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Plant species richness and composition in the arable land of Kosovo

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Abstract

This study investigates today's plant species richness and composition in cultivated and recently abandoned arable land of Kosovo. Relationships between these aspects of vegetation and both environmental features and agricultural management measures are studied at the regional and plot scale. In 2006, 432 vegetation relevés with a standard plot size of 25 m² were recorded in cultivated fields. In 2007, data collection focussed on 41 plots in arable fields that had been abandoned the year before. With respect to the environment, data analysis accounts for topography, soil base-richness and moisture, and geographic location. As to the management, crops and weed control are considered. A total number of 235 species was documented. In comparison to literature dating back to about 1980, the regional weed flora considerably changed. At the plot scale, today's weed flora of Kosovo is fairly species-poor and species composition is rather uniform between plots. According to General Regression Model analyses, Indicator Species Analyses and Detrended Correspondence Analyses, species richness and composition mainly differ between crops and weed management, with highest mean species richness in recently abandoned and lowest in herbicide-treated maize fields.

Keywords:

weed flora, weed vegetation, agriculture, weed management, land-use change

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Introduction

Kosovo is situated in the submediterranean floristic region that is known for its rich flora, especially in near natural habitats (cf. e.g., Fritsch 1909, 1918, Rexhepi 1976, Millaku 1999, Stevanović et al. 2003). According to the report of the United States Agency for International Development (USAID) on the biodiversity of Kosovo (Ard-Bioflor Iqc. Consortium 2003), about 1.800 to 2.500 higher plant species occur in the area, including 13 endemic to Kosovo and about 150 to 200 species restricted to the Balkan Peninsula, Europe's major hotspot of biodiversity (Griffiths et al. 2004). However, as stated in the USAID report, the knowledge on the regional flora (e.g., Kojić et al. 1975, Banjska 1977, Lozanovski et al. 1980a, Kojić 1986) is still incomplete or might be outdated. Due to land-use changes in the recent past, the latter may be especially true for the flora of the arable land. Thus, as also stated in the report, further efforts in floristic mapping need to be undertaken.

About 20 to 30 years ago, the vegetation of Kosovo's arable land was documented by Kojić & Pejčinović (1982). Results of this documentation were also published by Pejčinović (1987) and Pejčinović & Kojić (1988). According to these publications, the vegetation of the arable land was species-rich and differentiated in relation to environmental features and agricultural management. A contemporary documentation of today's arable weed vegetation of Kosovo has not been available to date.

Thus, essential data to evaluate Kosovo's weed flora and vegetation and potential changes since about 1980 have been widely unavailable. However, such an evaluation is urgently needed for at least two reasons: to sustain the development and implementation of both nature conservation strategies and concepts on multifunctional and sustainable agriculture (cf. Otte et al. 2007). This is especially important against the background that the Republic of Kosovo aims to meet the attitudes and regulations of the European Community for its further development.

Since centuries, the arable weed flora and vegetation of Kosovo has been affected by multiple environmental features and management measures at various spatial scales. With respect to the regional scale, differences in climate may be highly important for species pools of sub-regions. Besides direct climate effects related to ecological processes at the level of populations, differences in production systems depending on climate may significantly act as filters for species pools (c.f. Gurevitch et al. 2006). For Kosovo, climate effects were shown as being important for the spatial distribution of plant species in forests (e.g., Krasniqi 1968), but to date this aspect was not considered in research with respect to the regional arable weed flora. At the plot scale, agricultural management measures such as ploughing in spring or autumn, mechanical weed control and herbicide application, and environmental features such as soil quality may be expected to be the main factors affecting both richness and composition of arable weed vegetation (cf. Šarić 1991, Schneider et al. 1994 and, for Kosovo, Susuri 1998, Susuri et al. 2001, Mehmeti & Demaj 2006). Some recent comparative studies conducted in cultivated arable fields of selected municipalities in Kosovo (e.g., Susuri et al. 2001, Mehmeti 2003, 2004, Mehmeti & Demaj 2006) clearly exemplify a reduction in species richness resulting from herbicide application. Further, as shown by Kojić & Pejčinović (1982), species composition and richness in arable fields depend on the cultivated crop, with low diversity especially in maize fields. However, analogous to the situation described above, a region-wide and comprehensive study on relationships between arable weed vegetation and both environment and agricultural management has not been conducted in Kosovo to date.

Given this background, our study aims at the following: (i) to contribute to the ongoing floristic mapping of Kosovo, (ii) to serve as a reference database for future studies on land-use (change) and its effects on the regional arable weed flora and vegetation, and (iii) to provide quantitative information on the relationships between the vegetation of the arable land and both environmental features and agricultural management measures in this part of the world. In this context, we focus on the following hypotheses, referring to the regional and plot scale:

1. At the regional scale, the arable weed flora has changed since about 1980.

2. At the regional scale, today's arable weed flora differs between two sub-regions characterised by differences in climatic conditions, agricultural production systems, and settlement history.

3. At the plot scale, today's arable weed vegetation is related to environmental features and agricultural management measures.

Study area

The Republic of Kosovo covers an area of 10.877 km² in the centre of the Balkan Peninsula. The entire region is divided into three zones that developed in the Oligo-Miocene (cf. Gashi & Spaho 2002): (i) two plains, the Dukagjini plain in the western and the Kosova plain in the eastern part, and (ii) adjacent hilly areas divided by rivers mainly originating in the (iii) surrounding mountain areas. The elevation ranges from 265 m to 2656 m above sea level, with about 80 % of the entire area below 1.000 m. In the larger part of Kosovo's plains and adjacent hilly areas, climate and soils are suitable for agricultural land use.

Figure 1. Land fragmentation in Kosovo is pronounced today. The picture shows a mosaic landscape that in many parts of Kosovo has resulted from fragmentation of formerly large arable fields since about 1990. Weed species such as *Papaver rhoeas* and *Tripleurospermum perforatum*, to be seen in the foreground, occur along the field edges, but are often missing in the field center. The picture was taken in the eastern part of Kosovo (hilly area near Livoç) in May 2007. Photo by R. Waldhardt.

Figure 2. Cultivation of pepper concentrates on the western part of Kosovo (Dukagjini Plain near Krusha e Madhe) in May 2007. Many fields like this are kept mostly free of weeds by herbicide use or mechanical weed control. Photo by R. Waldhardt.

The climate is moderate continental with warm summers and cold winters. In the plains and the adjacent hilly areas, air temperature may range from 20 °C to 35 °C. In the Kosovo plain, about 170-200 days per year are frost-free and the mean annual rainfall is about 650 mm. In the Dukagjini plain, the annual rainfall is higher (about 780 mm) and the frost-free period is longer (up to 225 days) than in the Kosova plain, indicating pronounced Mediterranean climate influence in the western part of Kosovo.

According to a digital map of soil types (scale 1 : 50000) provided by the Chair of Soil Sciences at Prishtina University (cf. Elezi et al. 2004) and referring to the WRB-soil classification (IUSS Working Group WRB 2006), the most frequent soil types in the plains are fluvisols. In the hilly areas vertisols, cambisols and regosols are widespread. In general, the agricultural soils are significantly modified. Especially irrigation (mainly in the western part of Kosovo) and soil alteration are crucial factors that have impacted pedogenetic processes over centuries.

In 1991, about 300.000 ha were used as cultivated arable land. However, until 1996, the area of cultivated arable land decreased to 264.000 ha (Statistical Office of Kosovo 2002), and the area of abandoned arable land increased significantly. This land-use change reflects both political and socioeconomic changes and conflicts during the post-communist transformation process as part of the former Federal Republic of Yugoslavia, from which the Republic of Kosovo declared its independence of in 2008. Today, still about 10-15 % of the agricultural land is fallow land. However, in the recent past, the reasons for abandonment changed: The fallow land nowadays includes land that either left the agricultural sector as construction land, or was abandoned from cultivation due to poor soil quality (e.g., shallow calcerous soils) or high prices of variable cost (e.g. costs for fertiliser, seed, and fuel).

Today, the agricultural land of Kosovo is mainly used for subsistence production. About 88 % of the agricultural land is owned by private farmers, whereas only 12 % are managed by enterprises (Statistical Office of Kosovo 2006). The process of land privatisation is not yet completed. About 80 % of the agricultural land is managed in small farms, each comprising less than 5 ha. Thus, in comparison to the predominant cultivation of large fields during the socialist period, land fragmentation is pronounced (Zajmi 1996). Mean field size is below 1 ha. However, with respect to landscape structure and land fragmentation (Fig. 1), comprehensive data have not been available to date. In 2005, the most important crops (about 100.000 ha) were wheat and maize (mainly mixed-cropping of maize and beans), whereas other agricultural products such as pepper, onion and tomato were grown on much less acreage (about 4.000 ha; Statistical Office of Kosovo 2006) and concentrate on the western part influenced by Mediterranean climate (Fig. 2). Mainly for economic reasons and due to a lack of supply, pesticide use has remained restricted to parts of the arable land since about 1990 - but was formerly common, including spraying from airplanes since 1980. The level of fertilisation also decreased significantly in the last two decades. However, reliable and differentiated information considering the entire region is not available.

Material and methods

Vegetation sampling

In 2006, vegetation was documented on a total number of 432 cultivated arable fields, randomly distributed in the agricultural land of the study region (Fig. 3). On each field, one 5 m x 5 m plot was investigated. The location of each plot was recorded with the help of a GPS using the UTM system. To avoid edge effects, the minimum distance of each plot to the field border was 10 m. Vegetation was surveyed between May and August. The cover of crops and all other vascular plants was estimated as shown in Tab. 1.

It is well known from previous studies (cf. e.g., Waldhardt 1994) that abandoned arable fields in the earliest stage of vegetation succession often act as favourable habitats for arable weed species. We therefore, and due to the recently increasing proportion of abandoned arable land in Kosovo, additionally sampled the vegetation of 41 recently abandoned arable fields (first year of abandonment), again randomly distributed in the study region. Sampling was conducted in 2007, again between May and August. Information on the past land use of the abandoned fields, such as the date of the last tillage before abandonment, spring or autumn, was not gained. However, it may be assumed that abandonment was mainly after harvest in late summer to autumn 2006, as in most cases the vegetation of these fields was already well established in spring 2007.

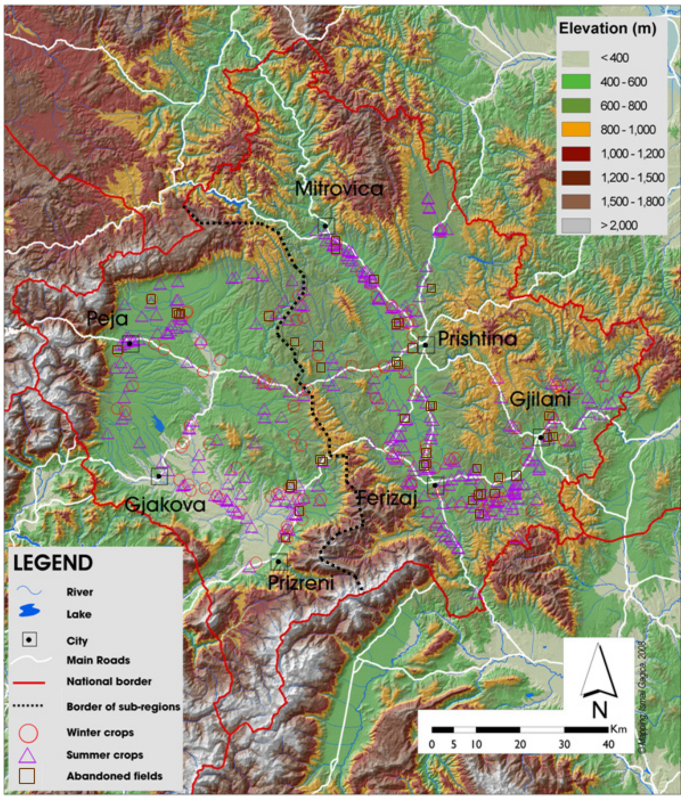

Figure 3. Location of the investigated arable fields classified as winter crop, summer crop and recently abandoned fields in two sub-regions of Kosovo. The two sub-regions differ in climate (a pronounced Mediterranean climate in the western part) and agricultural production systems (production of vegetables such as pepper, tomato and onion and, moreover, irrigation concentrate on the western part).

Nomenclature follows Wisskirchen & Haeupler (1998) and, for those species that are not listed there, Tutin et al. (1964-1993). In the results and discussion chapter, we distinguish between 'arable weeds s.str.' and other species such as grassland or ruderal species. The term 'arable weeds s. str.' is applied to those species that according to the phytosociological classification of Hüppe & Hofmeister (1990) characterise different vegetation types of the subclass Violenea arvensis HÜPPE & HOFMEISTER 1990 of the arable land in Germany and that may also be addressed as 'arable weeds s. str.' in the study region (cf. appendix 1). Moreover, the term is applied to species that in Kosovo mainly occur in the arable land, but are not mentioned in this publication.

Table 1. Species cover (abundance/dominance) as recorded in the field and transformed to values of 'mean percentage species cover' as considered in the quantitative analyses of this study.

A	r	+	1	2m	2a	2b	3	4	5
A (%)	0.1	1	2.5	10	15	20	37.5	62.5	87.5

A: species cover (abundance/dominance) as recorded in the field (according to Barkman et al. 1964). A (%): mean percentage species cover as considered in the analysis.

Documentation of environmental and land-use data

For each plot, altitude (meters above sea level), relative topographic position (four classes ranging from the plain floor to the hilltop), and soil type were documented. Information on soil types was derived from the digital map mentioned above and validated in the field. Based on this information, each plot was assigned to a certain class of soil base-richness (three classes representing a gradient from base-poor to calcareous) and also to a certain class of soil moisture in late spring (three classes representing a gradient from dry to moist). Soil classification with respect to base-richness and moisture (Tab. 2) considered information on the quality of soil types given by the IUSS Working Group WRB (2006) and the author's expertise on soil properties in Kosovo. Further, each plot was assigned to one of two sub-regions (Fig. 3) delineated under consideration of literature (e.g., Kojić & Pejčinović 1982, Schmitt 2008), maps and the author's expertise on within-regional differentiation of climate and production systems (cf. the previous chapter on the study region), topography and also settlement history in the study region.

Additionally, information on the way of weed control, provided by farmers, was recorded for a subset of 40, i.e. about 10 %, of the investigated cultivated arable fields (10 maize fields with herbicide use and 10 maize fields without herbicide use, but with mechanical weed control; 10 wheat fields with herbicide use and 10 wheat fields without any weed control). The plots belonging to the four groups were randomly distributed in the study region.

Table 2. Classification of soil base-richness and soil moisture in late spring based on soil types. For classification, information on soil types (IUSS Working Group WRB 2006) and the author's expertise on soil properties in Kosovo were considered.

Soil type	B	M	Soil type	B	M
calcaric fluvisols	3	3	eutric fluvisols	2	3
calcaric regosols	3	1	eutric gleysols	2	3
calcaric vertisols	3	1	eutric regosols	2	1
chromic cambisols	2	2	eutric vertisols	2	1
dystric cambisols	1	2	mollic leptosols	2	1
dystric fluvisols	1	3	stagnic podzoluvisol	1	2
dystric regosols	1	1	umbric gleysols	1	3
dystric vertisols	1	1	umbric leptosols	1	1
eutric cambisols	2	2			

B = class of soil base-richness (1: base-poor; 2: base-rich; 3: calcareous).
M = class of soil moisture in late spring (1: dry; 2: mesic; 3: moist).

Data analysis to test the first hypothesis

The first hypothesis was investigated under consideration of the above mentioned publications of Banjska (1977), Lozanovski et al. (1980a), Kojić & Pejčinović (1982), Kojić et al. (1975), Kojić (1986) and our data from 2006 and 2007. We compared the regional species pools (pooled species lists; cultivated crops were excluded from comparison) of the arable land recorded about 30 years ago with the species list derived from our data. For each species recorded in this study, we calcultated its relative frequencies of occurrence, separately for winter crop (n = 117), summer crop (n = 315), cultivated (n = 432), recently abandoned (n = 41), and all investigated fields (n = 473). The relative frequency *rf* (%) of a certain species *a* was calculated as

$$rf_a(\%) = (p_a / p)*100\ \%$$

where p_a is the number of plots, in which species a was recorded, and *p* is the number of plots in the dataset.

Moreover, we calculated the relative total cover of each species, separately for winter crop, summer crop, cultivated, and recently abandoned fields. The relative total cover *rc* (%) of a certain species s_x was calculated as

$$rc_{s_x}(\%) = \left(\sum_{p=1}^{n} c_{s_x} / \sum_{p=1}^{n}\left(\sum_{s=1}^{m} c_s\right)\right) * 100\ \%$$

where *c* is the species 'mean percentage cover' (cf. Tab. 1), *n* is the number of plots *p* in the dataset and *m* is the number of all species *s* in the dataset.

Additionally, information on species frequencies in the cultivated land was roughly derived from the former literature and compared with our dataset. However, data collection clearly differed between the considered former studies and our research. In contrast to our study, e.g., vegetation scientists in the past often deliberately selected species-rich fields and plots were not standardised with respect to size and localisation in the fields. Therefore, we do not compare past and today's species frequencies in detail. For the same reason, we do not compare past and today's species richness at the plot scale.

Data analysis and statistics to test the second hypothesis

To test hypothesis two, we randomly selected 135 plots per sub-region, estimated their total species richness and qualitatively compared the flora between the two sub-regions. Cultivated crops as well as species with less than three occurrences were excluded from comparison. Further, we conducted an Indicator Species Analysis (Dufrêne & Legendre 1997, McCune & Grace 2002) to determine indicator species for the two sub-regions. This analysis, considering both frequency and percentage cover of the tested species, was applied to the same dataset of 135 plots per sub-region. The Indicator Species Analysis was carried out with the help of the software package PC ORD 5 (McCune & Mefford 1999). Percentage species cover was considered as given in Tab. 1. Significance of indicator values was tested by Monte-Carlo permutation tests with 5000 runs, only considering species with indicator values above 15.

Data analysis and statistics to test the third hypothesis

With respect to hypothesis three, we tested (A) the importance of determinants of species richness at the plot scale (α-species richness sensu Whittaker 1972), (B) differences in species composition between the considered classes (crop classes, classes of topographic position, soil base-richness and soil moisture) and (C) gradients in the sampled vegetation, reflecting β diversity.

(A) To quantify determinants of α-species richness (cultivated crops were not considered), the following predictor variables were included in two General Regression Model (GRM) analyses with species richness as response variable: the UTM coordinates, the altitude above sea level, and the belonging to a certain class of topographic position, soil base-richness and moisture. Estimates of variance explained were calculated from the ratios of the sums of squares of a significant predictor variable to the total sum of squares in the respective model. In the first GRM analysis, only the data of cultivated arable fields (n = 432) were considered; the second GRM analysis was performed using the data of the abandoned fields (n = 41).

Focussing on the weed management and its potential effects on α-species richness, we additionally performed Student's unpaired t-tests, separately for the 20 selected maize resp. 20 wheat fields. Analysis was conducted using the software Statistica 6.0 (StatSoft Inc. 2001).

(B) Considering the entire dataset sampled in 2006 and 2007 (n = 473), Indicator Species Analyses (see above) were applied to test for indicators of the crop classes and the classes of topographic position, soil base-richness and soil moisture. Again cultivated crops were excluded from the analyses.

(C) Gradients in the sampled vegetation were detected in a Detrended Correspondence Analysis (DCA) (McCune & Grace 2002) comprising the entire dataset sampled in 2006 and 2007 (n = 473). In the 'main matrix' (vegetation data) the samples were distinguished under consideration of three crop classes (winter crops, summer crops, no crops = recently abandoned fields). Again, percentage species cover was considered as given in Tab. 1. Due to the fact that in 2006 data collection concentrated on cultivated arable fields, whereas in 2007 recently abandoned fields were investigated, we did not test for year effects in differences between the vegetation datasets of both years. In the 'second matrix' (environmental data) we distinguished between: (i) the four classes of relative topographic position, (ii) the three classes of soil base-richness, and (iii) the three classes of soil moisture. Further, we included (iv) the data on altitude and (v) the GPS coordinates of the plots. In an analogous way, we performed a DCA only considering the vegetation and environmental data of the abandoned fields (dataset sampled in 2007; n = 41). In both cases, data were arcsine squareroot transformed prior to analyses, and crop species as well as rare species with less than three (in the analysis of the entire dataset) or two occurrences (in the analysis of the abandoned fields) were excluded. Axes were rescaled and rare species were not down-weighted (due to their high proportion in the dataset). Method of detrending was by segments. To see how well the distances in the ordination spaces represent the distances in the original, unreduced spaces, we calculated the coefficient of determination (r^2) between distances in the ordination space and distances in the original space ('after-the-fact' evaluations under consideration of the relative Euclidean distances in the 'main matrices'). In order to detect correlations between ordination axes and site conditions Pearsons-r (Krebs 1999) was calculated based on the sample scores of ordination axes and environmental variables. We created joint plots; angles and lengths of environmental overlays tell the direction and strength of the relationships. DCA analysis was performed using software package PC ORD 5. In general, results may strongly depend on the structure of the considered datasets and the discussion of results needs to critically reflect on this. Against this background, Tab. 3 gives an overview on how the investigated plots are distributed among the considered environmental and management classes.

Results

Today's and past arable weed flora in Kosovo (Hypothesis 1)

The overall species number in the vegetation sampled in 2006 and 2007 is 235; among these, 94 species may be addressed as arable weed species s. str. (appendix 1). 140 species are recorded in winter crop fields (n = 117), 160 species in summer crop fields

Table 3. Percentage belonging of the investigated plots to environmental and management classes.

Class	**CF** (n=432)	**AF** (n=41)	**Class**	**CF** (n=432)	**AF** (n=41)
Relative topographic position			**Sub-region**		
plain floor	72.7	75.6	western part	31.9	26.8
lower slope	19.9	19.5	eastern part	68.1	73.2
upper slope	5.1	4.9	**Crop class**	(n=473)	
hilltop	2.3	-	summer crop fields	65.5	
Soil base-richness			winter crop fields	25.8	
base-poor	45.8	61.2	recently abandoned fields	8.7	
base-rich	25.3	14.4			
calcareous	28.9	24.4			
Soil moisture					
dry	32.4	19.5			
mesic	22.0	29.3			
moist	45.6	51.2			

CF: cultivated fields;
AF: recently abandoned fields;
summer crop fields (n): maize/beans (151), maize (92), vegetables (64), others (8);
winter crop fields (n): wheat (116), barley (1).
Altitude of plots ranges from 305 to 1089 m, with n < 400 m: 50; 400-500 m: 91; 500-600 m: 264; >600 m: 68.

Figure 4. Mixed cropping of maize and beans on a dystric vertisol in the eastern part of Kosovo with high cover of *Amaranthus retroflexus*. The picture was taken in early July 2006. Photo by A. Mehmeti.

(n = 315) and 139 species in recently abandoned fields (n = 41). 108 species contribute to the overall species richness of both cultivated and abandoned fields.

In our study, the most frequent species (rf > 25 %; n = 473) are in decreasing order of frequency: *Convolvulus arvensis*, *Cirsium arvense*+, *Chenopodium album*+, *Amaranthus retroflexus*+ (Fig. 4), *Echinochloa crus-galli*, *Polygonum aviculare*+, *Elymus repens* and *Consolida regalis*+. Among these species are also those with high relative overall cover (rc >10 %) in either winter crop, summer crop or recently abandoned fields. These species are marked with +. Only one more species, *Tripleurospermum perforatum*, reaches a high overall cover above ten (rc = 10.4 % in recently abandoned fields). In contrast, 187 species are recorded in less than 5 % of the investigated plots, in most cases with low relative overall cover (rc < 1%), and thus are found to be rare in today's arable land of Kosovo. 55 arable weed species s. str. contribute to this group of rare species.

Some of the rare arable weed species s. str. reach higher frequencies in the investigated recently abandoned fields (that were most probably abandoned in late summer or autumn 2006; Fig. 5) than in the cultivated fields (mainly summer crop fields). This is especially true for species that typically occur in winter crop fields (e.g., *Adonis aestivalis*, *Agrostemma githago*, *Anthemis austriaca*, *Caucalis platycarpos*, *Lithospermum arvense*, *Ranunculus arvensis*, *Vicia pannonica*). Moreover, some less rare arable weed species s. str. that also typically occur in winter crop fields (e.g., *Alopecurus myosuroides*, *Anagallis arvensis*, *Avena fatua*, *Centaurea cyanus*, *Consolida regalis*, *Matricaria recutita*, *Papaver rhoeas*, *Tripleurospermum perforatum*) reach higher frequencies in the investigated recently abandoned than in the cultivated fields. On the other hand, several arable weed species s. str. that typically concentrate on summer crop fields (e.g., *Amaranthus retroflexus*, *Chenopodium album*, *Galinsoga parviflora*, *Persicaria maculasa*, *Polygonum aviculare*, *Sinapis arvensis*) reach lower frequencies in the recently abandoned than in the cultivated fields.

Figure 5. Recently abandoned field on a eutric fluvisol west of Prishtina with *Adonis aestivalis* and *Consolida regalis*. The picture was taken in May 2007. Photo by R. Waldhardt.

Most of the species sampled in 2006 and 2007 were also found by Kojić et al. (1975), Banjska (1977), Lozanovski et al. (1980a), Kojić & Pejčinović (1982), and / or Kojić (1986) about 30 years ago. In these studies, 23 species documented in our study were not recorded, and 25 species were documented that are not found in our study. Most of the species that were found only either in our study or in the past are grassland and ruderal species, which only occasionally occur on arable land. However, in the latter group, eight species may be addressed as arable weed species s. str. (*Amaranthus albus*, *Lathyrus aphaca*, *Lathyrus nissolia*, *Orlaya grandiflora*, *Raphanus raphanistrum*, *Scleranthus annuus*, *Vaccaria pyramidata* and *Xanthium spinosum*). Moreover, *Agrostemma githago*, *Aristolochia clematitis*, *Bifora radians*, *Caucalis platycarpos*, *Cynodon dactylon* and *Portulaca oleracea*, were more frequent in the arable land of Kosovo in the past.

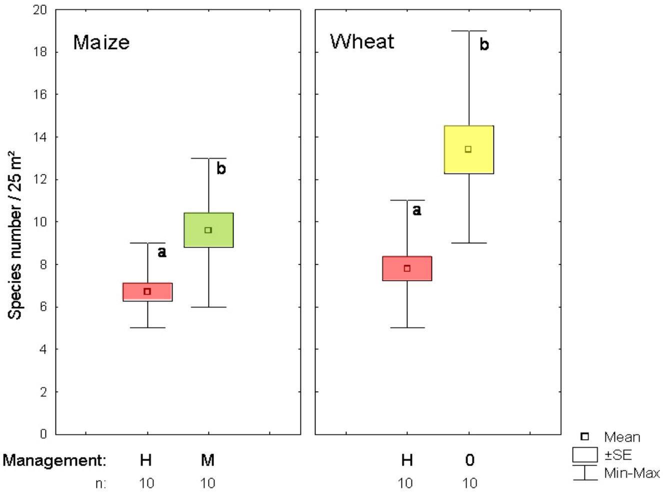

Figure 6. Weed management and species richness at the plot scale. Comparsion of the plant species in 40 selected arable fields of Kosovo with different weed control measurements. H: herbicide use; M: mechanical weed control in maize; 0: without any weed control in wheat; a, b: significant differences in mean species numbers (Student's t-test).

Today's flora and indicator species in the cultivated arable land of two sub-regions of Kosovo (Hypothesis 2)

The species richness of the two sub-regions is very similar. Given an overall number of 107 species occurring in more than three of the considered 270 arable fields, 98 species are recorded in the western part, while 102 species are found in the eastern part. The 14 species that are recorded in just one of the two sub-regions are mainly grassland species such as *Rumex obtusifolius*, *Daucus carota* or *Salvia pratensis*, which only occasionally occur on arable land.

However, in the Indicator Species Analysis, two arable weed species that occur in both sub-regions are detected as indicator species ($p < 0.05$; indicator values in % in brackets): *Datura stramonium* (17.2), with high percentage species cover mainly in maize and vegetable, oc-

Table 4. Indicator species of summer and winter crop fields in Kosovo. The analysis is based on a dataset comprising 473 standardised plots in arable land, classified as summer crop fields, winter crop fields and recently abandoned fields.

Summer crop fields (n = 315)				Winter crop fields (n = 117)			
	IV	LF*	LLS*		IV	LF*	LLS*
Amaranthus retroflexus	77.3	T	S	*Viola arvensis*	40.2	T	W
Echinochloa crus-galli	58.6	T	S	*Consolida regalis*	35.4	T	S
Chenopodium album	40.8	T	S	*Centaurea cyanus*	25.7	T	W
Sonchus arvensis	41.2	G, H	S				
Polygonum aviculare	40.5	T	S				
Persicaria maculosa	24.4	T	S				
Hibiscus trionum	19.4	T	S				
Datura stramonium	17.1	T	S				

Significance obtained by Monte-Carlo permutations test ($p < 0.001$); only species with indicator value > 15 are listed. IV: indicator value (%); LF: life form (T: therophyte, G: geophyte, H: hemicryptophyte); LLS = leaf life span (W: overwintering green; S: summer green);

* according to Ellenberg et al. (1992).

Table 5. Indicator species of recently abandoned arable fields in Kosovo. The analysis is based on a dataset comprising 473 standardised plots in arable land, classified as summer crop fields, winter crop fields and recently abandoned fields.

Arable weed species				Ruderal and grassland species			
	IV	LF*	LLS*		IV	LF*	LLS*
Papaver rhoeas	56.7	T	S	*Lactuca serriola*	56.1	H, T	W
Tripleurospermum perforatum	39.2	T	W	*Taraxacum sect. Ruderalia*	45.7	H	W
Avena fatua	37.4	T	V	*Conyza canadensis*	34.7	T, H	S
Anthemis austriaca	31.6	T	W	*Trifolium repens*	22.7	C, H	W
Alopecurus myosuroides	26.5	T	W	*Rumex obtusifolius*	20.7	H	W
Matricaria recutita	23.1	T	W	*Vicia cracca*	19.8	Hli	S
Bifora radians	22.7	T	S	*Filago vulgaris agg.*	18.4	T	S
Galium aparine	21.7	Tli	V	*Melilotus officinalis*	15.3	H	S
Vicia pannonica	20.2	T	S				
Anthemis arvensis	18.8	T	W				
Consolida hispanica	17.1	T	S				
Plantago intermedia	15.1	H, T	S				

Significance obtained by Monte-Carlo permutation tests ($p < 0.001$); only species with indicator value > 15 are listed. IV: indicator value (%); LF: life form (T: therophyte, G: geophyte, H: hemicryptophyte); LLS = leaf life span (W: overwintering green; S: summer green; V: spring green); * according to Ellenberg et al. (1992).

curs more frequently and with higher abundance in the western part of the country. *Convolvulus arvensis* (46.6), with high cover mainly in maize and wheat, is more common in the eastern part.

Determinants of today's species richness and composition of Kosovo's weed vegetation (Hypothesis 3)

At the plot scale, species richness (α-species richness) is fairly low today, as already published in Mehmeti et al. (2008): Only between 2 and 26 species per plot are recorded. Mean species numbers in cultivated fields range from 8 (in vegetables) to 10 (in winter wheat), and species numbers are not significantly different between crops. In recently abandoned fields, mean species richness is significantly higher (18.8 species per plot). Based on the GRM analyses considering either the whole dataset (n = 473; no significant results) or only the abandoned fields (n = 41; no significant results), the UTM coordinates, the altitude above sea level, and the belonging to a certain class of topographic position, soil base-richness and moisture do not explain the given amplitude of α species richness.

Comparison of species richness in fields with different ways of weed control (n = 40) reveals that, in both maize and wheat, the species richness of herbicide treated plots is significantly lower than of plots with mechanical weed control (maize) or without any weed control (wheat). In comparison of the investigated groups, the highest mean species number is found in wheat without any weed control, the lowest in herbicide treated maize fields (Fig. 6).

Differences in the species composition between the crop classes become apparent from the results of the Indicator Species Analysis for crop classes (n = 473). Seven summer annual species (plus one 'summer green' geo-/hemicryptophyte; terminology of leaf life span according to Ellenberg et al. 1992) are detected as indicator species of summer crop fields; three winter annual species indicate winter crop fields (Tab. 4). The plots of the recently abandoned fields are indicated by a large number of arable weed species, short-lived ruderals and grassland species (Tab. 5). No indicator species are found for the classes of topographic position, soil-base richness and soil moisture.

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The DCA analysis of the entire vegetation dataset (n = 473) clearly illustrates differences in species composition between crop classes. In Fig. 7, three groups become obvious with respect to the crop classes along the first DCA axis. The vegetation in summer crop fields (in the left part of the diagram) is highly similar among itself (low β-diversity between the plots), the vegetation of winter crop fields (in the center of the diagram) is less similar among itself, and the vegetation of the recently abandoned fields (in the right part) is highly diverse (high β-diversity, i.e. species turnover, between the plots). With respect to the second DCA axis, it is noteworthy that 13 of the 20 herbicide-treated, but only 7 of the 20 unsprayed plots are in the upper half of the diagram. None of the environmental variables taken into account shows a significant correlation with the DCA axes in the joint plot.

Focussing on the species distribution (Fig. 8) along the first DCA axis, summer green therophytes such as *Setaria viridis* and *Xanthium strumarium*, which mainly occur in summer crop fields, characterise the left part of the DCA diagram with scores of species. Winter green therophytes such as *Anagallis arvensis* and *Capsella bursa-pastoris*, which mainly occur in winter crop fields, are found in the center, and perennial plants concentrate on the right part of the DCA diagram. The distribution of the indicator species listed in Tab. 4 and 5, which are highlighted in colour in Fig. 8, is in accordance with the DCA results that clearly reflect the arrangement of summer crop, winter crop and recently abandoned fields along the first DCA axis.

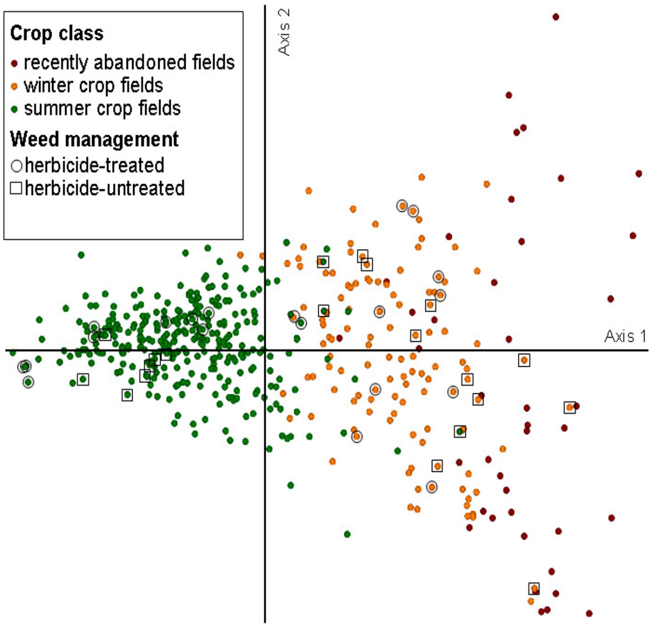

Figure 7. DCA diagram with scores of 432 cultivated and 41 recently abandoned arable plots. Given a high total inertia of 12.51 and a gradient length along the first axis of 3.98, most of the variance in the original dataset is accounted for by the first axis ($r^2 = 0.33$), while the second ($r^2 = 0.06$) and third axes ($r^2 = <0.1$) are of much lower importance. According to the DCA, vegetation of the arable land of Kosovo mainly differs between crop classes.

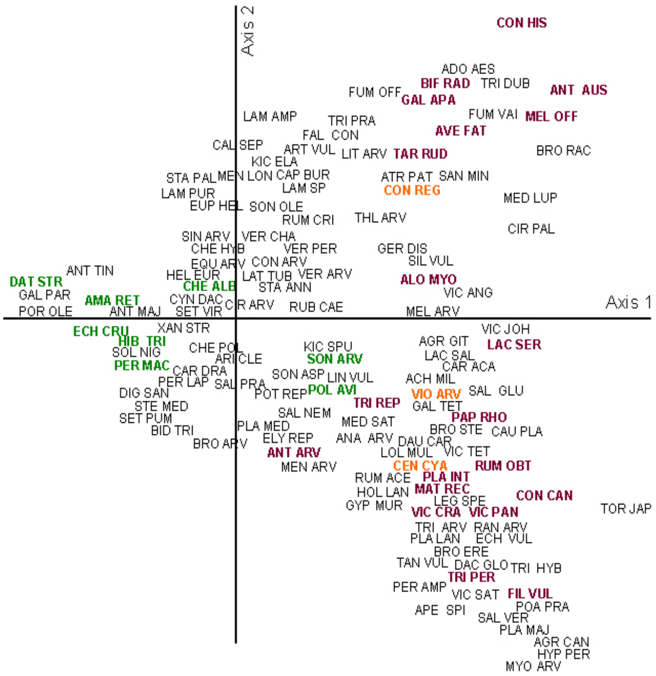

Figure 8. DCA diagram with scores of species in 432 cultivated and 41 recently abandoned arable plots. Only species occurring in more than three plots are shown. Abbreviation of species names as in appendix 1. Given a high total inertia of 12.51 and a gradient length along the first axis of 3.98, most of the variance in the original dataset is accounted for by the first axis ($r^2 = 0.33$), while the second ($r^2 = 0.06$) and third axes ($r^2 = <0.1$; not shown here) are of much lower importance. Indicator species of crop classes (cf. Table 4 and 5) are highlighted in colour (green: indicators of summer crop fields; orange: indicators of winter crop fields; brown: indicators of recently abandoned fields).

As shown in Fig. 9, relations between species composition and environmental variables become obvious in the DCA, if only the abandoned fields are taken into account. The environmental data are not related to the variance along the first axis. However, the second DCA

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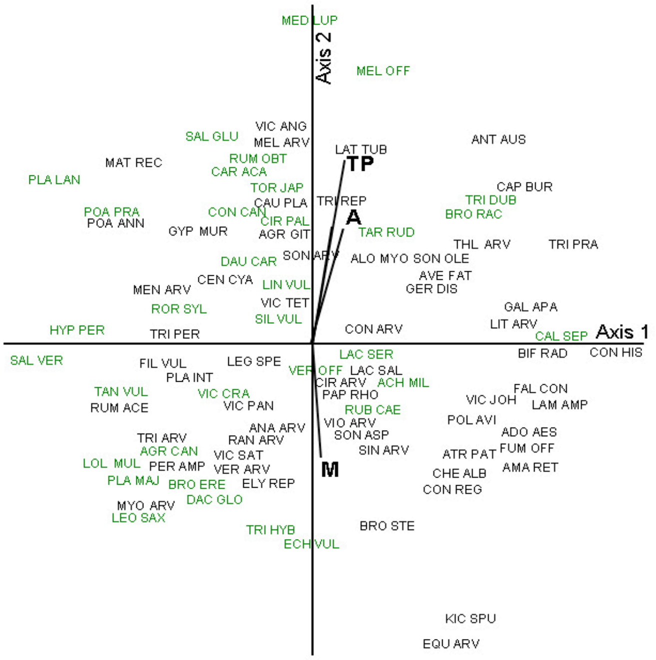

Figure 9. DCA diagram of recently abandoned arable plots (n = 41). Given a total inertia of 5.47 and a gradient length along the first axis of 3.65, most of the variance in the original dataset is accounted for by the first axis ($r^2 = 0.24$) and second axis ($r^2 = 0.15$), while the third axis ($r^2 = 0.08$; not shown here) is of much lower importance. Joint plot with scores of all species occurring in more than two plots. TP: relative topographic position; A: altitude (above sea level); M: soil moisture. Overlay vectors (cutoff r^2 value: 0.2) were rescaled to 200 % for easier visual interpretation. Non-arable perennials in green colour. Abbreviation of species names as in appendix 1.

axis displays correlations with topographic position (Pearson-r = 0.54), altitude (r = 0.44) and soil moisture (r = -0.44). Focussing on the species pattern of the DCA diagram, it becomes obvious that non-arable perennials such as *Plantago lanceolata*, *Hypericum perforatum*, *Daucus carota*, *Tanacetum vulgare* and *Bromus erectus* are more frequent in the left part of the diagram.

Discussion

Discussion of hypothesis 1 'At the regional scale, the arable weed flora has changed since about 1980.'

The arable weed flora of Kosovo, i.e. the regional species pool of the arable land, has considerably changed since about 1980: (i) Today, four highly competitive weeds, three summer annuals and one geophyte, are most frequent in the arable land of Kosovo. (ii) Several arable weed species s. str. are less frequent in comparison to the publication of Kojić & Pejčinović (1982). (iii) Eight arable weed species s. str. that contributed to the arable weed flora of Kosovo about 30 years ago are not surveyed in our study. In general, these results are in line with many publications on the arable weed flora and vegetation at the plot to the regional scale from different parts of the world (e.g., Volenik & Knezević 1984, Hilbig & Bachthaler 1992, Wilson & Aebischer 1995, Weiner et al. 2001, Lososová et al. 2004, Baessler & Klotz 2005, Gabriel et al. 2005, Pyšek et al. 2005, Waldhardt 2007, Fried et al. 2008), especially from 'productive regions', i.e. regions with highly fertile soils and suitable climate. From these studies and from monitoring and experimental studies (e.g., Lozanovski et. al 1980b, Arlt & Juttersonke 1992, Momirović et al. 1996, Susuri et al. 2001, Tuesca et al. 2001, Shrestha et al. 2002, Simić et al. 2003, Stešević & Jovović 2003, Bischoff 2004, Mehmeti 2003, 2004, Farkas 2006, Korolova et al. 2006, Mehmeti & Demaj 2006), the main reasons for both species endangerment and predominance are generally well known:

Species endangerment may be explained by e.g., herbicide sensitivity of weeds, modern seed cleaning techniques, lack of light in dense crops, short crop rotations, maize production, intensive soil tillage, decline in landscape complexity, and abandonment of cultivation. The predominance of species may be favoured by e.g., herbicide resistance, similar life cycles and habitat preferences of weeds and crops, high seed production, (moderately) persistent seed banks, rhizomes, and nitrophily. With respect to the major weeds in maize, a resistance to atrazine-related herbicides - which have been used in Kosovo and adjacent regions since decades - may be most important (e.g., Janjić et al. 2003, Pavlović et al. 2008).

Discussion of hypothesis 2 'At the regional scale, today's arable weed flora differs between two sub-regions characterised by differences in climatic conditions, agricultural production systems, and settlement history.'

Our results do not reveal pronounced differences in the arable weed flora between the western and the eastern part of Kosovo. The species pool of both sub-regions is largely identical. In that, the second hypothesis is not verified, indicating that either the differences between the distinguished sub-regions are too small, or the weed flora is highly affected by (an) other factor(s) operating in the entire region. In this context, herbicide use may be crucial, as herbicide use highly affects the arable weed vegetation at the plot scale (cf. Fig. 6 and discussion of hypothesis 3). This assumption may be supported by the ecology of the two indicator species, *Datura stramonium* and *Convolvulus arvensis*, which significantly differ in their frequencies and / or cover between the two sub-regions and are difficult to control chemically.

Datura stramonium, an invasive weed species, which most probably originates from Mexico but has been found in Europe since about 1600 (Wein 1954), is obviously more typical of the western part of Kosovo where it reaches high abundances in maize and vegetables. Since several decades, *Datura stramonium* has led to severe crop losses in Kosovo and adjacent areas of the Balkan Peninsula, especially in maize (Kojić & Ajder 1989, Oljaća et al. 2007). According to the European Weed Research Society (EWRS 2008), *Datura stramonium* has become frequent on arable land not just on the Balkan Peninsula but also in other parts of southern Europe and, due to its toxicity and as a highly competitive weed, causes increasing problems for agriculture (e.g., in Hungary in vegetable production). Some main reasons for its spread in summer crop fields and vegetables are obvious: Similar to the predominant summer annual species mentioned above, its seeds mainly germinate in late spring (high germination rates between 20-30 °C; cf. Lauer 1953), its seed bank is persistent (Benvenuti 1995), and herbicide resistances are known (e.g., Williams et al. 1995, Stanković et al. 1996). *Datura stramonium* may produce seeds until late autumn, if temperatures are above freezing and adequate water is present (Heeger 1956). This might explain the 'higher importance' of *Datura stramonium* in the western part of Kosovo, where the frost free period is longer and the annual rainfall is higher than in the eastern part.

Convolvulus arvensis, the indicator species for the eastern sub-region, is less frequent and reaches lower abundances in vegetable than in maize. All over Europe, Convolvulus arvensis is a problematic weed in maize and other crops, as this geophyte is generally difficult to control chemically (e.g., Pfirter et al. 1997, Rusu et al. 2007) and may reach high abundances especially in no-tillage and reduced tillage systems (Jurado-Expósito et al. 2005). Thus, the 'lower importance' of *Convolvulus arvensis* in the western sub-region might indicate a comparatively high tillage intensity and / or intensive mechanical weed control in vegetable production.

Apart from these two species, the second hypothesis is not verified, indicating that either (i) the differences between the distinguished sub-regions are too small, or (ii) the weed flora is highly affected by (an) other factor(s) operating in the entire region. In this context, herbicide use may be crucial, as herbicide use highly affects α-species richness at the plot scale (cf. Fig. 6 and discussion of hypothesis 3) and both indicator species are difficult to control chemically.

Discussion of hypothesis 3 'At the plot scale, today's arable weed vegetation is related to environmental features and agricultural management measures.'

At the plot scale, α-species richness does not differ between crop classes or classes of topographic position, soil base-richness and soil moisture. However, with respect to agricultural management practices, species richness differs between different ways of weed management (cf. Fig. 6). This indicates that weed control, and especially herbicide application, might be the most important limiting factor of α-species richness in the arable land of Kosovo today.

With respect to species composition at the plot scale, both the Indicator Species Analyses (Tab. 4 and 5) and the DCA analyses (Fig. 7 and 8) highlight clear differences between the distinguished crop classes. This is in accordance with results of other studies from Central Europe and the Balkan Peninsula (e.g., Kojić & Pejčinović 1982, Šinžar et al. 1996, Pysek et al. 2005). Focussing on environmental features, the vegetation composition of recently abandoned arable land differs in relation to several physical site characteristics (relative topographic position, altitude above sea level, soil-moisture; cf. Fig. 9). All these results are in accordance with our third hypothesis.

Given the pattern of herbicide-treated and unsprayed plots along the second DCA axis of the cultivated fields (Fig. 7), vegetation differentiation might also reflect herbicide effects. Moreover, given the pattern of non-arable perennial species along the first axis in the DCA of the recently abandoned fields (Fig. 9), vegetation differentiation might also be related to the past land use (cf. Waldhardt 1994) and / or the quality of the surrounding habitats (Gabriel et al. 2005): More non-arable perennials should be expected to occur in fields, if the period of abandonment was longer, past land use was less intensive with respect to e.g., herbicide use, plots were temporarily abandoned before this study and / or habitat diversity in the surrounding was high. However, the discussion of these potential determinants of vegetation differentiation has to remain speculative for three reasons. Information on herbicide use was not available for most of the studied cultivated fields. Detailed information on the date of abandonment of the studied abandoned fields was not available. The surroundings of the investigated fields were not surveyed.

In our study, vegetation differentiation along environmental gradients is low. This may be partly explained by the structure of our datasets (cf. Tab. 3): As large areas of the arable land of Kosovo are situated in two plains and we randomly selected the investigated plots, most of the plots are located on highly fertile soils in these plains. Thus, environmental gradients may be comparatively low in our study. Moreover, as in many other parts of the world (cf. publications listed in the discussion of hypothesis 1), agricultural management measures such as irrigation, fertilisation and herbicide use may have resulted in a vast homogenisation of site conditions and the predominance of only a few highly competitive arable weeds. As a consequence, in large parts of today's arable land in Kosovo and elsewhere the development and occurrence of weed species is so strongly hindered that formerly known relations between environmental site conditions and flora / vegetation patterns do not exist anymore or have become superimposed.

Summarising discussion

From our study, it is most obvious that today's flora and vegetation of the cultivated arable land in Kosovo is negatively affected by (i) weed control (especially herbicide use) that reduces α species richness and most probably favours herbicide-resistant species and (ii) maize production that is highly unsuitable for those species, which concentrate on winter crop fields. Moreover, as in other parts of Europe, (iii) the abandonment of cultivation, especially on shallow calcareous soils, might endanger several weed species in Kosovo that belong to the phytosociological alliance Caucalidion platycarpi Tx. 1950 (e.g., *Adonis aestivalis*, *Caucalis platycarpos*, *Legousia speculum-veneris*). However, for several reasons, a detailed evaluation of the drivers of changes is difficult: (i) In our study, the comparison of the past and today's arable weed flora of Kosovo has to remain vague, mainly due to the differences in data sampling between the past and today. (ii) Detailed information on land management at the plot scale, and (iii) appropriate data on landscape structure and dynamics at the landscape scale are not easily available. (iv) Given the facts that not only current, but also the legacy of past land use are relevant for today's vegetation in agricultural landscapes, and that land-use practices have significantly changed in Kosovo in the recent past, the understanding of changes in the weed flora becomes even more difficult.

Although in Kosovo the agricultural management practices have significantly changed in the last 20 years, today's production systems are obviously unsuitable for the establishment of a rich arable weed flora and vegetation on most cultivated fields. At the same time, a high species richness at the regional scale and, moreover, a comparatively high α-species richness and a much more differentiated vegetation of recently abandoned fields indicate potentials for future development. These would probably become even more apparent if the vegetation at field margins was also taken into account (cf. Waldhardt 1994). In this context, we suggest comparative studies in field centres and margins, especially on frequencies and population sizes of the most rare weed species. Moreover, we suggest soil seed bank analyses, and population biological studies on selected rare species to quantify the development potential and the endangerment of the arable flora and vegetation that should be considered in future production systems and nature protection measures.

Conclusions

With this study, we contribute to the ongoing floristic mapping of Kosovo, which largely has neglected the arable land since about 30 years. Based on random sampling covering the entire agricultural land of Kosovo, we provide information on species occurrence, frequency and cover. At the same time, our data may serve as a reference for future studies on land-use (change) and its effects on the arable weed flora and vegetation in Kosovo. Moreover, we provide quantitative information on the relationships between the vegetation of the arable land and both environmental features and agricultural management measures.

Wheat and maize production predominate the arable land of Kosovo, resulting in a low α-species richness in large areas of the region. In that, today's arable land use may not be considered as ecologically sustainable. However, potentials for future development have become obvious from our study, especially with respect to the regional species richness and comparatively high α species richness and β-species richness of recently abandoned fields. To facilitate the arable land flora and vegetation of Kosovo, measures such as the implementation of wider crop rotations and less intensive weed control would be most welcome. However, such measures need to be integrated in production systems that, at the same time, are sustainable with respect to landscape functions other than providing space for biodiversity. Against the background of the economic situation of Kosovo, this holds especially true for the production function. We thus conclude that, multi-, inter- and transdisciplinary research activities on sustainable arable land use in Kosovo need to be strengthened. At the same time, further political and socioeconomic stabilisation in Kosovo will be a prerequisite for sustainable land development and hopefully this will be achieved in the near future.

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Appendix 1

Species recorded in this study and in former studies on the flora and vegetation of the arable land in Kosovo.
C: cultivated fields; A: recently abandoned fields; K: species on arable land documented in vegetation relevés by Kojić & Pejčinović (1982); KBLK: species contributing to the regional flora according to Kojić et al. (1975), Banjska (1977), Lozanovski et al. (1980a) and Kojić (1986); W: winter crop fields; S: summer crop fields; rf: relative frequency; rc: relative overall cover; oc: species occurrence; AW: arable weed species s. str. in accordance with Hüppe & Hofmeister (1990) or, indicated by *, to own expertise on Kosovo's arable weed flora; ABBR: abbreviation of species names as in Fig. 8 and 9. Nomenclature in accordance with Wisskirchen & Haeupler (1998) or, indicated by **, Tutin et al. (1964-1993).

Species recorded …	**… in this study**									**… in former studies**		**AW**	**ABBR**
Year of investigation (C; A) or publication (K; KBLK)	**C** 2006						**A** 2007		**C + A** 2006 + 2007	**K** 1982	**KBLK** 1975 to 1986		
	W		**S**		**W + S**								
number of investigated plots	*117*		*315*		*432*		*41*		*473*	*33*			
number of species	*140*		*160*		*204*		*139*		*235*	*106*	*236*		
	rf (%)	rc (%)	rf (%)	rc (%)	rf (%)	rc (%)	rf (%)	rc (%)	rf (%)	oc	oc		
Acer negundo	0.9	<0.1			0.2	<0.1			0.2				ACE NEG
Adonis vernalis	0.9	<0.1			0.2	<0.1			0.2		+		ADO VER
Aethusa cynapium			0.3	<0.1	0.2	<0.1			0.2		+	+	AET CYN
Agrostis capillaris	1.7	0.7			0.5	0.2			0.5		+		AGR CAP
Agrostis sp.			0.3	<0.1	0.2	<0.1			0.2				AGR SP.
Alchemilla vulgaris agg.			0.3	<0.1	0.2	<0.1			0.2		+		ALC VUL
Amaranthus blitoides			0.6	0.1	0.5	0.1			0.5		+	+*	AMA BLI
Anagallis foemina	0.9	<0.1			0.2	<0.1			0.2		+	+	ANA FOE
Anthemis arvensis	6.0	1.4	5.7	0.6	5.8	0.9			5.3	+	+	+	ANT ARV
Anthemis tinctoria			1.0	<0.1	0.7	<0.1			0.6		+		ANT TIN

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Antirrhinum majus			1.6	<0.1	1.2	<0.1			1.1				ANT MAJ
Apera spica-venti	7.7	1.5	0.3	<0.1	2.3	0.5			2.1		+	+	APE SPI
Arrhenatherum elatius	0.9	1.0			0.2	0.3			0.2		+		ARR ELA
Artemisia vulgaris	3.4	0.1	0.3	<0.1	1.2	0.1			1.1		+		ART VUL
*Avena ludoviciana***			0.3	<0.1	0.2	<0.1			0.2		+	+*	AVE LUD
Ballota nigra			0.3	<0.1	0.2	<0.1			0.2		+		BAL NIG
Bidens tripartita			2.2	<0.1	1.6	<0.1			1.5		+		BID TRI
Bromus arvensis			1.0	<0.1	0.7	<0.1			0.6		+		BRO ARV
Bromus sp.	0.9	<0.1			0.2	<0.1			0.2	+			BRO SP.
Campanula persicifolia			0.3	<0.1	0.2	<0.1			0.2				CAM PER
Campanula sp.	0.9	<0.1	0.3	<0.1	0.5	<0.1			0.5				CAM SP.
Cardaria draba			1.3	<0.1	0.9	<0.1			0.8	+	+		CAR DRA
Centaurea calcitrapa			0.6	<0.1	0.5	<0.1			0.5		+		CEN CAL
Centaurea sp.	0.9	<0.1	0.3	<0.1	0.5	<0.1			0.5				CEN SP.
Chaenorhinum minus			0.3	<0.1	0.2	<0.1			0.2		+		CHA MIN
Chenopodium hybridum	2.6	0.2	5.4	0.2	4.6	0.2			4.2		+		CHE HYB
Chenopodium polyspermum	5.1	0.3	8.3	0.5	7.4	0.4			6.8		+	+	CHE POL
Cichorium intybus	0.9	0.2	0.3	<0.1	0.5	0.1			0.5	+	+		CIC INT
Datura stramonium			16.8	1.3	12.3	0.9			11.2	+	+	+*	DAT STR
Daucus sp.	0.9	<0.1			0.2	<0.1			0.2				DAU SP.
Digitaria sanguinalis	0.9	<0.1	7.9	0.3	6.0	0.3			5.5		+	+*	DIG SAN
Echinochloa crus-galli	1.7	<0.1	58.4	9.5	43.1	6.6			39.4	+	+	+*	ECH CRU
Epilobium parviflorum			0.3	<0.1	0.2	<0.1			0.2		+		EPI PAR
Epilobium tetragonum	0.9	<0.1			0.2	<0.1			0.2		+		EPI TET
Equisetum palustre			0.3	0.2	0.2	0.1			0.2		+		EQU PAL
Eragrostis pilosa			0.3	<0.1	0.2	<0.1			0.2		+		ERA PIL
Erigeron annuus	1.7	0.2			0.5	0.1			0.5		+		ERI ANN
Erucastrum gallicum			0.3	<0.1	0.2	<0.1			0.2				ERU GAL

Eryngium campestre	0.9	<0.1	0.3	<0.1	0.5	<0.1		0.5	+	+		ERY CAM
Euphorbia cyparissias	0.9	<0.1			0.2	<0.1		0.2	+	+		EUP CYP
Euphorbia esula	0.9	<0.1	0.3	<0.1	0.5	<0.1		0.5		+		EUP ESU
Euphorbia falcata	1.7	<0.1			0.5	<0.1		0.5		+	+	EUP FAL
Euphorbia helioscopia	3.4	0.1	4.8	0.1	4.4	0.1		4.0	+	+	+	EUP HEL
Falcaria vulgaris			0.6	<0.1	0.5	<0.1		0.5		+		FAL VUL
*Filago montana***	1.7	<0.1			0.5	<0.1		0.5		+		FIL MON
Galeopsis ladanum	0.9	<0.1			0.2	<0.1		0.2		+		GAL LAD
Glechoma hederacea			0.3	<0.1	0.2	<0.1		0.2		+		GLE HED
Gnaphalium uliginosum	0.9	<0.1			0.2	<0.1		0.2		+		GNA ULI
Gypsophila repens			0.3	<0.1	0.2	<0.1		0.2		+		GYP REP
Heliotropium europaeum	0.9	<0.1	3.8	0.4	3.0	0.3		2.7	+	+	+*	HEL EUR
*Hibiscus trionum***			19.0	1.9	13.9	1.3		12.7	+	+	+*	HIB TRI
Hieracium pilosella	0.9	<0.1			0.2	<0.1		0.2	+	+		HIE PIL
Hippocrepis emerus			0.3	<0.1	0.2	<0.1		0.2				HIP EME
Holcus lanatus	2.6	0.5	0.6	<0.1	1.2	0.2		1.1		+		HOL LAN
Kickxia elatine	1.7	0.1	1.0	<0.1	1.2	<0.1		1.1		+	+	KIC ELA
Lactuca quercina			0.6	<0.1	0.5	<0.1		0.5		+		LAC QUE
Lamium sp.	0.9	<0.1	0.6	<0.1	0.7	<0.1		0.6				LAM SP.
Lithospermum purpurocaeruleum	0.9	<0.1	0.3	<0.1	0.5	<0.1		0.5		+		LIT PUR
Lycopus europaeus			0.3	<0.1	0.2	<0.1		0.2		+		LYC EUR
Lythrum salicaria			0.6	<0.1	0.5	<0.1		0.5	+	+		LYT SAL
Malva sylvestris			0.3	<0.1	0.2	<0.1		0.2	+	+		MAL SYL
Medicago falcata			0.3	<0.1	0.2	<0.1		0.2		+		MED FAL
Medicago minima	0.9	<0.1			0.2	<0.1		0.2		+		MED MIN
*Medicago orbicularis***			0.3	<0.1	0.2	<0.1		0.2		+		MED ORB
Medicago x varia	1.7	<0.1			0.5	<0.1		0.5				MED VAR
Mentha longifolia	1.7	0.1	1.0	0.4	1.2	0.3		1.1		+		MEN LON

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Nigella arvensis	1.7	<0.1			0.5	<0.1		0.5		+	+	NIG ARV
Papaver dubium			0.6	<0.1	0.5	<0.1		0.5		+	+	PAP DUB
Phragmites australis	0.9	<0.1			0.2	<0.1		0.2		+		PHR AUS
Picris hieracioides agg.	1.7	<0.1			0.5	<0.1		0.5		+		PIC HIE
Portulaca oleracea			7.0	0.3	5.1	0.2		4.7	+	+	+*	POR OLE
Potentilla reptans	0.9	<0.1	1.0	<0.1	0.9	<0.1		0.8	+	+		POT REP
Ranunculus repens			0.3	<0.1	0.2	<0.1		0.2	+	+		RAN REP
Rhinanthus minor	0.9	0.3			0.2	0.1		0.2		+		RHI MIN
Salvia nemorosa	0.9	<0.1	1.0	<0.1	0.9	<0.1		0.8		+		SAL NEM
Salvia pratensis	1.7	0.1	1.9	0.4	1.9	0.3		1.7		+		SAL PRA
Sanguisorba minor	2.6	0.1			0.7	<0.1		0.6		+		SAN MIN
Setaria pumila			2.5	0.9	1.9	0.7		1.7	+	+	+*	SET PUM
Setaria sp.			0.3	<0.1	0.2	<0.1		0.2				SET SP.
Setaria viridis	1.7	0.1	9.5	0.9	7.4	0.7		6.8	+	+	+*	SET VIR
Sherardia arvensis	0.9	<0.1			0.2	<0.1		0.2	+	+	+	SHE ARV
Silene noctiflora	0.9	<0.1			0.2	<0.1		0.2		+	+	SIL NOC
Solanum nigrum			14.0	0.7	10.2	0.5		9.3	+	+	+*	SOL NIG
Sonchus sp.			0.6	<0.1	0.5	<0.1		0.5				SON SP.
Sorghum halepense			0.6	<0.1	0.5	<0.1		0.5	+	+	+*	SOR HAL
Stachys palustris	5.1	0.6	4.8	0.2	4.9	0.3		4.5		+		STA PAL
Stellaria media agg.			2.9	0.1	2.1	0.1		1.9		+	+	STE MED
Symphytum officinale			0.3	<0.1	0.2	<0.1		0.2		+		SYM OFF
Symphytum sp.			0.3	<0.1	0.2	<0.1		0.2				SYM SP.
Tanacetum corymbosum			0.3	<0.1	0.2	<0.1		0.2		+		TAN COR
Tragopogon pratensis			0.3	<0.1	0.2	<0.1		0.2		+		TRA PRA
Trifolium montanum			0.3	<0.1	0.2	<0.1		0.2		+		TRI MON
Veronica chamaedrys	0.9	<0.1	1.0	<0.1	0.9	<0.1		0.8		+		VER CHA
Veronica hederifolia agg.			0.3	<0.1	0.2	<0.1		0.2	+	+	+	VER HED

Veronica officinalis			0.3	<0.1	0.2	<0.1			0.2		+		VER OFF
Xanthium strumarium	7.7	0.5	11.7	1.0	10.6	0.8			9.7	+	+	+*	XAN STR
Achillea millefolium agg.	3.4	0.1	0.6	<0.1	1.4	0.1	7.3	0.1	1.9	+	+		ACH MIL
Adonis aestivalis	0.9	<0.1			0.2	<0.1	12.2	0.1	1.2		+	+	ADO AES
Agrostemma githago	7.7	0.4	0.3	<0.1	2.3	0.2	17.1	0.3	3.6	+	+	+	AGR GIT
Alopecurus myosuroides	8.5	4.8	4.8	0.3	5.8	1.7	39.0	2.8	8.7		+	+	ALO MYO
Amaranthus retroflexus			80.3	18.8	58.6	13.0	7.3	0.2	54.2	+	+	+*	AMA RET
Ambrosia artemisiifolia			0.3	<0.1	0.2	<0.1	2.4	<0.1	0.4		+		AMB ART
Anagallis arvensis	19.7	1.2	6.7	0.2	10.2	0.5	29.3	2.2	11.9	+	+	+	ANA ARV
Anthemis austriaca			0.3	<0.1	0.2	<0.1	31.7	7.0	2.9		+	+*	ANT AUS
Aristolochia clematitis			3.8	0.4	3.0	0.3	2.4	<0.1	2.9	+	+	+*	ARI CLE
Atriplex patula	16.2	1.3	1.6	0.1	5.6	0.5	17.1	0.2	6.6		+	+	ATR PAT
Avena fatua	9.4	0.6	1.3	<0.1	3.5	0.3	46.3	0.7	7.2	+	+	+	AVE FAT
Bifora radians	8.5	1.1	1.0	<0.1	3.0	0.4	26.8	3.8	5.1	+	+	+	BIF RAD
Bromus erectus	0.9	<0.1			0.2	<0.1	4.9	0.3	0.6		+		BRO ERE
Bromus sterilis	0.9	<0.1			0.2	<0.1	4.9	0.2	0.6		+	+*	BRO STE
Bupleurum rotundifolium	0.9	<0.1			0.2	<0.1	2.4	<0.1	0.4		+	+	BUP ROT
Calystegia sepium	2.6	0.3	3.8	0.2	3.5	0.3	4.9	<0.1	3.6		+		CAL SEP
Capsella bursa-pastoris	0.9	<0.1	6.7	0.2	5.1	0.1	4.9	0.4	5.1	+	+	+	CAP BUR
Carduus acanthoides	2.6	0.1	0.3	<0.1	0.9	<0.1	9.8	0.1	1.7	+	+		CAR ACA
Caucalis platycarpos	3.4	0.1			0.9	<0.1	12.2	0.1	1.9	+	+	+	CAU PLA
Centaurea cyanus	22.2	5.0	9.8	0.3	13.2	1.8	43.9	2.8	15.9	+	+	+	CEN CYA
Centaurea scabiosa			0.3	<0.1	0.2	<0.1	2.4	0.1	0.4		+		CEN SCA
Chenopodium album	53.0	6.8	79.7	15.6	72.5	12.9	39.0	1.5	69.6	+	+	+	CHE ALB
Cirsium arvense	69.2	10.7	74.0	13.3	72.7	12.9	68.3	3.6	72.3	+	+	+*	CIR ARV
Cirsium palustre	0.9	<0.1	0.3	<0.1	0.5	<0.1	12.2	0.4	1.5		+		CIR PAL
Consolida regalis	76.1	11.5	3.5	0.2	23.1	4.1	51.2	8.3	25.5	+	+	+	CON REG
Convolvulus arvensis	68.4	6.5	74.9	6.0	73.1	6.5	85.4	2.0	74.2	+	+	+*	CON ARV

Conyza canadensis	8.5	0.3	1.3	<0.1	3.2	0.2	39.0	2.4	6.3	+	+		CON CAN
Cynodon dactylon	2.6	0.3	4.8	0.9	4.2	0.7	2.4	0.1	4.0	+	+	+*	CYN DAC
Dactylis glomerata	0.9	0.2			0.2	0.1	4.9	0.3	0.6		+		DAC GLO
Daucus carota	9.4	0.4	1.0	<0.1	3.2	0.1	22.0	0.2	4.8	+	+		DAU CAR
Echium vulgare			0.3	<0.1	0.2	<0.1	4.9	0.3	0.6		+		ECH VUL
Elymus repens	9.4	1.9	33.3	4.7	26.9	3.9	31.7	5.6	27.3	+	+	+*	ELY REP
Equisetum arvense	5.1	0.5	14.6	1.6	12.0	1.3	7.3	1.1	11.6	+	+	+*	EQU ARV
Fallopia convolvulus	41.9	3.3	16.8	0.7	23.6	1.8	34.1	1.1	24.5	+	+	+	FAL CON
Filago vulgaris agg.	1.7	<0.1			0.5	<0.1	19.5	0.3	2.1				FIL VUL
Fumaria officinalis	0.9	<0.1	1.3	<0.1	1.2	<0.1	9.8	0.4	1.9		+	+	FUM OFF
Galeopsis pubescens	0.9	<0.1			0.2	<0.1	2.4	<0.1	0.4		+		GAL PUB
Galeopsis tetrahit	8.5	1.4	0.3	<0.1	2.5	0.5	2.4	<0.1	2.5		+		GAL TET
Galinsoga parviflora	1.7	0.1	13.7	1.6	10.4	1.1	2.4	<0.1	9.7	+	+	+*	GAL PAR
Galium aparine	18.8	2.0	2.2	0.1	6.7	0.8	34.1	1.7	9.1	+	+	+*	GAL APA
Galium sylvaticum			0.3	<0.1	0.2	<0.1	2.4	0.1	0.4		+		GAL SYL
Geranium dissectum			1.0	<0.1	0.7	<0.1	9.8	0.1	1.5	+	+	+	GER DIS
Geranium molle			0.3	<0.1	0.2	<0.1	2.4	<0.1	0.4		+		GER MOL
Gypsophila muralis	2.6	0.6	1.6	<0.1	1.9	0.2	4.9	0.1	2.2		+		GYP MUR
Kickxia spuria	17.1	0.7	5.4	<0.1	8.6	0.4	7.3	0.1	8.5	+	+	+	KIC SPU
Lactuca serriola			0.6	<0.1	0.5	<0.1	56.1	0.8	5.3	+	+		LAC SER
Lamium amplexicaule	1.7	0.1	5.7	0.2	4.6	0.1	9.8	0.2	5.1	+	+	+	LAM AMP
Lamium purpureum	0.9	<0.1	4.4	0.1	3.5	0.1	2.4	0.1	3.4	+	+	+	LAM PUR
*Lathyrus sativus***	0.9	<0.1			0.2	<0.1	2.4	0.1	0.4		+	+*	LAT SAT
Lathyrus tuberosus	6.8	0.4	11.7	0.6	10.4	0.5	7.3	0.1	10.1	+	+	+	LAT TUB
Legousia speculum-veneris	5.1	0.1			1.4	<0.1	4.9	<0.1	1.7		+	+	LEG SPE
Linaria vulgaris	12.0	0.4	5.4	0.2	7.2	0.3	17.1	0.3	8.1	+	+		LIN VUL
Lithospermum arvense	1.7	<0.1	1.6	<0.1	1.6	<0.1	4.9	0.1	1.9	+	+	+	LIT ARV
Lolium multiflorum	1.7	0.2	0.6	0.2	0.9	0.2	7.3	0.1	1.5	+	+	+*	LOL MUL

Lolium perenne			0.3	<0.1	0.2	<0.1	2.4	0.1	0.4		+		LOL PER
Lysimachia vulgaris	0.9	<0.1			0.2	<0.1	2.4	0.1	0.4		+		LYS VUL
Matricaria recutita	19.7	0.9	4.1	0.1	8.3	0.5	31.7	2.3	10.3		+	+	MAT REC
Medicago lupulina	0.9	<0.1	0.6	<0.1	0.7	<0.1	4.9	0.7	1.1	+	+		MED LUP
Medicago sativa	0.9	<0.1	0.6	<0.1	0.7	<0.1	2.4	0.1	0.8		+		MED SAT
Melampyrum arvense	6.0	0.2	1.3	<0.1	2.5	0.1	9.8	0.2	3.1	+	+	+	MEL ARV
Melilotus officinalis	2.6	0.2	0.3	<0.1	0.9	0.1	17.1	1.1	2.3		+		MEL OFF
Mentha arvensis	7.7	0.5	8.9	0.8	8.6	0.7	22.0	0.7	9.8	+	+	+*	MEN ARV
Myosotis arvensis	0.9	<0.1			0.2	<0.1	12.2	1.3	1.2		+	+	MYO ARV
Papaver rhoeas	17.9	0.5	0.6	<0.1	5.3	0.3	63.4	4.5	10.3	+	+	+	PAP RHO
Persicaria amphibium	0.9	<0.1	0.3	<0.1	0.5	<0.1	7.3	0.1	1.1		+		PER AMP
Persicaria lapathifolia	4.3	0.1	5.4	0.6	5.1	0.5	2.4	<0.1	4.9	+	+	+	PER LAP
Persicaria maculosa	6.0	0.5	30.8	1.9	24.1	1.5	2.4	<0.1	22.2		+	+	PER MAC
Phleum pratense			0.3	<0.1	0.2	<0.1	2.4	<0.1	0.4		+		PHL PRA
Plantago lanceolata	8.5	0.3	1.9	<0.1	3.7	0.2	12.2	0.5	4.4	+	+		PLA LAN
Plantago major intermedia	7.7	0.6	1.6	0.1	3.2	0.3	22.0	0.5	4.8				PLA INT
Plantago major major	0.9	<0.1			0.2	<0.1	9.8	0.3	1.0		+		PLA MAJ
Plantago media	8.5	0.2	9.5	0.2	9.3	0.2	2.4	<0.1	8.7	+	+		PLA MED
Poa annua			0.3	<0.1	0.2	<0.1	4.9	0.1	0.6		+		POA ANN
Poa pratensis	0.9	<0.1			0.2	<0.1	12.2	0.2	1.2	+	+		POA PRA
Polygonum aviculare agg.	65.8	13.7	30.2	1.9	39.8	5.9	24.4	1.8	38.5	+	+		POL AVI
Ranunuclus arvensis			0.3	<0.1	0.2	<0.1	12.2	0.1	1.2	+	+	+	RAN ARV
Rubus caesius	13.7	0.9	9.8	0.3	10.9	0.6	12.2	0.2	11.0	+	+		RUB CAE
Rumex acetosella	5.1	0.1	1.0	<0.1	2.1	0.1	4.9	0.1	2.3		+		RUM ACE
Rumex crispus	2.6	<0.1	0.6	<0.1	1.2	<0.1	2.4	<0.1	1.3	+	+		RUM CRI
Rumex obtusifolius	0.9	<0.1	1.0	<0.1	0.9	<0.1	22.0	0.2	2.7		+		RUM OBT
Salvia glutinosa	0.9	<0.1			0.2	<0.1	7.3	0.1	0.8				SAL GLU
Salvia verticillata	0.9	<0.1			0.2	<0.1	7.3	0.8	0.8		+		SAL VER

Securigera varia			0.3	<0.1	0.2	<0.1	2.4	0.1	0.4		+		SEC VAR
Silene vulgaris	2.6	0.1	0.3	<0.1	0.9	<0.1	4.9	0.1	1.2		+		SIL VUL
Sinapis arvensis	1.7	<0.1	15.9	2.0	12.0	1.4	9.8	1.0	11.8		+	+	SIN ARV
*Smyrnium perfoliatum***			0.3	<0.1	0.2	<0.1	2.4	<0.1	0.4			+*	SMY PER
Sonchus arvensis	6.0	0.5	12.1	1.2	10.4	1.0	56.1	1.2	14.4	+	+	+	SON ARV
Sonchus asper	10.3	0.2	8.9	1.0	9.3	0.8	14.6	0.2	9.8		+	+	SON ASP
Sonchus oleraceus	18.8	0.5	20.3	1.0	19.9	0.9	22.0	0.6	20.1	+	+	+	SON OLE
Stachys annua			1.9	<0.1	1.4	<0.1	2.4	<0.1	1.5		+	+	STA ANN
Tanacetum vulgare	1.7	0.1	0.3	<0.1	0.7	<0.1	4.9	0.1	1.1		+		TAN VUL
Taraxacum sect. Ruderalia	3.4	0.1	6.0	0.1	5.3	0.1	51.2	0.8	9.3	+	+		TAR RUD
Thlaspi arvense	5.1	0.5	0.6	<0.1	1.9	0.1	4.9	<0.1	2.2	+	+	+	THL ARV
Trifolium arvense	6.0	0.1	0.3	<0.1	1.9	<0.1	9.8	0.4	2.6	+	+		TRI ARV
Trifolium dubium	1.7	0.1	0.3	<0.1	0.7	<0.1	12.2	0.1	1.7		+		TRI DUB
*Trifolium incarnatum***	0.9	<0.1			0.2	<0.1	2.4	<0.1	0.4		+	+*	TRI INC
Trifolium pratense	10.3	0.3	2.9	0.1	4.9	0.2	7.3	0.1	5.1		+		TRI PRA
Trifolium repens	3.4	0.1	4.1	0.1	3.9	0.1	26.8	0.7	5.9	+	+		TRI REP
Tripleurospermum perforatum	12.0	3.0	4.8	0.3	6.7	1.0	46.3	10.4	10.1		+	+	TRI PER
Veronica arvensis	1.7	0.1	1.3	0.3	1.4	0.2	4.9	<0.1	1.7		+	+	VER ARV
Veronica persica	6.8	0.5	3.5	0.1	4.4	0.2	2.4	0.1	4.2	+	+	+	VER PER
Vicia angustifolia	1.7	0.1			0.5	<0.1	4.9	0.1	0.9		+	+	VIC ANG
Vicia cracca	3.4	0.1	2.9	0.1	3.0	0.1	22.0	1.9	4.6	+	+		VIC CRA
Vicia johannis	0.9	<0.1			0.2	<0.1	4.9	<0.1	0.6		+	+*	VIC JOH
Vicia pannonica	2.6	0.1			0.7	<0.1	22.0	1.2	2.5	+	+	+	VIC PAN
Vicia sativa agg.	2.6	0.2	0.3	<0.1	0.9	0.1	7.3	0.1	1.5	+	+	+	VIC SAT
Vicia tetrasperma			0.3	<0.1	0.2	<0.1	12.2	0.2	1.2		+	+	VIC TET
Viola arvensis	29.1	1.9	4.8	0.2	11.3	0.8	56.1	3.1	15.2		+	+	VIO ARV
Agrostis canina							14.6	0.6	1.3		+		AGR CAN
Althaea hirsuta							2.4	<0.1	0.2		+		ALT HIR

Althaea officinalis				2.4	<0.1	0.2		+		ALT OFF
Bromus racemosus				9.8	1.8	0.8		+		BRO RAC
Campanula rotundifolia				2.4	0.1	0.2				CAM ROT
Chenopodium ficifolium				2.4	<0.1	0.2		+	+*	CHE FIC
Conium maculatum				2.4	<0.1	0.2		+		CON MAC
Conringia orientalis				2.4	0.4	0.2		+	+	CON ORI
Consolida hispanica				17.1	3.6	1.5		+	+*	CON HIS
Cruciata laevipes				2.4	<0.1	0.2		+		CRU LAE
Erodium cicutarium				2.4	<0.1	0.2		+	+	ERO CIC
Festuca pratensis				2.4	0.4	0.2		+		FES PRA
Festuca rubra agg.				2.4	<0.1	0.2				FES RUB
Fumaria vaillantii				2.4	0.1	0.2		+	+*	FUM VAI
Galium album				2.4	<0.1	0.2	+	+		GAL ALB
Geranium pusillum				2.4	<0.1	0.2		+		GER PUS
*Haynaldia villosa***				2.4	0.1	0.2			+*	HAY VIL
Hypericum perforatum				7.3	0.8	0.6		+		HYP PER
Hypochaeris radicata				2.4	0.3	0.2		+		HYP RAD
Lactuca saligna				7.3	0.1	0.6	+	+		LAC SAL
Leontodon saxatilis				4.9	<0.1	0.4				LEO SAX
Mentha × piperita agg.				2.4	0.1	0.2				MEN PIP
Rorippa sylvestris				4.9	0.1	0.4		+		ROR SYL
Scutellaria hastifolia				2.4	<0.1	0.2		+		SCU HAS
Senecio vernalis				2.4	<0.1	0.2		+		SEN VER
Torilis japonica				7.3	0.1	0.6		+		TOR JAP
Trifolium alpestre				2.4	<0.1	0.2		+		TRI ALP
Trifolium hybridum				7.3	0.1	0.6		+		TRI HYB
Verbascum phlomoides				2.4	0.1	0.2		+		VER PHL
Verbena officinalis				4.9	<0.1	0.4	+	+		VER OFF

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Vicia villosa				2.4 0.1	0.2		+	+	VIC VIL
Amaranthus albus						+	+	+*	
Arctium lappa						+	+		
Centaurea jacea						+	+		
Centaurium erythraea						+	+		
Chondrilla juncea						+	+		
Holcus mollis						+	+		
Lathyrus aphaca						+	+	+	
Lathyrus nissolia						+	+	+	
Lotus corniculatus						+	+		
Minuartia verna						+	+		
Nasturtium officinale						+	+		
Onopordum acanthium						+	+		
Orlaya grandiflora						+	+	+	
Panicum capillare						+	+		
Poa trivialis						+	+		
Prunella vulgaris						+	+		
Pteridium aquilinum						+	+		
Raphanus raphanistrum						+	+	+	
Sambucus ebulus						+	+		
Scleranthus annuus						+	+	+	
Stachys recta						+	+		
Symphytum tuberosum						+	+		
Vaccaria pyramidata						+	+	+	
Vulpia myuros						+	+		
*Xanthium spinosum***						+	+	+*	