFER Occitanie, the Conservatoire Botanique des Pyrénées et Midi-Pyrénées (CBNPMP), and the CPIE Pays Gersois—associations and public organizations dedicated to environmental conservation, ecological transition, and sustainable management of agricultural landscapes. The Coteaux-de-Gascogne refers to a territory within the Gers department (32) in southwestern France, covering approximately 260,000 hectares and characterized by open agro-pastoral habitats. Over recent decades, grasslands have been in decline due to the intensification of agricultural practices within the Occitanie region (**DRAAF Occitanie, 2020**). These landscapes own some habitats of community interest like low-land hay meadows (HIC6510) as referred to in the *Habitats Directive* (**Council of the European Communities, 1992**). In response to threats faced by open agro-pastoral habitats at the LIFE Coteaux-Gascons scale, such as the decreasing of open agro-pastoral habitats conservation status and the disruption of their ecological continuities, intensification of agricultural practices, and the interdependence of biodiversity and grazing, a total budget of €3,534,968 has been allocated to support cross-disciplinary actions—spanning social, economic, and ecological dimensions. The global objective is to restore and preserve the ecological continuity in open agro-pastoral habitats.

The objective of the CBNPMP in collaboration with the UMR1201 INRAE-Dynafor, is to assess efficiency of grasslands restoration measures using commercial or local seed mixtures. A successful restoration would be considered if a convergence to identified target grasslands within the department having a plant community presenting satisfying species saturation level. Local seed mixtures are seeds collected directly among target grasslands, presenting a high species diversity, while commercial seed mixtures (from the COUVER06 program) present a low diversity (until 11 species) and are composed of selected, agronomic species obtained from seed producers.

The ecological restoration seeks to initiate or accelerate ecosystem recovery following damage, degradation, or destruction (**Society for Ecological Restoration, n.d.**). While passive ecological restoration is widely applied in grassland restoration as a cost-effective approach (**Prach & Hobbs, 2008**), relying on natural regeneration processes and spontaneous succession, active restoration—through the use of plant material and mechanical interventions—can accelerate and optimize these natural mechanisms (**Kiehl et al., 2010 ; Török et al., 2011**). Restoration can refer to removing invasive species, or reintroducing a lost species or a lost ecological function (**Society for Ecological Restoration, n.d.**). As local ecotypes are generally better adapted to their native environments, the use of commercial seed sources may reduce genetic diversity and dilute locally adapted gene pools (**Lesica & Allendorf, 1999; Wilkinson, 2001; Gallagher & Wagenius, 2016**) which may threaten longterm species persistence (**Hoffmann & Sgrò, 2011**). The commercial seed mixtures are often composed of low-diversity, highly competitive species, which can limit the recruitment of new species and slow successional dynamics (**Marrs, 1993; Manchester et al., 1999; Lepŝ et al., 2007**). Competitive communities can also act as barriers to seedling recruitment (**Török et al., 2009**), also hindering regeneration processes led by propagules abilities to disperse which are known to be limited (**Ruprecht, 2006**). In contrast, high-diversity seed mixtures or those including late-successional species—which do not exclude competitive species—are associated with greater long-term restoration success (**Manchester et al., 1999; Van der Putten et al., 2000; Lepŝ et al., 2007**). Nevertheless, both commercial and local seed mixtures can ultimately meet grassland restoration objectives, although commercial often require longer timeframes to do so (**Prach et al., 2014**).

The literature provides detailed descriptions of grassland successional dynamics which are in part influenced by individual fitness and dispersal modes. In the process of grassland restoration, four main stages are generally expected (**Collins & Adams, 1983**): (1) the *pioneer species stage*,

rapidly followed by (2) the *annual species stage*—both with a cooccurrence of ruderal and annual competitive species, primarily driven by the soil seed bank and dispersal processes (**Brown & Southwood, 1987; Maharning, Mills & Adl, 2009; Török et al., 2010**); (3) the *herbaceous perennial species stage* associated to decrease of species turn-over and species richness due to competitive-exclusion of weak competitors (**Török et al., 2010**); and finally, (4) the *late perennial community stage*, expecting a dominance of perennial, erect, and tall individuals forming functionally specific communities (**Fukami et al., 2005**), including progressive recruitment of late-stage species.

This study aims to evaluate plant community restoration using either local or commercial seed mixtures within an agricultural landscape. Our main objective was to assess whether grassland restoration using local seed mixtures accelerates the early taxonomic and functional convergence toward target plant communities, compared with commercial seed mixtures. More specifically, we investigate the following questions :

[1] Does ecological restoration of agricultural grasslands using local versus commercial seed mixtures promote a faster convergence of plant communities composition toward target grasslands after sowing?

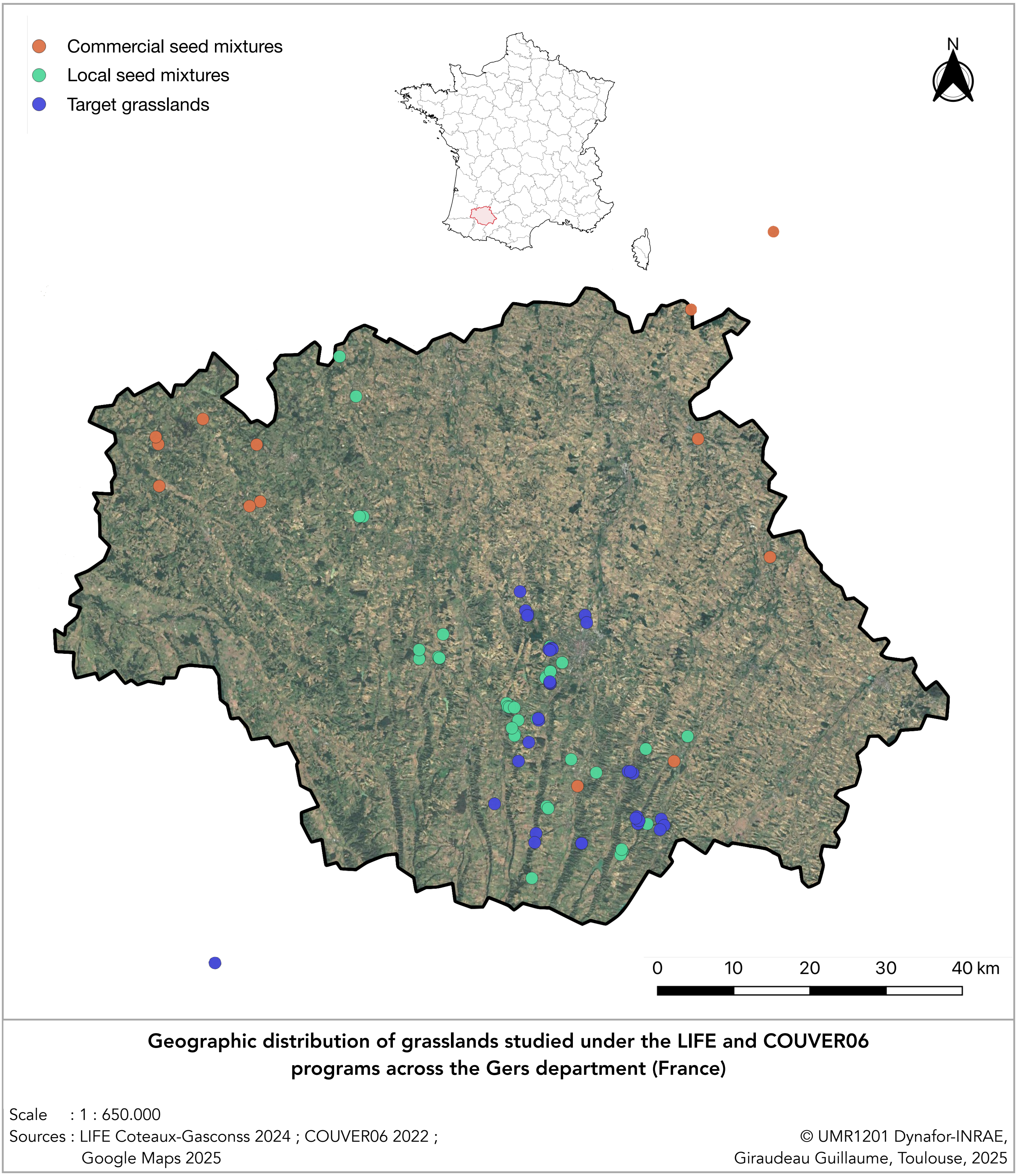
(Hypothesis 1) Commercial seed mixtures are composed of competitive species with limited adaptation to local environmental conditions. Consequently, they will constrain community development and delay the convergence toward target grasslands.

(Hypothesis 2) Local seed mixtures, sourced from target communities, will result in plant communities that are more similar to the target grasslands and will facilitate a faster successional trajectory compared to commercial mixtures.

[2] Do the functional traits of restored grasslands differ between local and commercial seed mixtures during the first three years, and do they converge toward the expected functional profiles?

(Hypothesis 1) Local seed mixtures are expected to promote functionally closer communities to those observed in Target grasslands, whereas the low-diversity commercial seed mixtures are likely to result in more functionally constrained and distinct trait patterns due to their competitive species composition.

(Hypothesis 2) The lower competitive pressure in grasslands restored with local seed mixtures will foster greater functional diversification by promoting the establishment of a broader range of target traits, contributing to increased community complexity.



Map. 1. Spatial distribution of age 1 to 3 studied grasslands within the Gers department, southwestern France. Target grasslands are included from the LIFE program. Number of *Commercial* = 13, *Local* = 43, and *Target* grasslands = 34 (coordinates for all 50 referential grasslands were not available).

2 . Material and Methods

2. 1 - *Study Area*

The study was conducted on grasslands located across the Gers department (France) (**Map. 1**), which covers a total area of 6,257 km² (43°43′ N; 0°6′ E). The department is predominantly characterized by various agricultural practices, which in 2020 occupied 4,484.99 km². Over the past five decades, croplands and managed lands have continued to expand at the expense of natural landscapes in the department. They are mostly represented by agricultural cultivation (40%), animal farms (35%) and viticulture (17%; **DRAAF Occitanie, 2020**). According to **INSEE** (**2023**), the population density was 30.8 inhabitants per km² in 2021, significantly below the national average of 108 inhabitants per km². Gers experiences an oceanic climate, with a mean annual temperature of 13.4 °C and average annual precipitation of 847 mm (**Climate-Data, 2025**). Topographically, the elevation ranges from 60 to 390 meters, gradually decreasing towards the north. The landscape is predominantly hilly, with clay-rich molasse formations on hilltops and colluvial deposits along the slopes, which are favorable to agriculture. These are interspersed with numerous valley bottoms characterized by fertile alluvial deposits.

2. 2 - *Grasslands sample*

Three categories of grasslands were included in this study, hereafter: grasslands restored using commercial seed mixtures (“Commercial”) ; grasslands restored using local seed mixtures (“Local”) and target, reference grasslands (“Target”).

Sixty grasslands were restored using commercial seed mixtures between 2007 and 2020. Plant communities were monitored in 2022 in the COUVER06 program (**Prud’Homme et al., 2023**) led by the CBNPMP, which preceded the current LIFE initiative. This study includes grasslands sown one (n = 3), two (n = 7), and three (n = 3) years before monitoring. They are located in the northwestern part of the department, on alluvial substrates, while others lie on molasse or gravity deposits. Global grasslands areas range from 0.67 to 8.38 ha, with slopes from <1° to 27° and altitudes between 62 and 300 m. Seed mixtures included *Lolium perenne, Onobrychis viciifolia subsp. viciifolia, Schedonorus arundianceus, Dactylis glomerata, Trifolium repens, T. pratense, T. incarnatum var. incarnatum*, *Lotus corniculatus, Medicago sativa subsp. sativa* and *Phleum pratense*, although species composition varied based on grassland conditions and management goals.

Image. 1. Photographs of grasslands sown with local seed mixtures. Panels **A–B**: One year old grasslands. Panels **C–D**: Two years old grasslands. Panels **E–F**: Three years old grasslands. **Note**: occasional grazing (E) and crushed (D) management on certain grasslands have influenced community structure and reduced vegetation homogeneity.

Grasslands restored using local seed mixtures belong to the ongoing LIFE program, with 43 grasslands sown between 2022 and 2024. This study include grasslands sown one (n = 30), two (n = 9), and three (n = 4) years before monitoring (**Image. 1**). They are located in the central and south-central areas of the department, on molasse or gravity-derived substrates. Global grasslands areas range from 0.14 to 13.48 ha and elevations from 95 to 295 m. Seed mixtures were directly harvested from nearby Target grasslands by brushing or cutting, with no species selection. In most cases, local mixtures were blended with commercial ones (0–50%) to meet first year forage production requirements. The exact seed source varied across grasslands depending on local availability.

Fifty Target grasslands were identified by CBNPMP as species-rich and representative of late-successional stages. Grasslands are estimated to be at least 10 years old, with some exceeding 20 years. They are also located in the central and south-central parts of the department, on similar substrates, with areas ranging from 0.2 to 52.88 ha and altitudes between 125 and 295 m.

2. 3 - Sampling method

Plant community composition and structure was monitored by the CBNPMP using a standardized stigmatist phytosociological survey method (**Braun-Blanquet, 1928**). This method involves surveying a representative, predominant, and homogeneous vegetation patch by recording all vascular plant species, using presence–absence data and cover estimates based on the Braun-Blanquet classification system, within a minimum area of 20 m², continuing until no additional species are encountered. All inventories were conducted in May, in 2022 for commercial seed mixtures, 2025 for local seed mixtures et no year information was given for Target grasslands.

2. 4 - Trait species selection

To assess the functional dynamics of plant species during the first three years following sowing, we selected a set of functional traits commonly used in the literature to illustrate early dynamical successions (**Landsberg, Lavorel & Stol, 1999; Rodríguez et al., 2003; Kahmen & Poschlod, 2008**). The traits considered were: plant height (maximum, minimum, and mean), lifespan, phenology (start, end, and duration of flowering), nitrophily, and pollination mode. We focused on traits available for botanical data in the public database *Baseflor* (**Julve, 1998**) and the literature source *Flora Gallica* (**Tison & de Foucault, 2014**), and compiled a trait database by cross-referencing all inventoried species. *Plant height* (in cm) was selected as a proxy for nutrient-use strategy and competitive ability (**Westoby, 1998; Funk et al., 2016**).

Lifespan (binary) followed Raunkiaer's classification (**Raunkiaer, 1934**) of plant strategies to survive winter cold, allowing us to distinguish the shift between annuals (0–therophytes) and perennials (1–geophytes, hemicryptophytes) during the successional dynamic. *Phenology* (in months) was described through the species' flowering period, including start, end, and duration. *Nitrophily* reflects the species' affinity for nitrogen-rich environments, based on Ellenberg indicator values (**Ellenberg, 1992**), and serves as a proxy for disturbance tolerance. *BioticVector* (binary) was considered as an indicator of resource availability and the dispersion of propagules: abiotic pollination (0–anemogamy, autogamy) versus biotic pollination (1–entomogamy). All identifications limited to the genus level or higher, to woody species, to non-native cultivated species, as well as and duplicate records were excluded from the analysis.

2. 5 - Data processing and statistical analyses

We characterized the syntaxonomic classes of the Target grasslands to provide an insight of their ecological patterns. We first followed the statistical method of **Assini et al., (2014)** using Braun-Blanquet cover-abundance scores converted into percentage cover values (+ = 0.1%, 1 = 5%, 2 = 17.5%, 3 = 37.5%, 4 = 62.5%, 5 = 87.5%) into a hierarchical classification with a Euclidean distance matrix, appropriate for quantitative data, combined with complete linkage agglomeration to reduce bias toward highly abundant species. Then, syntaxonomic classes were associated to grasslands by considering the maximum occurrence of species associated to classes using the unreleased database FlorealData 2 developed by the phytosociologist François Prud'Homme from the CBNPMP, which is a translation of the *Prodrome des végétation de France* (**Roux, Bioret & Thébaud**, **2024**). Finally, we optimized the clustering ordination using the phytosociological diagonalization method. Syntaxons were subsequently validated by the CBNPMP.

Considering the available temporal data for grasslands, we selected data from one to three years after restoration in both Commercial and Local conditions. Data cleaning included the correction of input errors and the exclusion of outliers showing clear ecological inconsistencies. To ensure statistical robustness and comparability across grassland conditions, the sample sizes from the Local and Target grasslands were bootstrapped to match the Commercial dataset (total = 13: 1-year-old = 3, 2-years-old = 7, 3-years-old = 3). The bootstrap model is a resampling-based method designed to capture the maximum representative variance of the overall dataset. It was based on Braun-Blanquet cover-abundance scores converted into percentage cover values and replicated 1000 times. From these iterations, the subset of Local and Target grasslands exhibiting the highest within-condition variance was selected to represent the final sample.

Finally, the total sample size was : 39 grasslands (Local = 13; Commercial = 13; Target = 13).

We compared species traits values between sowing condition using ANOVA models to analyse difference in the variance of community-weighted means (CWMs) calculated on species percentage cover values. To avoid projection bias due to small sample sizes in some age groups (e.g. 1year-old and 3-year-old grasslands, n = 3 each), data were pooled across all ages and analyzed by grassland conditions. CWMs were incorporated into a correlation matrix to examine inter-trait relationships. Some selected traits showed strong correlations (thresholds > 0.8 or < –0.8): *Minimum Plant Height* × *Mean Plant Height* (r = 0.82), *Maximum Plant Height* × *Mean Plant Height* (r = 0.99) and *Late Flowering* × *Long Flowering* (r = 0.93). We selected *Mean Plant Height* as a unique growth-related variable as well as *Early Flowering* and *Late Flowering* to explain phenology. We assessed the normality of residuals using the Shapiro–Wilk test and checked for homoscedasticity with Levene's test. When both assumptions were satisfied, a one-way ANOVA was performed, followed by Tukey's HSD post hoc test. Although *BioticVector* deviated slightly from normality, it was selected due to an acceptable visual distribution. When assumptions were violated, a non-parametric Kruskal-Wallis test was applied, followed by pairwise Dunn tests. Significance thresholds were set at $p < 0.05$ and $p < 0.01$ for Dunn test to reinforce the model robustness and limit type I error.

We calculate the Quadratic Entropy index (Rao's Q; **Botta-Dukát, 2005**) of the functional diversity (FD) by using the *FD package* (**Laliberté, Legendre, & Shipley, 2014**). The Rao's Q (FD_Q) index is a deviation of the Simpson index which expresses the average difference of functions between two randomly selected individuals with replacements (**Botta-Dukát, 2005**). This analysis was conducted on the following functional traits: *BioticVector, Nitrophily, Mean Plant Height, Early* and *Late flowering.* Then, *Lifespan, Maximum* and *Minimum Plant Height,* and *Flowering long* were excluded due to insuffisant variability as required by FD_Q, and also to avoid trait correlation in FD_Q calculations. Trait values were standardized based on traits standard deviation using species percentage cover values to equally weighted traits in the measure (**Botta-Dukát, 2005**).

According to **Prach et al., (2014**), we applied the Detrended Correspondence Analysis (DCA) using the *Vegan package* (**Oksanen et al., 2008**), an unimodal ordination method, to explore theoretical species optima and their occurrence patterns across grasslands and following an ecological gradient. The analysis was performed on a site-by-species matrix in long format, using percentage cover values that were logarithmically transformed to reduce the influence of dominant

species and provide a better insight of rare species. DCA is appropriate when the length of the first ordination axis exceeds 4 standard deviation (SD) units, which typically indicates major community turnover—i.e., a replacement of at least 50% of the species along the ecological gradient (**Lepš & Šmilauer, 2003**). The choice of the DCA was supported by the standard deviation value of the model (SD = 5.05). To facilitate interpretation, isoclines were added to the ordination plots using the number of target species as an informative variable.

The similarity between sown conditions and Target grasslands were assessed using Non-metric Multidimensional Scaling (NMDS) using the *Vegan package* (**Oksanen et al., 2008**). We constructed two Sites × Species matrix based on both percentage cover values and presence-absence data. NMDS was performed using the metaMDS function with Bray-Curtis distances for abundance data and Jaccard distances for presence-absence data. Analyses were run with 1,000 permutations and represented in two dimensions ($k = 2$). To assess the homogeneity of multivariate dispersion among age or seed condition groups, we used the betadisper function ($p \geq 0.05$), confirmed with TukeyHSD post-hoc test ($p < 0.05$), then followed by a PERMANOVA to test for significant differences between group centroids. Analysis were conducted on R software (4.4.2).

3 . Results

3. 1 - Plant data

We report here the botanical survey data across the studied grassland conditions (Commercial, Local and Target), using bootstrapped samples to enable reliable comparisons of phytosociological protocols. The phytosociological surveys recorded a total of 47, 99, and 101 plant species in the Commercial, Local, and Target grasslands, respectively. Species richness per grassland ranged from 3 to 24 in Commercial, 10 to 48 in Local, and 17 to 32 in Target grasslands, with an average of 11, 24, and 25 species, respectively. Most species were classified as *Least Concern* (LC) according to the regional conservation status, with 45 (Commercial), 92 (Local), and 94 (Target) LC species recorded. Notably, only Target grasslands included a specie with *Vulnerable* (VU) status within the Gers department: *Euphorbia verrucosa*. A total of 10 (Commercial), 30 (Local), and 29 (Target) species were identified as ZNIEFF determinant species (Zones Naturelles d'Intérêt Écologique, Faunistique et Floristique). Additionally, 1, 3, and 1 cultivated species were recorded (*Avena sativa, Cichorium endivia, Vicia sativa*), along with 0, 2, and 1 introduced species

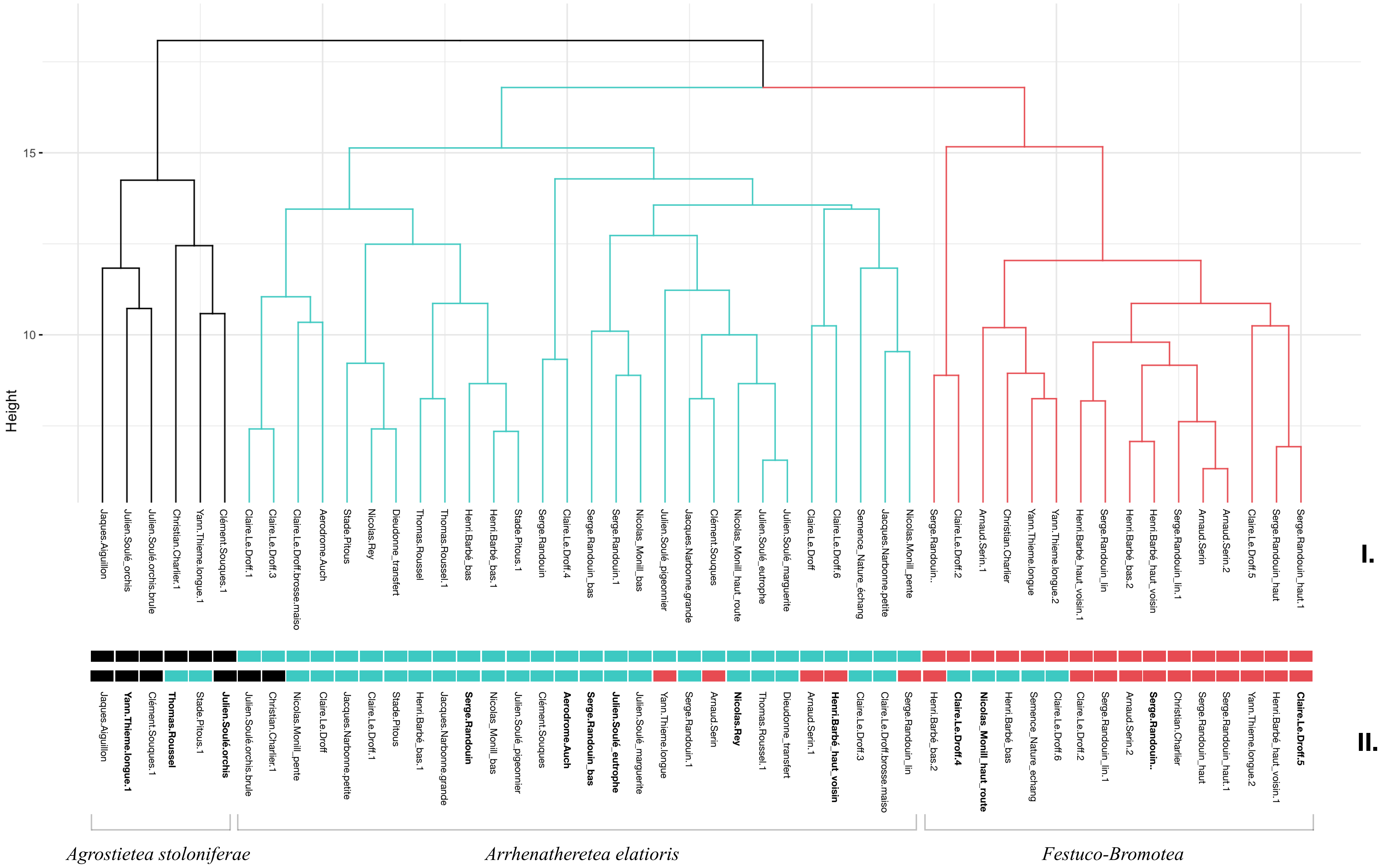


Fig.. 1. Hierarchical classification following the method of **Assini et al (2014)** with the the statistical analyse for identification of syntaxonomic classes among Target grasslands **(I.),** and phytosociological analyse resulting in a second ordination **(II.)**. Syntaxonomic classes were identified using FlorealData 2. ***k*** = 3. **Bold** nomenclatures = Target grasslands selected into the bootstrapped model. **n** = 50.

(*Crepis sancta, Veronica persica*) in Commercial, Local and Target grassland conditions, respectively. One cryptogenic taxon was identified in the Local grassland conditions: *Arrhenatherum elatius subsp. bulbosum*, based on the **INPN** (**2025**) data. The global botanical campaign (non bootstrapped) observation refers to a total of 228 vascular plant species among the 106 grasslands from one- to three- years and Target grasslands.

3. 2 - Target grasslands clustering

The clustering analysis segmented Target grasslands into three groups (k = 3) corresponding to syntaxonomic classes (**Fig. 1**). This level of segmentation was chosen to preserve interpretation at the class scale and to highlight broad ecological trends among Target grasslands. Based on the literature, the identified classes were *Agrostietea stoloniferae* (n = 6; **de Foucault & Catteau, 2012**), *Arrhenatheretea elatioris* (n = 28; **de Foucault, 2016**), and *Festuco-Brometea* (n = 16; **Royer & Ferrez, 2020**). These syntaxonomic classes, all associated with grassland habitats, differ mainly along a moisture gradient. *Agrostietea stoloniferae* grasslands are linked to mineral, mesotrophic to eutrophic soils, often subject to clogging and flooding, with characteristic species such as *Agrostis stolonifera, Holcus lanatus,* or *Ranunculus acris*. *Arrhenatheretea elatioris* correspond to mowed or lightly grazed grasslands, ranging from mesohygrophilous to mesophilous and mesotrophic to eutrophic conditions, with species like *Arrhenatherum elatius* or *Dactylis glomerata*. Finally, *Festuco-Brometea* are characterized by grasslands dominated by hemicryptophytic species under mesophilous to xerophilous conditions, with species such as *Ononis spinosa* and *Bromopsis erecta*.

3. 3 - Composition similarity between restored and target grasslands

Calibration of the NMDS ordination method referring to community composition (presence-absence) and community structure (Braun-Blanquet scores) was performed, with Stress = 0.185 and 0.211, respectively (**Table. 1**). A Betadisper test was applied following the NMDS to verify the homogeneity of dispersion within grassland age categories and grassland conditions groups. We globally observed homoscedasticity in groups dispersion, except for the community composition with age groups (ANOVA $p = 0.022$), and for community structure with grassland conditions groups (ANOVA $p = < 0.01$). The Tukey HSD post-hoc test indicated that comparisons of *1-year-old* × *3-years-old* groups ($p = 0.028$) with presence-absence data, and *Commercial* × *Local*, *Commercial* × *Target* grasslands categories ($p = < 0.01$) with cover percentage values are not valid due to heterogenous dispersion around centroids (**Table. 1**).

	A	*B*		*A*	*B*
Stress	0.185	0.211		0.185	0.211
Betadisper	**0.022**	0.098		0.944	**<0.01**
TukeyHSD					
• *Age groups*			• *Grassland groups*		
1-2	-	-	*C-R*	-	**<0.01**
3-1	**0.028**	-	*C-L*	-	**<0.01**
3-2	-	-	*Tar-L*	-	-
Tar-1	-	-			
Tar-2	-	-			
Tar-3	-	-			

PERMANOVA	*B* / *A*	*C1*	*C2*	*C3*	*L1*	*L2*	*L3*	*Tar*
Age groups								
C year 1	*(C1)*	-	0.61	0.8	0.1	0.09	0.4	**0.01**
C year 2	*(C2)*	0.17	-	0.98	**<0.01**	**0.01**	0.12	**<0.01**
C year 3	*(C3)*	0.3	0.15	-	0.1	0.15	0.4	**0.01**
L year 1	*(L1)*	0.1	**0.01**	0.2	-	0.59	0.4	0.17
L year 2	*(L2)*	**<0.01**	**<0.01**	**<0.01**	**0.02**	-	0.59	0.91
L year 3	*(L3)*	0.2	**0.02**	0.2	0.1	0.41	-	0.36
Tar	*(Tar)*	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**0.02**	-

Grassland groups	*C*	*L*	*Ref*
C	-	**<0.01**	**<0.01**
L	**<0.01**	-	0.51
Tar	**<0.01**	**<0.01**	-

Table. 1. PERMANOVA results comparing NMDS groupings based on (A) presence–absence data using Jaccard distance, and (B) cover percentage values data using Bray–Curtis distance. Bold values indicate statistically significant differences between conditions or age groups ($p < 0.05$). Stress values reflect the goodness of fit of the NMDS ordinations; values ≤ 0.2 are considered acceptable. Group dispersion (i.e., variation in distance to centroid) was assessed using a Betadisper ANOVA. When dispersion was significant, a post-hoc Tukey HSD test was performed to identify specific group differences in variance. Highlighted values refer to groups with significant betadisper. Abbreviations: C = *Commercial*, L = *Local*, Tar = *Target* grasslands; The numbers 1, 2 and 3 following the letters stand for, respectively one-year-old, two-years-old and three-years-old grasslands. Total $n = 39$.

In contrast, a PERMANOVA test was applied to assess pairwise centroid similarity between age and grassland conditions groups. Regarding comparisons, results showed that within the Local condition, L1–L2 (*p* = 0.02; **Fig. 2 A1**) exhibited a significant difference in terms of species composition, whereas L2–L3 (*p* = 0.41; **Fig. 2 A1**) did not. For the Commercial condition, no clear distinction was observed between any of the age classes. Particular attention can be paid to comparisons of Commercial and Local age groups with Target grasslands. Commercial and Local grassland conditions, independently, showed similar species cover pattern between age classes. While C1-L1 (*p* = 0.1) and C1-L2 (*p* = 0.09) showed significant differences between almost all age classes; C1–L1 (*p* = 0.1) and C3–L3 (*p* = 0.2; **Fig. 2 A1**) displayed specific similarities. In addition, C1–L3 (*p* = 0.4), C2–L3 (*p* = 0.12), C3–L1 (*p* = 0.1), C3–L2 (*p* = 0.15), and C3–L3 (*p* = 0.4) showed close similarities in species cover percentage values, while C2–L1 (*p* < 0.01) and C2–L2 (*p* = 0.01; **Fig. 2 B1**) did not.

The similarity of plant communities between grassland conditions was assessed across all ages (n = 13). Significant differences were observed between each grassland condition regarding community composition, while community structure was only comparable between Local and Target grasslands, for which no significant differences were noted (*p* = 0.51) (**Table. 1**). NMDS projections displayed similarities between grassland conditions depending on the use of presence–absence data or percentage cover values. The selected grasslands revealed a temporal pattern within commercial and local seed mixtures, where species composition progressively converges toward the Target grasslands during the first three years (**Fig. 2 A1**). Divergence appears to be most pronounced in Local grasslands at age class 1. Some two- and three-year-old Local grasslands are closer to the Target condition compared to Commercial grasslands of the same age classes.

These relations become more evident when age classes are pooled (**Fig. 2 A2**). Divergence appears to be most pronounced in Local grassland condition at 1-year-old. Some two- and three-years-old Local grasslands are closer to the Target condition compared to Commercial grasslands of the same age classes. Ordination based on percentage cover values revealed a more linear pattern, commercial species abundance are less similar to Target than Local grasslands (**Fig. 2 B2**). While grassland dynamics was expected to naturally converge toward the target community in terms of composition and structure. Local grasslands displayed a reversed pattern, with age class 1 plots more similar to the Target grasslands than age class 3. Ultimately, Commercial grasslands exhibited strong similarity (**Fig. 2 B1**).

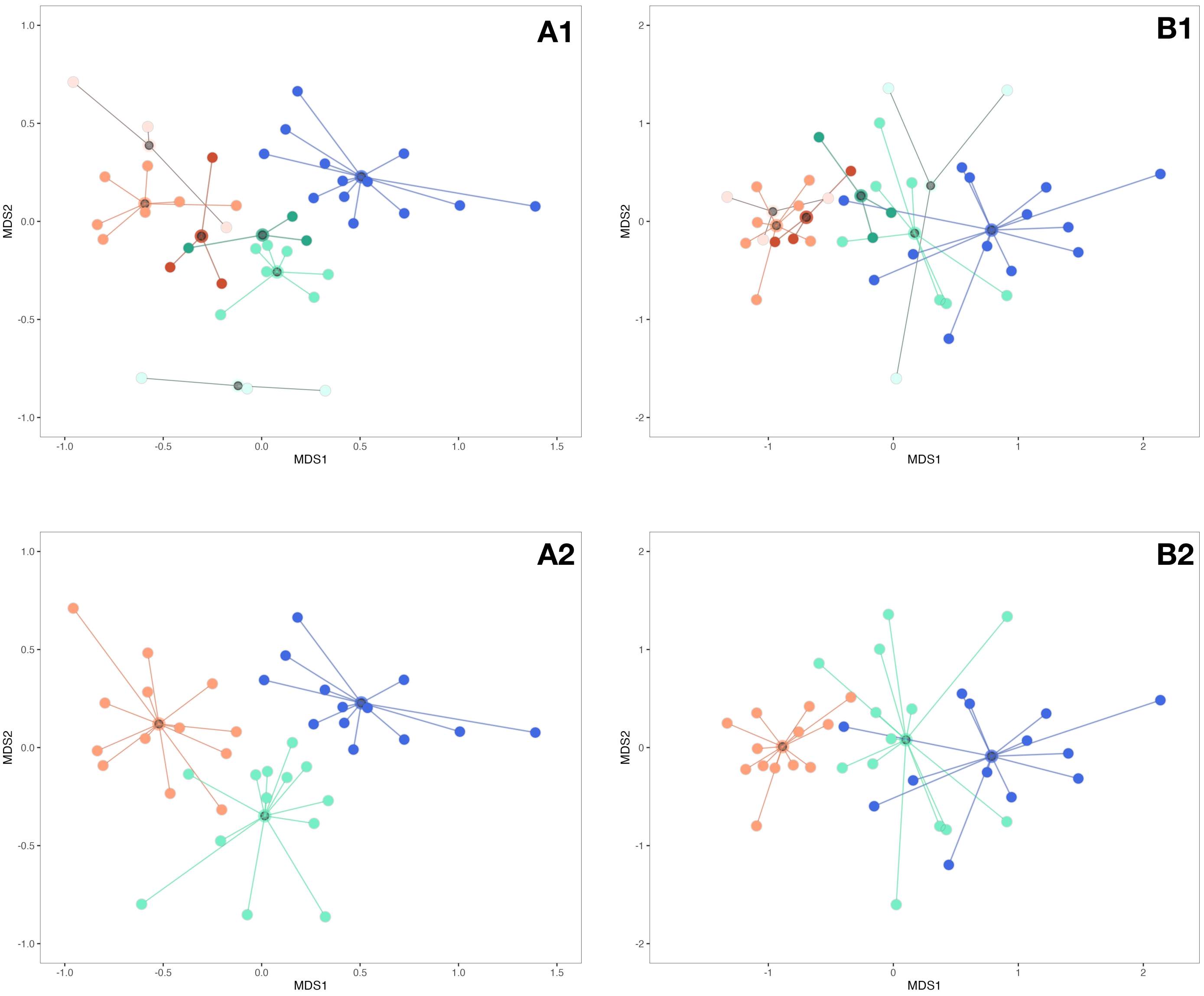


Fig. 2. Non-metric Multidimensional Scaling (NMDS) ordination of Target grasslands and restored Local and Commercial grasslands. Panels A1 and A2: NMDS based on Jaccard distance using presence–absence data (*Stress* = 0.185). Panels B1 and B2: NMDS based on Bray–Curtis distance using abundance-cover data derived from Braun–Blanquet scores (*Stress* = 0.211). Groupings are based on age (Panels A1 and A2) and seed mixture (Panels B1 and B2). Color coding: light, intermediate, and dark shades indicate one-year-old, two-yers-old, and three-years-old grasslands, respectively. Green = *Local*; Red = *Commercial*; Blue = *Target* grasslands. Total *n* = 39 including bootstrapped subsets of 13 grasslands each for Target and Local grasslands.

3. 4 - *Functional divergence during early grassland development stages*

Traits data were converted into community weighted means (CWMs) values and tested in a correlation matrix to delineate correlation and anti-correlation patterns (**Table. 2**). Significant deviations from normality were observed for *BioticVector* ($p = 0.045$) and *Perennial* traits ($p < 0.01$), while *Nitrophily* showed heteroscedasticity ($p = 0.047$) (**Table. 2**). ANOVA revealed significant differences for *BioticVector* ($p = 0.03$), *Late Flowering* ($p = 0.044$), and *Mean Plant Height* ($p = 0.002$). Tukey HSD post hoc tests showed significant pairwise differences for: *Mean Plant Height* ($p = 0.023$) between Local and Commercial grassland conditions, *BioticVector* ($p = 0.048$) and *Mean Plant Height* ($p = 0.002$) between Target and Commercial grasslands, *Late Flowering* ($p = 0.037$) between Target and Local grasslands. For traits that violated normality or homoscedasticity assumptions, non-parametric Kruskal-Wallis tests were used. Significant differences were found for *Perennial* ($p = 0.008$) and *Nitrophily* ($p = 0.003$). These were further examined with Dunn post hoc tests, identifying significant pairwise differences for: *Perennial* ($p = 0.005$) for local and commercial seed mixtures, *Nitrophily* ($p = 0.005$) between Target and Commercial grasslands (**Table. 2**).

The distribution of functional traits was graphically represented to improve the understanding of community dynamics (**Fig. 3**). Overall, commercial and local seed mixtures resulted in more nitrophilous communities during the first three years post-restoration, contrasting with the nitrogen preferences observed in Target grasslands, which were more associated with a broader range of meso-oligotrophic to oligotrophic conditions. This difference was particularly noticeable between Commercial and Target grassland conditions (**Fig. 3 A**). Grassland communities were predominantly composed of perennial species. While Commercial grasslands were almost exclusively characterized by perennial species, Local grasslands included a larger proportion of annuals. Target grasslands appeared intermediate in their lifespan composition, and no clear distinction in these relative proportions was observed with other conditions (**Fig. 3 B**).

Dispersal modes were largely dominated by abiotic vectors across all grassland conditions. Commercial grasslands showed a significantly higher occurrence of species relying on abiotic dispersal mechanisms, particularly anemogamy, compared to Target grasslands. In contrast, Local and Target grasslands favored biotic dispersal modes, including entomogamy, indicating a shift toward more ecologically specialized pollination and dispersal strategies (**Fig. 3 C**). Commercial grasslands were distinguished by their greater mean plant height, with taller communities on average (~75 cm), showing clear differences compared to other conditions. Target grasslands presented shorter communities (~55 cm), while Local grasslands showed intermediate values.

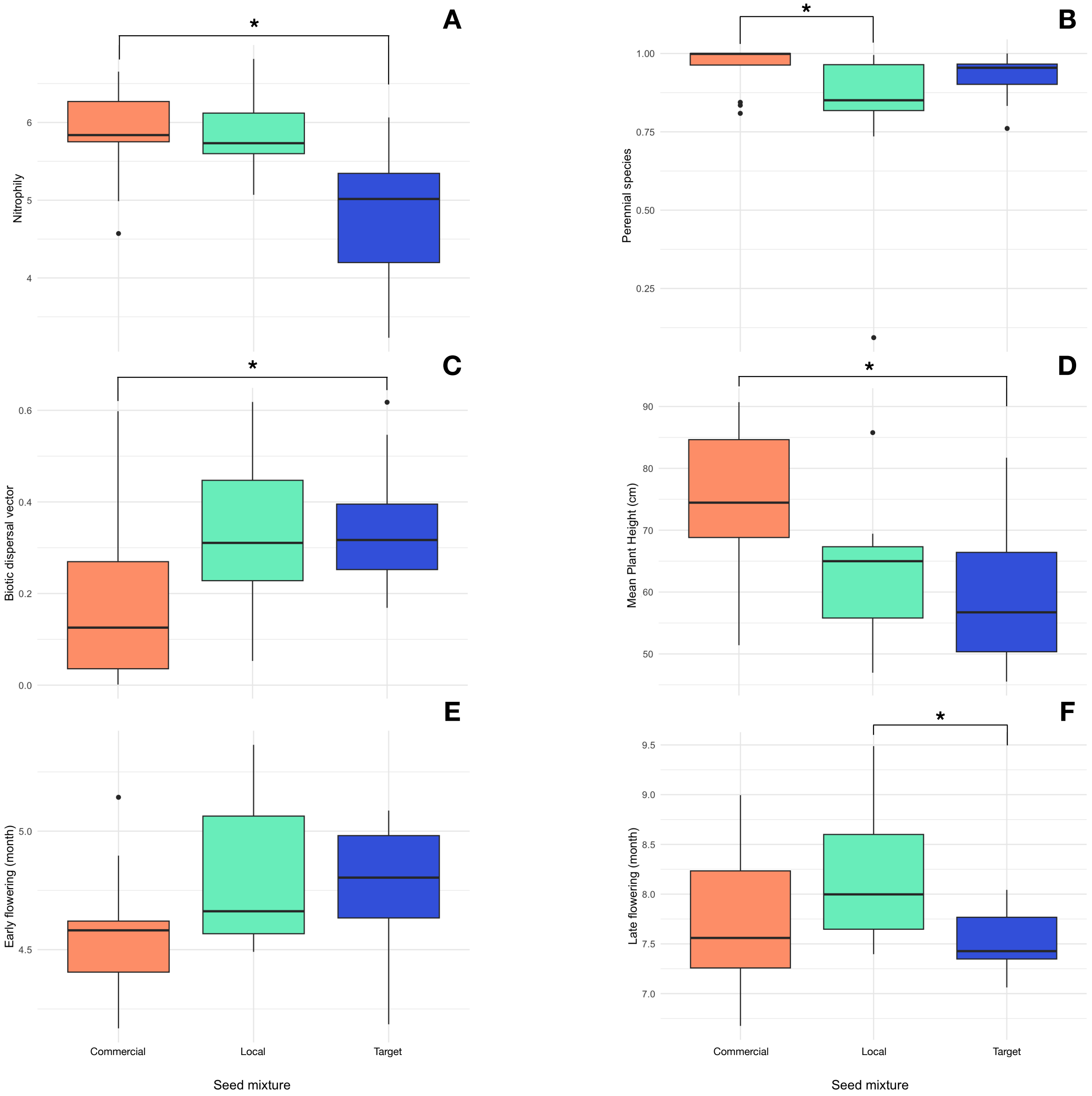


Fig. 3. Community-weighted means (CWMs) of species traits in grasslands ranging from one- to three-years-old after sowing, under two grassland conditions: Commercial, Local, including Target grasslands. Asterisks (*) indicate significant differences based on one-way ANOVA + Tukey (*Mean Plant Height, BioticVector*) and Kruskal-Wallis + Dunn (*Nitrophily*, *Perennial species*) tests (significance threshold: $p < 0.05$; Dunn test $p < 0.01$). Total $n = 39$ including bootstrapped subsets of 13 grasslands each for Target and Local grasslands.

(**Fig. 3 D**). The onset of flowering was relatively similar across all conditions, generally beginning between mid-April and early May, although Commercial grasslands appeared slightly more precocious (**Fig. 3 E**). In contrast, the end of flowering was delayed in Local grasslands, extending until early August, whereas Commercial and Target grasslands generally ended flowering by mid-July (**Fig. 3 F**). Target grasslands exhibited a narrower flowering window, while the other two conditions displayed more extended end flowering durations.

Rao's Q (FD_Q) showed a similar pattern during the first year after sowing regardless of grassland conditions (**Fig. 4**). Divergence occurs during the second year, with Local grasslands expressing a higher functional diversity related to a higher probability of randomly selecting two distinct species within a community that exhibit different functional traits, as well as a more balanced distribution of traits among communities. An unexpected pattern with a decreasing tendency of FD_Q may be observed in the third year. Results are more relevant by observing the FD_Q values of combined years datas, which express clearest tendency of FD_Q during early stages. Globally, Local grasslands showed a higher functional diversity, while Commercial and Target grasslands showed lower, closer values of FD_Q.

3. 5 - Plant species turnover in grasslands successional dynamic

The ordination accounted for a high proportion of variance along the first two axes (DCA1 = 54.69%; DCA2 = 32.3%; **Fig. 5 & 6**). We observed along the first axis (DCA1) that species occurrences aligned along a trophic gradient, indicating that grasslands were ordered according to their trophic level, whereas DCA2 remained difficult to interpret. The restored grasslands were positioned on the left side of the diagram, corresponding to mesotrophic conditions, and showed a trend toward less mesotrophic conditions similar to *Agrostietea stoloniferae* and *Arrhenatheretea elatioris* grasslands (**Fig. 5**). Mapping clustering results onto Target grasslands confirmed the presence of this gradient within target communities. *Agrostietea stoloniferae* and *Arrhenatheretea elatioris* grasslands were associated with intermediate trophic levels, with the latter spanning a range from mesotrophic to meso-oligotrophic conditions, while *Festuco-Brometea* grasslands clustered at the far right, reflecting a more strictly meso-oligotrophic character. Commercial grasslands were strongly associated with nutrient-rich soils and hosted fewer target species compared to Local grasslands, where early stages accumulated a greater number of target species. Most two- and three-years-old Local grasslands reached levels comparable to Target grasslands.

Correlation matrix		*MiP*	*MaP*	*BioV*	*Pe*	*Ni*	*EF*	*LaF*	*LoF*	*MeP*
Species traits										
Minimum plant height	*(MiP)*	1	-	-	-	-	-	-	-	-
Maximum plant height	*(MaP)*	0.72	1	-	-	-	-	-	-	-
BioticVector	*(BioV)*	-0.45	-0.6	1	-	-	-	-	-	-
Perennial	*(Pe)*	0.02	0.19	-0.14	1	-	-	-	-	-
Nitrophily	*(Ni)*	0.06	0.41	-0.19	-0.33	1	-	-	-	-
Early flowering	*(EF)*	0.32	-0.02	0.29	0.16	-0.24	1	-	-	-
Late flowering	*(LaF)*	-0.49	-0.19	0.22	-0.02	0.47	-0.04	1	-	-
Long flowering	*(LoF)*	-0.56	-0.15	0.06	-0.09	0.52	-0.49	**0.89**	1	-
Mean plant height	*(MeP)*	**0.82**	**0.99**	-0.59	0.16	0.36	0.04	-0.26	-0.25	1

Statistical analysis	*Local × Commercial × Target grasslands*						
	Shapiro	*Levene*	*ANOVA*	*Kruskal*		*Tukey*	*Dunn*
	p value				*Pairwise*		
BioticVector	**0.045**	0.657	**0.03**	-	L-C		
Perennial	**<0.01**	0.21	-	**0.008**	*MeP*	**0.023**	-
Nitrophily	0.563	**0.047**	-	**0.003**	*Pe*	-	**0.005**
Early flowering	0.517	0.775	0.096	-	T-C		
Late flowering	0.236	0.131	**0.044**	-	*BioV*	**0.048**	-
Mean plant height	0.842	0.858	**0.002**	-	*MeP*	**0.002**	-
					Ni	-	**0.005**
					T-L		
					LaF	**0.037**	-

Table. 2. Overview of statistical analyses conducted on species traits. The correlation matrix presents community-weighted means (CWM) of species traits in grasslands ranging from one- to three-years-old after sowing, under two grassland conditions: Commercial and Local, including Target grasslands. Strong correlations are highlighted in bold (thresholds: > 0.8 or < –0.8). Statistical analyses assessed the normality of residuals (Shapiro–Wilk test) and homoscedasticity (Levene's test). When both assumptions were met, one-way ANOVA was applied followed with pairwise Tukey test; otherwise, Kruskal-Wallis followed with Dunn tests were used. Bold values indicate statistically significant differences ($p < 0.05$; $p < 0.01$ (Dunn test)). Only significant results are presented for pairwise tests. L = *Local* ; C = *Commercial* ; T = *Target* grasslands. Total $n = 39$ including bootstrapped subsets of 13 grasslands each for Target and Local grasslands.

The ordination also provided insights into species occurrence depending on trophic gradient and grassland conditions (**Fig. 6**). Most species from commercial seed mixtures were associated to early stages of Commercial grasslands, whereas *Trifolium pratense* and *Lotus corniculatus* were more frequent in Local and Target grasslands, and *Onobrychis viciifolia subsp. viciifolia* was absent from the Commercial condition. Among the eleven species sown in Commercial grasslands, *Trifolium incarnatum* and *Phleum pratense* were never recorded, neither in Local or Target grasslands. Spontaneous species such as *Luzula campestris* and *Stellaria graminea* occurred early in Commercial grasslands under nutrient-rich conditions. After two to three years, Commercial grasslands showed little change in species composition, aside from occasional arrivals like *Arrhenatherum elatius* or *Poa trivialis*. One-year-old Local grasslands exhibited species like *Rumex crispus, Poa trivialis* and *Lolium perenne*, while two-years-old ones displayed a higher diversity compared to one-year-old, including observed species in Target grasslands such as *Anthoxanthum odoratum*, *Bromus erecta, Schedonorus arundinaceus*, and *Dactylis glomerata*. Most of the *Arrhenatheretea elatioris* species appeared within the three first years, while rare occurrences of *Festuco-brometea* species were observed at early stages (e.g. *Vicia cracca, Muscari neglectum*). Other species, like *Pimpinella saxifraga* and *Lotus maritimus* occurred in a single nutrient-rich Target grassland close to Commercial ones.

4 . Discussion

4. 1 - Functional and compositional successional trajectories

Our results demonstrated that Commercial grasslands exhibited greater divergence in both community composition and functional traits compared to Target grasslands, three years after restoration. For instance, grassland restoration following land-use change is usually characterized by a transient dominance of annual species during the early successional stages (**Collins & Adams, 1983; Foster & Tilman, 2000; Török et al., 2010**). Our findings revealed a low proportion of annual species, particularly in Commercial grasslands.

This pattern may result from the nature of selected species included in the commercial seed mixtures, together with historical land-use practices. Local seed mixtures showed a proportion of annual species (~20% in mean), although perennial species occurred, those collected from the Target grasslands are not selected for agricultural practices, and likely less agressives, while the commercial seed mixtures were particularly dominated by perennials.

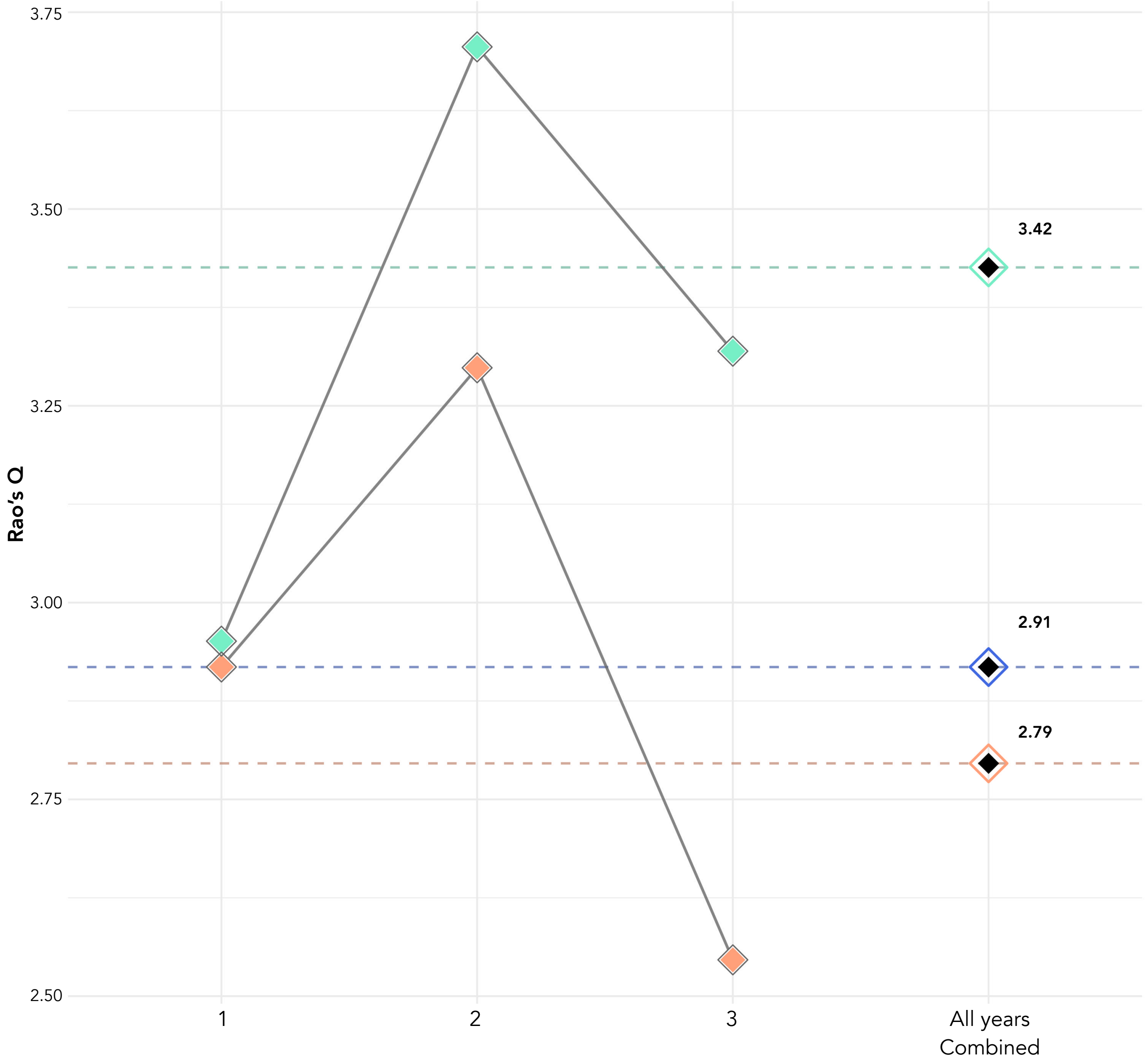


Fig. 4. Quadratic entropy index (Rao's Q) of functional diversity indices in grasslands ranging from one to three years after sowing, as well as across all years combined, under Commercial, Local and Target grassland conditions. Rao's Q = Quadratic Entropy. Color code: Green = *Local*; Orange = *Commercial*; Blue = *Target* grasslands. The numbers 1, 2 and 3, respectively represent one-year-old, two-years-old and three-years-old grasslands. Total *n* = 39, including bootstrapped subsets of 13 grasslands each for Target and Local grasslands.

These restored community composition likely reflect a deficiency in annual species in the seed mixtures and an overrepresentation of perennials that possess competitive advantages in later successional stages (**Grime, 1998**). This trend may have been reinforced by the prior depletion of the soil seed bank in Commercial grasslands, a consequence of intensive agricultural activities such as ploughing (**Gustafsson, 2002)**. In contrast, Local grasslands showed varied land-use histories with grasslands, fallow-lands, or cultures, which may have supported the persistence of residual seed banks, including annual species.

As ecological studies typically use Detrended Correspondence Analysis (DCA) to illustrate temporal gradients (**Török et al., 2010; Prach et al., 2014**), in our case, DCA proved more relevant for ordinating the samples along a trophic gradient (**Fig. 5**). The trophic conditions observed in the Target grasslands were consistent with the phytosociological literature (**de Foucault & Catteau, 2012; de Foucault, 2016; Royer & Ferrez, 2020**), and our nitrophily trait values (**Appendix A**). The *Festuco-Brometea* class generally corresponds to more oligotrophic conditions, whereas *Arrhenatheretea elatioris* and *Agrostietea stoloniferae* represent intermediate conditions often influenced by agro-pastoral practices such as grazing and mowing. Commercial and Local grasslands favored more target (*Rumex crispus, Dactylis glomerata, Arrhenatherum elatius*) and non target (*Rumex obtusifolius, Galium aparine, Anisantha sterilis*) nitrophilous species than Target grasslands (**Appendix B; Fig. 6**), although Local grasslands were more broadly distributed along the trophic gradient. **Tilman & Wedin,** (**1991a**) observed that nutrient-rich environments are typically associated with the early stages of grassland succession, which is relevant with our results. In Commercial grasslands, this pattern was likely amplified by a higher soil fertiliy prior to restoration, as suggested by the higher trophic levels observed. However, the lack of detailed historical data limits our ability to fully understand the specific management practices that may have contributed to the current trophic levels in restored grasslands. According to **Tilman & Wedin,** (**1991a, 1991b**), the dominance of late successional species observed notably in Commercial grassland may therefore result from high nitrogen availability, since late-successional species tend to be superior competitors under high N availably. This dynamic may help explain the observed dominance of late-successional perennial species such as *Dactylis glomerata* and *Schedonorus arundinaceus*—often exceeding 85% cover particularly in Commercial grasslands.

The early promotion of perennial, competitive communities is known to encourage the "successional slow-down" (**Lepš, 1987; Török et al., 2008**). Once grassland communities reach a perennial-dominated stage (**Foster & Tilman, 2000; Török et al., 2008**), the resulting dense

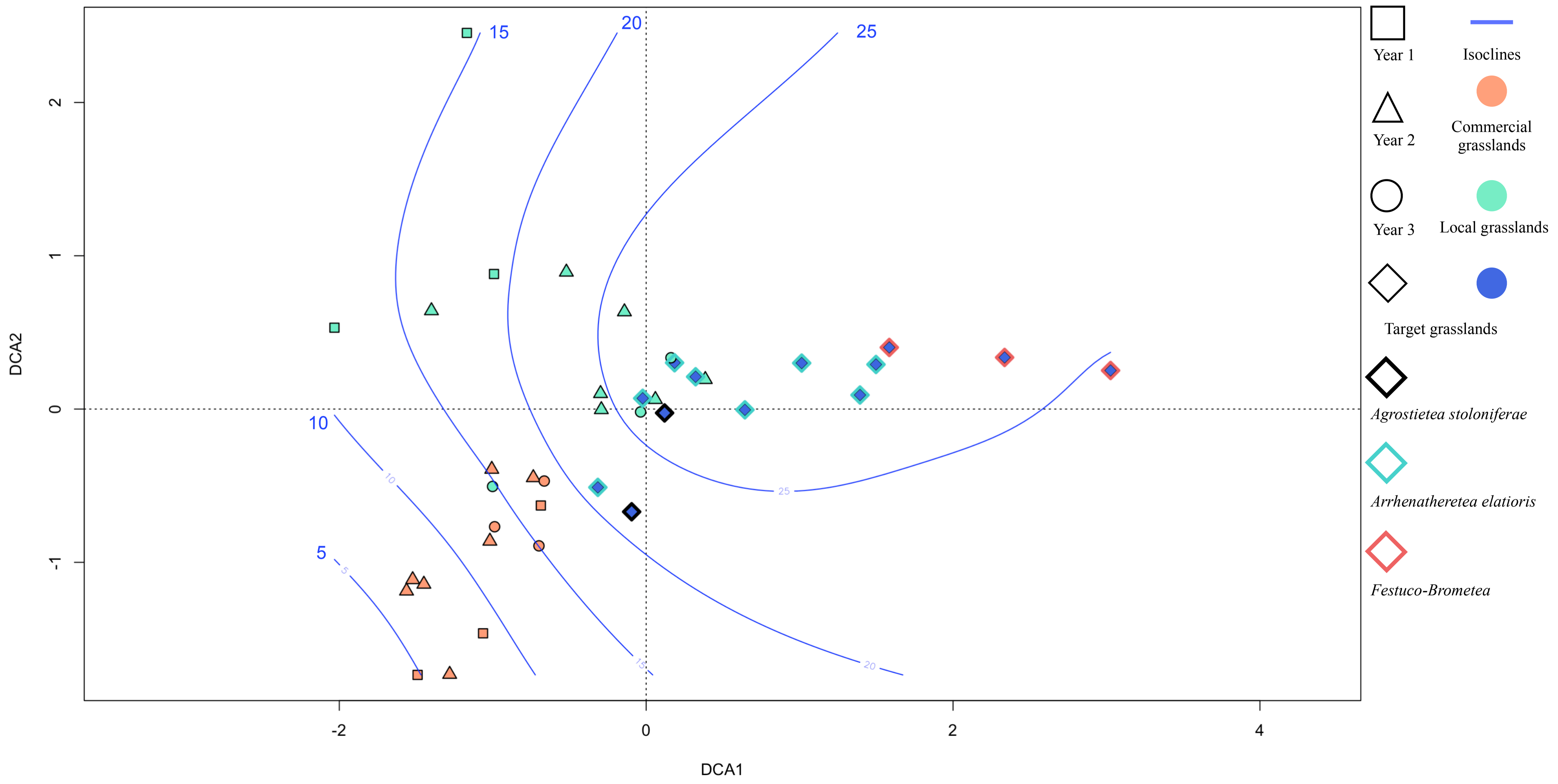


Fig. 5. DCA ordination of grasslands with isoclines representing the number of target species. Geometry codes explain age since sowing: □ = 1 ; △ = 2 ; ○ = 3 ; ◇ = Target grasslands. Color codes explain seed mixture condition: green: Local ; orange: Commercial ; blue: Target grasslands. Diamond borders color code explain the syntaxonomic classe of Target grasslands : black: *Agrostietea stoloniferae*; light blue: *Arrhenatheretea elatioris*; red: *Festuco-Brometea*. Total n = 39, including bootstrapped subsets of 13 each for Target and Local grasslands.

vegetation—driven by high competitive potential—can significantly limit species turnover (**Török et al., 2009; Albert, 2014**) and reduce the regenerative capacity of the community, particularly for short-lived and herbaceous species (**Török et al., 2012**). Furthermore, commercial seed mixtures are often designed with a focus on enhancing productivity for forage purposes. These high-yielding mixtures tend to establish dense and closed vegetation (**Maharning, Mills & Adl, 2009**), intensifying interspecific competition (**Marrs, 1993; Prach et al., 2014**). This was corroborated by the higher mean plant height recorded in Commercial grasslands, notably driven by the dominance of tall perennial grasses of *Schedonorus arundinaceus* and *Dactylis glomerata*, whose growth is further supported by residual soil nutrient enrichment. The competitive structure of these communities can inhibit the long-term establishment of target species, due both to a "canopy effect" that limits recruitment opportunities and to the scarcity of niche renewal (**Critchley et al., 2006; Török et al., 2009**). Although target communities are themselves dominated by perennials (**Fukami et al., 2005**), the persistent dominance of competitive perennials—especially when established within the first three years—can constrain successional dynamics and restrict the trajectory toward the desired late-successional grassland stages (**Török et al., 2010**). While the Commercial grasslands did not reveal structural fluctuation across years (**Fig. 2 B1 & B2**)—indicating that dominant species maintained their prevalence over time—communities diversity gradually increased, showing convergence toward the Target and two- to three-years-old Local grasslands (**Fig. 2 A1 & A2**). Restored grasslands trajectories tended toward Target grasslands, with Local grassland communities remaining closer and a higher accumulation of target species.

The substantial dominance of wind-specialized graminoid species in Commercial grasslands, directly accounts for the observed trends of these communities toward abiotic dispersal vectors, while biotic dispersal remain rare. Most species associated with biotic dispersal—whether originally included in the seed mixture or co-occurring spontaneously—failed to establish or were present at very low relative abundances. In contrast, both Local and Target grasslands exhibited a more balanced representation of dispersal strategies, indicating more favorable conditions for biotic interactions such as pollination which is a valuable ecosystem service. The extended duration of flowering phenology observed in Local grassland communities may reflect their composite origin, sourced from Target grasslands and enriched with commercial seeds. When comparing beta diversity across grassland types (**Appendix C**), numerous species were shared between Local grasslands and both Commercial and Target grasslands. Local communities were often characterized by more generalist species, exhibiting either delayed flowering onset

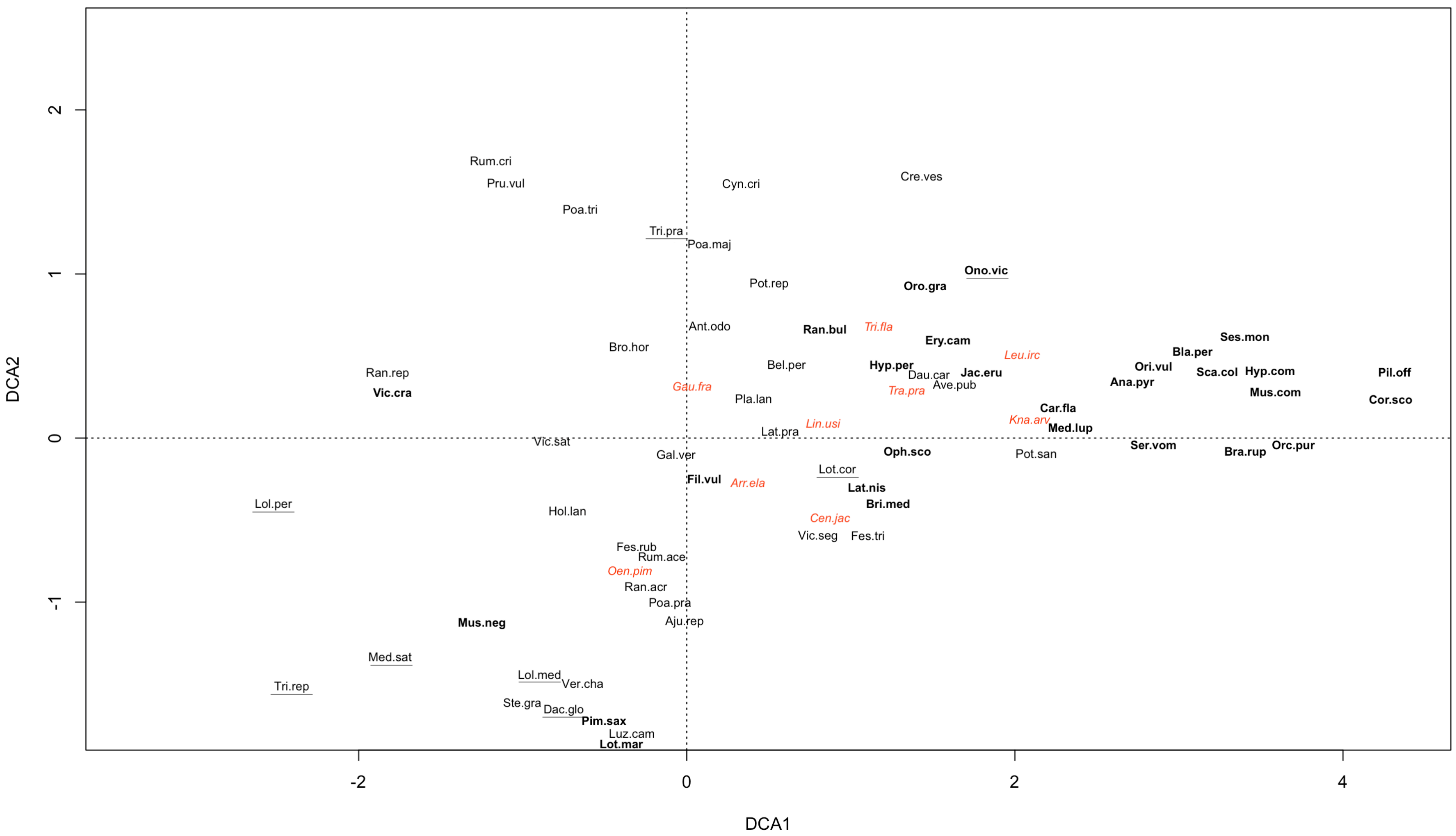


Fig. 6. DCA ordination of target species occurrence optimum. Nomenclature code: normal = *Agrostietea stoloniferae* species; *italic* = *Arrhenatheretea elatioris* species; **bold** = *Festuco-Brometea* species; underlined = Commercial seed mixtures species. Specie names were contracted to the three first characters for genus and species, complete names are referred to **Annexe**. Total *n* = 39, including bootstrapped subsets of 13 each for Target and Local grasslands. See correspondances in **Botanical survey** p.59. Lol.med (*Lolium mediterraneum* = *Schedonorus arundinaceus*)

(*Cirsium arvense*) or prolonged flowering periods (*Bellis perennis*, *Convolvulus arvensis*, *Medicago sativa*), which are rarely represented in the observed late-successional stages.

The measure of FD_Q did not allowed to captured the overall functional diversity of traits. Interestingly, although Target grasslands were expected to exhibit greater functional diversity, Local grasslands displayed higher FD_Q values. These results align with previously described functional trait patterns. Target grasslands showed narrower trait distributions within communities—particularly in terms of flowering phenology and balanced dispersal strategies—suggesting a tendency toward more specialized communities. This specialization was cleared when comparing trait values between the syntaxonomic classes of Target grasslands (**Appendix D**). In contrast, the relatively low FD_Q observed in Commercial grasslands likely reflects their reduced species diversity and strong dominance patterns. These communities were functionally characterized by tall, perennial, nitrophilous species with early phenology. In both Commercial and Target grasslands, the likelihood of randomly selecting the same or functionally similar species intra-communities was higher than in Local grasslands. The greater co-expressed biodiversity (n = 34) and shared species with both Target (n = 32) and Commercial (n = 8) grasslands observed in Local grasslands (**Appendix C**) may further contribute to increased variability in functional traits. Compared to Commercial grasslands, the Local ones showed a higher diversity in species seeds, less opportunity for perennial, competitive species dominance, favoring expression of a higher functional diversity. Compared to Target grasslands, the Local ones showed higher functional diversity earlier in succession, more modified physico-chemical conditions, and premature and less specialized communities.

To conclude, we observed a delayed convergence of Commercial grasslands toward Target grassland communities. After three years, Commercial grasslands remained less diversified and supported fewer target species than Local grasslands. This discrepancy is largely attributed to seed mixture composition: Local seed mixtures, sourced mainly from Target grasslands, directly facilitated the establishment of target species. The low functional diversity observed in Commercial grasslands was linked to both species-poor seed mixtures and competitive exclusion. Conversely, the high functional diversity and trait values observed in Local grasslands is not inherently indicative of restoration success, in this case it likely reflects an ongoing transitional phase between early colonization and long-term community specialization. Finally, our result support that using local seed mixtures promote a faster convergence of plant communities composition and functionality toward ancient, diversified grasslands, within the first three years.

4. 2 - Assessment of potential study biases

We initially planned to analyse traits species along a temporal gradient to delineate year classes (from one- to three-years-old grasslands) using a linear model. However, data segregation of Local and Commercial grasslands according to the available data (1-year-old = 3 ; 2-years-old = 7 ; 3-years-old = 3) was inoperable due to their relatively low abundances. We observed substantial and invalid variations in such sample size, even bootstrapping age classes did not permit to provide a well representation of the variability existing within grasslands conditions. **Jenkins & Quintana-Ascencio** (**2020**) request a minimum sample size of $n = 8$ when variance is low, however, our data were more related to high variance suggesting a minimum of $n = 25$ to fit with the model. Our data were not matching with these conditions, for this reason we choose to combined year classes and re-conduct to overall traits analyses through boxplots, also to measure the NMDS and the quadratic entropy (Rao's Q). Age classes for the quadratic entropy were voluntary represented to observe year inflexions explaining the global tendency, but also inconsistencies notably with the functional diversity collapsing occurring at year three. Age classes for the NMDS was also informative of the possible variations existing within and between studied conditions, but cannot be trustfully interpreted. Year by year results would have been more relevant to explain functional patterns, however without comparison elements, we are only able to explain global tendencies.

A common bias in the use of community weighted means (CWMs) lies in the fixed and overly optimistic trait values attributed to species, which can lead to Type I errors—detecting a relationship between species and a studied variable where none actually exists (**Peres-Neto et al., 2017**). In reality, species continuously adjust their traits through trade-offs which continuously fluctuate around an adaptative optimum (**Muscarella & Uriarte, 2016**). The same authors also estimate in forest communities that nearly 25% of the species could significantly oppose to the CWMs optimality for a trait. Also, temporal variability further drives local functional variation (**Chesson & Warner, 1981**), however, considering that grasslands restoration occurred with a delay of up to five years between Local and Commercial conditions, it was not possible to rule out a temporal influence on species traits. Therefore, trait-based analyses provide an overview of community functionality within the restored and Target grasslands and must be interpreted precociously.

4. 3 - Historical practices in restored grasslands

Although restored grasslands were expected to be relatively homogeneous in terms of pre-restoration conditions (as all were assumed to have been perennial crop fields), a collaborative agro-sociological internship conducted by Laurie Piquée at the CBNPMP revealed a wide range of historical land-use trajectories across the restored grasslands sown with Local seed mixtures. These practices varied considerably: 2 grasslands were natural or semi-natural, and 4 were deteriorated persisting for up to 20 years, 2 were fallow lands, and 4 were agricultural activities. Thus, the existing Local grasslands likely contain more or less constitutive seed banks. Otherwise, Commercial restored grasslands exclusively inherit from agricultural practices (mainly cereals and corn; **DRAAF Occitanie, 2020**) and soil enrichment before restoration measures. However, no information was provided regarding the duration of these agricultural activities. The soil seed bank is recognized as a key regenerative driver during the initial stages of grassland succession (**Török et al., 2012; Aavik & Helm, 2018**), facilitating early community assembly. Nevertheless, its role diminishes over time, as long-term seed persistence is typically inversely related to dispersal capacity—highlighting the dichotomy between two distinct reproductive strategies (**Klinkhamer, 1987; Thompson et al., 1996**). Most grassland species tend to form short-lived seed banks (**Milberg, 1992**).

Since our study focuses on the first three years post-restoration, we hypothesis that intensive agricultural practices may had shaped a depleted soil seed banks in Commercial grasslands, impacting early regeneration processes. By contrast, the more complex trajectories of Local grasslands likely supported a constitutive seed bank, contributing to higher co-expressed species diversity during early succession (**Appendix C**). However, this interpretation must be approached with caution. The current study does not allow for a definitive disentanglement of the respective contributions of the soil seed bank and the initial species diversity of the Local seed mixtures in shaping community assembly.

4. 4 - Landscape factors and species recruitment importance

As mentioned by **Aavik & Helm (2018)**, the presence of genetically diversified populations and propagule dispersal abilities may be determinant to success spontaneous processus of the restoration. However, the rupture of the connectivities between populations is known to increase genetic bottleneck within the populations leading to a reduced adaptive potential to local environmental conditions, as well as community abilities to be resilient in the face of environmental

and anthropic pressures (**Hoffmann & Sgrò, 2011; Aavik & Helm, 2018**). As grassland plant species are mostly related to wind dispersal, propagules abilities to travel long distance remain low, the theoretical maximal dispersal was assessed to be about 250m, but travelling such distance could be considered as a very rare event (**Tackenberg, Poschlod & Bonn, 2003**). Efficient dispersal would be related from tens to one hundred meters distance (**Prach et al., 2015**), while some species families are well specialized to long distance travelling, such as the *Asteraceae* equipped with easy wind capture structures as pappus (**Poschlod & Jackel, 1993**) and the *Orchidaceae* which have a very low seed mass (< 0,05g; **Burrows, 1986**).

As wind dispersal is unreliable, the literature highlights the key role of biotic vectors in seed dispersal and their impact on grassland restoration success. In addition to mowing, the studied grasslands were subject to grazing by different types of livestock (e.g., sheep, cattle), in some cases intensively, in others alternately or sporadically. Herbivores, like sheep, might be able to transport in their wool, millions of seeds from hundreds of species during a single vegetation season (**Fischer et al., 1995; Fischer et al., 1996**) and over distances up to 100 km within 40 days (**Poschlod et al., 1995; Poschlod, 1996**). Landscape level and connectivities should be considered in restoration projets, because the long-term success of restoration is largely determined by seed arrival and the recruitment of late-stage target species (**Poschlod et al., 1995; James, 2011; Aavik & Helm, 2018**), as well as the formation of the soil seed bank is tightly dependent of species dispersal factors, and propagules abilities to reach the expected grasslands (**Bakker et al, 1996**).

4 . 5 - Seed mixtures effect

Composing local seed mixtures is a complex task, notably constrained by the availability of suitable source grasslands (which depends on farmers' willingness), and by technical limitations such as equipment availability and harvesting conditions. Seed collection is conducted within a narrow time window, with Target grasslands visited successively (sometimes multiple times each) to harvest the greatest possible number of species at seed maturity. Seeds collected at different times and from multiple grasslands are pooled and rapidly delivered to land managers to address logistical and technical constraints. This introduces a first level of heterogeneity: managers depend on the seed mixtures available at a given moment. As a result, each sown mixture may represent one, two, or even three of the identified syntaxonomic classes. A second source of heterogeneity stems from the mixing of local seed mixtures with commercial ones. Observations from the LIFE and COUVER06 programs highlighted that local mixtures alone could not meet managers' forage objectives during the first restoration year, unlike commercial mixtures.

To meet agro-economic requirements, commercial seeds were added in varying proportions (0–50%), depending on managers' expectations and needs. Finally, a third layer of variability arises from unrecorded practices by grassland managers, who, according to the complementary sociological survey, frequently introduce additional species—often *Fabaceae*—to increase nitrogen content and improve forage quality for livestock. The quantity of these additions is neither reported nor standardized, ranging from, we quote "a handful" to "2 or 3 buckets". Standardizing the composition of the seed mixtures would have enabled a more precise understanding of assembly mechanisms under both Local and Commercial sowing conditions. It would notably help to determine whether seed mixture composition influences emerging species and community trajectory over time.

4 . 6 - Implications for practice and stakeholder collaboration

Ecological restoration using seeds collected from mature grasslands is a promising approach for accelerating restoration and conserving target species. Seed mixture composition appears to play a pivotal role in community assembly. Prior studies have shown that a dominance of grasses exceeding 70% of the seed mix can hinder the establishment of non-target perennial herbaceous species and constrain community trajectories (**Van der Putten et al., 2000; Lepš et al., 2007**). Harmonizing the initial seed composition—either by establishing fixed proportions among the three main syntaxons when sourcing from target grasslands, or by standardizing commercial mixtures—may help reduce inter-grasslands variability and stochasticity in community assembly. Such an approach would provide greater control over early-stage dynamics and facilitate more predictable successional outcomes.

Further investigations should encompass a broader sample of grasslands to mitigate the unpredictable variability in environmental and biotic conditions among communities. As highlighted by **Jenkins & Quintana-Ascencio (2020)**, a minimum of eight grasslands, per age class would enhance the robustness of statistical analyses and strengthen ecological inference.

Extending the monitoring period beyond the first three years post-restoration is also critical, as this timeframe may not sufficiently capture the slow down successional dynamics—particularly the recruitment of late-successional species. Monitoring over a minimum of five years would allow for the assessment of long-term vegetation trajectories, especially in relation to the diminishing influence of the soil seed bank and the increasing role of dispersal-driven processes. This would require spatially fixed sampling of grasslands, ideally in collaboration with land managers committed to maintaining consistent management practices over time. To further contextualize

recruitment trajectories, historical land-use should be accounted for by distinguishing, at minimum, former croplands and old grasslands, as these legacies are expected to differentially affect the composition and persistence of the soil seed bank. Former croplands are often associated with seed bank depletion, while long-established grasslands may act as reservoirs for target species.

Given the critical role of dispersal and landscape connectivity in shaping successional outcomes (**Poschlod et al., 1995; James, 2011**), future research should incorporate a landscape-scale perspective to evaluate the potential for propagule influx from adjacent habitats. In the absence of data on grazer movements, the spatial configuration of restored grasslands, and the species composition of neighboring grasslands, it remains difficult to predict the contribution of surrounding landscape elements to recruitment processes. Targeted floristic surveys of adjacent grasslands could help identify potential source communities and clarify their role as species reservoirs. Additionally, investigating both anthropogenic and biotic dispersal vectors—such as seed transport via agricultural machinery and grazing livestock—could offer valuable insights into mechanisms of colonization and emergence.

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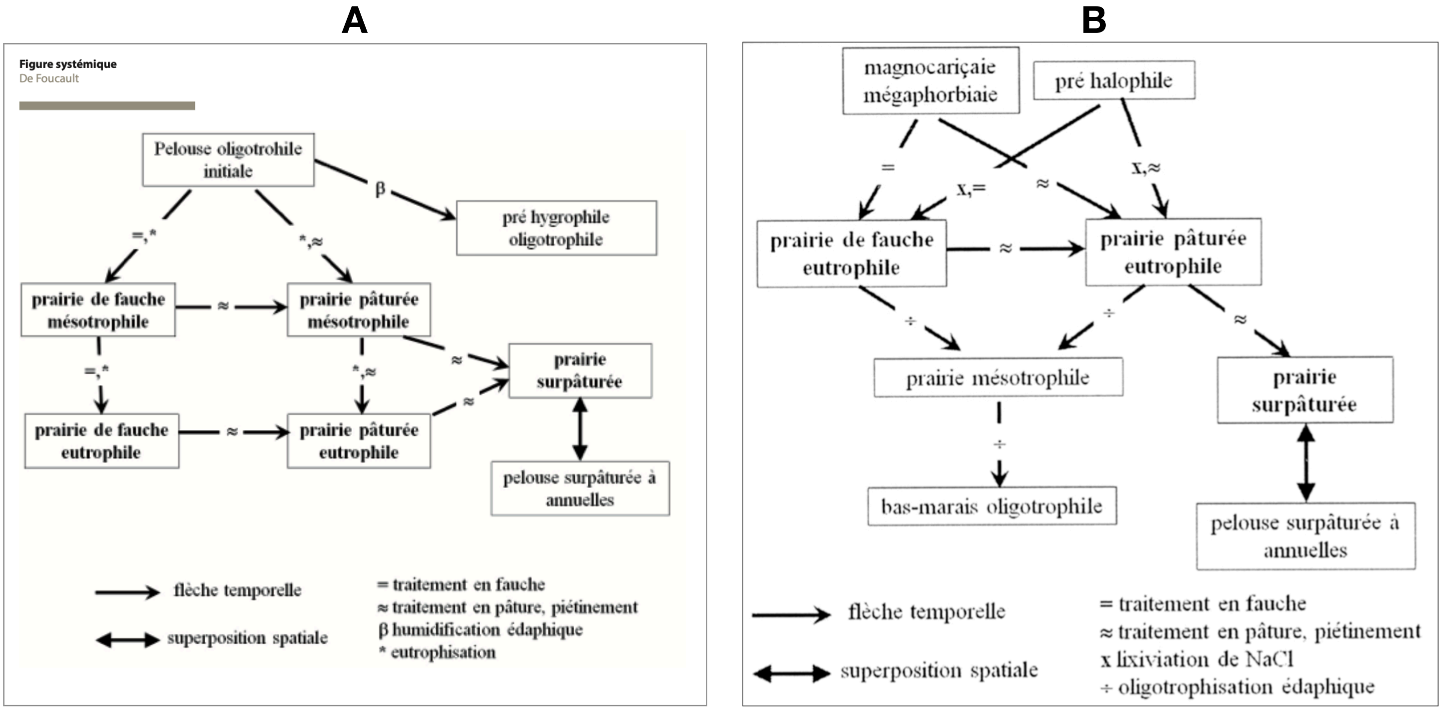
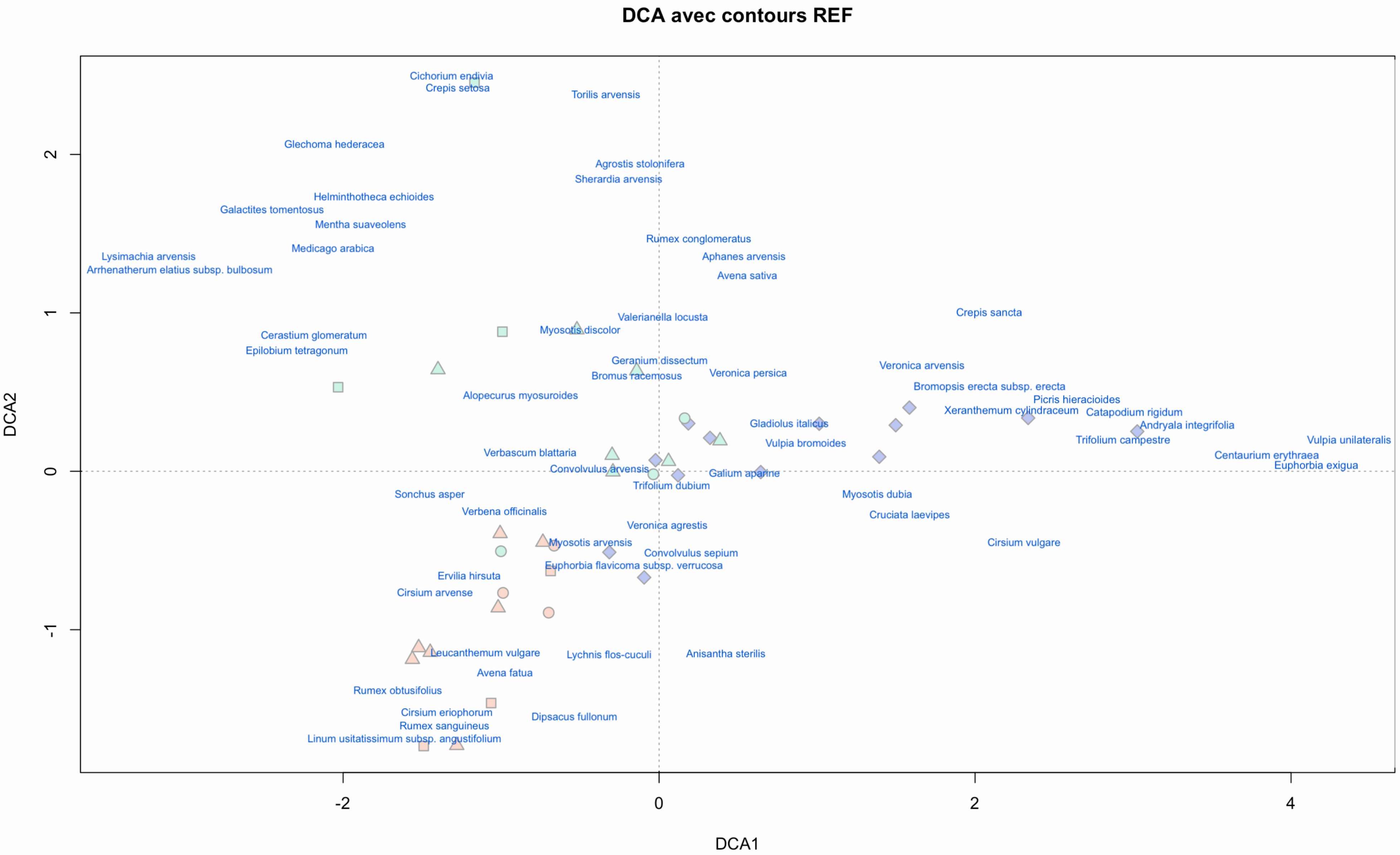
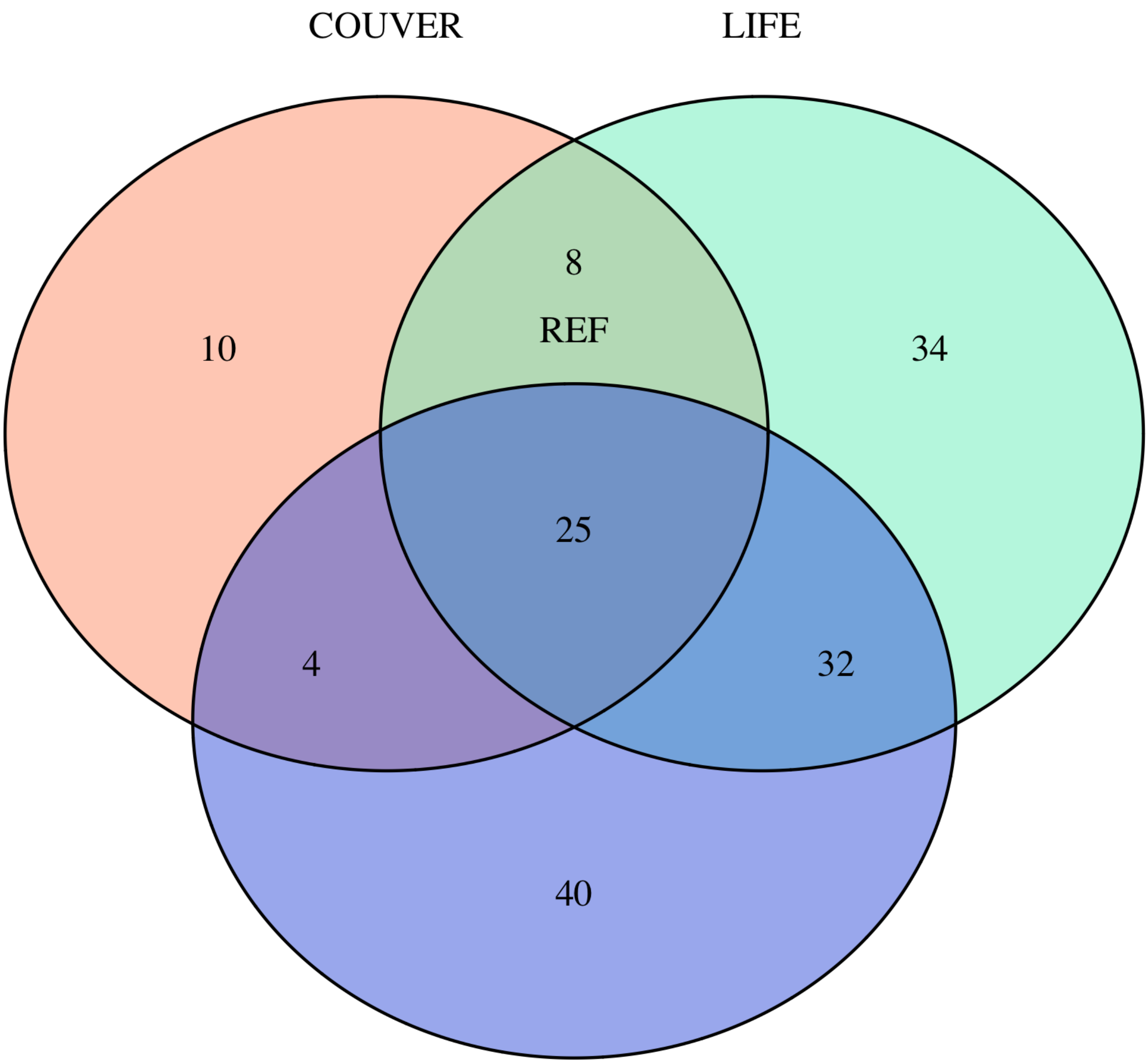
Appendix



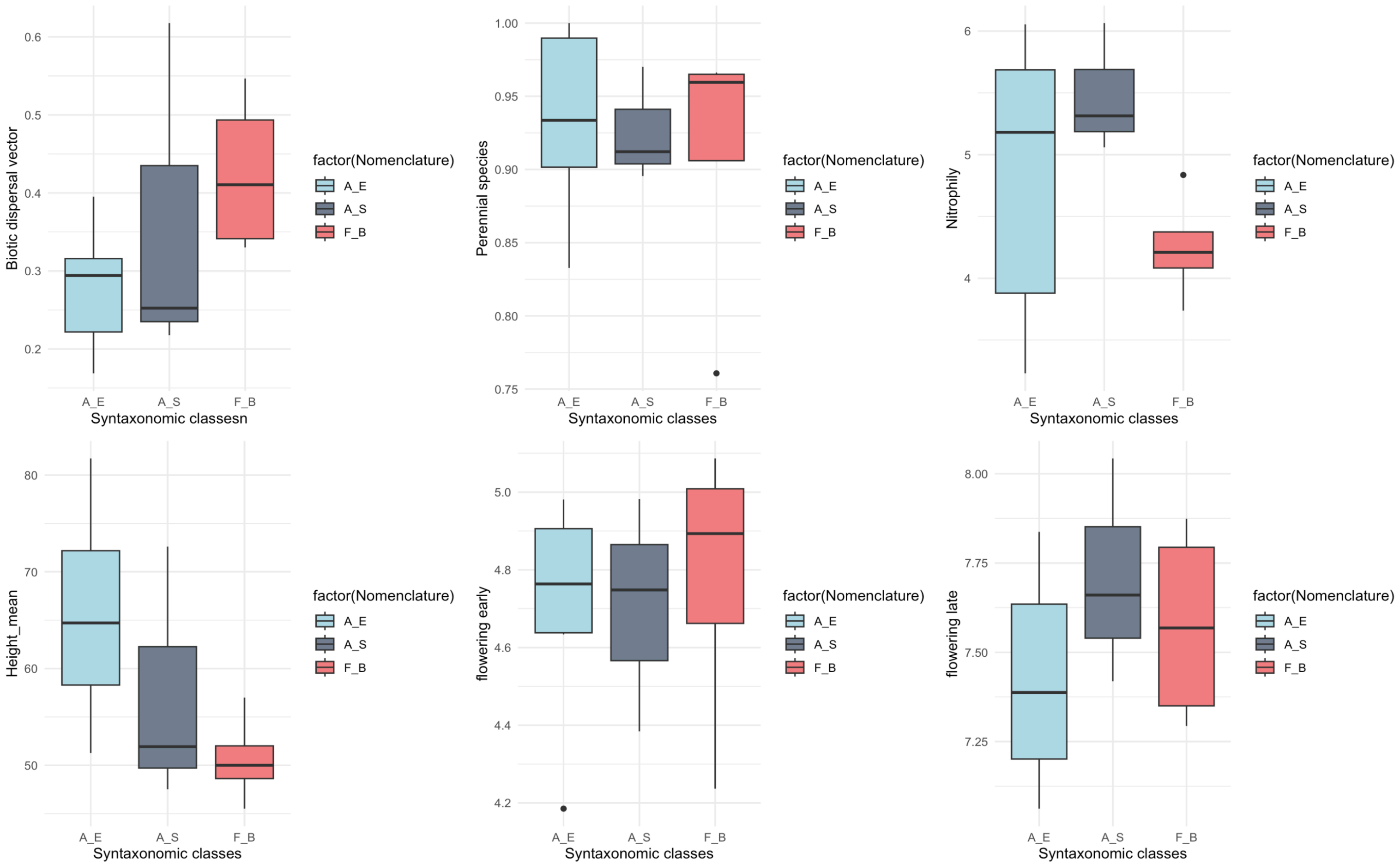
Appendix A. Successional trajectories of (**A**) *Arrhenatheretea elatioris* grasslands according to **de Foucault** (**2016**), (**B**) *Agrostietea stoloniferae* grasslands accord to **de Foucault & Catteau** (**2012**). Both *Arrhenatheretea elatioris* and *Agrostietea stoloniferae* grasslands share several species. These communities are commonly influenced by management practices such as mowing and grazing. However, they are highly susceptible to eutrophication, and their successional trajectories tend to shift rapidly toward nutrient-enriched, intermediate states. In contrast, the reverse dynamic—restoring lesser nutrient-rich conditions—occurs more slowly and requires sustained management interventions.



Appendix B. DCA ordination of grasslands representing species and co-expressing species not observed in Target grasslands. Geometry codes explain age since sowing: □ = 1 ; △ = 2 ; ○ = 3 ; ◇ = Target grasslands. Color codes explain seed mixture condition: green: Local ; orange: Commercial ; blue: Target grasslands. Total $n = 39$, including bootstrapped subsets of 13 each for Target and Local grasslands.



Appendix C. Bêta diversity comparing unique and shared species observed between and within grassland conditions. Color code: Orange = COUVER (Commercial grasslands); Green = LIFE (Local grasslands); Bleu = REF (Target grasslands). Total *n* = 39, including bootstrapped subsets of 13 sites each for Target and Local grasslands.



Appendix D. Community-weighted means (CWMs) of species traits in Target grasslands depending of syntaxonomic classes. Nomenclature: **A_E** = *Arrhenatheretea elatioris* (n = 6); **A_S** = *Agrostietea stoloniferae* (n = 3); **F_B** = *Festuco-Brometea* (n = 4). Total *n* = 13.

Species_List

Species	Familly	Local	Commercial	Reference	Red_list_France	Red_list_Midi_Pyrénées	Determinency	Indigénat
Achillea millefolium L.	Asteraceae	1	-	1	LC	LC	-	Indigenous
Adonis annua L.	Ranunculaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Agrimonia eupatoria L.	Rosaceae	1	-	1	LC	LC	-	Indigenous
Agrostis capillaris L.	Poaceae	-	1	1	LC	LC	-	Indigenous
Agrostis stolonifera L.	Poaceae	1	-	1	LC	LC	-	Indigenous
Ajuga reptans L.	Lamiaceae	-	-	1	LC	LC	-	Indigenous
Allium vineale L.	Amaryllidaceae	1	-	-	LC	LC	-	Indigenous
Alopecurus myosuroides Huds.	Poaceae	1	1	-	LC	LC	-	Indigenous
Alopecurus pratensis L.	Poaceae	1	-	1	LC	LC	-	Indigenous
Anacamptis morio (L.) R.M.Bateman, Pridgeon & M.W.Chase	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Anacamptis pyramidalis (L.) Rich.	Orchidaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Andryala integrifolia L.	Asteraceae	-	-	1	LC	LC	-	Indigenous
Anisantha sterilis (L.) Nevski	Poaceae	1	1	1	LC	LC	-	Indigenous
Anthemis cotula L.	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Anthoxanthum odoratum L.	Poaceae	1	1	1	LC	LC	-	Indigenous
Aphanes arvensis L.	Rosaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Arctium minus (Hill) Bernh.	Asteraceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Arctium sp.	Asteraceae	1	-	-	-	-	-	-
Arrhenatherum elatius (L.) P.Beauv. ex J.Presl & C.Presl	Poaceae	1	1	1	LC	LC	-	Indigenous
Arrhenatherum elatius subsp. bulbosum (Willd.) Schübler & G.Martens	Poaceae	1	-	-	LC	LC	ZNIEFF	Cryptogenic
Avena fatua L.	Poaceae	1	1	-	LC	NE	ZNIEFF	Indigenous
Avena sativa L.	Poaceae	1	-	-	NE	-	-	Cultivated
Avenula pubescens (Huds.) Dumort.	Poaceae	1	-	1	LC	LC	-	Indigenous
Bellis perennis L.	Asteraceae	1	-	1	LC	LC	-	Indigenous
Blackstonia perfoliata (L.) Huds.	Gentianaceae	1	-	1	LC	NE	ZNIEFF	Indigenous
Brachypodium rupestre (Host) Roem. & Schult.	Poaceae	-	-	1	LC	LC	-	Indigenous
Briza media L.	Poaceae	1	-	1	LC	NE	-	Indigenous
Bromopsis erecta (Huds.) Fourr.	Poaceae	1	-	1	LC	LC	-	Indigenous
Bromus commutatus Schrad.	Poaceae	-	-	1	LC	-	ZNIEFF	Indigenous
Bromus hordeaceus L.	Poaceae	1	-	1	NE	LC	-	Indigenous
Bromus racemosus L.	Poaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Bryonia dioica Jacq.	Cucurbitaceae	-	-	1	LC	LC	-	Indigenous
Buglossoides arvensis (L.) I.M.Johnst.	Boraginaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Capsella bursa-pastoris (L.) Medik.	Brassicaceae	1	-	-	LC	LC	-	Indigenous
Cardamine pratensis L.	Brassicaceae	-	-	1	LC	LC	-	Indigenous
Carex divulsa Stokes	Cyperaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Carex flacca Schreb.	Cyperaceae	1	-	1	LC	LC	-	Indigenous
Carex spicata Huds.	Cyperaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Catapodium rigidum (L.) C.E.Hubb.	Poaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Centaurea jacea L.	Asteraceae	1	-	1	LC	LC	-	Indigenous
Centaurea nigra L.	Asteraceae	-	-	1	DD	LC	ZNIEFF	Indigenous
Centaurium erythraea Rafn	Gentianaceae	-	-	1	LC	NE	-	Indigenous
Cerastium fontanum subsp. vulgare (Hartm.) Greuter & Burdet	Caryophyllaceae	1	1	1	LC	LC	-	Indigenous
Cerastium glomeratum Thuill.	Caryophyllaceae	1	-	1	LC	LC	-	Indigenous
Cicer arietinum L.	Fabaceae	1	-	-	-	-	-	Cultivated
Cichorium endivia L.	Asteraceae	1	-	-	-	-	-	Cultivated
Cichorium intybus L.	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Cirsium arvense (L.) Scop.	Asteraceae	1	1	1	LC	LC	-	Indigenous
Cirsium eriophorum (L.) Scop.	Asteraceae	-	1	1	LC	LC	ZNIEFF	Indigenous
Cirsium tuberosum (L.) All.	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Cirsium vulgare (Savi) Ten.	Asteraceae	1	-	1	LC	LC	-	Indigenous
Clinopodium sp.	Lamiaceae	-	-	1	-	-	-	-
Convolvulus arvensis L.	Convolvulaceae	1	1	1	LC	LC	-	Indigenous
Convolvulus sepium L.	Convolvulaceae	-	-	1	LC	LC	-	Indigenous
Coronilla scorpioides (L.) W.D.J.Koch	Fabaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Crepis biennis L.	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Crepis capillaris (L.) Wallr.	Asteraceae	-	1	-	LC	LC	-	Indigenous

Crepis pulchra L.	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Crepis sancta (L.) Bornm.	Asteraceae	1	-	1	-	LC	-	Introduite
Crepis setosa Haller f.	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Crepis sp.	Asteraceae	1	-	-	-	-	-	-
Crepis vesicaria L.	Asteraceae	1	1	1	LC	LC	ZNIEFF	Indigenous
Cruciata laevipes Opiz	Rubiaceae	-	-	1	LC	LC	-	Indigenous
Cynoglossum creticum Mill.	Boraginaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Cynosurus cristatus L.	Poaceae	1	-	1	LC	LC	-	Indigenous
Dactylis glomerata L.	Poaceae	1	1	1	LC	LC	-	Indigenous
Dactylorhiza fuchsii (Druce) Soó	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Daucus carota L.	Apiaceae	1	1	1	LC	LC	-	Indigenous
Dipsacus fullonum L.	Caprifoliaceae	1	-	1	LC	LC	-	Indigenous
Elytrigia repens (L.) Desv. ex Nevski	Poaceae	1	-	-	LC	LC	-	Indigenous
Epilobium tetragonum L.	Onagraceae	1	-	-	LC	LC	-	Indigenous
Equisetum sp.	Equisetaceae	1	-	-	-	-	-	-
Equisetum telmateia Ehrh.	Equisetaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Ervilia hirsuta (L.) Opiz	Fabaceae	1	1	1	LC	LC	-	Indigenous
Eryngium campestre L.	Apiaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Euphorbia exigua L.	Euphorbiaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Euphorbia helioscopia L.	Euphorbiaceae	1	-	-	LC	LC	-	Indigenous
Euphorbia verrucosa L.	Euphorbiaceae	-	-	1	VU	VU	-	Indigenous
Festuca auquieri Kerguélen	Poaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Festuca rubra L.	Poaceae	1	1	1	LC	LC	-	Indigenous
Festuca sect. *Aulaxyper*	Poaceae	-	-	1	-	-	-	-
Festuca trichophylla (Ducros ex Gaudin) K.Richt.	Poaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Filipendula ulmaria (L.) Maxim.	Rosaceae	-	-	1	LC	LC	-	Indigenous
Filipendula vulgaris Moench	Rosaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Fragaria viridis Weston	Rosaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Galactites tomentosus Moench	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Galium album Mill.	Rubiaceae	1	-	1	LC	LC	-	Indigenous
Galium aparine L.	Rubiaceae	1	-	1	LC	LC	-	Indigenous
Galium verum L.	Rubiaceae	1	-	1	LC	LC	-	Indigenous
Gaudinia fragilis (L.) P.Beauv	Poaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Genista tinctoria L.	Fabaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Geranium columbinum L.	Geraniaceae	1	-	1	LC	LC	-	Indigenous
Geranium dissectum L.	Geraniaceae	1	1	1	LC	LC	-	Indigenous
Geranium pusillum L.	Geraniaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Gladiolus communis L.	Iridaceae	1	-	-	-	LC	ZNIEFF	Introduite
Gladiolus italicus Mill.	Iridaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Glechoma hederacea L.	Lamiaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Helminthotheca echioides (L.) Holub	Asteraceae	1	-	1	LC	LC	-	Indigenous
Himantoglossum hircinum (L.) Spreng.	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Hippocrepis comosa L.	Fabaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Holcus lanatus L.	Poaceae	1	-	1	LC	LC	-	Indigenous
Hypericum hirsutum L.	Hypericaceae	-	-	1	LC	LC	-	Indigenous
Hypericum perforatum L.	Hypericaceae	1	-	1	LC	LC	-	Indigenous
Hypericum tetrapterum Fr.	Hypericaceae	1	-	-	LC	LC	-	Indigenous
Hypochaeris radicata L.	Asteraceae	1	1	1	LC	LC	-	Indigenous
Jacobaea erucifolia (L.) G.Gaertn., B.Mey. & Scherb.	Asteraceae	-	-	1	LC	LC	-	Indigenous
Jacobaea vulgaris Gaertn.	Asteraceae	1	-	1	LC	LC	-	Indigenous
Juncus bufonius L.	Juncaceae	1	1	-	LC	LC	-	Indigenous
Knautia arvensis (L.) Coult.	Caprifoliaceae	1	-	1	LC	LC	-	Indigenous
Lactuca virosa L.	Asteraceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Lamium purpureum L.	Lamiaceae	1	-	-	LC	LC	-	Indigenous
Lapsana communis L.	Asteraceae	1	-	-	LC	LC	-	Indigenous
Lathyrus aphaca L.	Fabaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Lathyrus hirsutus L.	Fabaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Lathyrus latifolius L.	Fabaceae	-	-	1	LC	LC	-	Indigenous
Lathyrus nissolia L.	Fabaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Lathyrus pratensis L.	Fabaceae	1	-	1	LC	LC	-	Indigenous

Legousia speculum-veneris (L.) Chaix	Campanulaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Lemna minor L.	Araceae	-	-	1	LC	LC	-	Indigenous
Leucanthemum ircutianum DC.	Asteraceae	1	-	1	LC	-	-	Indigenous
Leucanthemum vulgare Lam.	Asteraceae	-	1	-	DD	LC	-	Indigenous
Linum strictum L.	Linaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Linum usitatissimum L.	Linaceae	1	-	1	LC	LC	-	Indigenous
Linum usitatissimum subsp. *angustifolium* (Huds.) Thell.	Linaceae	1	1	-	LC	LC	ZNIEFF	Indigenous
Lolium multiflorum Lam.	Poaceae	1	-	1	LC	LC	-	Indigenous
Lolium perenne L.	Poaceae	1	1	1	LC	LC	-	Indigenous
Lotus corniculatus L.	Fabaceae	1	1	1	LC	LC	-	Indigenous
Lotus hirsutus L.	Fabaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Lotus maritimus L.	Fabaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Luzula campestris (L.) DC.	Juncaceae	-	-	1	LC	LC	-	Indigenous
Lychnis flos-cuculi L.	Caryophyllaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Lysimachia arvensis (L.) U.Manns & Anderb.	Primulaceae	1	-	-	LC	LC	-	Indigenous
Lysimachia foemina (Mill.) U.Manns & Anderb.	Primulaceae	1	-	-	LC	NE	-	Indigenous
Malva neglecta Wallr.	Malvaceae	1	-	-	LC	LC	-	Indigenous
Malva sylvestris L.	Malvaceae	1	-	-	LC	LC	-	Indigenous
Medicago arabica (L.) Huds.	Fabaceae	1	1	1	LC	LC	ZNIEFF	Indigenous
Medicago lupulina L.	Fabaceae	1	-	1	LC	LC	-	Indigenous
Medicago polymorpha L.	Fabaceae	1	-	-	LC	DD	ZNIEFF	Indigenous
Medicago sativa L.	Fabaceae	1	1	1	LC	DD	-	Indigenous
Mentha aquatica L.	Lamiaceae	-	-	1	LC	LC	-	Indigenous
Mentha suaveolens Ehrh.	Lamiaceae	1	-	1	LC	LC	-	Indigenous
Muscari comosum (L.) Mill.	Asparagaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Muscari neglectum Guss. ex Ten.	Asparagaceae	-	1	1	LC	LC	ZNIEFF	Indigenous
Myagrum perfoliatum L.	Brassicaceae	1	-	-	-	LC	ZNIEFF	Indigenous
Myosotis arvensis (L.) Hill	Boraginaceae	1	1	1	LC	LC	-	Indigenous
Myosotis discolor Pers.	Boraginaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Myosotis dubia Arrond.	Boraginaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Myosotis sp.	Boraginaceae	1	-	-	-	-	-	-
Neotinea ustulata (L.) R.M.Bateman, Pridgeon & M.W.Chase	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Nigella damascena L.	Ranunculaceae	1	-	-	LC	-	-	Indigenous
Nigella sp.	Ranunculaceae	-	-	1	-	-	-	-
Oenanthe pimpinelloides L.	Apiaceae	1	1	1	LC	LC	ZNIEFF	Indigenous
Onobrychis viciifolia Scop.	Fabaceae	1	-	1	LC	-	-	Indigenous
Ononis spinosa subsp. *procurrens* (Wallr.) Briq.	Fabaceae	-	-	1	LC	DD	-	Indigenous
Ophrys apifera Huds.	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Ophrys scolopax Cav.	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Orchis anthropophora (L.) All.	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Orchis purpurea Huds.	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Orchis simia Lam.	Orchidaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Origanum vulgare L.	Lamiaceae	1	-	1	LC	LC	-	Indigenous
Orobanche gracilis Sm.	Orobanchaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Orobanche sp.	Orobanchaceae	-	-	1	-	-	-	-
Papaver rhoeas L.	Papaveraceae	1	-	-	LC	LC	-	Indigenous
Phalaris arundinacea L.	Poaceae	-	-	1	LC	LC	-	Indigenous
Phleum pratense L.	Poaceae	-	-	1	LC	LC	-	Indigenous
Picris hieracioides L.	Asteraceae	1	-	1	LC	LC	-	Indigenous
Pilosella officinarum Vaill.	Asteraceae	-	-	1	LC	LC	-	Indigenous
Pimpinella saxifraga L.	Apiaceae	-	-	1	LC	LC	-	Indigenous
Plantago lanceolata L.	Plantaginaceae	1	1	1	LC	LC	-	Indigenous
Plantago major L.	Plantaginaceae	1	-	1	LC	LC	-	Indigenous
Plantago media L.	Plantaginaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Poa annua L.	Poaceae	1	-	-	LC	LC	-	Indigenous
Poa bulbosa L.	Poaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Poa pratensis L.	Poaceae	1	1	1	LC	LC	-	Indigenous
Poa trivialis L.	Poaceae	1	1	1	LC	LC	-	Indigenous
Polygala calcarea F.W.Schultz	Polygalaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Potentilla reptans L.	Rosaceae	1	-	1	LC	LC	-	Indigenous

Poterium sanguisorba L.	Rosaceae	1	1	1	LC	LC	-	Indigenous
Prunella vulgaris L.	Lamiaceae	1	-	1	LC	LC	-	Indigenous
Prunus spinosa L.	Rosaceae	-	-	1	LC	LC	-	Indigenous
Pyracantha coccinea M.Roem.	Rosaceae	-	-	1	DD	-	-	Indigenous
Quercus pubescens Willd.	Fagaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Ranunculus acris L.	Ranunculaceae	1	1	1	LC	LC	-	Indigenous
Ranunculus arvensis L.	Ranunculaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Ranunculus bulbosus L.	Ranunculaceae	1	1	1	LC	LC	-	Indigenous
Ranunculus parviflorus L.	Ranunculaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Ranunculus repens L.	Ranunculaceae	1	1	1	LC	LC	-	Indigenous
Raphanus raphanistrum L.	Brassicaceae	1	-	-	LC	LC	-	Indigenous
Rapistrum rugosum (L.) All.	Brassicaceae	1	-	-	LC	LC	-	Indigenous
Rhamnus alaternus L.	Rhamnaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Rhinanthus alectorolophus (Scop.) Pollich	Orobanchaceae	1	1	-	LC	DD	ZNIEFF	Indigenous
Rosa canina L.	Rosaceae	-	-	1	LC	LC	-	Indigenous
Rubus grp. *fruticosus*	Rosaceae	-	-	1	-	-	-	-
Rubus sp.	Rosaceae	1	1	-	-	-	-	-
Rumex acetosa L.	Polygonaceae	1	1	1	LC	LC	ZNIEFF	Indigenous
Rumex acetosella L.	Polygonaceae	1	-	1	LC	LC	-	Indigenous
Rumex conglomeratus Murray	Polygonaceae	1	-	-	LC	-	-	Indigenous
Rumex crispus L.	Polygonaceae	1	1	1	LC	LC	-	Indigenous
Rumex obtusifolius L.	Polygonaceae	1	-	-	LC	LC	-	Indigenous
Rumex sanguineus L.	Polygonaceae	-	1	-	LC	LC	ZNIEFF	Indigenous
Salvia pratensis L.	Lamiaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Sanguisorba officinalis L.	Rosaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Scabiosa columbaria L.	Caprifoliaceae	-	-	1	LC	LC	-	Indigenous
Lolium mediterraneum (Hack.) Banfi, Galasso, Foggi, Kopecký & Ardenghi	Poaceae	1	1	1	LC	LC	-	Indigenous
Serapias vomeracea (Burm.f.) Briq.	Orchidaceae	1	1	1	LC	DD	ZNIEFF	Indigenous
Seseli montanum L.	Apiaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Sherardia arvensis L.	Rubiaceae	1	-	1	LC	LC	-	Indigenous
Silene latifolia Poir.	Caryophyllaceae	1	-	-	LC	LC	-	Indigenous
Sinapis alba L.	Brassicaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Sonchus asper (L.) Hill	Asteraceae	1	1	1	LC	LC	-	Indigenous
Stellaria graminea L.	Caryophyllaceae	1	-	1	LC	LC	-	Indigenous
Succisa pratensis Moench	Caprifoliaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Taraxacum sect. *Ruderalia*	Asteraceae	1	1	1	-	-	-	-
Torilis arvensis (Huds.) Link	Apiaceae	1	-	-	LC	LC	-	Indigenous
Tragopogon pratensis L.	Asteraceae	1	-	1	LC	LC	-	Indigenous
Trifolium campestre Schreb.	Fabaceae	1	-	1	LC	LC	-	Indigenous
Trifolium dubium Sibth.	Fabaceae	1	-	-	LC	LC	-	Indigenous
Trifolium incarnatum L.	Fabaceae	1	-	-	LC	LC	-	Indigenous
Trifolium medium L.	Fabaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Trifolium pratense L.	Fabaceae	1	1	1	LC	LC	-	Indigenous
Trifolium repens L.	Fabaceae	1	1	1	LC	LC	-	Indigenous
Trisetum flavescens (L.) P.Beauv.	Poaceae	1	-	1	LC	LC	-	Indigenous
Tritictum aestivum	Poaceae	1	-	-	-	-	-	Cultivated
Tritictum turgidum	Poaceae	1	-	-	-	-	-	Introduite
Triticum sp.	Poaceae	1	-	-	-	-	-	-
Valerianella dentata (L.) Pollich	Caprifoliaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Valerianella locusta (L.) Laterr.	Caprifoliaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Verbascum blattaria L.	Scrophulariaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Verbena officinalis L.	Verbenaceae	1	-	1	LC	LC	-	Indigenous
Veronica agrestis L.	Plantaginaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Veronica arvensis L.	Plantaginaceae	1	-	1	LC	LC	-	Indigenous
Veronica chamaedrys L.	Plantaginaceae	-	-	1	LC	LC	-	Indigenous
Veronica persica Poir.	Plantaginaceae	1	-	-	-	-	-	Introduite
Veronica serpyllifolia L.	Plantaginaceae	1	-	-	LC	LC	-	Indigenous
Veronica verna L.	Plantaginaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Vicia bithynica (L.) L.	Fabaceae	1	-	-	LC	LC	ZNIEFF	Indigenous
Vicia cracca L.	Fabaceae	1	-	1	LC	LC	-	Indigenous
Vicia faba L.	Fabaceae	1	-	-	-	-	-	Cultivated
Vicia sativa L.	Fabaceae	1	1	1	-	LC	-	Cultivated
Vicia segetalis Thuill.	Fabaceae	-	-	1	LC	LC	-	Indigenous
Vulpia bromoides (L.) Gray	Poaceae	1	-	1	LC	LC	ZNIEFF	Indigenous
Vulpia myuros (L.) C.C.Gmel.	Poaceae	1	-	1	LC	LC	-	Indigenous
Vulpia unilateralis (L.) Stade	Poaceae	-	-	1	LC	LC	ZNIEFF	Indigenous
Xeranthemum cylindraceum Sm.	Asteraceae	1	-	1	LC	LC	ZNIEFF	Indigenous