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Dramatic decline in the Swiss arable flora since the 1920s

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ABSTRACT

Arable weeds are among those groups of plants that are most threatened in Europe due to management intensification and efficient cleaning of crop seeds in modern agriculture. Plant species loss in arable fields had been assessed in many European countries about 30 years ago, and has gained renewed interest during the last few years. A rich historical data set on plots where arable weeds had historically been recorded in Switzerland enabled the study of changes in arable weed species since the 1920s onward. In total, 232 locations with historical plots were revisited. There, we recorded all plant species and their abundances on 100m^2 plots. Across all plots the average number of species per plot declined dramatically by more than 60% during the last 90 years. Most species decreased in frequency, but common species stayed more frequent, while rare species – often characteristic weeds of traditionally managed crop fields – decreased in frequency or even disappeared. Plant groups with increasing species numbers and frequency were mostly neophytes, grasses and species with high nutrient demand. The above mentioned decline in species number and frequency of rare and characteristic weed species suggests that more effective conservation measures than hitherto taken are needed to ensure their preservation.

1. Introduction

Arable weeds are defined as plants that preferably grow in cultivated fields, but are not intentionally sown or planted. In Europe, arable weeds mainly evolved from Mediterranean species during the domestication and development of cereal crops during the last 5000 years (Holzner and Immonen, 1982). Weed species evolved functional traits that allow them to survive in the regularly disturbed habitats of arable fields (Scholz, 1996). The introduction of new crop species from the New World after 1496 led to an even richer arable flora as new weed species were introduced (Holzner and Immonen, 1982). However, during the last 100 years, rapid changes in agricultural practices had a major impact on the number and abundance of arable weeds. Today, farming practices in Europe are characterized by high input of fertilizers and pesticides (Herzog et al., 2006), which results in minimal intra-crop competition for nutrients and a reduction of weeds. Crop plants thus grow in higher densities and higher yields are achieved, but the accompanying arable weed flora is strongly and negatively affected (Robinson and Sutherland, 2002). Furthermore, crop seed cleaning has become more efficient, and seeds of arable weeds are thus no longer spread on fields *via* crop seeding (Van Elsen, 1994). In consequence, arable weeds species became rare and many are red listed all across Europe (Storkey et al., 2012). For instance, 137 out of 176 arable weeds are red-listed in Switzerland (Moser et al., 2002). Additionaly, a study in Oxfordshire/UK showed that weed species that had already been rare 40 years ago were mostly absent from arable fields today (Sutcliffe and Kay, 2000).

A meta-analysis of changes in the numbers of arable species across Europe showed on average a 20% reduction of species per field between 1939 and 2012 (Richner et al., 2014). However since the 1980s, the negative trend in the arable flora is believed to have slowed, stopped or even reversed due to the implementation of agri-environmental schemes that should benefit biodiversity, such as field strips or a generally lower input of fertilizers and lower use of pesticides (Decrem et al., 2007). Indeed, several recent studies from Europe suggested higher current species numbers in arable weeds than found in former surveys (e.g. Baessler and Klotz, 2006; Májeková et al., 2010 but see Fried et al., 2009; Meyer et al., 2013).

Every plant species has a unique set of traits. Changes in species composition of arable fields therefore also lead to changes in plant traits in arable weed communities (Violle et al., 2007; Navas, 2012). Plant traits typical of arable weeds of traditional fields are high

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seed longevity and short or even annual lifecycles (Thompson et al., 1998; Scholz, 1996). In contrast, contemporary arable fields are supposed to harbor many grasses, neophytes (introduced to Europe after 1496) and nitrophileous species, species that are ubiquitous or herbicide resistant and species that have even shorter life-cycles than the characteristic arable weeds of traditional fields (Otte et al., 2006; Fried et al., 2009). Therefore, the slow-down in species loss or even species gain recorded in several recent studies may be due to new species such as neophytes and pesticide-tolerant species, rather than an increase of characteristic (older) weed species (Otte et al., 2006). This change in diversity and composition of arable weed communities may also change the community plant trait spectrum, potentionally influencing ecosystem services provided by the biodiversity on arable fields (Franke et al., 2009). These services include e.g. food and shelter for beneficial organisms such as wild bees and ladybugs providing crop pollination and pest control (Isaacs et al., 2008) or protection from soil erosion (Pimentel et al., 1995). In addition, the recreational effect on people experiencing a colourful (weed-rich) arable landscape constitutes another ecosystem service of arable weeds (Junge et al., 2011).

In this study, we investigated changes in the species number and frequency of arable weeds, red listed species and characteristic arable plants by revisiting 232 locations where historical records on arable weeds had been taken in Switzerland. In addition, we investigated changes in plant traits of arable weed communities in time. Specifically, we asked the following two questions: (1) How did the species number and frequency of arable weed species change between historical and contemporary fields and (2) how did plant traits change over time?

2. Material and methods

2.1. Selection of historical plots and locations for re-survey

In order to test for changes in the flora of arable fields, we resurveyed 232 locations where plots recording arable weeds were made prior to 1990. The historical plots were obtained from a large vegetation database at Agroscope Reckenholz in Zurich. We selected historical plots and the related records of all occurring plant species of wheat, barley, beet or potato fields from studies conducted between 1927 and 1990. Other crop types were not taken into account as they are only rarely present in the historical surveys. We assigned these historical plots to the biogeographic regions of Switzerland delimited by Gonseth et al. (2001), i.e. Jura, JU; Swiss Plateau, ML; northern Alps, NA; southern Alps, SA; eastern central Alps, EZA and western central Alps, WZA. We also assessed whether the historical plots contained species that are currently red-listed in Switzerland (Moser et al., 2002). Subsequently, we took a stratified random sample of the whole dataset to obtain equal numbers of plots per (a) biogeographic region, (b) botanists of the historic plots (i.e. Volkart (1933), Buchli (1936), Salzmann (1939), Brun-Hool (1963) and Waldis (1986)), (c) red list status (i.e. a red listed plant species was present on the plot or not) and (d) crop type. We selected 700 locations. Locations that only showed grasslands on current aerial photographs (Swisstopo, 2010) were discarded. We revisited the sites of 515 historical plots

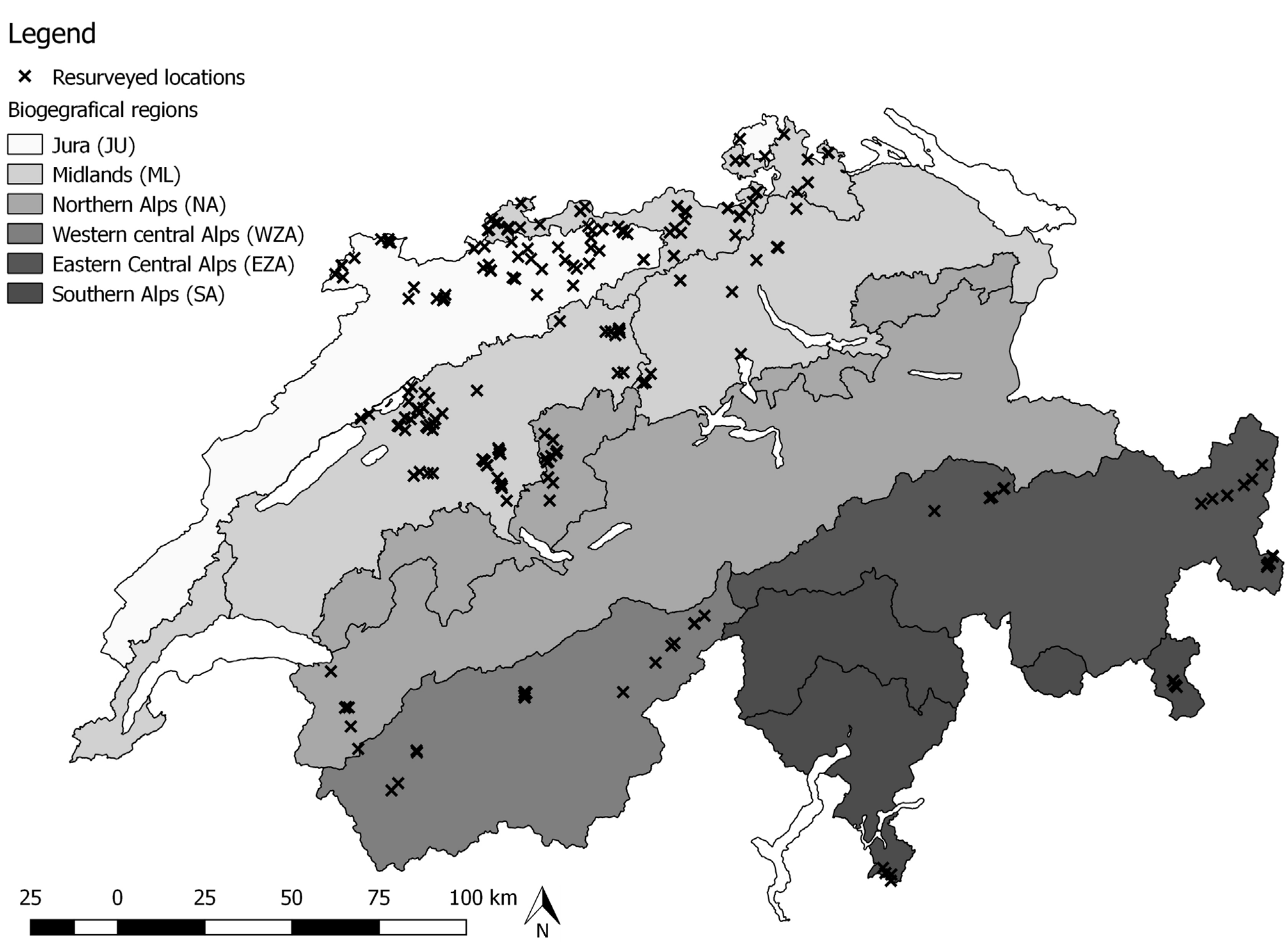

Fig. 1. Map of all revisited locations in Switzerland (n = 232).

in 2011 or 2012. Exact plot locations were often missing for the historical plots. To identify the location of historical plots, we relied on the original historical references in combination with a spatial analysis in ArcGIS (ESRI, 2009) using historical maps of Switzerland (Swisstopo, 2010). We were able to locate the historical plots with an accuracy between 10 m and 500m, but more than 50% of the plots were located with an accuracy of at least 50m. Our re-survey thus corresponds to a semi-permanent plot design (Michalcovà et al., 2011; Fig. 1). We only performed plant records (see below) on historical plots if a field had not changed into built-up area, if we found the same crop type as in the historical survey inside the site-specific accuracy and if the field had not already been harvested. This procedure resulted in a total of 232 locations that we re-surveyed (1927–36: N = 110 plots, 1937–46: N = 43 plots, 1947-56: N = 17 plots, 1957–66: N = 25 plots, 1967–76: N = 14 plots, 1977–86: N = 15 plots, 1990: N = 8 plots), each containing one historical plot with a complete list of arable weed species, their abundance according to the method of Braun-Blanquet (1928) and an indication of crop type and cover.

The 232 resurveyed sites were distributed between 245 m and 1670 m above sea level, and represent the six biogeographic regions of Switzerland. Mean annual temperature in Switzerland across regions with revisited plots varies between 5.5 °C and 10.5 °C, and mean annual rainfall varies between 545 mm and 1900 mm (MeteoSchweiz, 2013).

2.2. Contemporary floristic data

We recorded the floristic composition of contemporary fields in a rectangular plot of 100m^2. The plots were placed at least 3 m from field margins, to avoid the influence of the field-margin. Information on plot size and survey procedure for historical plots was sometimes missing or fragmentary. If plot size was given for the historical plots, it was always equal or smaller to 100m^2. Nevertheless and in order to check whether small sizes of historical plots posed problems for our statistical analysis, we established a species area curve based on the historical data from Brun-Hool (ETH, Zurich, unpublished data). The minimum area to find more than 90% of the species increased from 15m^2 in the 1950s to 100m^2 in the 1980s. By comparing rather smaller historical to potentially larger contemporary plots, we rather overestimated current than underestimated historical arable weed communities.

For contemporary plots, we recorded all plant species and estimated their abundance according to the method of Braun-Blanquet (1928). Additional species found in field margins were also listed. Species taxonomy was based on Lauber and Wagner (2001). We revisited plots between April and early September, approximately at the same date when the historical *surveys* had been carried out. For every contemporary plot we also recorded crop type and the percentage of soil covered by crop (crop cover) and other plants (total weed cover). All contemporary plot records were done by the same person (Nina Richner).

2.3. Plant traits

We established the Red-List status (Moser et al., 2002) and the Z- and L- species status (BAFU/BLW, 2008) of all species recorded. Z species are characteristic for traditionally managed fields. They are nowadays mostly red listed and target species in conservation management (Walter et al., 2013). L species are also characteristic of arable habitats, but are more wide-spread, abundant and less threatened in Switzerland (Walter et al., 2013).

We further analyzed changes in the following traits according to Landolt et al. (2010): indicator value (similar to Ellenberg indicator values) for light and nutrients, growth form (herbs, grasses), life-history (start and duration of flowering), ecological group (forests, wetlands, unfertilized dry meadows, fertilized meadows, weedy and ruderal habitats, pioneer situations and others), time of introduction to Europe (Indigenous: native or naturally migrated species; archaeophyte: non-native species introduced before 1496; neophyte: non-native species introduced after 1496) and geographic distribution area (A: other continents than Europe; B: Europe and other continents; C: European Mediterranean region only; D: only European lowlands excluding the Mediterranean; E: only European mountains). Additionally, we noted whether a species was characteristic for one of the arable plant communities of Delarze and Gonseth (2008); (i.e. Aphanion, Caucalidion, Polygono-Chenopodion, Fumaria-Euphorbion, Panico-Setarion, Eragrostion). The above mentioned plant traits are listed for all recorded plants in Appendix A.

2.4. Statistical analysis

All statistical analyses were done in R 3.0 (R Development Core Team, 2013) using the packages vegan and FD. Taxa that could not be identified to species level were only included in the analyses of species number, but were excluded from all other analyses. To test for differences in average species number, in red listed, Z species and L species between historical and contemporary plots, separate pairwise two-tailed Wilcoxon-tests were first applied to the entire dataset and for each biogeographic region (see above) separately. For plant traits, the community weighted mean (CWM) per plant trait per plot was first computed and then again tested between historical and contemporary plots using separate pairwise, two-tailed Wilcoxon-tests for the entire dataset only. The same test was applied to the number of species characteristic for specific arable communities according to Delarze and Gonseth (2008).

To test, if the magnitude of change in species numbers between historical and contemporary plots was influenced by the geographical region or the year in which a historical plots had been surveyed, we performed backward model selection using general

Table 1
Total arable weed species number across all plots in Switzerland and mean species number per plot (± standard error SE) of historical and contemporary plots (N = 232) for all weed species (with plants of field borders either included or not included), red list species (Moser et al., 2002), Z- and L- species (see text; Walter et al., 2013) and characteristic species for arable communities (Delarze and Gonseth, 2008).

	Total historical number	Mean historical number per plot	Total contemporary number	Mean contemporary number per plot	Total contemporary number with borders	Mean contemporary number with borders
All species	295	22.7 ± 0.53	214	7.9 ± 0.47	322	20.4 ± 0.42
Red list species	42	1.0 ± 0.08	15	0.2 ± 0.05	20	0.4 ± 0.08
Z-species	34	09 ± 0.08	15	0.2 ± 0.05	19	0.4 ± 0.07
L-species	92	4.9 ± 0.18	55	0.9 ± 0.1	98	2.9 ± 0.18
Characteristic species	111	12.1 ± 0.35	59	3.4 ± 0.21	92	8.7 ± 0.27

linear models, with a Poisson distribution and log-link function, and different combinations of region, year of the historical plot, accuracy of localization and crop type and their pairwise interaction as explanatory variables and the absolute values of the difference in total species number between paired historical and contemporary plots as response variable. We selected the best fitting model using step.AIC from the R-package “mass” (AIC: Akaike's Information Criterion) and sequential likelihood-ratio tests (Burnham and Anderson, 2002).

Finally, we performed a nonparametric multidimensional scaling (NMDS) in R of the whole dataset using Bray-Curtis distances calculated from abundance data in order to show changes in species composition across time and crop-type. We did not remove rare species as they were in the special focus of our study. To test for significance we used a PerMANOVA test.

3. Results

A total of 295 arable weed species was recorded in the historical plots from Switzerland and 214 occurred in contemporary plots (Table 1). In the contemporary plots, we found 49 species which were not present in the historical plots. Most of these additional species were common species or neophytes such as *Geranium pyrenaicum*, *Galinsoga ciliata* or *Nicandra physalodes*. In the contemporary plots, we did not relocate 130 species which had been present in the historical plots. Over 25% of these species were characteristic for traditionally managed arable fields (e.g. *Anagallis foemina, Papaver argemone, Agrostemma githago, Ajuga chamaepitys* and *Legousia speculum-veneris*; for the full list see Appendix B). There were 42 red listed species in the historical plots compared to 15 in contemporary plots, the number for L-species changed from 92 to 55 species, Z-species declined from 34 to 15 species and that for characteristic species from 111 to 59 (Table 1). One hundred and twenty-one historical plots contained red listed species, compared to 24 contemporary plots.

The most frequent species in historical plots was *Fallopia convolvulus* (61.6% of all historical plots), while in contemporary plots it was *Chenopodium album* (37.9% of all contemporary plots). Seven of the 15 historically most frequent species were still in the current “top 15” and all of them were in the current “top 30” list (Table 2). However, the frequency of common species was much higher in historical than in contemporary plots. Mean species frequency between historical and contemporary plots declined by 52% from 7.7% to 3.7% (Wilcoxon: V = 11022, $p < 0.001$; Appendix B). Historically, 107 species occurred in more than ten plots. Today, only 53 species were present in more than ten plots. Most species that were no longer present in contemporary plots already had a frequency of occurrence of less than 5% in the historical plots.

Table 2
The fifteen most frequent species (percentage of occupied plots from a total of 232 plots) in historical and contemporary plots. Frequencies of the fifteen most frequent historical and contemporary species are given in bold.

Species	Historical	Contemporary
Agropyron repens (L.) P. Beauv.	37.5	21.6
Anagallis arvensis L.	37.9	2.6
Capsella bursa-pastoris (L.) Medik.	**41.8**	12.5
Chenopodium album L.	**57.8**	**37.9**
Cirsium arvense (L.) Scop.	**38.4**	9.1
Convolvulus arvensis L.	**47.4**	14.2
Echinochloa crus-galli (L.) P. Beauv.	2.6	**16.8**
Fallopia convolvulus (L.) Á. Löve	**61.6**	**22.8**
Galeopsis tetrahit L.	**50.9**	13.4
Galium aparine L.	**46.6**	12.1
Lolium multiflorum Lam.	4.3	**20.3**
Lolium perenne L.	5.6	**21.1**
Myosotis arvensis Hill	**56.9**	6.9
Poa trivialis L.	**40.5**	**24.6**
Polygonum aviculare L.	**59.1**	**32.8**
Polygonum persicaria L.	**44.4**	**14.7**
Ranunculus repens L.	**57.3**	9.9
Stellaria media (L.) Vill.	34.1	**14.7**
Taraxacum officinale aggr.	**49.1**	**35.8**
Trifolium repens L.	33.2	**15.5**
Veronica persica Poir.	28.4	**29.7**
Viola arvensis Murray	**56.0**	**17.2**

Average species number per plot significantly decreased from an average 22.7 weed species in historical plots to an average of only 7.9 weed species in contemporary plots (Wilcoxon V = 24318, $p < 0.001$), a decrease of 65%. The average numbers of red list species per plot, declined significantly between historical and contemporary plots from 0.97 to 0.22 (−77%), for Z species from 0.87 to 0.22 (−75%) and for L species from 4.94 to 0.94 (-81%; Wilcoxon: V = 3954.5, $p < 0.001$; V = 6170.5, $p < 0.001$ and V = 25951, $p < 0.001$, respectively; Table 1). Average total arable weed cover per plot declined by 92% from 69.1 ± 3.0% in historical plots to 5.8 ± 0.8% in contemporary plots. The average number of species characteristic for arable fields based on Delarze and Gonseth (2008) decreased from 9.02 ± 0.4 to 0.57 ± 0.1 per plot (Wilcoxon: V = 17281, $p < 0.001$) between historical and contemporary plots. Including field borders did increase the average number in the respective species group for contemporary plots (Table 1). However, compared to historical the decrease was still significant.

The CWM of grass species per plot increased significantly from 0.004 in historical to 0.28 in contemporary plots (Wilcoxon: V = 3770.5, $p < 0.001$), while those of herbs decreased (V = 20762, p-value <0.001; Table 3). Plant species characteristic of fertilized meadows (V = 7332, *p*-value <0.001) and annuals (V = 16846, $p < 0.001$) significantly increased at the expense of weedy or ruderal species when historical and contemporary plots were compared. The average CWM of neophytes and nitrophileous species increased (V = 3330, $p < 0.05$; V = 5976, $p < 0.001$, respectively; Table 3). Species with high indicator values for nutrients increased (V = 2572.5, p-value <0.001) but species typical for dry meadows decreased (V = 1123.5, $p < 0.05$). Species with low indicator values for light decreased (V = 6637.5, $p < 0.001$; Table 3). For native species and such with a short flowering time and high seed longevity, the average CWM per plot declined when comparing historical with contemporary plots (V = 16706, $p < 0.001$; V = 10606, $p < 0.001$; V = 16482, $p < 0.001$, respectively; Table 3).

Average species number of arable weeds per plot did not decrease evenly across the six biogeographic regions of Switzerland (Table 4). Species numbers in Central and Southern Alps stayed about the same, whereas species numbers declined dramatically in the Swiss Plateau, Northern Alps and Jura declined (Table 4). The best general linear model on differences in species numbers between historical and contemporary plots showed significant effects for biogeographic region only (Start AIC = 1678.7, End AIC = 1674.6), and whether the variables crop type, year of the historical survey, accuracy of localization nor interactions were included in the best model (Table 5). This means that changes were not due to inaccuracies in the historic dataset but were influenced by other factors having a different extent of influence in the six biogeographic regions.

In the nonmetric multidimensional scaling (NMDS, Fig. 2a and b), we found significant differences in community composition between historical and contemporary plots of root crops (F = 12.845, R2 = 0.119, $p < 0.001$, Stress type 1: 0.16; Fig. 2a) and cereal crops (F = 10.149, R2 = 0.077, $p < 0.001$, Stress type 1: 0.21, Fig. 2b). Remarkably, the scatter in contemporary plots was much

Table 3
Average community weighted mean (CWM with standard error SE) of arable weed plant traits increasing and decreasing in value for historical and contemporary surveys in Switzerland (N = 232). ***: p < 0.001, *: p < 0.05 according to Wilcoxon-Tests.

	Historical	SE	Contemporary	SE	V-value	
Increasing						
Indicator value nutrients	3.64	0.02	3.86	0.02	2572.5	***
Indicator value light	3.63	0.01	3.76	0.02	7898.5	***
Nitrophileous species	2.56	0.05	3.28	0.06	5976	***
Grasses	0.00	0.00	0.28	0.03	3770.5	***
Ecological group fertilized meadow	0.17	0.01	0.28	0.02	7332	***
Neophytes	0.00	0.00	0.08	0.02	3330	*
Decreasing						
Flowering time	4.20	0.02	3.87	0.05	10606	***
Seed longevity	3.89	0.02	3.72	0.04	16482	***
Characteristic species	0.58	0.03	0.39	0.03	17281	***
Herbs	0.98	0.01	0.71	0.03	20762	***
Indigenous species	0.79	0.03	0.59	0.03	16706	***
Ecological group dry meadows	0.04	0.01	0.02	0.01	1123.5	*
Ecological group weed/ruderal	0.82	0.01	0.73	0.02	16846	***

Table 4
Mean number of weed plant species per plot in Switzerland (with standard error SE) per biogeographic region and historical and contemporary plots. N = number of plots per region.

Biogeographic region	N	Point in time	Mean number	SE
Jura	43	Historical	27.4	1.16
		Contemporary	6.8	1.08
Swiss Plateau	120	Historical	24.5	0.66
		Contemporary	6.3	0.50
Northern Alps	20	Historical	19.9	1.17
		Contemporary	7.0	1.04
Eastern Central Alps	18	Historical	17.0	0.73
		Contemporary	13.3	1.36
Southern Alps	8	Historical	17.3	1.25
		Contemporary	14.8	2.21
Western Central Alps	23	Historical	13.1	1.47
		Contemporary	11.9	1.26

Table 5
Results from the best general linear model on the difference in total arable weed species number between paired historical and contemporary plots in Switzerland (StepAIC: Start AIC = 1678.7, End AIC = 1674.6), (ML: Plateau, NA: northern Alps, EZA: eastern central Alps, SA: southern Alps, WZA: western central Alps. ***: p < 0.001, ns: not significant.

	Estimate	SE	z-value	
JU	−20,558	1.340	**15.344**	***
ML	**2.316**	**1.562**	**1.483**	**ns**
NA	**7.958**	**2.378**	**3.347**	***
EZA	**16.891**	**2.466**	**6.848**	***
SA	**18.058**	**3.383**	**5.338**	***
WZA	**19.341**	**2.270**	**8.521**	***

larger than in historical plots for both crop types, indicating that historical weed communities were more similar to each other than contemporary communities are.

4. Discussion

We recorded a general decline of the number of arable weeds from historical to contemporary plots across Switzerland. Historical communities harbored more species characteristic for traditionally managed fields, more red listed species and also more L and Z species and showed a higher weed cover than contemporary plots. Contemporary plots harbored more neophytes and grasses, less red-listed and few L or Z species and showed lower weed cover. However, the historically most common species were largely the same as today, even though they mostly decreased in frequency as well.

Our results indicate a significant decline in average species number and cover per plot of about 65% and 90%, respectively, of arable weeds in cultivated fields in Switzerland over the last 90 years. These losses are consistent with the results of a recent study from Germany where a decline in average species number per plot of 70% and in cover per plot of 90% was documented (Meyer et al., 2013). With over 75%, the decline was even more pronounced for red-listed species than for the general weed flora in the present study (and similarly high for L and Z species, indicative of arable fields). Many threatened arable weeds have vanished or decreased significantly.

A decreasing weed frequency and abundance is not necessarily undesirable in cases of noxious weeds such as *Cirsium arvense* or *Galium aparine* (Holzner, 1982). However, in our study the loss in species numbers was more pronounced for species characteristic of traditionally managed fields such as *Adonis aestivalis* or *Scleranthus annuus*. This finding is in agreement with many other European studies on the decline of the characteristic weeds of traditionally managed arable fields (e.g. Walker et al., 2009; Meyer et al., 2013).

The historical plots were neither uniformly dispersed across the biogeographic regions of Switzerland nor across the 90 years of the studied time period. Nevertheless, the general linear models performed suggested that (1) the number of arable weeds decreased less in alpine regions than in the Swiss Plateau and that there was no influence of the year of the historical plots were surveyed on the difference in species numbers between historical and contemporary plots. The latter result is rather surprising as one would expect that the majority of change in arable weed communities occurred shortly after World War II (Poschlod, 2015). In spite of this expectation, our results suggested that the loss in arable weeds from crop fields was a rather gradual process although differing between biogeographic regions.

The observed difference in the change of average species number of arable fields among biogeographic regions in Switzerland probably reflects higher intensification of agriculture in the Swiss Plateau as compared with mountainous regions, specifically in the valleys of the Central and Southern Alps. Several reasons account for this less pronounced decline in mountainous regions. First, the topography of mountain valleys rarely allows large and intensively managed fields, and yields are lower at higher elevations (Stöcklin et al., 2007). The few farmers in mountainous regions thus often farm in an organic way and emphasize

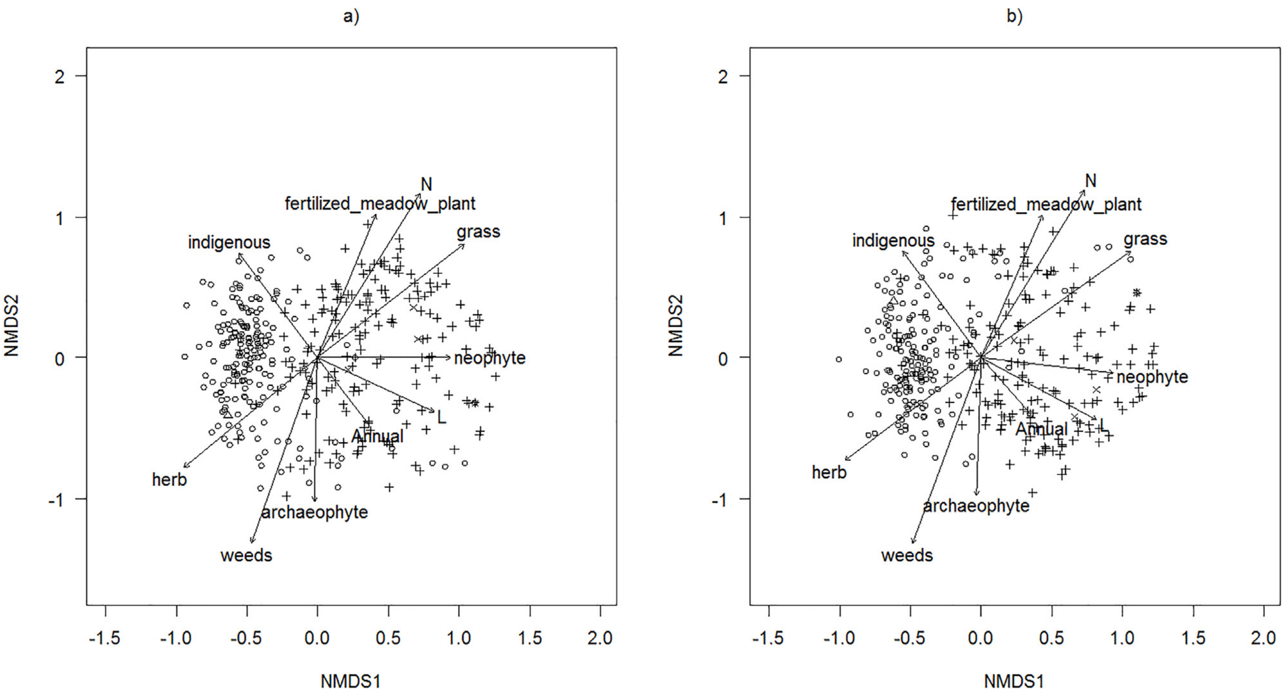

Fig. 2. NMDS (stress = 0.2) showing historical and contemporary plots of arable weeds in cereal (a) and root crop (b) fields. Circles: historical plots; pluses: contemporary plots. Arrows show high percentage of the following plant groups: fertilized meadow plant = plants characteristic for fertilized meadows, grass = grass species, neophyte = neophyte species, annual = annual species, archeophytes = non-native species introduced before 1496, weed = species characteristic for cultivated fields, herb = herbaceous species, indigenous = native or naturally migrated species, N = high indicator value for nutrients.

ecological compensation areas for which they get subsidies (Schweizerische Eidgenossenschaft, 2014). Second, the rich topography of mountain valleys supports a particularly high regional species diversity. This is also true for arable weed communities (Braun-Blanquet, 1970). In contrast, in the Swiss Plateau, the arable flora remains more constant across larger spatial extend and is less diversified (Waldis, 1986). Third, at higher elevation, some crops which are usually used in crop rotation with cereal crops, cannot be grown due to climatic limitations. The weed flora of arable fields in mountain areas is thus less disturbed by crop rotation than it is in lowland regions. All these reasons should lead to better preservation of arable weed communities in mountain valleys than in the Swiss Plateau.

We found a clear trend of increasing number and frequency of neophytes in our study across Switzerland. For example, we found *Galinsoga ciliata* 22 times and *Amaranthus retroflexus* 56 times in contemporary plots compared to none and four occurrences in historical plots. This increase in newly introduced arable weed species poses new risks, but also new chances for both agricultural production as well as nature conservation. On the one hand, there could be a reduction in yield due to neophyte weeds (Gulden et al., 2003), but the latter also may provide new food resources for farmland birds (Holland et al., 2006). In accordance with Otte et al. (2006) and Lososová and Simonová (2008), neophytes replaced native species from historical to contemporary plots in our study as well; a process that might also be related to the introduction of new crop species, which brought along associated weeds (Holzner and Immonen, 1982).

We found distinct changes between historical and contemporary plots in several plant traits. These changes in plant traits were likely due to the higher herbicide application, more fertilizer input and different sowing dates in present day agricultural practice as compared with historical agricultural management (Herzog et al., 2006; Richner et al., 2014). Species adapted to nutrient rich sites and the indicator value for nutrients per plot increased. This process was possibly due to increased post-second world war fertilizer input in agriculture. Since the 1990s a decrease in fertilizer input has been recorded (Decrem et al., 2007; BFS, 2013a, 2013b). This positive development might lead – in the longer run – to a decrease of nitrophileous species again. However, soils are mostly saturated with nutrients, and the effect of less agricultural nutrient input might by counterbalanced by the high contemporary N-input from the atmosphere with values of 0.1 – 0.7 kg per hectare and year (Vitousek et al., 1997).

Grass weeds such as *Echinochloa crus-galli* or *Lolium perenne* increased in frequency and in their average CWM. This might be due to the use of broadleaf-selective herbicides. As herbicides were designed to protect cereals – which are grasses – grass weeds are not antagonized (Wrucke and Arnold, 1985). As many grasses belong to the ecological group of species from fertilized meadows, the increase of species from this ecological group found in the present study could also be explained by the high input of fertilizers (see above).

The increase of species with a short flowering time found in the present study was in line with other studies on arable weeds and was potentially caused by a shift in sowing season from spring to autumn for many cereals during the last century (Storkey et al., 2013). The increase in species with short flowering times might thus be due to altered competition during the emerging phase of seedlings. While crop and weeds germinate at around the same time in spring sown crops, crop plants sown in autumn are already well establish in spring and hence are more competitive (Fried et al., 2008). A shorter flowering time allows plants to complete their reproductive cycle faster and is, therefore of advantage (Grime, 1977). The observed shorter flowering time and the lower weed cover detected in contemporary fields also translate into fewer resources for bees and other pollinating insects (Franke et al., 2009).

The indicator value for light slightly but significantly increased in our study suggesting that shade-tolerant species declined while light-demanding species increased from historical to contemporary plots. At first sight, this result is counter-intuitive. The literature however reports both decreases (Smart et al., 2003; Lososová et al., 2008) but also increases in shade-tolerant arable weeds from historical to contemporary surveys (Fried et al., 2009; Walker et al., 2009). Increases could be explained by the fact that today's cereal varieties have shorter stems and more erect leaves leading to lower light interception. Thus, more light could actually penetrate to the ground (Fossati and Paccaud, 1986). However, the latter hypothesis would need critical testing. Alternatively, the decline in shade-tolerant species could also be explained by the reduction in hedges and small woodlots interspersed among contemporary agricultural fields (Antrop, 2004). Hedges and woodlots harbor many shade-tolerant species, which also disperse to adjacent fields and rather frequently grow there. In fact, in our data set we observed typical forest species such as *Aegopodium podagraria, Knautia dipsacaifolia* and *Rubus caesius* in the historical plots, but these species were no longer detected in contemporary plots. With the eradication of hedges and small woodlots from farmlands, shade-tolerant species can no longer reach and disperse to crop fields, thus causing light indicator values to slightly increase.

It has been shown that the intensification of agricultural practices has homogenized arable weed communities and has therefore also reduced the variety of their plant traits (Meyer et al., 2013). Also in the present study, we could distinguish the weed communities of historical and contemporary plots based on their floristic composition in nonmetric multidimensional scaling, and species numbers, red listed, L and Z species as well as arable weed cover changed dramatically between historical and contemporary plots. In contrast, the formerly common species were still the common weed species today (Sutcliffe and Kay 2000; Dessaint et al., 2007). However, the scatter in the floristic composition of contemporary plots was distinctly larger than among historical plots. This indicated that historical weed communities were more similar to each other than contemporary communities are. Although contradictory at first sight, this result does not necessarily conflict with the homogenization of weed communities reported in other studies (e.g. Cirujeda et al., 2011; Dessaint et al., 2007; Meyer et al., 2013). Most historical plots harbored many and rather diverse species. Therefore, species numbers were high, but the difference in species composition among plots was not. As contemporary plots contained on average only about seven species per $100 m^2$ and most of the occurring species had low frequencies across the sampled plots, the difference in species composition between contemporary plots increased, as each species unique to particular plots gets a high weight in comparison with other plots. In other words, one always encounters the same few common arable weed species, but in different abundances, and fields differ rather strongly in the few less common species still occurring.

5. Conclusions

The general decline in number and frequency of arable weed species and the change in plant traits of arable weeds found in this study for Switzerland suggests that the latter's preservation is still not secured, despite the various measures implemented for the conservation of arable weed communities during the last twenty years. More focused conservation measures, but also their more widespread application are necessary. Such measures should not only take place in regions where arable weed diversity is still high – although these regions certainly have priority – but also in currently depauperate regions that had a historically rich arable flora and where seeds of arable weeds might still occur in seed banks (Kurtz and Heinken, 2011). One possibility is to install more, larger and wider unsprayed field margins or to use adequate seed mixtures for establishing arable production-systems which promote rare arable weeds. Additionally, it would be valuable for conservation to characterize the attributes of contemporary arable communities, in which rare weed species could hitherto survive, as they could serve as references or as examples for "good" practices. Nevertheless, the presently ongoing fast change in modern arable weed communities due to new weedy neophytes might jeopardize these efforts. This immigration of arable neophytes therefore needs to be surveyed and their ecological costs but also their potential benefits (e.g. for ecosystem services; Mack et al., 2000) need to be assessed.

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Appendix A.

Plant traits used for the arable weed species recorded in the present study. RL(Red List Status): regionally extinct (RE), critically endangered (CR); endangered (EN); vulnerable (VU); nearly threatened (NT); least concern (LC); data deficient (DD); not evaluated (NE),;UZL: rare (Z) or typical, but more abundant species of agricutural land (L) species (BAFU/BLW, 2008); ecological group: 1 = forest plant; 2 = mountain plant; 3 = pioneer of the lowland; 4 = water plant; 5 = wetland plant; 6 = unfertilized dry meadow plant; 7 = weed or ruderal plant; 8 = fertilized meadow plant; –=: not listed; introduction to Switzerland: I: idiochrophyt = native or naturally immigrated species; A = archaeophyt, species introduced before AD 1496; N = neophyte, species introduced after AD 1496; range: A = outside Europe; B = Europe and other continents; C = around the Mediterranean; D = lowland Europe; E = European Mountains; characteristic species of arable weed communities of traditionally managed fields, based on Delarze and Gonseth (2008); L: indicator value for light; N: indicator value for nutrients.

Species name	RL	UZL	Ecological group	Introduction	Range	Growth form	Flower-ing time [month]	Startof flowering	Character-istic species	L	N	Annu-al
Achillea millefolium aggr.	LC		–	I	B	herb	4	5	no	4	3	no
Acinos arvensis (Lam.) Dandy	LC	L	6	I	C	herb	4	6	no	4	1	no
Adonis aestivalis L.	VU	Z	7	I	B	herb	3	5	yes	3	2	yes
Adonis flammea Jacq.	EN	Z	7	I	C	herb	3	5	yes	3	2	yes
Aegopodium podagraria L.	LC		1	I	B	herb	3	5	no	2	4	no
Aethusa cynapium L.	LC	L	7	I	B	herb	5	6	yes	3	4	no
Agropyron intermedium (Host) P. Beauv.	LC		3	I	B	grass	3	5	no	4	3	no
Agropyron repens (L.) P. Beauv.	LC		7	I	B	grass	3	6	no	4	4	no
Agrostemma githago L.	VU	Z	7	A	C	herb	3	6	yes	4	3	no
Agrostis capillaris L.	LC		8	I	B	grass	3	6	no	3	2	no
Agrostis stolonifera L.	LC		5	I	B	grass	2	6	no	4	3	no

(*Continued*)

Species name	RL	UZL	Ecological group	Introduction	Range	Growth form	Flower-ing time [month]	Startof flowering	Character-istic species	L	N	Annu-al
Ajuga chamaepitys (L.) Schreb.	NT	L	7	I	C	herb	5	5	yes	4	2	no
Ajuga reptans L.	LC		8	I	B	herb	4	4	no	3	3	no
Alchemilla vulgaris aggr.	LC		–	I	B	herb	5	5	no	3	4	no
Alopecurus myosuroides Huds.	LC	L	7	A	B	grass	5	5	yes	4	3	yes
Alopecurus pratensis L.	LC		8	I	B	grass	3	5	no	4	4	no
Alyssum alyssoides (L.) L.	LC	L	6	I	C	herb	2	4	no	4	2	no
Amaranthus blitum L.	LC		7	I	C	herb	3	7	yes	4	4	yes
Amaranthus hypochondriacus L.	LC		–	N	A	herb	3	7	no	4	4	yes
Amaranthus retroflexus L.	LC		7	N	A	herb	3	7	yes	4	4	yes
Anagallis arvensis L.	LC	L	7	A	C	herb	4	6	yes	4	3	yes
Anagallis foemina MilL.	NT	L	7	A	C	herb	4	6	yes	3	3	yes
*Anagallis minima (*L.) E. H. L. Krause	EN	Z	7	I	B	herb	4	6	no	4	2	no
Anchusa arvensis (L.) M. Bieb.	LC	L	7	A	C	herb	5	5	yes	4	4	no
Androsace maxima L.	CR	Z	7	I	B	herb	2	4	yes	4	3	yes
Anthemis arvensis L.	VU	Z	7	I	C	herb	5	5	yes	4	4	yes
Anthemis cotula L.	VU		7	A	C	herb	6	5	yes	4	3	yes
Anthemis tinctoria L.	NT		7	I	C	herb	4	6	no	4	2	no
Anthriscus sylvestris (L.) Hoffm.	LC		8	I	D	herb	6	4	no	3	4	no
*Apera spica-venti (*L.) P. Beauv.	LC		7	A	B	grass	3	6	yes	3	4	no
Aphanes arvensis L.	NT	L	7	I	C	herb	6	4	yes	3	3	yes
Arabidopsis thaliana (L.) Heynh.	LC		7	I	C	herb	3	3	yes	4	3	no
Arctium lappa L.	LC	L	7	I	B	herb	4	7	no	3	5	no
Arenaria serpyllifolia L.	LC	L	7	I	D	herb	3	5	no	4	3	no
*Arrhenatherum elatius (*L.) J.	LC		8	J	C	grass	2	6	no	3	4	no
Artemisia absinthium L.	LC	L	7	I	B	herb	3	7	yes	4	4	no
Artemisia verlotiorum Lamotte	LC		7	N	A	herb	3	9	no	4	4	no
Artemisia vulgaris L.	LC		7	I	B	herb	3	7	no	4	4	no
Atriplex patula L.	LC		7	A	B	herb	3	7	yes	4	4	yes
Avena fatua L.	NT		7	A	C	grass	3	6	no	4	3	yes
Avena sativa L.	LC		7	J	C	grass	2	6	no	4	4	yes
Bellis perennis L.	LC		8	I	B	herb	6	2	no	4	4	no
Bifora radians M. Bieb.	CR		7	A	B	herb	4	5	yes	4	4	yes
Brassica napus L.	LC		7	J	C	herb	2	4	no	4	4	no
Brassica rapa L. *subsp. campestris* (L.) A. R. Clapham	VU		7	A	d	herb	2	4	yes	4	4	yes
Bromus arvensis L.	VU	Z	7	A	B	grass	3	6	yes	3	3	yes
Bromus hordeaceus L.	LC		8	J	B	grass	3	5	no	4	4	yes
Bromus racemosus L. *subsp. commutatus* (Schrad.) Syme	VU		7	A	C	grass	2	5	no	3	3	yes
Bromus secalinus L.	EN	Z	7	J	D	grass	2	6	no	3	3	yes
Bromus squarrosus L.	LC	L	7	N	A	grass	3	5	no	4	4	yes
Bromus sterilis L.	LC		7	A	B	grass	3	5	no	3	4	yes
Buglossoides arvensis (L.) I. M. Johnst.	LC	L	7	I	B	herb	4	4	yes	3	4	no
Bunium bulbocastanum L.	LC	L	6	I	D	herb	2	6	yes	4	2	no
Bupleurum rotundifolium L.	EN	Z	7	A	C	herb	4	5	yes	4	2	yes
Calystegia sepium (L.) R. Br.	LC		7	I	B	herb	4	6	no	3	4	no
Camelina microcarpa DC.	VU	Z	7	A	B	herb	2	5	yes	4	3	no
Campanula rapunculoides L.	LC	L	3	I	B	herb	4	6	no	3	3	no
Campanula rapunculus L.	LC	L	6	I	B	herb	3	5	no	3	3	no
Capsella bursa-pastoris (L.) Medik.	LC		7	I	C	herb	6	3	yes	4	4	no
Cardamine hirsuta L.	LC		7	A	C	herb	3	3	yes	4	4	no
Carex hirta L.	LC		7	I	D	grass	4	4	no	3	3	no
Carum carvi L.	LC		8	I	B	herb	4	5	no	4	3	no
Caucalis platycarpos L.	VU	Z	7	A	C	herb	3	5	yes	3	2	yes
Centaurea cyanus L.	NT	L	7	I	C	herb	5	6	yes	4	3	no
Centaurea jacea L. *subsp. jacea*	LC	L	8	I	D	herb	4	6	no	4	3	no
Centaurea scabiosa L. *subsp. scabiosa*	LC	L	6	I	B	herb	3	6	no	4	2	no
Centaurium pulchellum (Sw.) Druce	VU	Z	5	I	B	herb	5	6	no	4	3	no
Cerastium arvense L. *subsp. strictum (*W. D. J. Koch) Schinz & R. Keller	LC		2	I	E	herb	3	6	no	5	2	no
Cerastium fontanum Baumg. *subsp. vulgare* (Hartm.) Greuter & Burdet	LC		8	I	B	herb	3	4	no	3	3	no
Cerastium glomeratum Thuill.	LC	L	7	I	C	herb	6	4	yes	4	3	no
Chaenorrhinum minus (L.) Lange	LC		7	A	C	herb	5	6	yes	4	4	yes
Chaerophyllum aureum L.	LC	L	8	I	B	herb	3	6	no	3	4	no
Chaerophyllum hirsutum L.	LC		8	I	E	herb	4	5	no	3	4	no
Chenopodium album L.	LC		7	A	B	herb	3	7	yes	4	4	yes
Chenopodium hybridum L.	LC	L	7	A	B	herb	3	7	yes	4	4	yes
Chenopodium polyspermum L.	LC		7	A	B	herb	3	7	yes	4	4	yes
Chondrilla juncea L.	NT	L	6	I	B	herb	4	6	no	4	3	no
Cichorium intybus L.	LC	L	7	A	B	herb	3	7	no	5	3	no
Cirsium arvense (L.) Scop.	LC		7	I	B	herb	3	7	no	3	4	no
Clinopodium vulgare L.	LC	L	6	I	B	herb	3	7	no	4	2	no
Consolida regalis Gray	VU	Z	7	A	C	herb	4	6	yes	3	3	yes
Convolvulus arvensis L.	LC		7	A	B	herb	4	6	yes	4	3	no
*Conyza canadensis (*L.) Cronquist	LC		7	N	A	herb	3	7	yes	4	3	no

Cornus sanguinea L.	LC		1	I	D	herb	2	5	no	3	3	no
Crepis capillaris Wallr.	LC		8	I	D	herb	5	6	no	4	3	no
Crepis tectorum L.	VU	Z	7	I	B	herb	4	6	no	4	4	no
*Cynodon dactylon (*L.) Pers.	LC		7	N	A	grass	3	7	no	4	3	no
Dactylis glomerata L.	LC		8	I	B	grass	5	5	no	3	4	no
Daucus carota L.	LC	L	6	A	C	herb	3	6	no	4	2	no
Descurainia sophia (L.) *Prantl*	LC	L	7	I	B	herb	5	4	no	4	4	no
Dianthus carthusianorum L.		L	6	I	D	herb	5	6	no	4	2	no
Digitaria ischaemum (Schreb.) Muhl.	LC		7	A	B	grass	3	7	yes	4	4	yes
Digitaria sanguinalis (L.) Scop.	LC		7	A	B	grass	4	7	yes	4	4	yes
Dipsacus fullonum L.	LC	L	7	J	C	herb	2	7	no	4	4	no
*Echinochloa crus-galli (*L.) P. Beauv.	LC		7	A	A	grass	3	7	yes	3	5	yes
Echium vulgare L.	LC	L	6	I	B	herb	6	5	no	5	4	no
Epilobium angustifolium L.	LC		3	I	B	herb	3	6	no	4	4	no
Epilobium hirsutum L.	LC	L	5	I	B	herb	4	6	no	3	4	no
Epilobium tetragonum L. *subsp. tetragonum*	LC	L	5	I	B	herb	3	7	no	3	3	no
Equisetum arvense L.	LC		7	I	B	herb	3	3	no	4	3	no
Equisetum telmateia Ehrh.	LC		1	I	B	herb	3	3	no	3	3	no
Erigeron acer L. *subsp. acer*	LC		3	I	B	herb	4	6	no	5	2	no
*Erigeron annuus (*L.) Pers. *subsp. annuus*	LC		7	N	A	herb	5	6	no	4	4	no
Erodium cicutarium (L.) L'Hér.	LC	L	7	I	C	herb	6	3	yes	4	3	no
Erophila verna (L.) Chevall.	LC		7	I	B	herb	4	2	no	4	2	yes
*Erucastrum gallicum (*Willd.) O. E. Schulz	NT	L	7	I	D	herb	4	5	yes	4	2	no
Erysimum cheiranthoides L.	NT	L	7	I	B	herb	3	6	yes	4	4	no
Erysimum repandum L.	CR		7	I	B	herb	3	4	no	4	4	yes
Euphorbia cyparissias L.	LC	L	6	I	B	herb	4	4	no	4	2	no
Euphorbia exigua L.	LC	L	7	A	C	herb	6	5	yes	4	4	yes
Euphorbia helioscopia L.	LC		7	A	C	herb	6	4	no	4	4	yes
Euphorbia lathyris L.	NT		7	N	C	herb	3	6	no	3	3	no
Euphorbia peplus L.	LC		7	A	B	herb	5	6	yes	4	4	yes
Euphorbia platyphyllos L.	LC	L	1	I	C	herb	3	6	yes	3	3	yes
Euphorbia stricta L.	LC	L	1	I	B	herb	5	5	no	3	3	no
Euphrasia rostkoviana Hayne	LC		5	I	D	herb	5	5	no	3	0	no
Fagopyrum esculentum Moench	NT		7	A	B	herb	4	7	no	4	4	yes
Fallopia convolvulus (L.) Á. Löve	LC		7	A	C	herb	3	7	yes	4	3	yes
Festuca arundinacea Schreb. *subsp. arundinacea*	LC		5	I	B	grass	4	5	no	4	4	no
Festuca pratensis Huds.	LC		8	I	B	grass	4	5	no	3	0	no
Festuca rubra L.	LC		8	I	B	grass	5	5	no	3	0	no
Fumaria officinalis L. *subsp. officinalis*	LC		7	A	C	herb	NA	4	yes	4	4	yes
Fumaria schleicheri Soy.-Will.	VU	Z	7	A	B	herb	5	5	yes	3	4	yes
Gagea villosa (M. Bieb.) Sweet	EN	Z	7	I	C	herb	2	3	no	4	4	no
Galeopsis angustifolia Hoffm.	NT		3	I	D	herb	5	6	no	4	2	no
Galeopsis ladanum L.	NT	L	7	I	B	herb	5	6	yes	4	2	no
Galeopsis tetrahit L.	LC		7	I	D	herb	5	6	no	3	5	yes
*Galinsoga ciliata (*Raf.) S. F. Blake	LC		7	N	A	herb	4	7	yes	4	4	yes
Galinsoga parviflora Cav.	LC		7	N	A	herb	6	4	no	4	4	yes
Galium aparine L.	LC		7	I	B	herb	6	5	no	3	5	yes
Galium mollugo L.	LC		1	I	D	herb	NA	5	no	3	4	no
Galium spurium L.	NT	L	7	I	B	herb	5	5	no	3	5	yes
Galium tricornutum Dandy	EN	Z	7	I	C	herb	3	6	yes	4	4	yes
Geranium columbinum L.	LC	L	7	A	B	herb	5	5	yes	4	3	yes
Geranium dissectum L.	LC	L	7	A	B	herb	5	6	yes	4	3	yes
Geranium molle L.	LC	L	7	I	B	herb	5	5	no	4	4	no
Geranium pusillum L.	LC	L	7	A	B	herb	5	5	yes	4	4	no
Geranium pyrenaicum Burm. f.	LC		7	I	E	herb	5	5	no	3	4	no
Geranium rotundifolium L.	LC	L	7	A	C	herb	5	6	yes	4	3	no
Glechoma hederacea L. *subsp. hederacea*	LC		8	I	B	herb	2	4	no	3	3	no
Gnaphalium uliginosum L.	NT	L	7	I	B	herb	4	6	no	4	4	yes
Gypsophila muralis L.	EN		7	I	B	herb	4	7	no	4	1	yes
Helianthus annuus L.	LC		7	N	A	herb	4	7	no	4	4	yes
Heracleum sphondylium L. *subsp. sphondylium*	LC		8	I	D	herb	4	6	no	3	4	no
Hieracium lactucella Wallr.	LC	L	6	I	D	herb	6	5	no	4	2	no
Holcus lanatus L.	LC		8	I	D	grass	4	5	no	4	3	no
Holcus mollis L.	LC		7	I	D	grass	3	6	no	3	2	no
Holosteum umbellatum L.	LC	L	7	I	C	herb	3	3	yes	4	3	yes
Hordeum vulgare L.	LC		7	J	A	grass	2	3	no	4	3	yes
Hypericum humifusum L.	LC	L	7	I	D	herb	4	6	no	3	3	no
Hypericum perforatum L. *subsp. perforatum*	LC	L	6	I	B	herb	4	6	no	3	3	no
Isatis tinctoria L.	LC	L	7	I	B	herb	4	4	no	4	2	no
Juglans regia L.	LC		1	A	C	herb	1	5	no	3	4	no
Juncus bufonius L.	LC	L	5	I	B	grass	4	6	no	4	3	yes
Kickxia elatine (L.) Dumort.	VU	Z	7	A	C	herb	4	7	yes	4	3	yes
Kickxia spuria (L.) Dumort.	VU	Z	7	A	C	herb	4	7	yes	4	4	yes
Knautia arvensis (L.) Coult.	LC	L	8	I	B	herb	5	5	no	4	3	no
Knautia dipsacifolia Kreutzer	LC	L	1	I	E	herb	4	6	no	3	0	no
Lactuca perennis L.	LC	L	6	I	D	herb	3	5	no	5	2	no
Lactuca serriola L.	LC		7	I	B	herb	3	7	no	4	3	no
Lamium album L.	LC	L	7	I	B	herb	4	5	no	3	5	no
Lamium amplexicaule L.	LC	L	7	I	B	herb	6	3	yes	4	4	no

(*Continued*)

Species name	RL	UZL	Ecological group	Introduction	Range	Growth form	Flower-ing time [month]	Startof flowering	Character-istic species	L	N	Annu-al
Lamium maculatum L.	LC		7	I	D	herb	6	4	no	3	4	no
Lamium purpureum L.	LC		7	A	C	herb	6	2	yes	4	4	no
Lapsana communis L.	LC		1	I	B	herb	NA	6	no	4	0	no
Lathyrus pratensis L.	LC	L	–	I	B	legume	2	6	no	3	3	no
Lathyrus tuberosus L.	VU	Z	7	A	A	legume	2	6	yes	4	3	no
*Legousia speculum-veneris (*L.) Chaix	VU	Z	7	A	C	herb	2	6	yes	4	3	yes
*Lepidium campestre (*L.) R. Br.	LC	L	7	I	B	herb	3	4	yes	4	4	no
Leucanthemum vulgare Lam.	LC		–	I	B	herb	6	5	no	4	3	no
Linaria vulgaris Mill.	LC	L	7	I	B	herb	5	6	no	4	3	no
Lolium multiflorum Lam.	LC		8	N	C	grass	3	6	no	4	4	no
Lolium perenne L.	LC		8	I	B	grass	5	5	no	4	4	no
Lolium temulentum L.	CR	Z	7	A	C	grass	2	6	yes	3	4	yes
Lotus corniculatus L. *subsp. corniculatus*	LC		8	I	B	legume	3	5	no	3	0	no
Lysimachia nummularia L.	LC		1	I	D	herb	2	6	no	2	4	no
Lythrum salicaria L.	LC		5	I	B	herb	4	6	no	3	3	no
Matricaria discoidea DC.	LC		7	N	A	herb	6	5	no	4	5	yes
Matricaria recutita L.	LC		7	I	C	herb	5	5	yes	4	1	no
Medicago lupulina L.	LC	L	8	A	C	legume	5	5	no	3	3	no
*Medicago minima (*L.) L.	LC	L	6	I	C	legume	2	5	no	4	2	no
Medicago sativa L.	LC		8	A	C	legume	3	6	no	4	3	no
Melampyrum arvense L.	VU	Z	7	I	B	herb	3	6	yes	4	3	yes
Melilotus officinalis (L.) Lam.	LC		7	A	B	legume	5	6	no	4	3	no
Mentha arvensis L.	LC	L	7	I	B	herb	3	7	yes	4	4	no
Mercurialis annua L.	LC	L	7	A	B	herb	6	5	yes	4	4	no
Miscanthus sinensis	NE		–	N	A	grass	NA	8	no	4	4	no
Muscari comosum (L.) Mill.	LC		7	I	C	herb	3	4	no	4	3	no
Muscari racemosum (L.) Mill.	NT	L	7	I	C	herb	3	3	yes	4	3	no
Myosotis arvensis Hill	LC	L	7	I	B	herb	6	4	no	4	3	no
Myosotis stricta Roem. & Schult.	LC		6	I	B	herb	3	3	no	4	2	yes
Myosoton aquaticum (L.) Moench	LC	L	1	I	B	herb	5	6	no	3	4	no
*Neslia paniculata (*L.) Desv. *subsp. paniculata*	VU	Z	7	I	C	herb	5	5	yes	3	3	yes
Odontites vernus (Bellardi) Dumort. *subsp. serotinus* Corb.	VU	Z	5	I	B	herb	3	8	no	4	1	no
Odontites vernus (Bellardi) Dumort. *subsp. vernus*	VU	Z	7	J	D	herb	2	6	no	4	4	yes
Ononis repens L.	LC	L	6	I	D	herb	4	6	no	4	2	no
Ornithogalum umbellatum L.	LC	L	7	I	D	herb	2	4	yes	4	3	no
Oxalis fontana Bunge	LC		7	N	A	herb	5	6	yes	4	0	no
Papaver argemone L.	VU	Z	7	A	C	herb	3	4	yes	3	3	no
Papaver dubium L. *subsp. dubium*	LC	L	7	J	C	herb	3	5	yes	3	3	no
Papaver dubium L. *subsp. lecoqii* (Lamotte) Syme	LC	L	7	J	C	herb	3	5	yes	3	3	no
Papaver rhoeas L.	LC	L	7	A	C	herb	5	5	yes	3	3	no
Pastinaca sativa L.		L	8	J	B	herb	3	5	no	4	3	no
*Petrorhagia prolifera (*L.) P. W. Ball & Heywood	LC	L	6	I	C	herb	5	6	yes	4	2	yes
Phleum pratense L.	LC		8	J	B	grass	3	6	no	4	4	no
Phragmites australis (Cav.) Steud.	LC		4	I	B	grass	4	7	no	3	3	no
Picea abies (L.) H. Karst.	LC		1	I	D	herb	1	5	no	1	3	no
Picris hieracioides L.	LC		8	I	B	herb	5	6	no	4	4	no
Pimpinella major (L.) Huds.	LC	L	8	I	D	herb	4	6	no	3	3	no
Pisum sativum L. *subsp. arvense* (L.) Asch. & Graebn.	DD		7	A	C	legume	NA	5	no	3	3	yes
Plantago lanceolata L.	LC		8	I	B	herb	6	4	no	3	3	no
Plantago major L. *subsp. intermedia* (Gilib.) Lange	LC		7	I	B	herb	5	6	no	4	3	no
Plantago major L. *subsp. major*	LC		7	I	B	herb	5	6	no	4	4	no
Plantago media L.	LC	L	6	I	E	herb	4	5	no	4	2	no
Poa alpina L.	LC		2	I	B	grass	4	6	no	4	4	no
Poa annua L.	LC		7	I	B	grass	6	1	no	4	4	no
Poa pratensis L.	LC		8	I	B	grass	3	5	no	4	3	no
Poa trivialis L.	LC		8	I	B	grass	2	6	no	3	4	no
Polygonum aviculare L.	LC		7	I	B	herb	3	5	no	4	4	yes
Polygonum bistorta L.	LC	L	2	I	B	herb	4	5	no	3	4	no
Polygonum hydropiper L.	LC	L	7	I	B	herb	4	7	no	3	4	no
Polygonum lapathifolium L. *subsp. lapathifolium*	LC		7	I	D	herb	4	7	no	5	4	yes
Polygonum minus Huds.	LC		7	I	B	herb	4	7	no	3	4	no
Polygonum mite Schrank	LC		7	I	D	herb	4	7	no	3	4	no
Polygonum persicaria L.	LC		7	I	B	herb	4	7	yes	4	4	yes
Portulaca oleracea L. *subsp. oleracea*	LC		7	A	C	herb	4	6	yes	4	4	yes
Potentilla anserina L.	LC		7	I	B	herb	5	5	no	4	4	no
Potentilla reptans L.	LC		7	I	B	herb	3	6	no	4	4	no
Prunella vulgaris L.	LC		8	I	B	herb	4	6	no	4	3	no
Ranunculus acris L. *subsp. acris*	LC		2	I	B	herb	NA	4	no	3	3	no
Ranunculus acris L. *subsp. friesianus* (Jord.) Syme	LC		8	I	D	herb	6	4	no	3	4	no

Ranunculus arvensis L.	VU	Z	7	A	C	herb	3	5	yes	3	3	yes
Ranunculus repens L.	LC		7	I	B	herb	5	5	yes	3	4	no
Ranunculus sardous Crantz	CR		7	I	C	herb	3	5	no	4	3	yes
Raphanus raphanistrum L.	LC		7	I	B	herb	6	5	yes	4	4	yes
*Rhinanthus alectorolophus (*Scop.) Pollich	LC	L	5	I	D	herb	4	5	no	4	3	yes
Rhinanthus minor L.	LC	L	5	I	B	herb	5	5	no	4	2	yes
Rorippa islandica (Gunnerus) Borbás	NT	L	5	I	D	NA	NA	6	no	4	3	no
Rorippa sylvestris (L.) Besser	LC	L	7	I	D	herb	3	6	no	4	4	no
Rubus caesius L.	LC		1	I	B	herb	4	6	no	2	4	no
Rubus fruticosus aggr.	Lc		–	I	B	herb	5	5	no	3	4	no
Rubus idaeus L.	LC		1	I	B	herb	2	5	no	3	4	no
Rumex acetosa L.	LC		8	I	B	herb	4	5	no	4	3	no
Rumex acetosella L. *subsp. acetosella*	LC		7	I	B	herb	4	5	no	5	2	no
Rumex crispus L.	LC		7	I	B	herb	2	7	no	4	4	no
Rumex obtusifolius L.	LC		8	I	D	herb	3	6	no	4	4	no
Sagina apetala Ard.	NT	L	7	I	C	herb	5	5	no	4	1	no
Sagina procumbens L.	LC		7	A	B	herb	5	5	no	4	4	no
Salvia pratensis L.	LC	L	6	I	C	herb	4	5	no	4	2	no
Saponaria officinalis L.	LC	L	7	I	B	herb	3	7	no	3	4	no
Saxifraga tridactylites L.	LC	L	3	I	C	herb	4	3	no	4	2	yes
Scandix pecten-veneris L.	EN	Z	7	A	B	herb	3	5	yes	4	3	yes
Scleranthus annuus L. *subsp. annuus*	VU	Z	7	J	B	herb	7	4	yes	4	2	no
Secale cereale L.	LC		7	J	B	herb	3	5	no	5	3	no
Securigera varia (L.) Lassen	LC	L	6	I	B	leguem	3	6	no	3	2	no
Sedum acre L.	LC	L	3	I	B	grass	2	6	no	5	1	no
Senecio vulgaris L.	LC		7	A	C	herb	6	2	yes	4	4	no
Setaria pumila (Poir.) Roem. & Schult.	LC		7	A	A	grass	4	7	yes	4	4	yes
Setaria verticillata (L.) P. Beauv.	LC		7	A	A	grass	4	6	yes	4	4	yes
Setaria viridis (L.) P. Beauv.	LC		7	A	C	grass	3	7	yes	4	4	yes
Sherardia arvensis L.	LC	L	7	I	C	herb	6	5	yes	4	3	yes
Silene dioica (L.) Clairv.	LC	L	8	I	D	herb	6	4	no	3	4	no
Silene noctiflora L.	VU	Z	7	A	B	herb	4	6	yes	4	3	yes
Silene pratensis (Rafn) Godr.	LC	L	7	I	B	herb	6	5	no	4	4	no
Silene vulgaris (Moench) Garcke *subsp. vulgaris*	LC		6	I	D	herb	4	6	no	3	2	no
Sinapis arvensis L.	LC		7	A	C	herb	6	5	yes	4	4	yes
Sisymbrium officinale (L.) Scop.	LC	L	7	A	B	herb	4	5	no	4	4	no
Solanum nigrum L.	LC		7	I	B	herb	5	6	yes	4	4	yes
Solanum tuberosum L.	LC		7	J	A	herb	3	6	no	4	4	no
Solidago canadensis L.	LC		7	N	A	herb	3	8	no	3	3	no
Sonchus arvensis L. *subsp. arvensis*	LC		7	I	B	herb	NA	7	yes	3	4	no
Sonchus asper Hill	LC		7	I	B	herb	5	6	yes	4	4	no
Sonchus oleraceus L.	LC		7	J	B	herb	5	6	yes	4	4	no
Spergula arvensis L.	VU	Z	7	I	C	herb	3	6	no	3	3	yes
*Spergularia rubra (*L.) J. & C. Presl	LC		7	A	B	herb	5	5	no	4	3	no
Spergularia segetalis (L.) Don	RE		7	I	D	herb	2	5	no	4	3	yes
Stachys annua (L.) L.	VU	Z	7	A	C	herb	5	6	yes	4	2	yes
Stachys palustris L.	NT	L	5	I	B	herb	4	6	no	3	3	no
Stellaria graminea L.	LC		8	I	B	herb	3	5	no	3	3	no
Stellaria media (L.) Vill.	LC		7	I	C	herb	6	3	yes	3	4	no
Symphytum officinale L.	LC	L	5	I	B	herb	4	5	no	3	4	no
Taraxacum officinale aggr.	LC		8	I	B	herb	2	4	no	4	4	no
Teucrium botrys L.	NT	L	7	I	D	herb	4	6	no	4	2	no
Thlaspi arvense L.	LC		7	A	B	herb	3	4	yes	3	4	no
Thlaspi perfoliatum L.	LC		6	I	B	herb	2	4	no	4	3	no
Tragopogon pratensis L. *subsp. orientalis* (L.) Celak.	LC	L	8	I	B	herb	NA	5	no	4	3	no
Trifolium arvense L.	LC	L	7	I	C	legume	4	5	yes	4	1	no
Trifolium campestre Schreb.	LC	L	7	A	C	legume	5	5	no	4	2	no
Trifolium incarnatum L.	LC		8	I	C	legume	3	5	no	5	0	no
Trifolium pratense L. *subsp. pratense*	LC		8	I	B	legume	6	5	no	3	3	no
Trifolium repens L.	LC		8	I	B	legume	6	5	no	3	0	no
Tripleurospermum perforatum (Mérat) Laínz	LC		7	A	B	herb	5	6	no	4	4	no
Trisetum flavescens (L.) P. Beauv.	LC		–	I	B	grass	5	5	no	4	4	no
Triticum aestivum L.	LC		7	J	C	grass	2	6	no	5	4	no
Tussilago farfara L.	LC		3	I	B	herb	3	3	no	4	3	no
Urtica dioica L.	LC		7	I	B	herb	4	6	no	3	5	no
Valerianella dentata (L.) Pollich	VU	Z	7	A	C	herb	3	4	yes	4	4	yes
Valerianella locusta (L.) Laterr.	LC	L	7	I	C	herb	3	3	yes	4	4	no
Valerianella rimosa T. Bastard	EN	Z	7	A	C	herb	5	5	yes	4	4	yes
Verbascum thapsus L. *subsp. thapsus*	LC		7	I	B	herb	4	6	no	5	4	no
Veronica agrestis L.	LC	L	7	A	B	herb	6	3	yes	4	4	yes
Veronica arvensis L.	LC	L	7	I	C	herb	3	4	yes	3	4	yes
Veronica chamaedrys L.	LC		8	I	B	herb	3	4	no	3	4	no
Veronica filiformis Sm.	LC		8	N	E	herb	3	4	no	4	3	no
Veronica hederifolia L. *subsp. hederifolia*	LC		7	I	B	herb	4	3	yes	3	4	no
Veronica persica Poir.	LC		7	N	A	herb	6	2	yes	4	4	no
Veronica polita Fr.	LC	L	7	A	C	herb	6	3	yes	4	4	yes
Veronica serpyllifolia L.	LC		7	I	B	herb	5	5	no	4	4	no
Veronica triphyllos L.	VU	Z	7	I	C	herb	3	3	yes	4	3	yes
Vicia cracca L. *subsp. cracca*	LC	L	8	I	B	legume	NA	6	no	4	3	no

(*Continued*)

Species name	RL	UZL	Ecological group	Introduction	Range	Growth form	Flower-ing time [month]	Startof flowering	Character-istic species	L	N	Annu-al
Vicia cracca L. *subsp. incana (*Gouan) Rouy	LC		7	I	D	legume	NA	6	no	3	3	no
Vicia faba L.	LC		7	J	C	legume	2	6	no	3	4	yes
*Vicia hirsuta (*L.) Gray	LC		7	A	C	legume	6	5	yes	4	2	yes
Vicia sativa L.	LC		7	I	C	legume	5	5	no	4.5	0	no
Vicia sativa L. *subsp. nigra* (L.) Ehrh.	LC		7	I	C	legume	NA	5	yes	4.5	0	no
Vicia sativa L. *subsp. sativa*	LC		7	J	C	legume	NA	6	no	3	3	no
Vicia sepium L.	LC		8	I	B	legume	3	4	no	3	0	no
*Vicia tetrasperma (*L.) Schreb.	NT		7	A	B	legume	6	5	yes	3	2	yes
Vicia villosa Roth			7	I	C	legume	3	6	yes	3	3	no
Viola arvensis Murray	LC		7	A	C	herb	6	3	yes	3	3	no

Values for ecological groups, introduction, range, growth form, start of flowering time, indicator values, according to Landolt et al. (2010).

Appendix B.

Arable weed species with high change(over 60%) in frequency between historical and contemporary plots.

Species	Historical frequency [%]	Contemporary frequency [%]	Change in frequency [%]
Brassica napus L.	0.43	4.74	1000
Echinochloa crus-galli (L.) P. Beauv.	2.59	16.81	550
Amaranthus retroflexus L.	1.72	8.19	375
Lolium multiflorum Lam.	4.31	20.26	370
Ranunculus acris L. *subsp. friesianus* (Jord.) Syme	0.86	3.88	350
Lolium perenne L.	5.60	21.12	277
Pimpinella major (L.) Huds.	0.43	1.29	200
Dactylis glomerata L.	3.45	9.48	175
Solanum tuberosum L.	1.72	4.74	175
Adonis aestivalis L.	1.72	3.45	100
Festuca pratensis Huds.	0.86	1.72	100
Geranium molle L.	0.86	1.72	100
Lactuca serriola L.	0.43	0.86	100
Galinsoga ciliata (Raf.) S. F. Blake	0.00	4.31	–
Agropyron intermedium (Host) P. Beauv.	0.00	3.02	–
Triticum aestivum L.	0.00	3.02	–
Secale cereale L.	0.00	2.59	–
Avena sativa L.	0.00	2.16	–
Geranium pyrenaicum Burm. f.	0.00	1.72	–
Rorippa sylvestris (L.) Besser	0.00	1.72	–
Trifolium pratense L.	12.93	5.17	−60
Daucus carota L.	6.47	2.59	−60
Oxalis fontana Bunge	5.60	2.16	−61.54
Chenopodium polyspermum L.	25.00	9.48	−62
Veronica hederifolia L.	6.90	2.59	−62.5
Fallopia convolvulus (L.) Á. Löve	61.64	22.84	−63
Buglossoides arvensis (L.) I. M. Johnst.	8.19	3.02	−63
Galium mollugo aggr.	3.88	1.29	−66.5
Anchusa arvensis (L.) M. Bieb.	2.59	0.86	−66.5
Tripleurospermum perforatum (Mérat) Laínz	2.59	0.86	−66.5
Bunium bulbocastanum L.	1.29	0.43	−66.5
Bupleurum rotundifolium L.	1.29	0.43	−66.5
Lotus corniculatus L.	1.29	0.43	−66.5
Papaver dubium L. *subsp. lecoqii* (Lamotte) Syme	1.29	0.43	−66.5
Urtica dioica L.	1.29	0.43	−66.5
Polygonum persicaria L.	44.40	14.66	−67
Sonchus arvensis L.	18.97	6.03	−68
Lapsana communis L.	16.38	5.17	−68.5
Viola arvensis Murray	56.03	17.24	−69
Convolvulus arvensis L.	47.41	14.22	−70
Matricaria recutita L.	12.93	3.88	−70
*Capsella bursa-pastoris (*L.) Medik.	41.81	12.50	−70
Vicia cracca L. *subsp. cracca*	16.38	4.74	−71
Aethusa cynapium L.	22.41	6.47	−71
Glechoma hederacea L.	6.03	1.72	−71.5
Potentilla anserina L.	4.74	1.29	−72.5
Galeopsis tetrahit L.	50.86	13.36	−73.56
Galium aparine L.	46.55	12.07	−74
Veronica arvensis L.	18.53	4.74	−74.5
Papaver rhoeas L.	31.03	7.76	−75
Rumex obtusifolius L.	24.14	6.03	−75
Senecio vulgaris L.	10.34	2.59	−75
Anthriscus sylvestris (L.) Hoffm.	3.45	0.86	−75
Agrostis capillaris L.	1.72	0.43	−75
Carum carvi L.	1.72	0.43	−75
Melampyrum arvense L.	1.72	0.43	−75
Cirsium arvense (L.) Scop.	38.36	9.05	−76.5
Potentilla reptans L.	5.60	1.29	−77
Alchemilla vulgaris aggr.	3.88	0.86	−78
Setaria viridis (L.) P. Beauv.	3.88	0.86	−78
Mercurialis annua L.	6.03	1.29	−78.5
Heracleum sphondylium L.	12.50	2.59	−79
Ranunculus arvensis L.	8.62	1.72	−80
Bromus hordeaceus L.	2.16	0.43	−80
Euphorbia platyphyllos L.	2.16	0.43	−80
Galeopsis angustifolia Hoffm.	2.16	0.43	−80
Veronica serpyllifolia L.	2.16	0.43	−80
Achillea millefolium aggr.	31.03	6.03	−80.5
Equisetum arvense L.	26.72	5.17	−80.5
Medicago lupulina L.	6.90	1.29	−81.25
Rumex crispus L.	11.64	2.16	−81.5
Sonchus oleraceus L.	19.40	3.45	−82
Ranunculus repens L.	57.33	9.91	−82.5
Apera spica-venti (L.) P. Beauv.	25.43	4.31	−83
Kickxia elatine (L.) Dumort.	2.59	0.43	−83.5
Stachys palustris L.	2.59	0.43	−83.5
Veronica agrestis L.	2.59	0.43	−83.5
Fumaria officinalis L. *subsp. officinalis*	5.60	0.86	−84.5
Campanula rapunculoides L.	8.62	1.29	−85
Kickxia spuria (L.) Dumort.	9.05	1.29	−85.5
Spergula arvensis L.	6.03	0.86	−85.5
Arrhenatherum elatius (L.) J. & C. Presl	3.02	0.43	−85.5
Rhinanthus alectorolophus (Scop.) Pollich	3.02	0.43	−85.5
Sinapis arvensis L.	34.91	4.74	−86.5
Silene noctiflora L.	9.91	1.29	−87
Cerastium fontanum Baumg. *subsp. vulgare* (Hartm.) Greuter & Burdet	23.28	3.02	−87
Arenaria serpyllifolia L.	20.69	2.59	−87.5
Galium spurium L.	3.45	0.43	−87.5
Holcus lanatus L.	3.45	0.43	−87.5
Hypericum humifusum L.	3.45	0.43	−87.5

(*Continued*)

Species	Historical frequency [%]	Contemporary frequency [%]	Change in frequency [%]
Lamium amplexicaule L.	3.45	0.43	−87.5
Symphytum officinale L.	3.45	0.43	−87.5
Myosotis arvensis Hill	56.90	6.90	−88
Sonchus asper Hill	34.48	3.88	−88.75
Rumex acetosa L.	4.31	0.43	−90
Raphanus raphanistrum L.	25.43	2.16	−91.5
Atriplex patula L.	25.86	2.16	−91.5
Riccia glauca L.	5.17	0.43	−91.5
Tussilago farfara L.	5.17	0.43	−91.5
Vicia sepium L.	5.17	0.43	−91.5
Lathyrus pratensis L.	11.21	0.86	−92.5
Vicia tetrasperma (L.) Schreb.	12.07	0.86	−93
Anagallis arvensis L.	37.93	2.59	−93
Agrostemma githago L.	6.47	0.43	−93.5
Legousia speculum-veneris (L.) Chaix	6.47	0.43	−93.53
Valerianella locusta (L.) Laterr.	8.19	0.43	−94.5
Agrostis stolonifera L.	25.43	1.29	−95
Aegopodium podagraria L.	8.62	0.43	−95
Chaenorrhinum minus (L.) Lange	9.48	0.43	−95.5
Sherardia arvensis L.	11.64	0.43	−96.5
Cerastium glomeratum Thuill.	12.07	0.43	−96.5
Vicia sativa L. *subsp. nigra* (L.) Ehrh.	14.22	0.43	−97
Prunella vulgaris L.	14.66	0.43	−97
Aphanes arvensis L.	15.95	0.43	−97.5
Euphorbia exigua L.	20.26	0.43	−98
Mentha arvensis L.	23.71	0.43	−98
Vicia hirsuta (L.) Gray	25.86	0.43	−98.5
Chrysanthemum leucanthemum L.	15.95	0.00	−100
Sagina procumbens L.	15.52	0.00	−100
Vicia sativa L. *subsp. sativa*	12.50	0.00	−100
Plantago major L. *subsp. intermedia* (Gilib.) Lange	12.07	0.00	−100
Gnaphalium uliginosum L.	10.34	0.00	−100
Holcus mollis L.	10.34	0.00	−100
Polygonum mite Schrank	9.48	0.00	−100
Arabidopsis thaliana (L.) Heynh.	8.62	0.00	−100
Juncus bufonius L.	8.19	0.00	−100
Knautia arvensis (L.) Coult.	7.33	0.00	−100
Ranunculus acris L. *subsp. acris*	6.03	0.00	−100
Anagallis foemina Mill.	5.60	0.00	−100
Stellaria graminea L.	5.60	0.00	−100
Papaver dubium L.	5.17	0.00	−100
Centaurea scabiosa L. *subsp. scabiosa*	3.88	0.00	−100
Linaria vulgaris Mill.	3.88	0.00	−100
Picris hieracioides L.	3.88	0.00	−100
Scleranthus annuus L.	3.88	0.00	−100
Veronica chamaedrys L.	3.88	0.00	−100
Euphorbia peplus L.	3.02	0.00	−100
Rumex acetosella L.	3.02	0.00	−100
Odontites vernus (Bellardi) Dumort. *subsp. serotinus Corb.*	2.59	0.00	−100
Anthoceros spec.	2.16	0.00	−100
Chaerophyllum aureum L.	2.16	0.00	−100
Chaerophyllum hirsutum L.	2.16	0.00	−100
Papaver argemone L.	2.16	0.00	−100
Trifolium campestre Schreb.	2.16	0.00	−100
Valerianella dentata (L.) Pollich	2.16	0.00	−100
Valerianella rimosa T. Bastard	2.16	0.00	−100
Veronica polita Fr.	2.16	0.00	−100
Vicia sativa L.	2.16	0.00	−100
Acinos arvensis (Lam.) Dandy	1.72	0.00	−100
Crepis capillaris Wallr.	1.72	0.00	−100
Erysimum cheiranthoides L.	1.72	0.00	−100
Galeopsis ladanum L.	1.72	0.00	−100
Gypsophila muralis L.	1.72	0.00	−100
Lysimachia nummularia L.	1.72	0.00	−100
Myosoton aquaticum (L.) Moench	1.72	0.00	−100

Appendix C. : Additional Analyses.

Mean species number per plot (±standard error SE) of historical and contemporary plots (N = 232) for all weed species (with plants of field borders either included or not included) ***: $p < 0.001$, **: $p < 0.01$ according to Wilcoxon-Tests.

	Mean historical number per plot	Mean contemporary number per plot	Mean contemporary number with borders	V-value	
Mean species number	22.7 ± 0.53	7.9 ± 0.47	20.4 ± 0.42 20.4 ± 0.42	26565 9018.5	*** **

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