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Article

Biodiversity and Vegetation Succession in Vineyards, Moravia (Czech Republic)

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Abstract: Maintaining biodiversity in agricultural landscapes is a major challenge for environmental protection in Europe. Vineyards rely heavily on agrotechnical interventions such as herbicide use and tillage for weed control, which affect biodiversity and can lead to soil erosion and resistant weed populations. The fragmentation of agricultural landscapes affects biodiversity by altering community composition and often reducing plant population sizes and genetic diversity. However, it can also increase the abundance of certain species and enhance population resilience to environmental change. Vineyards can support high levels of biodiversity and provide ecosystem services due to their semi-natural habitat structure. This research evaluates vegetation biodiversity using phytosociological relevés in different vineyards. Our results show that species richness and biodiversity are significantly influenced by vineyard age and management type. This study highlights differences in the representation of plant functional groups, with perennial taxa in grassy inter-row contributing to anti-erosion functions and serving as food sources for pollinators. The root zone around vine trunks shows an increase in invasive species with vineyard age, posing a risk to the agroecosystem. Vineyards predominantly follow a ruderal ecological strategy, using nutrients and light efficiently, while tolerating management disturbances. Understanding these dynamics is critical for developing sustainable vineyard management practices that support biodiversity and ecological resilience, counteract the homogenization of agricultural landscapes, and promote the coexistence of viticulture and species-rich ecosystems.

Keywords: vegetation changes; plant diversity; habitat fragmentation; conservation management; microevolution

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1. Introduction

Preserving biodiversity in agricultural landscapes remains one of the main challenges for environmental protection in Europe [1,2]. Traditional small-scale agriculture co-created the current shape of the entire landscape and its biodiversity character [3,4]. The extensive management of traditional agriculture co-formed a high biodiversity [5,6]. However, current agriculture trends either intensify cultivation practices or abandon land use altogether, both of which threaten existing biodiversity [7].

Vineyards are often intensively managed and highly dependent on agrotechnical interventions in Europe [8–10]. The relationship between agriculture, biodiversity, and weed control in vineyards has become very important [11]. Different land management and weed control techniques significantly affect species richness and weed distribution in vineyards [12,13]. Certain weed species directly compete with the grapevine for water and nutrients, and, apart from this, they limit the vegetation biodiversity in the vineyard, which results in the reduced stability of vineyard ecosystems and a higher occurrence of pathogens and vine pests [14–17].

Weed control in vineyards is primarily achieved through herbicides and tillage. However, these methods promote erosion [18] and the emergence of resistant weed populations [19]. Soil erosion, exacerbated by a low soil organic matter content and a sloping terrain, is a major disadvantage of tillage [20,21]. While herbicides are cost-effective and efficient for weed control, their toxicity and negative environmental effects affect their use [22,23]. An alternative for vegetation management in vineyards is the establishment of cover crops in the inter-rows [24]. The choice of inter-row management strategy depends on winemaking traditions, pedo-climatic conditions, vineyard slope, and available machinery [25]. Inter-row cover crops are becoming increasingly popular. However, they compete with vines and can reduce vegetative growth and grape yield [21,26]. Often, a combination of vegetation management techniques, such as the "sandwich" rotation, is employed to mitigate these negative effects. This technique, developed in Switzerland, alternates strips of cultivated rows with grassy rows and is particularly recommended in areas with low rainfall [27–30].

In agricultural landscapes, the phenomenon of fragmentation is associated with a range of changes in biodiversity structure, community composition, abiotic conditions, and biotic interactions [31]. Fragmentation affects specific functional groups of organisms to different degrees [32] and alters community composition and competitive relationships between populations. Fragmentation and, especially, the edge effects of habitats can affect the distribution of living resources and, thus, evoke changes in the abiotic characteristics of habitats [33,34]. Changes in abiotic and biotic environmental characteristics induced by fragmentation can represent a selection pressure on populations of organisms. Fragmentation is often associated with reduced plant population size and availability of pollinators [35]. In plant populations, this induces a reduction in genetic diversity and an increase in inbreeding depression in the plant population [36]. Habitat fragmentation alters the landscape seed dispersal of wind-dispersed species [37]. However, most reactions of organisms to habitat fragmentation are positive and enhance the resistance of populations to a wide range of environmental conditions [38]. Fragmentation has the ability to produce persistent and often unpredictable outcomes, including surprising increases in the abundance of certain species. Long-time monitoring scales are essential to fully understand the consequences of fragmentation and be allowed to duly assess the effects of landscape fragmentation [31,39]. Increasing the diversity of vegetation in vineyards can maintain a higher landscape biodiversity and provide refuge and food source for various vertebrates and arthropods, including those which limit pests [40,41]. Although vineyards are intensively managed agroecosystems, they can host a great biodiversity of organisms [42,43] and provide a range of ecosystem services. Thanks to their special habitat structure, they have a semi-natural-to-natural character [21,44,45]. Vineyard vegetation can directly and indirectly provide several ecosystem services for grapevine production [21,46] and increase biological activity [47], infiltration water [48], and organic matter availability [49].

Thanks to the presence of vegetation in vineyards, the stability of the soil structure improves, organic matter stabilizes soil aggregates, and root systems protect the soil from erosion [49]. Vineyard vegetation also supports beneficial organisms important to grapevines [50] and boosts biodiversity [51,52]. Inter-rows can promote sustainability in viticulture by enabling a management system that fuels permanent or temporary vegetation cover with non-crop plant species, either as a mixture of sown cover crops or as spontaneous vegetation. The positive effect of cover crops on different levels of biodiversity and the related ecosystem services has been demonstrated by many studies [4,43,53,54].

The cultivation of grapevines creates conditions for a unique ecosystem consisting of vine plants, non-target vegetation, and other organisms. However, the study of vineyard vegetation has often overlooked the important feature of succession. Long-term and fragmented vineyard management, together with specific soil-climate conditions, influence vegetation succession in vineyards. Our study hypothesized that long-term vineyard conditions alter the course of succession and influence the representation of functional plant groups. The current study aimed to (i) determine trends in vineyard vegetation succession, (ii) identify changes in plant functional group representation during vineyard ageing, and (iii) clarify the application of plant ecological strategies during vineyard ecosystem succession. The central question of this research was the following: how do long-term vineyard conditions in the Dyjskosvratecký Valley, Moravia (Czech Republic), influence vegetation succession, changes in plant functional groups over time, and the application of plant ecological strategies within vineyard ecosystems?

2. Materials and Methods

2.1. Study Area and Charactersistics of the Vineyards

The selected vineyards are located on the edge of the Dyjskosvratecký Valley in South Moravia (Czech Republic). The altitude ranges between 240 and 320 m. The average annual temperature is 8.5 °C, and the annual rainfall is 470 mm. These data were taken from the nearest meteorological station of the Czech Hydrometeorological Institute in Kuchařovice [55–57].

This area belongs to the Moravian wine region, specifically the Znojmo wine subregion. A total of 44 vineyards of various ages were selected. The selected vineyards are located in the cadastral territories of 4 wine-growing municipalities. The Stará hora vineyard in the wine-growing village of Horní Dunajovice was established in 1995, 2000, 2020, and 2021. The Volné pole vineyard in the wine-growing village of Hostěradice was established in the years 1972, 2003, 2014, 2015, 2016, 2017, 2018, 2020, and 2021. The vine lines U Vinohradu in the wine-growing village of Miroslav were established in 2003, 2004, 2007, 2014, and 2019. The Weinperky vine line in the wine-growing village of Miroslav were established in the years 1996, 1998, 1999, 2001, 2002, 2003, 2004, 2008, 2009, 2011, 2014, 2015, and 2017. The Stará hora vineyards in the wine-growing village of Miroslavské Knínice were established in 2001. The Zolos vineyards in the wine-growing village of Miroslavské Knínice were established in 2014. The name of the vineyards, their year of establishment and GPS coordinates, the predominant soil type, and the area are shown in Table 1.

Table 1. General characteristics of the selected vineyards. The soil types follow the IUSS Working Group WRB [58].

Municipality	Vine Line	Year	GPS	Soil Type	Area (ha)
Horní Dunajovice	Frédy	1995	48°56′36.942″ N, 16°10′37.543″ E	chernozem	2.35
		2000	48°56′31.549″ N, 16°11′6.951″ E	cambisol	7.32
		2002	48°56′50.739″ N, 16°10′42.269″ E	chernozem	15.85
		2009	48°56′37.083″ N, 16°10′55.425″ E	chernozem, cambisol	4.38
		2016	48°56′45.850″ N, 16°10′39.508″ E	chernozem	1.9
		2018	48°56′41.433″ N, 16°10′38.154″ E	chernozem	2.25
		2021	48°56′38.423″ N, 16°10′38.040″ E	chernozem	3.03
Horní Dunajovice	Stará hora	1995	48°57′7.324″ N, 16°10′27.686″ E	chernozem, cambisol	4.13
		2000	48°57′1.878″ N, 16°10′51.851″ E	chernozem, cambisol	14.35
		2020	48°57′5.815″ N, 16°10′34.300″ E	chernozem	9.07
		2021	48°57′3.176″ N, 16°10′46.596″ E	chernozem	3.97
Hostěradice	Volné pole	1972	48°56′47.298″ N, 16°17′18.419″ E	chernozem, cambisol	10.23
		2002	48°56′59.237″ N, 16°17′12.561″ E	chernozem	17.09
		2003	48°56′55.483″ N, 16°17′20.826″ E	chernozem	8.54
		2014	48°57′25.162″ N, 16°17′17.557″ E	cambisol	15.22

		2015	48°57′36.249″ N, 16°17′15.639″ E	cambisol	7.66
		2016	48°57′20.646″ N, 16°17′10.774″ E	cambisol	19.65
		2017	48°57′4.665″ N, 16°16′57.111″ E	chernozem, cambisol	15.05
		2018	48°56′47.907″ N, 16°17′33.096″ E	chernozem	4.63
		2020	48°56′49.408″ N, 16°17′40.762″ E	chernozem	1.66
		2021	48°56′59.473″ N, 16°17′39.740″ E	chernozem	4.54
Miroslav	U vinohradu	2003	48°56′33.258″ N, 16°18′4.029″ E	chernozem	4.37
		2004	48°56′35.288″ N, 16°17′52.471″ E	chernozem, cambisol	2.69
		2007	48°56′42.228″ N, 16°17′59.485″ E	chernozem	2.79
		2014	48°56′34.780″ N, 16°17′56.997″ E	chernozem	1.22
		2019	48°56′40.443″ N, 16°17′51.188″ E	chernozem	1.58
Miroslav	Weinperky I	1996	48°55′55.163″ N, 16°18′56.924″ E	chernozem, cambisol	9.14
		2011	48°56′23.077″ N, 16°19′11.841″ E	chernozem, cambisol	5.89
		2014	48°56′15.517″ N, 16°19′1.103″ E	cambisol	2.4
		2015	48°56′9.683″ N, 16°19′2.032″ E	chernozem	5.98
		2017	48°56′11.229″ N, 16°18′54.074″ E	cambisol	2.44
Miroslav	Weinperky II	1996	48°56′22.790″ N, 16°18′25.823″ E	chernozem	2.35
		1998	48°56′20.679″ N, 16°18′18.850″ E	chernozem	8.63
		1999	48°55′57.286″ N, 16°18′19.773″ E	cambisol	3.91
		2000	48°56′2.005″ N, 16°18′18.074″ E	cambisol	3.91
		2001	48°56′13.216″ N, 16°18′32.461″ E	cambisol	8.63
		2002	48°56′24.941″ N, 16°18′9.886″ E 48°56′5.050″ N, 16°18′30.125″ E	cambisol	2.48
		2003	48°56′18.939″ N, 16°18′21.503″ E	chernozem	8.63
		2004	48°56′23.500″ N, 16°18′22.001″ E	chernozem	1.96
		2008	48°56′6.471″ N, 16°18′21.396″ E	cambisol	4.96
Miroslavské Knínice	Stará hora	2001	48°58′26.916″ N, 16°19′39.700″ E	chernozem, cambisol	5.35
	Zolos	2011	48°58′37.253″ N, 16°20′0.871″ E	cambisol	0.23

A conventional management system was applied in the evaluated vineyards. A similar type of management was employed in selected vineyards (Figure 1). There were 3 different habitats in the vineyards—a grassy inter-row (M1), a cultivated inter-row (M2), and a strip under the vine (PP) area around the trunks.

A mixture of grasses (*Lolium multiflorum*, *Lolium perenne*, *Festuca arundinacea,* and *Festuca pratensis*) and leguminous plants (*Onobrychis viciifolia* and *Trifolium pratense*) were sown in the grassy inter-row (M1) during the establishment of the vineyards. The vegetation of the grassy inter-row was maintained by mowing and mulching the biomass.

The cultivated inter-row (M2) in vineyards at most 3 years old was sown with a mixture of annual crops (*Phacelia tanacetifolia*, *Pisum sativum*, *Raphanus sativus*, *Sinapis alba*, *Trifolium alexandrinum*, *Trifolium incarnatum,* and *Vicia pannonica*) in the spring. During the summer, the vegetation was cut and ploughed into the soil.

In the strip area around the trunks where mechanization was not used, the vegetation was regulated by the application of herbicides and, alternatively, mechanically removed.

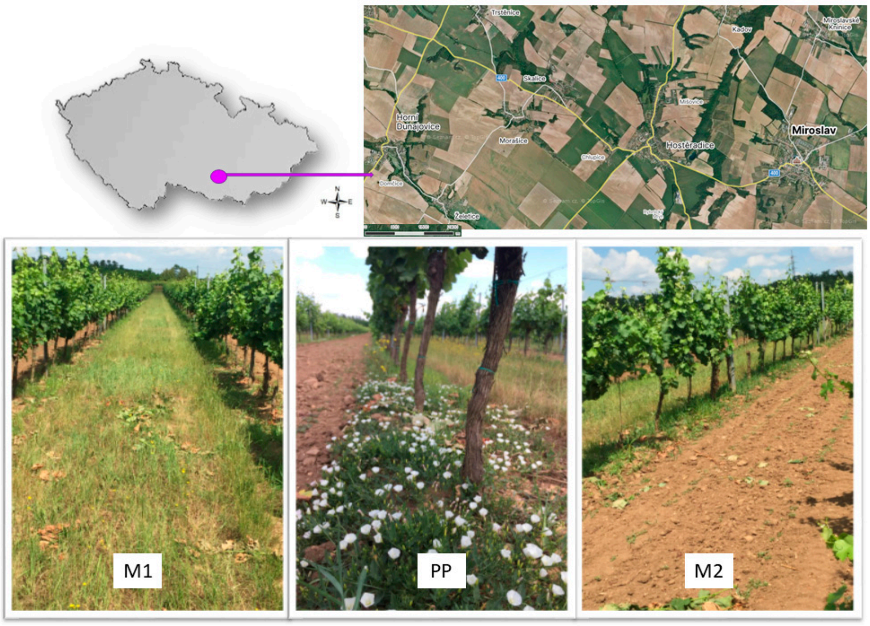

Figure 1. Map of the area of interest, vineyards, and three methods of vegetation management: (M1) grassy inter-row; (PP) strip under the vine; and (M2) cultivated inter-row.

2.2. Method of Vegetation Assessment

The vegetation was evaluated using the standard method of phytosociological relevés [59]. The size of each plot was 6 m^2, a rectangle measuring 1 by 6 m. The cover of all plant species was estimated and recorded as a percentage. The observation took place each year during the period between 2020 and 2023, in three vegetation optima (April, June, and October). The taxonomic nomenclature of the plants follows Kaplan et al. [60]. The full names of the plants and their groupings are given in Appendix A. Specimens of some of the plant species found were preserved and deposited in the herbarium of the Department of Plant Biology, Faculty of AgroSciences, Mendel University.

In each vineyard, three permanent plots (grassy inter-row (M1), cultivated inter-row (M2) and strip under the vine (PP)) were recorded in 4 repetitions. Permanent areas for recording the phytosociological relevés were chosen based on following parameters: the areas were adjacent to each other and located in three different habitats. During the four-year monitoring period, a total of 132 permanent relevés were recorded three times a year. The total number of phytosociological relevé records was 1584.

The identified plant species were divided into functional groups according to their biological properties. The first criterion was the division according to life span and taxonomy: (i) annual dicotyledons, (ii) perennial dicotyledons, (iii) annual monocotyledons, and (iv) perennial monocotyledons. The information was drawn from the Pladias database [61,62].

The second criterion was the division of the plant species into functional groups according to their importance in the vineyard ecosystem: (i) crops, (ii) legumes (*Fabaceae* family), (iii) annual weeds, (iv) deep-rooting species, (v) species with an anti-erosion effect (perennial grasses), and (vi) entomophilous species [61–63].

The third criterion divided the plant species into groups—native or alien—according to their origin with respect to the territory of the Czech Republic. Native plant species had to be present on the territory of the Czech Republic before the Neolithic time period. Alien taxa were divided into archaeophytes and neophytes according to the time at which they had been introduced by humans into the territory of the Czech Republic. The sorting of the species was carried out according to Pyšek et al. [64]. The alien species (archaeophytes and neophytes) were divided according to their invasion status. Casually introduced plant species were taxa whose survival in the area depended on repeated diaspore supply induced by human activity. Naturalized plant species had regularly multiplied in the area for a long time, independent of human activity. Invasive plant species were alien taxa that quickly spread over considerable distances over land. Following [64], the species were divided into the following categories: (i) native, (ii) casual archaeophytes, (iii) naturalized archaeophytes, (iv) invasive archaeophytes, (v) casual neophytes, (vi) naturalized neophytes, and (vii) invasive neophytes.

The fourth criterion divided the species according to ecological strategy. Grime [65,66] distinguished three basic ecological strategies of plants: (i) the competitive strategy (C), convenient in stable habitats where the resources are abundant, the conditions are not extreme, and disturbance is limited; (ii) the stress tolerance strategy (S), convenient in habitats with scarce resources and extreme and highly variable conditions, but with limited disturbance; and (iii) the ruderal strategy (R), convenient in habitats where the resources are abundant, the conditions are not extreme, but disturbance is frequent. Scores expressing a degree of "C", "S", or "R" were applied to the identified species. The rate was expressed as a percentage, and the sum of all three scores for each individual taxon was 100% [67].

The fifth criterion divided the species based on the categories of threatened species according to the national Red List of Vascular Plants of the Czech Republic [68]. The main category "A" includes taxa that are extinct or missing, while the main category "C" includes taxa which are threatened, including rarer taxa requiring attention and unclear cases.

The sixth criterion divided the species according to the successional age optimum, which is expressed as the median time in years from the moment of disturbance to the time when the taxon occurs during the succession. The optimum was determined to be in the range of 1 to 50 years. For the taxa whose optimum was a time longer than 50 years since the last disturbance and could not be calculated precisely due to a low number of successional stages, the value was set to 75 years [61].

2.3. Statistical Data Evaluation

The Kruskal–Wallis test was conducted separately for the strip under the vine (PP) and the two differently managed inter-rows (M1, M2) across seasons (spring, summer, and autumn). Analogously, the Kruskal–Wallis test was conducted separately for the seasons (spring, summer, autumn) and separately across the rows with grapevine (PP) and the two differently managed inter-rows (M1, M2). The Shapiro–Wilk test was utilized to assess the normality of the data distributions within each group, while the Levene test was employed to examine the homogeneity of the variances across groups. Both tests indicated significant departures from normality (all results with $p < 0.05$), justifying the use of the Kruskal–Wallis test for data analysis. Subsequently, post hoc pairwise comparisons were performed using the Dunn test, following significant results from the Kruskal–Wallis test. To account for multiple comparisons, the Bonferroni correction was applied. Linear regression analysis using the lm function in R was used to investigate the relationship between the number of species and the age of the vineyard. The lm model function was utilized to fit the linear regression models separately for each combination of seasons (spring, summer, and autumn) and variants (M1, M2, PP), resulting in a total of nine distinct models. Data analyses were conducted using the R statistical software [69].

3. Results

During the four-year monitoring period, 172 plant species were identified in the selected vineyards. The following taxa belonging to annual dicotyledonous species were identified: *Amaranthus powellii*, *Amaranthus retroflexus*, *Anagallis arvensis*, *Anagallis foemina*, *Anthemis arvensis*, *Atriplex patula*, *Atriplex sagittata*, *Brassicca napus* subsp. *napus*, *Camelina microcarpa*, *Camelina sativa*, *Capsella bursa-pastoris*, *Cerastium holosteoides*, *Consolida regalis*, *Conyza canadensis*, *Datura stramonium*, *Descurainia sophia*, *Erigeron annuus*, *Erodium cicutarium*, *Euphorbia helioscopia*, *Fagopyrum esculentum*, *Fallopia convolvulus*, *Fumaria officinalis*, *Galeopsis tetrahit*, *Galinsoga parviflora*, *Galium aparine*, *Geranium pusillum*, *Geranium robertianum*, *Holosteum umbellatum*, *Chelidonium majus*, *Chenopodium album*, *Chenopodium hybridum*, *Chenopodium polyspermum*, *Lactuca serriola*, *Lamium amplexicaule*, *Lamium purpureum*, *Lathyrus sativus*, *Linum usitatissimum*, *Malva neglecta*, *Matricaria discoidea*, *Mercurialis annua*, *Microthlaspi perfoliatum*, *Myosotis arvensis*, *Papaver rhoeas*, *Phacelia tanacetifolia*, *Pisum sativum*, *Polygonum aviculare*, *Portulaca oleracea*, *Raphanus sativus*, *Raphanus raphanistrum*, *Scleranthus annuus*, *Senecio jacobaea*, *Senecio vulgaris*, *Silene noctiflora*, *Sinapis alba*, *Solanum nigrum*, *Sonchus oleraceus*, *Stellaria media*, *Trifolium alexandrinum*, *Trifolium incarnatum*, *Tripleurospermum inodorum*, *Urtica urens*, *Veronica hederifolia*, *Vicia pannonica*, and *Viola arvensis.*

The following taxa belonging to perennial dicotyledonous species were identified: *Agrimonia eupatoria*, *Achillea millefolium*, *Ailanthus altissima*, *Alcea biennis*, *Anthyllis vulneraria*, *Arctium lappa*, *Arctium tomentosum*, *Artemisia absinthium*, *Artemisia vulgaris*, *Berteroa incana*, *Carduus acanthoides*, *Carlina vulgaris*, *Centaurea jacea*, *Cichorium intybus*, *Cirsium arvense*, *Convolvulus arvensis*, *Crataegus laevigata*, *Crepis biennis*, *Crepis capillaris*, *Cynoglossum officinale*, *Daucus carota*, *Echinops sphaerocephalus*, *Echium vulgare*, *Eryngium campestre*, *Euphorbia esula*, *Falcaria vulgaris*, *Fragaria vesca*, *Galium album*, *Galium verum*, *Geranium pyrenaicum*, *Geum urbanum*, *Humulus lupulus*, *Hypericum perforatum*, *Inula salicina*, *Juglans regia*, *Lamium album*, *Lamium maculatum*, *Lathyrus tuberosus*, *Lepidium draba*, *Ligustrum vulgare*, *Linaria vulgaris*, *Lotus corniculatus*, *Medicago lupulina*, *Medicago sativa*, *Melilotus albus*, *Melilotus officinalis*, *Nonea pulla*, *Onobrychis viciifolia*, *Onopordum acanthium*, *Parthenocissus inserta*, *Petrorhagia prolifera*, *Physalis alkekengi*, *Pilosella aurantiaca*, *Pilosella officinarum*, *Plantago lanceolata*, *Plantago major*, *Plantago media*, *Potentilla argentea*, *Potentilla reptans*, *Quercus petraea*, *Reseda lutea*, *Ribes aureum*, *Robinia pseudoacacia*, *Rosa canina*, *Rubus* sect. *Rubus*, *Rumex crispus*, *Rumex obtusifolius*, *Salvia pratensis*, *Sambucus nigra*, *Scabiosa ochroleuca*, *Securigera varia*, *Silene latifolia*, *Silene vulgaris*, *Symphytum officinale*, *Tanacetum vulgare*, *Taraxacum* sect. *Taraxacum*, *Tragopogon dubius*, *Tragopogon orientalis*, *Trifolium campestre*, *Trifolium pratense*, *Trifolium repens*, *Urtica dioica*, and *Vicia cracca.*

The following taxa belonging to annual monocotyledonous species were identified: *Apera spica-venti*, *Avena fatua*, *Bromus hordeaceus*, *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Hordeum murinum*, *Panicum miliaceum*, *Poa annua*, *Secale cereale*, *Setaria pumila*, *Setaria viridis*, *Setaria verticillata*, and *Triticum aestivum.*

The following taxa belonging to perennial monocotyledonous species were identified: *Arrhenatherum elatius*, *Calamagrostis epigejos*, *Dactylis glomerata*, *Elymus repens*, *Festuca arundinacea*, *Festuca pratensis*, *Festuca rubra*, *Lolium multiflorum*, *Lolium perenne*, *Luzula campestris*, *Poa pratensis*, and *Stipa pennata.*

The mean number of species per plot (6 m^2) differed, ranging from 1 up to 32. In general, higher species numbers were observed on the plots situated in the inter-rows (M1, M2), contrary to the rows below the grape trunks (PP). Increasing species numbers over the same season were found for all the three differently managed variants (Figure 2).

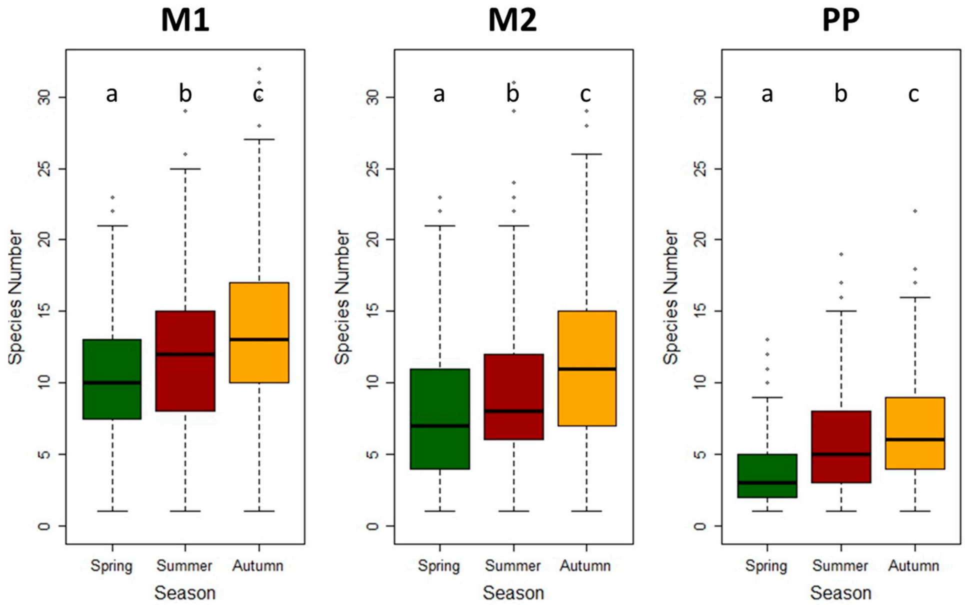

Figure 2. The box and whisker plots present the number of species in the phytosociological relevés. Individual seasons of the year are presented separately, and the differences are tested using the Kruskal–Wallis test (the letters above the boxes show the statistically significant results). Variants: M1 = grassy inter-row; M2 = cultivated inter-row; and PP = stripe below the grape trunks.

The number of plant species increased statistically significantly in the grassy inter-row (M1) with the age of vineyards. The number of plant species also increased statistically significantly in the strip area around the grapevine trunks with the age of the vineyard, but only during the summer season. In spring and autumn, the differences were not statistically significant. The changes in the number of plant species in the cultivated inter-rows were not statistically significant (Figure 3).

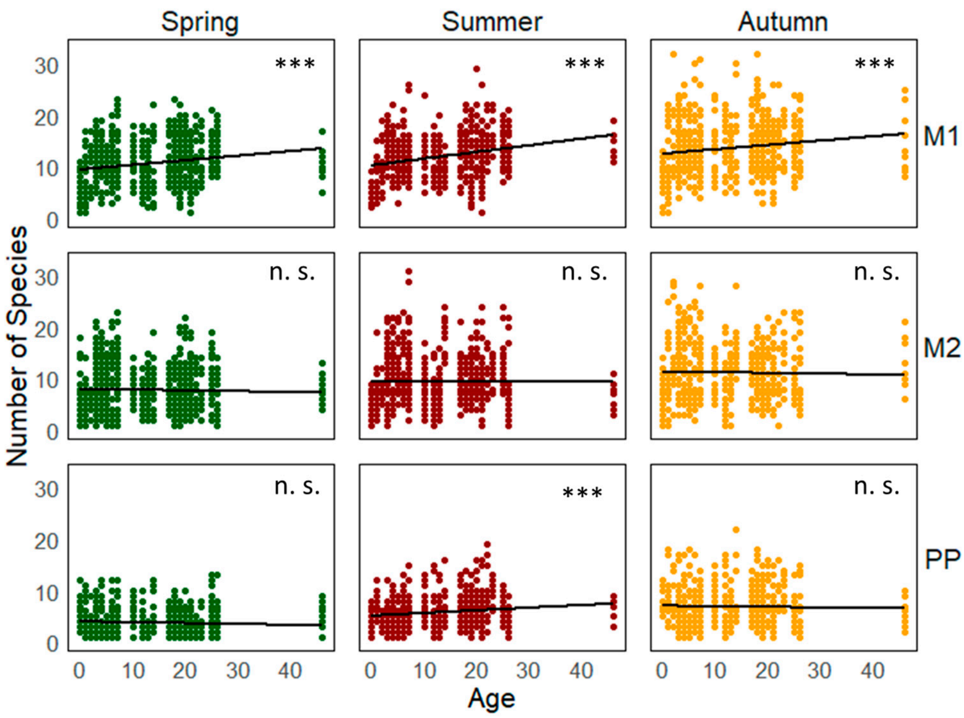

Figure 3. The relationship between the number of plant species and the age of the vineyards (years after establishment). The variants include M1 for grassy inter-rows, M2 for cultivated inter-rows,

and PP for stripes below the grape trunks. The asterisks (***) denote significant changes in species numbers when comparing vineyards with different establishment times (n. s.: M2 spring $p = 0.18$; M2 summer $p = 0.13$; M2 autumn $p = 0.15$; PP spring $p = 0.11$; and PP autumn $p = 0.12$).

The coverage development of the plant groups according to the length of the growing season and botanical division is shown in Figure 4. The representation of the plant groups changed with the age of the vineyard, the season, and the type of inter-row.

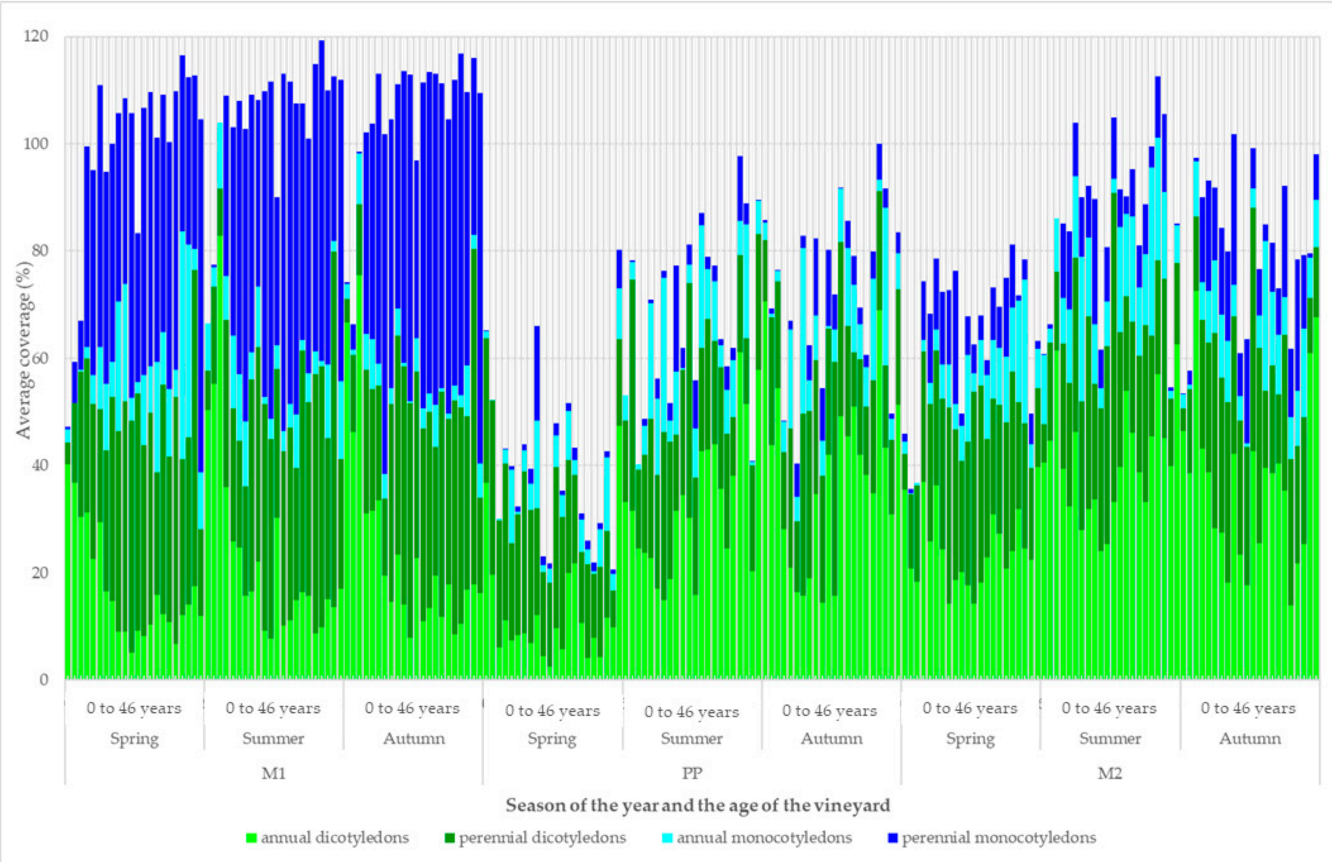

Figure 4. Development of the structure of vineyard vegetation cover according to biological properties.

In the grassy inter-row (M1), there was an increase in coverage in the vineyards that were up to 4 years old, in both the perennial dicotyledon and perennial monocotyledon groups. The increase was no longer evident in older vineyards. The coverage of the group of annual dicotyledonous plants gradually decreased with the age of the vineyards, up to 6 years, and then the share of coverage stagnated. The coverage of the group of annual monocots was higher in vineyards older than 6 years, but only in the spring evaluation period; in the other evaluation periods, the coverage stagnated.

There was a significant difference in coverage between seasons in the strip area around the grapevine trunks. In the spring, the coverage was significantly lower than in the summer or autumn. In the spring, the cover was dominated by perennial dicotyledonous species. In vineyards up to 7 years old, there was a decrease in coverage in the group of annual dicotyledons in summer and autumn. In older vineyards, the coverage of the group of annual dicotyledons increased.

In the cultivated inter-row (M2), the group of annual dicotyledons had a high coverage, especially in young and old vineyards. In vineyards between 5 and 14 years old, there was a decrease in coverage. In old vineyards, the coverage was higher in the group of annual monocotyledons.

The development of the coverage of the plant groups according to the functional groups is shown in Figure 5. In vineyards up to 4 years of age, there was an increase in the coverage of representatives of the *Fabaceae* family, entomophilous plants, and species with an anti-erosion effect in the grassy inter-row (M1). There was a significant difference in the coverage of plant groups between the seasons. During the spring, the coverage of the group of deep-rooting species was dominant. During the summer, the coverage of annual weeds decreased. In the older vineyards, the coverage of annual weeds increased in the cultivated inter-row (M2). There was a high coverage of the group of crops and representatives of the leguminous family.

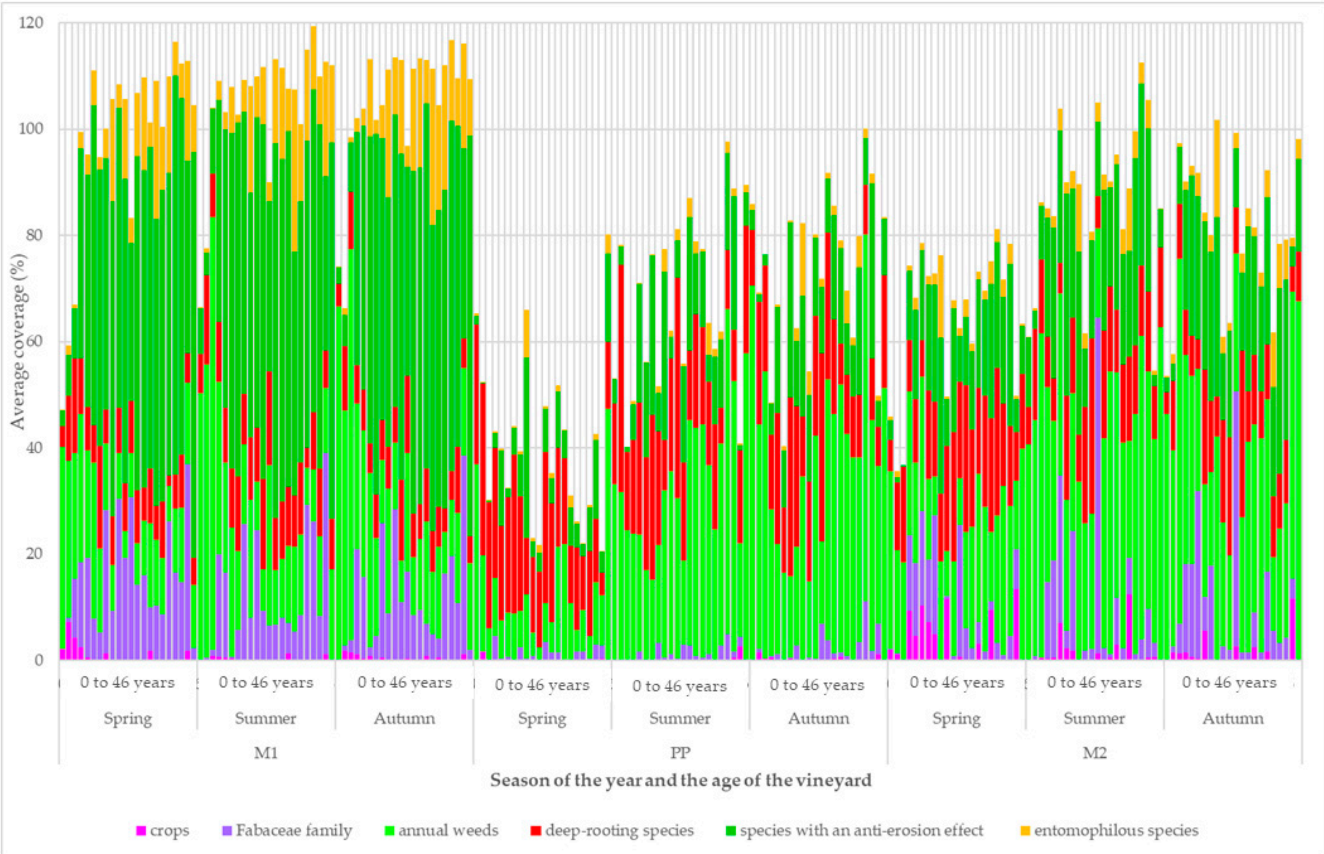

Figure 5. Development of the structure of vineyard vegetation cover according to functional groups.

In vineyards up to 7 years old, during the summer and autumn, the coverage of the group of annual weeds decreased. In older vineyards, the coverage of the annual weed group increased. In the cultivated inter-row (M2) of young vineyards, there was a high coverage of plant groups and representatives of the *leguminous* family. In vineyards aged 5 to 14 years, there was an increase in the coverage of deep-rooting species.

The development of plant group coverage according to origin and invasion status is demonstrated in Figure 6. The high coverage of species from the invasive archaeophyte group and invasive neophyte group was mainly in the strip area around the grapevine trunks and in the cultivated inter-row (M2). Indigenous plant species had the least coverage in these habitats.

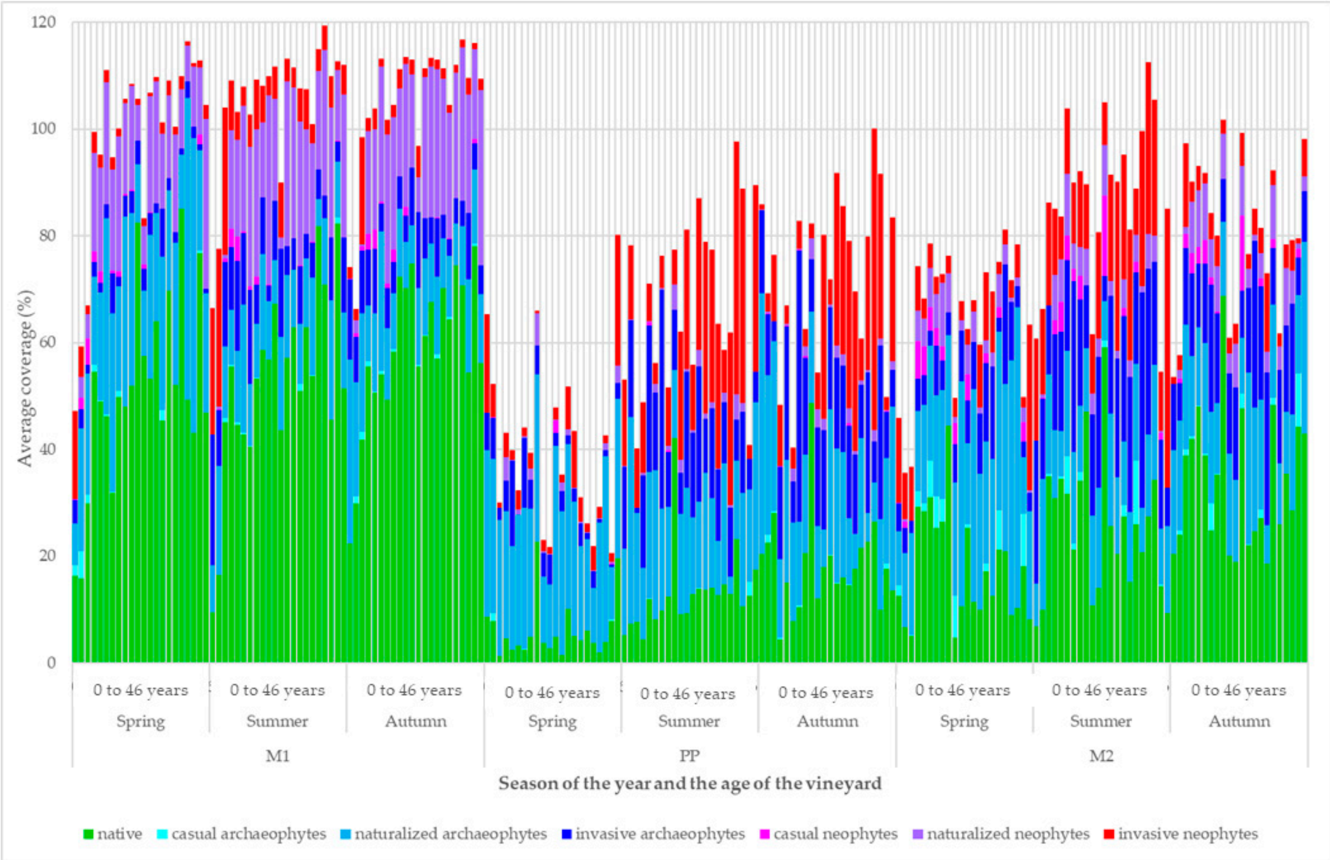

Figure 6. Development of the structure of vineyard vegetation cover according to functional groups.

The development of the coverage of the plant groups according to their ecological strategy is shown in Figure 7. In the grassy inter-row (M1) in vineyards aged up to 4 years, there was a stable ratio between the three basic strategies, with a slight predominance of the ruderal strategy. There was a markedly lower proportion of species with a stress-tolerant strategy in the strip area around the grapevine trunks. In the cultivated inter-row (M2), there was also a lower share of species with a stress-tolerant strategy and a stronger predominance of species with a ruderal strategy.

The development of the coverage of groups of species according to the extinction risk is depicted in Figure 8. The occurrence of threatened plant species was not high. They were found at all three sites, especially in vineyards older than 3 years. These were the taxa *Inula salicina*, *Nonea pulla*, *Petrorhagia prolifera*, *Pilosella aurantiaca*, *Silene noctiflora*, *Stipa pennata*, and *Urtica urens*.

The development of the coverage of the group of species according to the optimal age of succession is shown in Figure 9. Figure 9 illustrates the progressive development of vegetation cover within a vineyard, focusing on changes over time, as the vegetation matures and reaches its optimal successional age. The figure provides a detailed visual representation of how the structure of the vineyard's vegetation evolves, highlighting key stages and characteristics at various points in the succession process.

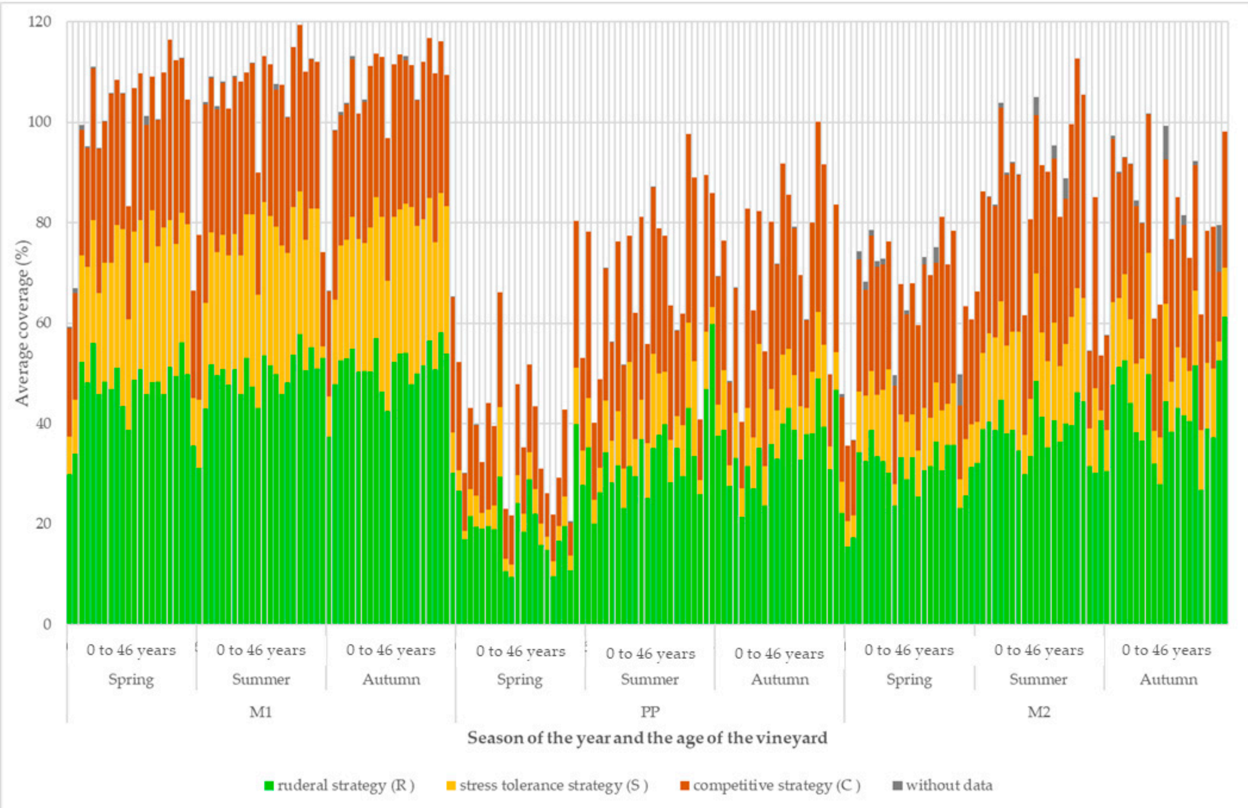

Figure 7. Development of the structure of vineyard vegetation cover according to the ecological strategy.

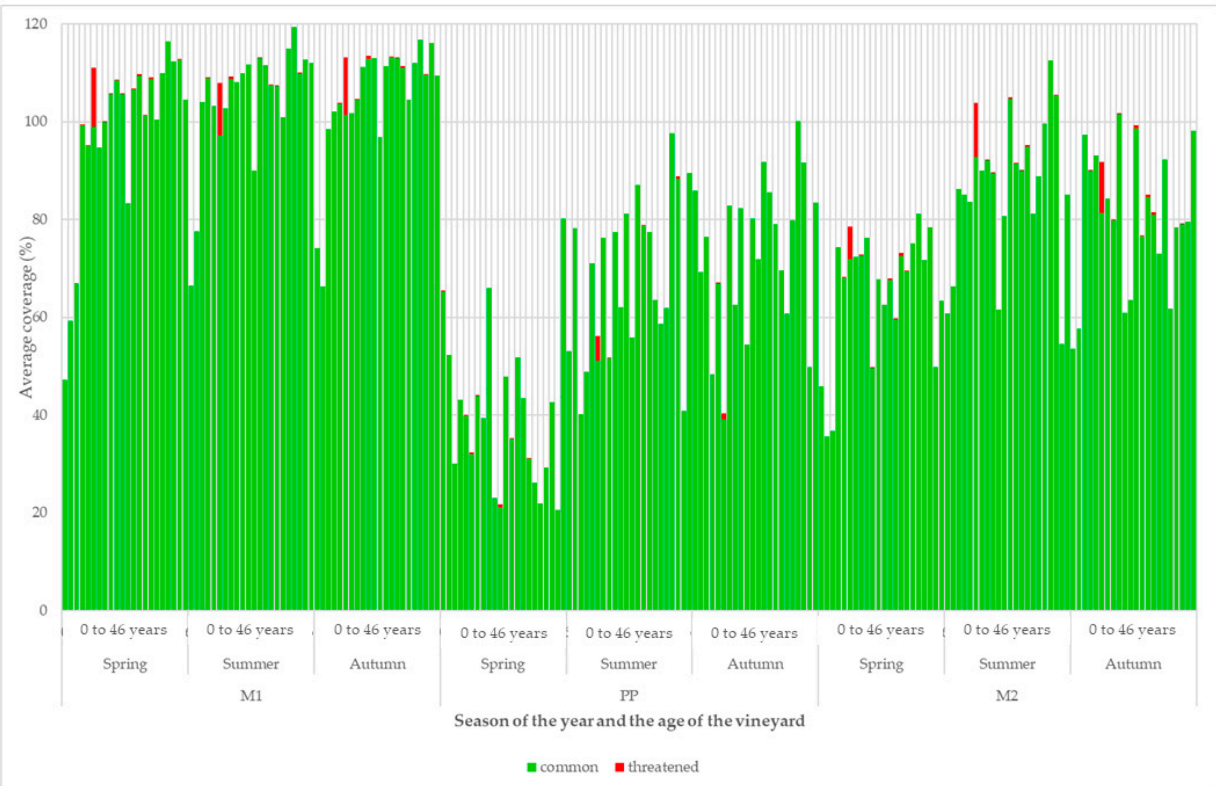

Figure 8. Development of the structure of vineyard vegetation cover according to the extinction risk.

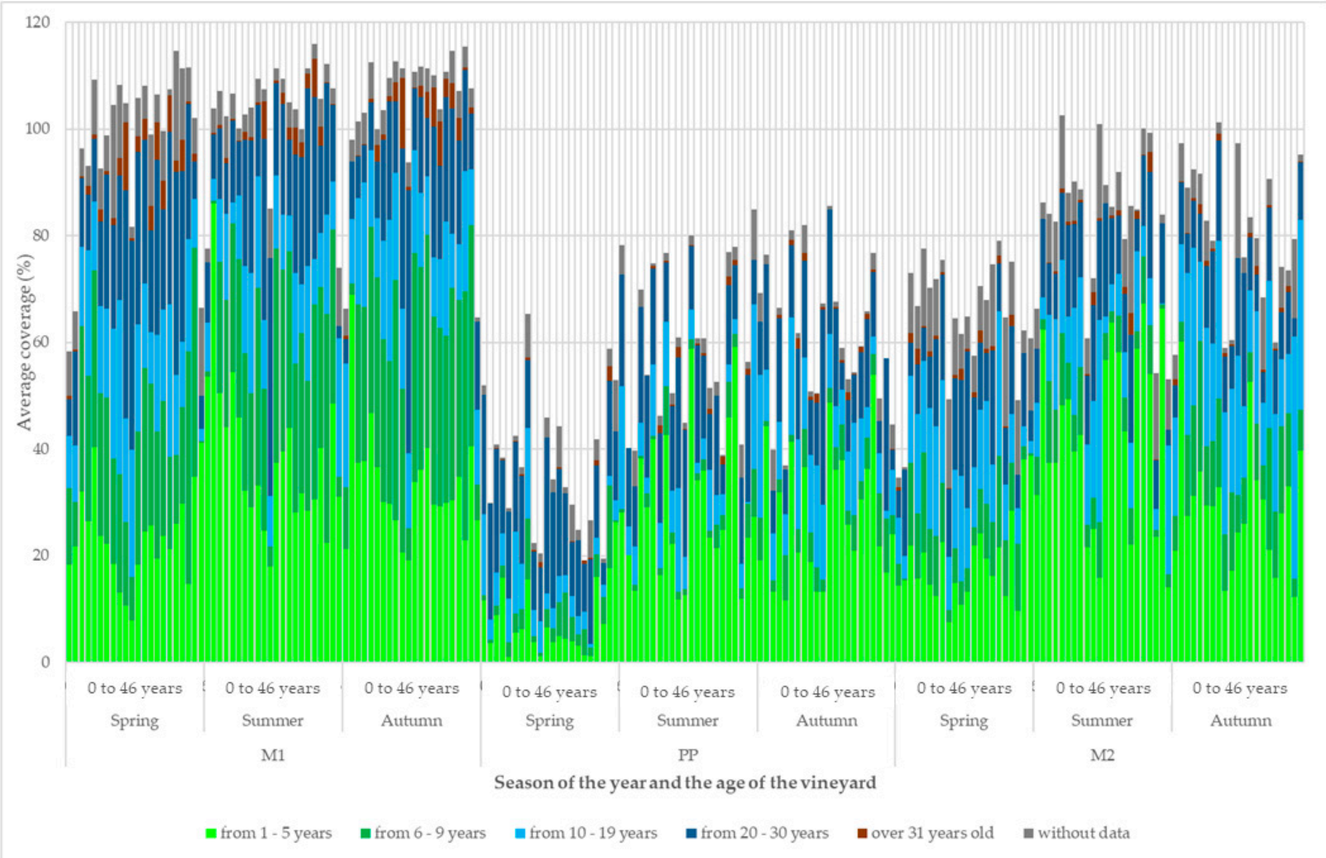

Figure 9. Development of the structure of vineyard vegetation cover according to the optimal successional age.

In the grassy inter-row (M1) in vineyards aged 12 to 16 years, there was a decrease in the coverage of the group with an optimal age of succession of 1 to 5 years, and, on the contrary, there was an increase in the coverage of the other groups. In vineyards older than 16 years, the proportion of groups according to the optimal age of succession did not change extensively. Species from the group with an optimum successional age of 1 to 5 years maintained their dominant coverage in the strip area around the grapevine trunk and in the cultivated inter-row (M2). In the cultivated inter-row (M2), the proportion of species with an optimum successional age of 10 to 29 years increased with growing vineyard age.

4. Discussion

Vineyards in agricultural landscapes support higher vegetation species diversity. The results show that different vegetation management practices create habitat heterogeneity within vineyard areas. This heterogeneity leads to the formation of habitats with varying levels of plant species representation, contributing to overall biodiversity.

The grassy inter-rows created more favourable conditions for the occurrence of a higher number of plant species. On the contrary, the lowest number of plant species appeared in the strip area around the grapevine trunks. It is evident that the method of regulation markedly affects the number of plant species. The applied herbicides have an important role in weed control in vineyards [70,71] but are also the main reason for the decline in biodiversity in agroecosystems [72–74]. The types of herbicides used are critical. As pointed out by Winkler et al. [75], a reduction in the use of herbicides leads to a change in the spectrum of vegetation species. Soil cultivation in vineyards is used primarily to control annual weeds [76–78]; however, certain plant taxa are able to adapt to this type of weed control.

The grassy inter-rows in vineyards are areas where certain plant groups thrive. Perennial taxa, known for their anti-erosion benefits, and indigenous taxa have substantial coverage in these areas. Although we did not measure erosion directly, the existing literature supports the role of perennial plants in reducing erosion. The species composition indicates that grassy inter-rows are important habitats with anti-erosion functions. Additionally, the high proportion of indigenous taxa limits the spread of non-indigenous species. The long-term, stable management of grass communities fosters the development of species-rich vegetation. Major changes in grassland management lead to shifts in species composition [79], and the grassy inter-rows of vineyards are well-suited for creating diverse plant communities. The vegetation of the strip area around the grapevine trunks has a markedly different composition. Annual dicotyledonous taxa, deep-rooting taxa, and taxa with an invasive status have substantial coverage there. The strip area around grapevine trunks is a habitat within vineyards where the vegetation is most regulated. Nevertheless, there is an important share of taxa that directly compete with the grapevine or pose a danger to the entire ecosystem. A high level of vegetation regulation apparently suppresses indigenous taxa and species with beneficial functions in relation to grapevines.

A cultivated inter-row favours to occurrence of annual taxa, deep-rooting taxa, indigenous archaeophytes, and domesticated archaeophytes. The repeated cultivation of the soil creates similar conditions to those on arable land; therefore, there is a higher coverage of annual taxa. The typical annual taxa in field crop stands are weeds. According to Kazakou et al. [80], tillage and herbicide use favour the profile of ruderal taxa, plants with a lower competitiveness and high seed production. According to Storkey et al. [81], regulatory interventions lead to the selection of plant taxa that have a rapid life cycle as well as taxa that competitively limit optimal grapevine development. This can be observed, from our results, mainly in habitats with intensive regulatory interventions (M2, PP). Despite their adverse properties, weeds also provide other functions: e.g., they serve as a source of food and shelter for a whole range of animals, which gives them an important place in the vineyard ecosystem [82–84]. Biomass regulation is also of great importance for reducing the risk of fires [85]. Moreover, the intensification of agriculture has led to the loss of biodiversity, the simplification of the plant community, and the deterioration of ecosystem stability [86–88]; yet, threatened species can also be part of the vineyard vegetation. However, their representation is not considerable.

The vegetation of vineyards is influenced by their age. This relationship was particularly evident in the grassy inter-rows, where there was a gradual increase in the number of plant species. However, when considering the changes in cover, these changes occurred mainly in young vineyards, up to 8 years of age (Figures 4–6). After this amount of time, the changes stabilized and became less pronounced. It could be assumed that the further course of vegetation succession was blocked due to vegetation regulation. This is also shown in Figure 8, where the share of species in the vegetation cover does not vary much in vineyards older than 5 years. The vegetation of the cultivated inter-rows changed only to a limited extent with the age of the vineyards, due to the cultivation of the soil, which returned the succession process to the initial stage of phytocenosis.

The conditions that the strip area around the grapevine trunks creates clearly increased the number of plant species with the growing age of the vineyards, but this was only noticeable in the summer season. The increase in the number of species was caused mainly by taxa with an invasive status. Plant taxa in vineyards most frequently apply a ruderal ecological strategy. This indicates sufficient nutrients and light in the vineyards and substantial disturbances. At sites in the cultivated inter-rows and strip areas around the grapevine trunks, the share of the R-strategy was more significant, while the share of the S-strategy decreased. The application of the S-strategy had a higher share in the grassy inter-rows. A similar proportion of S-strategy was reported by Winkler et al. [85] in the case of urban lawns. It can be presumed that the conditions of vineyards are of a stressful nature. Above all, the lack of water and the high insolation evoke stress in some taxa and can be part of the winemaking conditions—terroir. Plant taxa that apply a stress tolerance strategy allow these conditions to prevail. Regularly recurring disturbances and the application of herbicides generally occur in the cultivated inter-row and the strip area around the grapevine trunks. These factors give evidence for the application of an anthropogenic life strategy (A). According to Winkler et al. [89], the A-strategy is an adaptation to the conditions created by human civilization. It is therefore probable that the application of the A-strategy enables certain plant taxa to survive in vineyard conditions.

The primary ecosystem service of vineyards for farmers is the yield and quality of the grapes. These factors are influenced by grape variety, cultivation techniques, and the unique "terroir" conditions [90,91]. It is important to note that "terroir" conditions also play a crucial role in shaping vineyard vegetation. Griesser et al. [92] suggest that vineyard management strategies can adapt to climate change, maintain ecosystem functions, and enhance biodiversity. Similarly, Boinot et al. [93] emphasize that non-crop vegetation is essential for agroecosystems, particularly in mitigating climate change impacts and biodiversity loss crises.

The promotion of biodiversity is increasingly recognized among wine producers seeking to enhance the cultural value of agricultural landscapes [8,9]. Enhancing vegetation diversity in vineyards not only supports biodiversity but also enhances their esthetic appeal, fostering the coexistence of viticulture and diverse ecosystems.

5. Conclusions

The vegetation in vineyards creates a habitat for other organisms. It undergoes a succession with a very specific course. The succession of vegetation in vineyards differs according to the type of management used. In grassy inter-rows (M1), the number of plant species increases especially in young vineyards, until the ages of 5 to 8 years. After this time, the number of plant species stabilizes, which can be considered a blocked succession. The vegetation of the cultivated inter-row (M2) and the root zone changes little with age and remains in an initial phase of phytocenosis.

The representation of plant functional groups differs between habitats with different management types. During the ageing of vineyards, mainly perennial dicotyledonous and perennial monocotyledonous taxa predominate in the grassy inter-rows. Thanks to these taxa, the vegetation of a vineyard can serve primarily as a protection against erosion and a source of food for pollinators. In the strip area around the vine trunks, the number of plant species clearly increases with the age of the vineyard, mainly due to taxa with an invasive status. This habitat represents a risk zone from the point of view of the possible spread of non-native plant taxa in the agroecosystem.

The plant taxa growing in vineyards mainly follow a ruderal ecological strategy. This allows them to use nutrients and light more efficiently and survive the considerable disturbances associated with the regulation of vegetation in vineyards. Vineyards are an ecological niche that helps to create the conditions for the A-strategy as an adaptation to the conditions of human civilisation [89]. According to Mahaut et al. [94], understanding the impact of human activities on ecological and evolutionary dynamics requires a re-evaluation of ecological theories that were originally developed for natural ecosystems. They can hardly explain the reciprocal interactions between human activities and ecological and evolutionary processes.

Vineyards are an ecosystem with fragmented habitats that allow heterogeneous vegetation to flourish. As vineyards age, the vegetation changes, and the dynamics of the vineyard ecosystems become apparent. It is important to perceive vineyard vegetation not as an unchanging and stable community but as changing with changing dynamics. In young vineyards, the dynamics of change are faster, and, as the vineyard ages, the changes become slower. The vegetation of vineyards is a means of preventing the homogenisation of the agricultural landscape and allows the permanent coexistence of viticulture and species-rich ecosystems.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Names of the plant species present in the vineyards under study and classification of the plant species in groups.

Name	Authorship	Family	Biological Properties	Functional Groups	Groups on Native and Invasion Status	Ecological Strategy (C)	(S)	(R)	Treatened Species	Successional Age Optimum
Agrimonia eupatoria	L.	*Rosaceae*	perennial dicotyledons	entomophilous species	native	47.8	36.7	15.5	common	32
Achillea millefolium	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	22	58.8	19.2	common	23
Ailanthus altissima	(Mill.) Swingle	*Simaroubaceae*	perennial dicotyledons	deep-rooting species	invasive neophytes	74.9	21.3	3.8	common	27
Alcea biennis	Winterl	*Malvaceae*	perennial dicotyledons	entomophilous species	native	0	0	0	C2b	without data
Amaranthus powellii	S. Watson	*Amaranthaceae*	annual dicotyledons	annual weeds	invasive neophytes	57.4	20.4	22.2	common	1.5
Amaranthus retroflexus	L.	*Amaranthaceae*	annual dicotyledons	annual weeds	invasive neophytes	52.1	23.7	24.2	common	1.5
Anagallis arvensis	L.	*Primulaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	9.7	0	90.3	common	5
Anagallis foemina	Mill.	*Primulaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	16.7	9.9	73.6	C3	4
Anthemis arvensis	L.	*Asteraceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	21.3	0	78.4	common	10
Anthyllis vulneraria	L.	*Fabaceae*	perennial dicotyledons	legumes	native	51.6	4.6	43.8	common	18
Apera spicaventi	(L.) P. Beauv.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	naturalized archaeophytes	24.7	42.6	32.7	common	3
Agrimonia eupatoria	L.	*Rosaceae*	perennial dicotyledons	entomophilous species	native	47.8	36.7	15.5	common	32
Arctium lappa	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	79.1	7.9	13	common	8.5
Arctium tomentosum	Mill.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	79.1	7.9	13	common	8
Arrhenatherum elatius	(L.) J. Presl et C. Presl	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	invasive archaeophytes	23.1	40.3	36.5	common	25
Artemisia absinthium	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	36.9	21.9	41.2	common	8
Artemisia vulgaris	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	41.6	29.6	28.8	common	10
Atriplex patula	L.	*Chenopodiaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	53.9	0	46.1	common	4.5
Atriplex sagittata	Borkh.	*Chenopodiaceae*	annual dicotyledons	annual weeds	invasive archaeophytes	38.3	29	32.8	common	5

Avena fatua	L.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	naturalized archaeophytes	48.8	25.5	25.8	common	4
Berteroa incana	(L.) DC.	*Brassicaceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	9.9	52.1	38	common	16.5
Brassicca napus subsp. napus	L.	*Brassicaceae*	annual dicotyledons	crops	casual archaeophytes	58	0.3	41.8	common	without data
Bromus hordeaceus	L.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	naturalized archaeophytes	11.6	47.2	41.2	common	12
Calamagrostis epigejos	(L.) Roth	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	40.8	51.2	8	common	16
Camelina microcarpa	DC.	*Brassicaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	33.6	0	66.4	common	6.5
Camelina sativa	(L.) Crantz	*Brassicaceae*	annual dicotyledons	crops	casual archaeophytes	33.6	0	66.4	common	without data
Capsella bursa-pastoris	(L.) Medik.	*Brassicaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	43.4	0	56.6	common	2
Carduus acanthoides	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	71.5	0	28.5	common	8
Carlina vulgaris	L.	*Asteraceae*	annual dicotyledons	entomophilous species	native	27.8	0	72.3	common	4.5
Centaurea jacea	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	39.2	24.4	36.5	common	25
Cerastium holosteoides	(Spenn.) Möschl	*Caryophyllaceae*	annual dicotyledons	entomophilous species	native	0	9.7	90.3	common	15
Cichorium intybus	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	74.4	0	25.6	common	11
Cirsium arvense	(L.) Scop.	*Asteraceae*	perennial dicotyledons	deep-rooting species	invasive archaeophytes	80.8	0	19.2	common	10
Consolida regalis	S. F. Gray	*Ranunculaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	20.4	36.9	42.7	common	4
Convolvulus arvensis	L.	*Convolvulaceae*	perennial dicotyledons	deep-rooting species	naturalized archaeophytes	36	4.7	59.3	common	22
Conyza canadensis	(L.) Cronquist	*Asteraceae*	annual dicotyledons	annual weeds	invasive neophytes	35.4	9.6	55.1	common	5
Crataegus laevigata	(Poir.) DC.	*Rosaceae*	perennial dicotyledons	deep-rooting species	native	18	56.9	25.1	common	5
Crepis biennis	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	58.8	0	41.2	common	12.5
Crepis capillaris	(L.) Wallr.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	42.8	0	57.2	common	9.5
Cynoglossum officinale	L.	*Boraginaceae*	perennial dicotyledons	entomophilous species	native	58.3	0	41.7	common	20

Dactylis glomerata	L.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	29	37.3	33.7	common	32
Datura stramonium	L.	*Solanaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	71.3	0	28.7	common	without data
Daucus carota	L.	*Apiaceae*	perennial dicotyledons	entomophilous species	native	29.2	41.3	29.5	common	15
Descurainia sophia	(L.) Prantl	*Brassicaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	30.2	10.7	59.1	common	4.5
Digitaria sanguinalis	(L.) Scop.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	invasive archaeophytes	17	3.5	79.5	common	2
Echinochloa crus-galli	(L.) P. Beauv.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	invasive archaeophytes	41.8	12.4	45.8	common	1
Echinops sphaerocephalus	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	invasive neophytes	0	0	0	common	16
Echium vulgare	L.	*Boraginaceae*	perennial dicotyledons	entomophilous species	native	78.1	0	21.9	common	14.5
Elymus repens	(L.) Gould	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	33.8	35.9	30.3	common	8
Erigeron annuus	(L.) Pers.	*Asteraceae*	annual dicotyledons	annual weeds	invasive neophytes	41.3	13	45.8	common	30
Erodium cicutarium	(L.) L'Hér.	*Geraniaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	37.7	18.6	43.7	common	6
Eryngium campestre	L.	*Apiaceae*	perennial dicotyledons	entomophilous species	native	84.1	15.9	0	common	40
Euphorbia esula	L.	*Euphorbiaceae*	perennial dicotyledons	entomophilous species	native	5.7	27.8	66.5	common	19
Euphorbia helioscopia	L.	*Euphorbiaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	18.9	18.3	62.3	common	12
Fagopyrum esculentum	Moench	*Polygonaceae*	annual dicotyledons	crops	casual archaeophytes	0	0	0	common	without data
Falcaria vulgaris	Bernh.	*Apiaceae*	perennial dicotyledons	entomophilous species	native	75.4	11.7	12.9	common	27.5
Fallopia convolvulus	(L.) Á. Löve	*Polygonaceae*	annual dicotyledons	annual weeds	native	25.6	22.8	51.6	common	7.5
Festuca arundinacea	Schreb.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	49.9	27.4	22.7	common	1
Festuca pratensis	Huds.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	17.4	42.2	40.3	common	32

Festuca rubra	L.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	16.3	49.6	34.1	common	30
Fragaria vesca	L.	*Rosaceae*	perennial dicotyledons	entomophilous species	native	27.2	49.2	23.6	common	35
Fumaria officinalis	L.	*Fumariaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	19.3	0	80.7	common	19
Galeopsis tetrahit	L.	*Lamiaceae*	annual dicotyledons	annual weeds	native	33.1	0	66.9	common	9.5
Galinsoga parviflora	Cav.	*Asteraceae*	annual dicotyledons	annual weeds	invasive neophytes	15.5	32	52.5	common	2
Galium album	Mill.	*Rubiaceae*	perennial dicotyledons	entomophilous species	native	4.5	35.4	60.1	common	26
Galium aparine	L.	*Rubiaceae*	annual dicotyledons	annual weeds	native	12.2	0	87.8	common	28
Galium verum	L.	*Rubiaceae*	perennial dicotyledons	entomophilous species	native	1.3	71.8	26.9	common	34
Geranium pusillum	Burm. f.	*Geraniaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	38.9	18.4	42.7	common	6
Geranium pyrenaicum	Burm. f.	*Geraniaceae*	perennial dicotyledons	entomophilous species	naturalized neophytes	48.8	16.2	35	common	11
Geranium robertianum	L.	*Geraniaceae*	annual dicotyledons	entomophilous species	native	32	11.3	56.7	common	39
Geum urbanum	L.	*Rosaceae*	perennial dicotyledons	entomophilous species	native	31.7	32.8	35.5	common	40
Holosteum umbellatum	L.	*Caryophyllaceae*	annual dicotyledons	annual weeds	native	1.8	0	98.2	common	75
Hordeum murinum	L.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	naturalized archaeophytes	19.8	18	62.2	common	without data
Humulus lupulus	L.	*Cannabaceae*	perennial dicotyledons	deep-rooting species	native	47.3	30.1	22.7	common	35
Hypericum perforatum	L.	*Hypericaceae*	perennial dicotyledons	entomophilous species	native	6.7	52.6	40.7	common	23
Inula salicina	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	21.7	33.5	44.8	**C4a**	23
Chelidonium majus	L.	*Papaveraceae*	annual dicotyledons	annual weeds	native	54.7	6.6	38.8	common	29
Chenopodium album	L.	*Chenopodiaceae*	annual dicotyledons	annual weeds	native	30.5	34.1	35.4	common	3
Chenopodium hybridum	L.	*Chenopodiaceae*	annual dicotyledons	annual weeds	native	43.1	0	56.9	common	3
Chenopodium polyspermum	L.	*Chenopodiaceae*	annual dicotyledons	annual weeds	native	33.8	1.1	65	common	2
Juglans regia	L.	*Juglandaceae*	perennial dicotyledons	deep-rooting species	invasive archaeophytes	52.4	31.3	16.3	common	35
Lactuca serriola	L.	*Asteraceae*	annual dicotyledons	annual weeds	invasive archaeophytes	66.3	12.1	21.6	common	5
Lamium album	L.	*Lamiaceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	39.8	2.4	57.8	common	21

Lamium amplexicaule	L.	*Lamiaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	20.3	0	79.7	common	10.5
Lamium maculatum	L.	*Lamiaceae*	perennial dicotyledons	entomophilous species	native	32.1	16.1	51.8	common	15
Lamium purpureum	L.	*Lamiaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	23.2	0	76.8	common	25
Lathyrus sativus	L.	*Fabaceae*	annual dicotyledons	crops	casual archaeophytes	0	0	0	common	without data
Lathyrus tuberosus	L.	*Fabaceae*	perennial dicotyledons	deep-rooting species	naturalized archaeophytes	21.9	19.9	58.3	common	18
Lepidium draba	L.	*Brassicaceae*	perennial dicotyledons	deep-rooting species	naturalized archaeophytes	47.6	0	52.4	common	11
Ligustrum vulgare	L.	*Oleaceae*	perennial dicotyledons	deep-rooting species	native	27.7	64	8.3	common	43
Linaria vulgaris	Mill.	*Scrophulariaceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	10.7	25	64.3	common	10.5
Linum usitatissimum	L.	*Linaceae*	annual dicotyledons	crops	casual archaeophytes	2.1	0	97.9	common	without data
Lolium multiflorum	Lam.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	naturalized neophytes	17.4	38.6	44	common	1
Lolium perenne	L.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	18.5	29.3	52.3	common	8
Lotus corniculatus	L.	*Fabaceae*	perennial dicotyledons	legumes	native	11.5	19.1	69.4	common	15
Luzula campestris	(L.) DC.	*Juncaceae*	perennial monocotyledons	species with an anti-erosion effect	native	15.7	47.9	36.4	common	15
Malva neglecta	Wallr.	*Malvaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	11	33.6	55.5	common	1
Matricaria discoidea	DC.	*Asteraceae*	annual dicotyledons	annual weeds	naturalized neophytes	26.6	0	73.4	common	3
Medicago lupulina	L.	*Fabaceae*	perennial dicotyledons	legumes	native	22.4	19.9	57.7	common	13
Medicago sativa	L.	*Fabaceae*	perennial dicotyledons	legumes	naturalized neophytes	31	25.9	43.1	common	10.5
Melilotus albus	Medik.	*Fabaceae*	perennial dicotyledons	legumes	naturalized archaeophytes	36.5	0	63.5	common	18
Melilotus officinalis	(L.) Pall.	*Fabaceae*	perennial dicotyledons	legumes	naturalized archaeophytes	23.5	40.1	36.4	common	23
Mercurialis annua	L.	*Euphorbiaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	24.4	0	75.6	common	without data
Microthlaspi perfoliatum	(L.) F. K. Mey.	*Brassicaceae*	annual dicotyledons	annual weeds	native	0	0	0	common	45
Myosotis arvensis	(L.) Hill	*Boraginaceae*	annual dicotyledons	annual weeds	native	31.7	0	68.3	common	25
Nonea pulla	(L.) DC.	*Boraginaceae*	perennial dicotyledons	entomophilous species	native	48.4	0	51.9	C4a	30

Onobrychis viciifolia	Scop.	*Fabaceae*	perennial dicotyledons	legumes	naturalized neophytes	44.1	31.1	24.7	common	25
Onopordum acanthium	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	61.5	22.7	15.9	common	75
Panicum miliaceum	L.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	casual neophytes	0	0	0	common	without data
Papaver rhoeas	L.	*Papaveraceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	55	0	45	common	3
Parthenocissus inserta	(A. Kern.) Fritsch	*Vitaceae*	perennial dicotyledons	deep-rooting species	invasive neophytes	65.9	15.6	18.5	common	47
Petrorhagia prolifera	(L.) P. W. Ball et Heywood	*Caryophyllaceae*	perennial dicotyledons	entomophilous species	native	4.4	51.7	43.9	C4a	7
Phacelia tanacetifolia	Benth.	*Hydrophyllaceae*	annual dicotyledons	crops	casual neophytes	51.6	0	48.4	common	without data
Physalis alkekengi	L.	*Solanaceae*	perennial dicotyledons	crops	naturalized archaeophytes	0	0	0	common	without data
Pilosella aurantiaca	(L.) F. W. Schultz et Sch. Bip.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	42.4	0	57.6	C3	20
Pilosella officinarum	Vaill.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	9.6	26.3	64.1		27
Pisum sativum	L.	*Fabaceae*	annual dicotyledons	crops	casual archaeophytes	0	0	0	common	without data
Plantago lanceolata	L.	*Plantaginaceae*	perennial dicotyledons	entomophilous species	native	61.1	0.9	38	common	16
Plantago major	L.	*Plantaginaceae*	perennial dicotyledons	entomophilous species	native	82.3	0	17.7	common	6
Plantago media	L.	*Plantaginaceae*	perennial dicotyledons	entomophilous species	native	68.2	0	31.8	common	30
Poa annua	L.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	native	6.8	35	58.2	common	4
Poa pratensis	L.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	12.4	0	87.6	common	30
Polygonum aviculare	L.	*Polygonaceae*	annual dicotyledons	annual weeds	native	15.3	29.7	55	common	1
Portulaca oleracea	L.	*Portulacaceae*	annual dicotyledons	annual weeds	invasive archaeophytes	0.3	0	99.7	common	without data
Potentilla argentea	L.	*Rosaceae*	perennial dicotyledons	entomophilous species	native	21.3	50.4	28.3	common	19

Potentilla reptans	L.	*Rosaceae*	perennial dicotyledons	entomophilous species	native	35.3	29.3	35.4	common	22
Quercus petraea	(Matt.) Liebl.	*Fagaceae*	perennial dicotyledons	deep-rooting species	native	28.1	63.2	8.6	common	35
Raphanus sativus	L.	*Brassicaceae*	annual dicotyledons	crops	casual archaeophytes	62.1	0	37.9	common	without data
Raphanus raphanistrum	L.	*Brassicaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	63.2	0	36.8	common	4.5
Reseda lutea	L.	*Resedaceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	51	0	49.1	common	13
Ribes aureum	Pursh	*Grossulariaceae*	perennial dicotyledons	deep-rooting species	casual neophytes	31	58.3	10.8	common	without data
Robinia pseudoacacia	L.	*Fabaceae*	perennial dicotyledons	deep-rooting species	invasive neophytes	28.8	41.4	29.8	common	30
Rosa canina	L.	*Rosaceae*	perennial dicotyledons	deep-rooting species	native	16.6	50.2	33.2	common	35
Rubus sect. Rubus	Kaplan et al.	*Rosaceae*	perennial dicotyledons	deep-rooting species	native	46	39.1	14.9	common	without data
Rumex crispus	L.	*Polygonaceae*	perennial dicotyledons	deep-rooting species	native	65.1	0	35	common	7
Rumex obtusifolius	L.	*Polygonaceae*	perennial dicotyledons	deep-rooting species	native	80.6	0	19.5	common	7.5
Salvia pratensis	L.	*Lamiaceae*	perennial dicotyledons	entomophilous species	native	62.8	2.4	34.8	common	35
Sambucus nigra	L.	*Sambucaceae*	perennial dicotyledons	deep-rooting species	native	36.2	23.4	40.4	common	30
Scabiosa ochroleuca	L.	*Dipsacaceae*	perennial dicotyledons	entomophilous species	native	25.6	61.6	12.8	common	30
Scleranthus annuus	L.	*Caryophyllaceae*	annual dicotyledons	annual weeds	native	0	0.7	99.3	common	2
Secale cereale	L.	*Poaceae*	annual monocotyledons	crops	casual archaeophytes	0	0	0	common	without data
Securigera varia	(L.) Lassen	*Fabaceae*	perennial dicotyledons	legumes	native	39.6	1.6	58.9	common	25
Senecio jacobaea	L.	*Asteraceae*	annual dicotyledons	entomophilous species	native	65.6	0	34.4	common	35
Senecio vulgaris	L.	*Asteraceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	26.4	0	73.6	common	4
Setaria pumila	(Poir.) Roem. et Schult.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	invasive archaeophytes	38.4	24.7	37	common	4
Setaria viridis	(L.) P. Beauv.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	invasive archaeophytes	23.6	41.5	34.9	common	3
Setaria verticillata	(L.) P. Beauv.	*Poaceae*	annual monocotyledons	species with an anti-erosion effect	invasive archaeophytes	25.2	33.2	41.6	common	3

Silene latifolia subsp. alba	(Mill.) Greuter et Burdet	*Caryophyllaceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	51.2	0	48.8	common	10
Silene noctiflora	L.	*Caryophyllaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	49.3	4.8	45.9	**C4a**	3.5
Silene vulgaris	(Moench) Garcke	*Caryophyllaceae*	perennial dicotyledons	entomophilous species	native	48.1	0.2	51.7	common	26.5
Sinapis alba	L.	*Brassicaceae*	annual dicotyledons	crops	casual archaeophytes	56	0	44	common	without data
Solanum nigrum	L.	*Solanaceae*	annual dicotyledons	annual weeds	native	0	0	100	common	4
Sonchus oleraceus	L.	*Asteraceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	61.1	0	38.9	common	4
Stellaria media	(L.) Vill.	*Caryophyllaceae*	annual dicotyledons	annual weeds	native	5	0	95	common	11.5
Stipa pennata	L.	*Poaceae*	perennial monocotyledons	species with an anti-erosion effect	native	16.5	83.5	0	C3	75
Symphytum officinale	L.	*Boraginaceae*	perennial dicotyledons	entomophilous species	native	68.1	0	31.9	common	32
Tanacetum vulgare	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	59.1	18.3	22.6	common	18
Taraxacum sect. Taraxacum	Kirschner et al.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	55.4	0	44.7	common	without data
Tragopogon dubius	Scop.	*Asteraceae*	perennial dicotyledons	entomophilous species	naturalized archaeophytes	17.4	22.4	60.2	common	13
Tragopogon orientalis	L.	*Asteraceae*	perennial dicotyledons	entomophilous species	native	42	0	58	common	16
Trifolium alexandrinum	L.	*Fabaceae*	annual dicotyledons	legumes	casual neophytes	0	0	0	common	without data
Trifolium campestre	Schreb.	*Fabaceae*	perennial dicotyledons	legumes	native	9.2	41.7	49.1	common	14.5
Trifolium incarnatum	L.	*Fabaceae*	annual dicotyledons	legumes	casual neophytes	40.4	11.8	47.8	common	without data
Trifolium pratense	L.	*Fabaceae*	perennial dicotyledons	legumes	native	24.7	31.5	43.8	common	13
Trifolium repens	L.	*Fabaceae*	perennial dicotyledons	legumes	native	25.4	12.7	61.9	common	7
Tripleurospermum inodorum	(L.) Sch. Bip.	*Asteraceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	23.5	0	76.5	common	5
Triticum aestivum	L.	*Poaceae*	annual monocotyledons	crops	casual archaeophytes	39.3	22.8	37.9	common	without data
Urtica dioica	L.	*Urticaceae*	perennial dicotyledons	deep-rooting species	native	44.8	18.2	37.1	common	25

Urtica urens	L.	*Urticaceae*	annual dicotyledons	annual weeds	naturalized archaeophytes	22.1	32.1	45.8	C3	25
Veronica hederifolia	L.	*Scrophulariaceae*	annual dicotyledons	annual weeds	native	19.3	0	80.7	common	4.8
Vicia cracca	L.	*Fabaceae*	perennial dicotyledons	legumes	native	27.3	28.7	44	common	30
Vicia pannonica	Crantz	*Fabaceae*	annual dicotyledons	legumes	naturalized archaeophytes	0	0	0	C2t	without data
Viola arvensis	Murray	*Violaceae*	annual dicotyledons	annual weeds	native	30.8	1.6	67.6	common	6

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