GUIDELINES TO ESTABLISH FLOWER-RICH STRUCTURES IN URBAN AND RURAL AREAS

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Content

Introduction

Our culture landscape used to be constituted by a mosaic of various habitat types. However, due to different reasons, such as land consolidation, eutrophication, mulching, and abandonment many flower-rich landscape elements all but disappeared from our landscape (e.g. Beilin et al. 2014). Such loss is reflected in the decreasing numbers of not only rare species of plants and animals but also of species that had been quite common in the past (e.g. Ceballos et al. 2017, Garibaldi 2017, Pimm et al. 2014). Attempts on increasing diversity not only in rural but also in urban areas, e.g. along road verges, on roundabouts (see Fig. 1), in parks, schoolyards, or in front gardens have started to appear (e.g. Kowarik 2013, Kowarik & von der Lippe 2018).

Fig. 1: Roundabout with wild plants of regional origin, the city of Erfurt.

Methods to establish flower-rich structures

In intensively used agricultural areas as well as in urban areas, seed sources of target species are scarce or not existent. Therefore, it is necessary to actively introduce wild target plants from regional origin (example for seed propagation site see Fig. 2) via sowing, or transfer of seed-rich material from suitable donor sites (e.g. seed-rich green hay, seed-rich material from on-site threshing, raking material – methods described in Kiehl et al. 2010).

Fig. 2: Wild seed propagation site in Halle/Saale, Germany.

Selection of suitable sites

Selected sites should have a minimum wide of 3 m to minimize disturbances and encroachment of unwanted species by clonal growth. Existing species-poor grass swards must be disturbed thoroughly to provide establishment niches for introduced target species (e.g. Schmiede et al. 2012). Flower-rich structures can be established under different conditions (see Figure 4):

- Between field tracks and arable land or grassland (e.g. Kiehl et al. 2014, Kirmer et al. 2018)
- On south- or west-exposed sites on hedges or woodland edges
- In urban areas: along roads and pavements, on roundabouts, in city parks, front gardens, and schoolyards, in car parks and graveyards, but also on rooftops or along brownfield.

The southern side of a hedge
(photo: M. Necker)

West-exposed woodland edge
(photo: D. Jeschke)

Between field track and arable land
(photo: M. Necker)

In urban areas
(photo: D. Jeschke)

Fig. 4: Different conditions for establishing flower-rich vegetation (Kirmer et al. 2014).

Compilation of seed mixtures

Seed mixtures should contain only seeds of wild plants from regional seed propagation. Species-rich mixtures are better in establishing a sustainable vegetation, being more resilient against disturbance and extreme weather conditions. Target species must be chosen according to the soil conditions of the

restoration sites (nutrient-status, moisture) well as the restoration goal, e.g. erosion control, compensation, recreation, provision of nectar and pollen sources.

In urban areas, especially on nutrient-poor soil, gravel or sandy sites, a sowing density of 1.0-1.5 g/m² is sufficient. The majority of sown species should be forbs, optimally 25-30 species. Dependent on target vegetation and restoration goal, a few less competitive grass species can be added, e.g. *Briza media, Cynorurus cristatus, Anthoxanthum odoratum* on more mesic sites; *Koeleria cristata, Festuca ovina, Poa compressa* on dry grassland sites. On dry, sandy sites, *Corynephorus canescens* is very successful to stabilize loose surfaces, acting as a nurse plant for psammophytic grassland forbs. In urban areas, seed mixture only composed of forbs can be useful.

Permanent wildflower strips within Agri-Environmental Schemes on well-kept arable land can be sown with a density of 0.7-0.8 g/m². Here, usually, the seed mixtures contain only forbs. Farmers will get subsidies

If field margins or species-rich grasslands should be established on formerly species-poor grass-dominated sites, a higher sowing density of 1.5-2 g seeds/m² is recommended. The seed mixture should contain about 5 species of typical grasses (maximal 40 % grass seeds on total seed number) and 25-40 species of forbs. High-competitive grasses should be avoided in seed mixtures.

In establishing flower-rich structures, species can be chosen from different vegetation types, e.g. from fringe communities (*Geranion sanguinei* Th. Müller 1961, *Trifolion medii* Müller 1962), dry and mesic grasslands, and ruderal, dry sites. The seed mixtures should contain only wild forms of forbs and grasses to guarantee a sustainable development. Cultivars of grasses and clover can outcompete wild forbs in the long run. The propagation of indigenous seeds should take place within the respective countries, even better in defined regional production areas to assure a transparent production and avoid the introduction of neophytic species (e.g. coming from seed impurities). When there are transnational natural landscape units, binational production areas must be defined.

Site preparation

For successful species introduction into already existing grass swards, the sward has to be cut to a height of 3-5 cm. Afterwards, the sward has to be opened. This can be managed manually with a hoe or rake. For large area treatment, we recommend the use of a curry comb, harrow, rotary hoe, rotary strip seeder or flail chopper. During the last few years, different specialized machinery for grassland regeneration has been developed and is available in grassland dominated regions. Several assessments showed that the stronger the intervention and disturbance of the sward, the higher the rate of successful species establishment (Walker et al. 2004, Schmiede et al. 2012).

Areas that have been fallow for a long period may contain a high proportion of *Agrostis capillaris*, *Elymus repens, Cirsium arvense*, or *Rumex obtusifolius*, which without preliminary measures used to combat them, can prevent restoration success. Formerly intensively used grasslands generally contain a high potential for seeds and/or strongly competitive rhizomatous problematic species, such as *Ranunculus repens, Trifolium repens* or *Rorippa palustris*. Frequent harrowing (2-3 times) in two-week intervals is the best method of mechanical weed control.

Hospitable raw soils, as well as well-tended arable fields, are optimal sites to establish flower-rich structures.

Time of sowing

Most seeds ripen in late summer or autumn. Especially in regions with a continental climate, the time after the first big rainfalls in late summer till early autumn is best for sowing wild plants. But many seeds of herbaceous species need fluctuating temperature and moisture to break dormancy. These species will not germinate until the following spring. Species sown in spring which germinate in the following autumn have a diminished chance to establish if the canopy cover has already closed. Then again, spring sowing decreases losses caused by vermin and weather conditions compared to autumn sowing. In a drier climate with a high danger of desiccation, sowing between mid-April and mid-August should be avoided or the seedbed must be protected, for example with an additional mulch layer. According to our experience, moist conditions and deep topsoil favour the development of grasses. Herbs have an advantage on more nutrient-poor and drier sites. In practice, in a climate with prolonged droughts in late spring and early summer, the best sowing time is in late summer.

In a moist climate, as well as in mountainous areas, restoration with seeds or seed mixtures should take place at the beginning of the vegetation period to make optimal use of winter moisture and to guarantee the development of seedlings into plants capable of surviving the winter.

Sowing

The simplest method is manual sowing. To ensure uniform sowing, e.g. dry sand or semolina as well as soya grain, bean grain, or crushed maize can be added (up to 10 g/m²). The restoration site should be sown in two sowing operations at 90° to each other, with half of the material respectively, to avoid spreading too much seed on a part of the site. The use of a seed bowl is recommended. Manual sowing is sometimes the only practical method on remote areas without vehicle access or on smaller sites.

With appropriate vehicle access and moderate slope inclinations, large areas can be sown with conventional agricultural sowing machines. A common mistake is to bury the seeds in the soil. Wild plants need light for germination and therefore, seeds must stay on the surface. Cleaned meadow threshing and well-sieved hay-flowers can also be sown with standard commercial sowing devices. The differing sizes of soya grain, bean grain or crushed maize counteract separation of the grain fractions in seed mixtures. This is also beneficial for mechanical sowing of grasses with long awns.

First-year management

On former arable land and fallows, management is mandatory already in the first year after restoration (implementation in spring) or the following year (implementation in autumn). Especially on former arable land, the germination of weeds from the soil seed bank can hamper the establishment of target grassland species. The first cut is necessary as soon as the vegetation is closed and the annual ruderals emerging from soil seed bank reached knee-height. Depending on the productivity of the sites, the cutting frequency can be increased up to three or four cuts per year without impeding the development of target grassland species, if the cutting height is above 10-15 cm. Since target species are mostly in a rosette or juvenile stage, they are usually not damaged by mowing. Even if target species are already flowering at the time of cutting, the cut enhances their vegetative and root development. Since weeds are not resistant to mowing, they are effectively restricted in their development. If the cutting height is about 15-20(25) cm, the vegetation will flower again already after four weeks (see Fig. 5).

Fig. 5: Re-growth of sown wild plants four weeks after cutting with a forage harvester at 20-25 cm height in mid-May 2018. Flowering of annual (*Consolida regalis, Centaurea cyanus)* and perennial species (*Anthemis tinctoria*) from seed mixture. *Papaver rhoeas* emerged from the soil seed bank. Altogether, 49 wild plant species were sown mid-September 2017.

Follow-up management

Usually, normal management can be started in the second or third year after sowing. The canopy cover of sown perennial species will prevent the emergence of unwanted ruderals. If perennial ruderals (e.g. *Cirsium arvense, Rumex obtusifolius, Rumex crispus, Calamagrostis epigejos*) established on the site, selective mowing or even spraying can be necessary.

The management frequency must be adapted to the productivity of the site. On very productive sites, a clearing cut in late winter (until mid-March) can reduce biomass production during the vegetation period. An alternative is a second cut in late summer (in addition to the first cut in early summer) but cutting too late destroys hibernating habitats for insects.

To ensure flowering through the whole vegetation season, half of the site should be mown with the removal of biomass between mid-May and mid-June, and the second half 8-10 weeks later (Fig. 6). Usually, the re-growth provides hibernating structures (for insects) and food sources (for birds) during winter time. Mowing of sites should be alternated from year to year to avoid promotion of grasses due to late cutting. If an additional cut in late winter is necessary, the biomass should be left close-by.

Fig. 6: Perennial wildflower strip on arable land, shortly after cutting; the right site is cut in early June; the left site will be cut begin of August.

Monitoring

Monitoring restoration success is mandatory to avoid unwanted developments. Especially in the first 3-4 years, the sites should be visited on a regular basis. This needs appropriate financing, which has to be provided for in the initial restoration project. The amount of necessary funding depends on the aim of the monitoring itself. Possible parameters, listed in order of increasing monitoring effort, can be:

- the percentage of plant cover and bare soil
- the percentage cover of vascular plants and bryophytes/lichens. The last species group (usually defined as “biological soil crust”) has an important function on stony, dry soils, where it greatly contributes to soil formation
- species richness
- vascular plant composition (classical relevés), and especially the presence of invasive species, annual and perennial weeds and neophytes

Four years after restoration started, monitoring intervals can increase, although management should be controlled regularly.

Andrena hattorfiana on *Knautia arvensis*

Andrena flavipes on Anthemis tinctoria

Melanargia galathea

Aglais io

Example 1: Wildflower-strips in a city park and university campus; University of South Bohemia in České Budějovice

A pilot study of the effect of flower strips in urban areas has been established by the Restoration Ecology Group at the University of South Bohemia in České Budějovice, Czech Republic. At the turn of the years 2016 and 2017, several flowering strips were sown in the city park Stromovka and in the University Campus and areas of the Czech Academy of Sciences. The main aim of this study is to test the survival of sown species in mesic and dry conditions in an urban environment. At the same time, a basic survey of butterflies and hymenopterous insect took place. The following variants were realized:

D1 = sowing, dry sites, loamy-sand soil, only native wild plants
D2 = no sowing, dry sites, loamy-sand soil, extensive cutting (3-4x/year)
D3 = no sowing, dry sites, loamy-sand soil, intensive cutting (up to 6-8x/year)
M1 = sowing, mesic sites, sand-loamy soil, only native wild plants
M2 = no sowing, mesic sites, sand-loamy soil, extensive cutting (3-4x/year)
M3 = no sowing, mesic sites, sand-loamy soil, intensive cutting (up to 6-8x/year)

Fig. 7: Mesic flowering strip in Stromovka city park (České Budějovice, Czech Republic), two years since establishment (August 2018).

Tab 1: Number of sown and prevailing forbs in particular treatments in year 2017 and 2018.

	Dry			Mesic		
	D1	D2	D3	M1	M2	M3
	Flower strip	Extensive	Intensive (control)	Flower strip	Extensive	Intensive (control)
Number of sown nectarous or host forbs (2017)	43	-	-	27	-	-
2018 present	34	11	-	25	10	-
Number of other sown forbs (2017)	19	-	-	16	-	-
2018 present	12	1	-	14	1	-
Sowing density (g/m^2)	1	-	-	0,75	-	-

In the city park, 6 flowering strips were established and sown with seed mixture of 43 flowering plants. Only biannual and perennial species were used with the only exception *Centaurea cyanus* representing annual species. More than a half of sown species established in the first year and more than 90% of sown species established during the second year of survey. Among the most successful species were *Achillea millefolium, Anthemis tinctoria, Centaurea cyanus* and *Verbascum lychnitis.* Especially *Achillea* is an important nectar-producing plant for gossamer-winged butterflies (*Lycaenidae*). Moreover, out of the established sown species almost 65% are considered as nectar source or host plant for butterflies.

Fig. 8: Wildflower strip on a dry site in the Campus of the University of South Bohemia (České Budějovice, Czech Republic), two years since establishment (May 2018).

In the university campus, three wildflower strips were established by sowing 62 species. More than 70% established within two years. *Achillea millefolium*, *Anthemis tinctoria, Centaurea cyanus*, *C. stoebe*, *Cichorium intybus*, *Daucus carota*, *Leucanthemum vulgare,* and *Malva sylvestris* were the most successful ones. More than 70% of established sown species are important nectar sources or host plants for butterflies.

First-year management consisted of three cuts in June, August, and October with removal of biomass. Since there was no difference in species composition of both sown and spontaneously established species between wildflower strips established in autumn and in spring, both sowing variants were analysed together.

Altogether 129 species of plants were able to establish spontaneously from surroundings. Especially in the city park many species of competitive strong grasses (such as *Elytrigia repens*, *Agrostis capillaris*, *Poa trivialis*) or forbs (*Ranunculus repens, Rumex obtusifolius*) appeared in the strips. Hopefully, these unwanted species will decline in the following years with appropriate management.

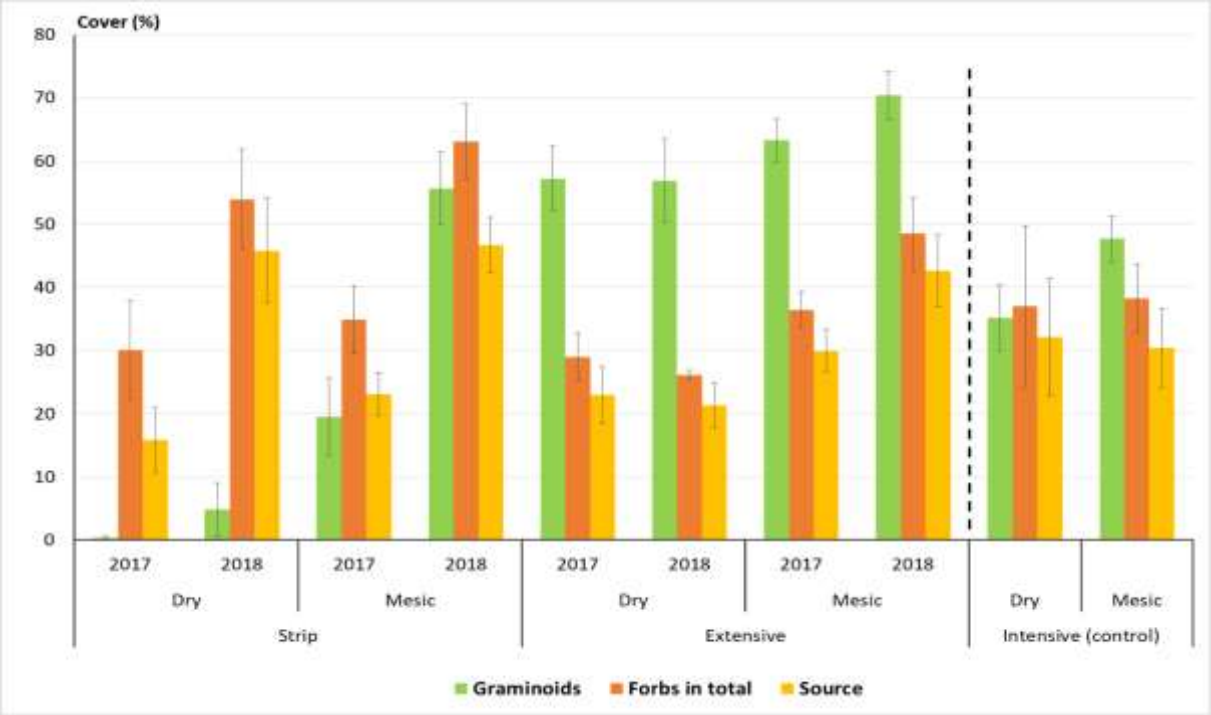

Fig. 9: Visualization of total cover (%) of three different groups of plants in dry and mesic sites with three different management approaches in two following years of survey.

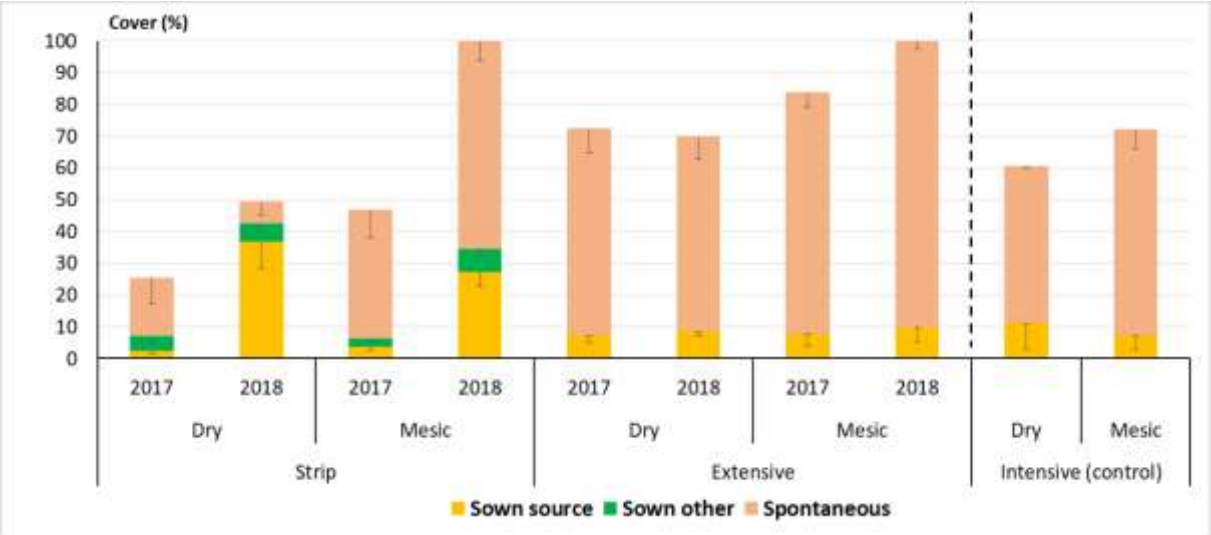

Fig. 10: Comparison of total cover (%) of sown species and spontaneously occurring species of plants in dry and mesic sites with three different management approaches in two following years of survey.

Wildflower strips are in contrast with their species-poor surroundings, which were intensively cut. Only 50 plant species were found altogether in all surveyed plots. Most of the cover of plots was comprised of grass species with the occasional appearance of *Taraxacum*, *Bellis perennis,* or *Glechoma hederaceae.* Appearance of other forbs was scarce and with very low cover. Unmown sites were a little bit species-richer (61 species), but the sites are still dominated by grasses.

From May to September 2017 and 2018, surveys of butterflies (Lepidoptera) as well as wild bees and wasps were made on the following sites:

- wildflower strips on mesic sites in city park Stromovka
- wildflower strips on dry sites in surroundings of Biology Centre (BC) and Campus of University of South Bohemia
- intensively cut lawns
- unmown sites in city park Stromovka and surroundings of Biology Centre (BC) and Campus of University of South Bohemia

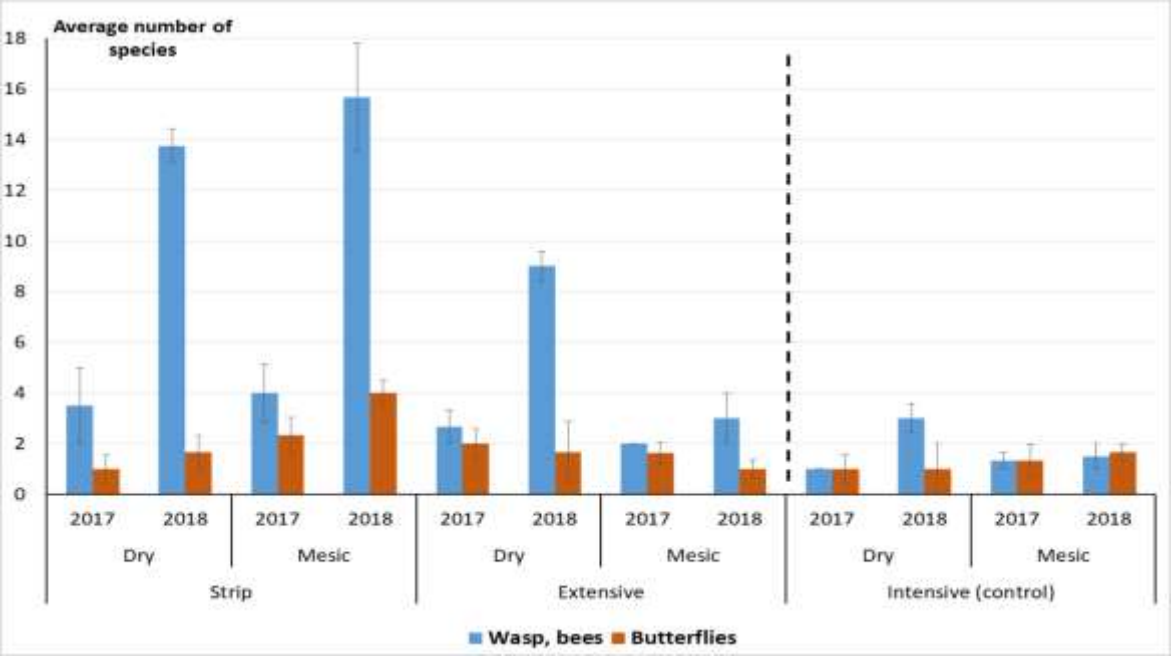

Fig. 11: Visualization of average number of species in plots of surveyed insect groups in dry and mesic sites with three different management approaches in two following years of survey.

In both study years, both, intensively and extensively managed sites hosted almost the same number of butterfly species and individuals. The number of wild bees and wasps and also their abundance were higher at extensive mown sites compared to intensively mown sites. However, at some intensive sites, no butterfly species was recorded during the whole season and also the number of wild bees and wasps was very low.

In both types of wildflower strips (dry, mesic) a higher number of wild bees and wasps was found in the second year of survey. In the mesic sites (city park Stromovka), the number of recorded species increased four times, i.e. from 12 (2017) to 52 (2018). In dry wildflower strips (University Campus), the number of species raised even five times, i.e. from 7 (in 2017) to 35 (2018). The number of species hosted by wildflower strips was higher than in extensively (21 species) and intensively (8 species) mown grasslands considered as control plots. Similarly, the abundance of wasps and bees in wildflower strips highly exceeded their surrounding extensively as well as intensively mown grasslands. The total abundance in the second year of survey reached 126 individuals in dry wildflower strips and 154 individuals in mesic strips. In contrast to these results, only 10 individuals were found in intensively mown dry grasslands and only two of them in intensively mown mesic grasslands. Several of the recorded species found in wildflower strips belonged to the Red List of the Czech Republic such as

Ectemnius lituratus, *Hylaeus annulatus*, *Hylaeus gibbus,* and *H. pectoralis.* Another interesting species for this region is *Heriades rubicola*.

Fig. 12: Common Blue *(Polyommatus icarus) belonged to the most* abundant butterfly species at the wildflower strips in the second year. Solitary bee *Andrena* sp. visits *Leucanthemum* flower.

In total, eight mostly common butterfly species were recorded: Green-veined White *(Pieris napi),* Small White *(Pieris rapae),* Large White *(Pieris brassicae)*, Map *(Araschnia levana),* Meadow brown *(Maniola jurtina),* Small Heath *(Coenonympha pamhpilus),* Small Copper *(Lycaena phlaeas)*, Common Blue *(Polyommatus icarus).* The Common Blue belonged to the most abundant species. Altogether 72 individuals of this species were recorded during the whole season with a maximum number of 34 individuals identified during one visit in September.

On the contrary, wildflower strips both in the city park Stromovka and in surroundings of the University Campus, hosted a higher number of species in the second year, which were even more abundant than in previous year. The highest abundance of species was recorded for both years in the end of August and beginning of September. Most of the recorded species occurred only on wildflower strips.

Fig. 13: Wildflower strips on dry sites in the Campus of the University of South Bohemia (České Budějovice, Czech Republic), second year since the establishment.

Butterflies at intensively mown areas (either meadows, parks, gardens or other urban green vegetation) are losing not only their habitats and host plants but also plants, which provide nectar to adult butterflies during the flight period. Unfortunately, this can be one of the reasons leading to a decrease of nonspecialized fairly common butterfly species. Flowering strips, which are mown in a proper time, can be an important help in our effort to maintain the biodiversity in an urban environment.

Fig. 14: Flowering strips provide food sources and habitats for many insect species living in urban sites; from top left to bottom right: *Trichodes apiarius, Oxythyrea funesta, Tettigonia viridissima, Rhinusa tetra*.

Example 2: Perennial wildflower strips in rural areas, Anhalt University of Applied Sciences, Bernburg, Germany

Perennial wildflower strips were established on arable land with very fertile Chernosem soil, in a block trial with seven variants and four repetitions (see Kirmer et al. 2016):

H1 = autumn sowing, loess sites, only native wild plants
H2 = autumn sowing, dry loess sites, only native wild plants
H3 = autumn sowing, loess sites, more structure-rich, only native wild plants
F1 = spring sowing, loess sites, native wild plants and cultivars
F2 = spring sowing, dry loess sites, native wild plants and cultivars
F3 = spring sowing, loess sites, more structure-rich, native wild plants and cultivars
FK = spring sowing, only cultivars (conventional mixture 'bee pasture')

Autumn sown variants (H1-3) were sown mid-September 2010, whereas spring-sown variants F1-3, and FK were implemented begin of April 2011. The long-term (1961-1990) yearly precipitation amounts to 469 mm, and the mean annual temperature to 9.1 °C.

First-year management consisted of one clearing cut without biomass removal mid-May 2011 at a height of c. 15-20 cm. Half of the sites was additionally cut mid-June 2011. Since 2012, the whole site was cut mid-March to reduce biomass production in summer. The second cut was done stepwise: half on the site was cut mid-June, and the second half beginning of August to ensure continuous flowering on the site during the whole vegetation season.

Tab. 2: Number of cultivar species, annual/biennial and perennial native forbs in seed mixtures sown in autumn 2010 or in spring 2011. The number of species found during surveys in 2015 is highlighted in green.

	Autumn sowing only native forbs			Spring sowing with native forbs and cultivars			Spring sowing only cultivars
	H1 loess	H2; loess/dry	H3; loess / structure-rich	F1 loess	F2 loess/dry	F3; loess / structure-rich	FK conventional
Number of sown cultivars	0	0	0	7	6	8	9
2015 present	-	-	-	0	0	0	0
Number of sown annual and biennial native forbs	8	8	10	6	3	9	0
2015 present	4	3	3	4	1	3	-
Number of sown perennial native forbs	17	22	22	11	13	19	0
2015 present	17	19	22	11	12	17	-
Sowing density (g/m²)	0.71	0.71	0.79	1.79	2.01	0.75	10.0

After five years of mulching twice a year, the wild seed mixtures maintained a species-, structure- and flower-rich vegetation, although the continuous later-mown variant had higher grass cover in 2015 (Fig. 15). The cultivar mixture was dominated by spontaneously established species (mostly grasses), already the second year (Fig. 16). The differences between wild seed and pure cultivar variants are highly significant. After five years, sown perennial wild forbs showed 50-60 % cover (Fig. 15-16, Fig. 18-19 left). The commercial mixture ('bee-pasture') completely failed (Fig. 16, Fig. 18-19 right).

Table 2 showed that most of the sown perennial native species (86-100 %) are still present after five years. All cultivar species vanished and the establishment rate of annual/biennial species is between 30 and 67 %.

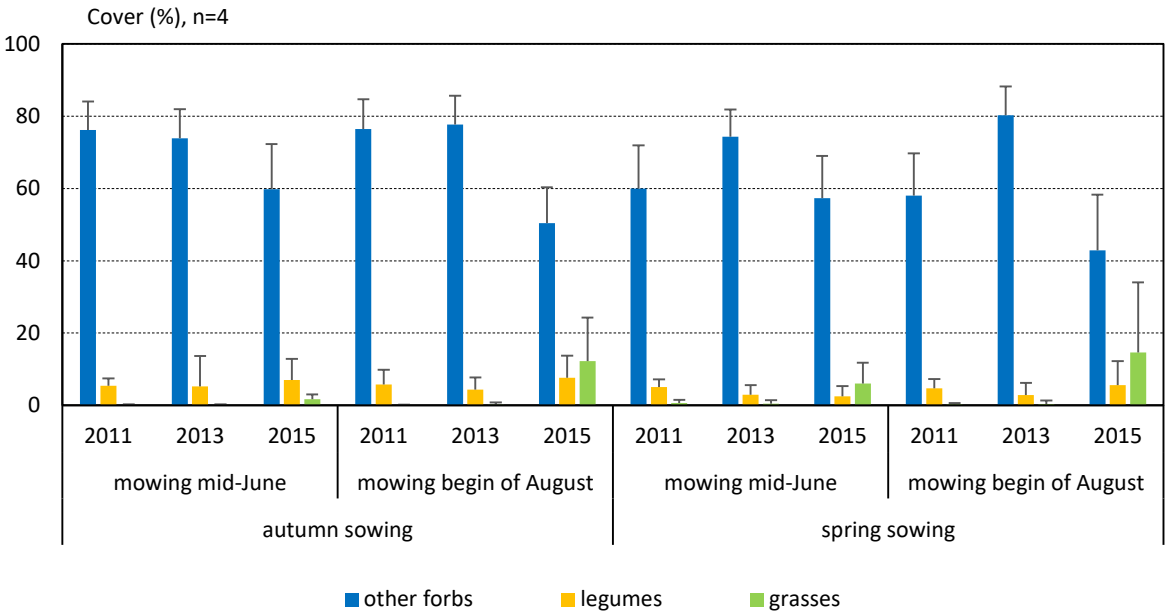

Fig. 15: Cover of functional groups (grasses, legumes, other forbs) on wild plant variants sown in autumn and in spring with different mowing time (mid-June, begin of August); one, three and five years after sowing.

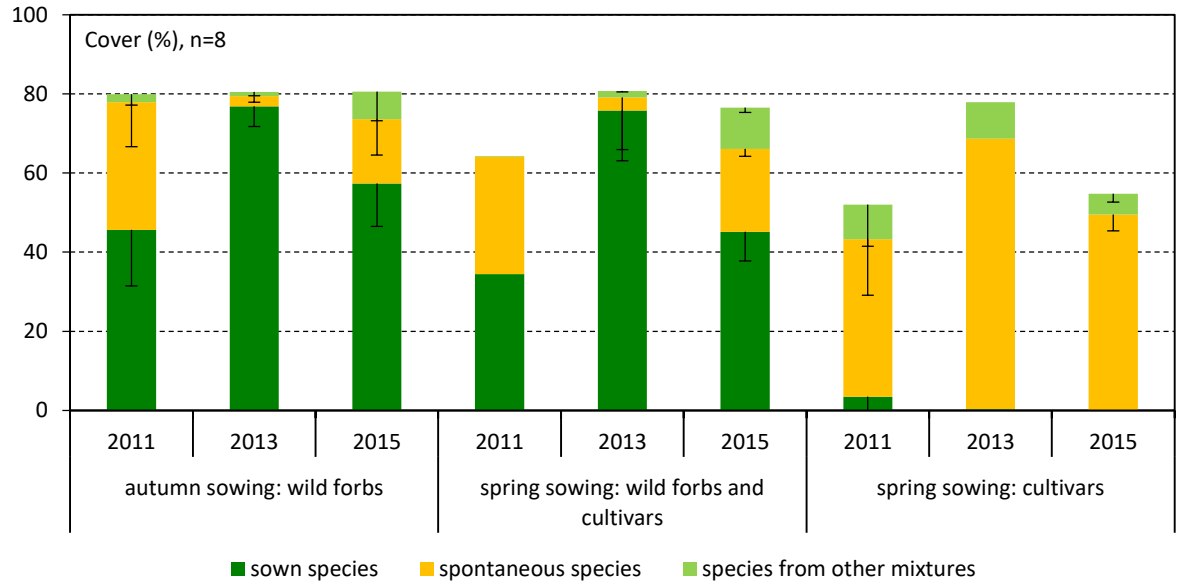

Fig. 16: Development of cover of sown and spontaneously establishing species as well as of species coming from other sowing variants; one, three and five years after sowing.

Surveys of butterflies/burnet moths were made in 2013 and 2014 within the scope of a bachelor thesis (Schmidt 2014). Results showed an increase on the wildflower strip trial (Fig. 17). On two arable fields (control sites), only 3, respectively 5 species were recorded in 2014.

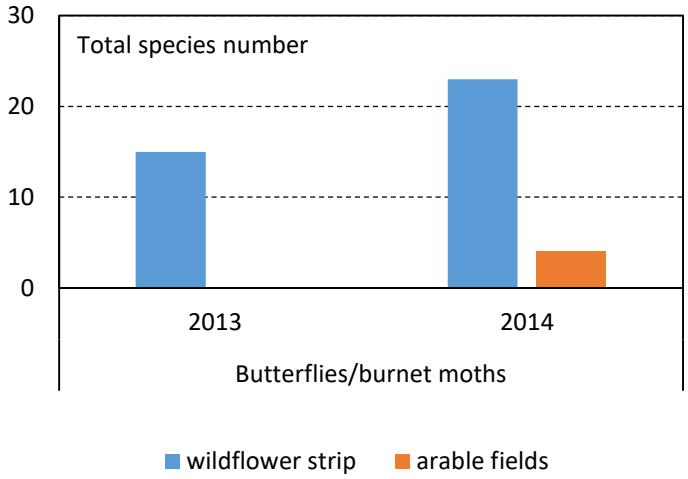

Fig. 17: Total number of butterflies/burnet moths recorded from May till September 2013 and April till September 2014 (line transect method with three 50x5-m sections; Schmidt 2014) on the wildflower strip trial and on two arable fields (control).

On very productive arable land (Chernozem), mulching two times a year (early March (all), mid-June (half), and begin of August (half)) was very successful. The stepwise cutting in summer guaranteed nectar and pollen sources during the whole vegetation season. Based on our results, recommendations were given to shape the Agri-Environmental Schemes 'perennial wildflower strips' for the CAP 2014-2020 in Saxony-Anhalt/Germany.

Fig. 18: Wildflower variant with the dominance of sown perennial forbs in May 2012 (left). Cultivar variant with the dominance of grasses (*Festulolium, Festuca rubra*) in May 2012 (right).

Fig. 19: Wildflower variant with dominance of sown perennial forbs in May 2015 (left). Cultivar variant with dominance of grasses (*Festuca rubra*) in June 2015 (right).

References

Beilin R., Lindborg, R., Stenseke, M., Pereira, H.M., Llausàs, A., Slätmo, E., Cerqueira, Y., Navarro, L., Rodrigues, P., Reichelt, N., Munro, N., Queiroz, C. 2014. Analysing how drivers of agricultural land abandonment affect biodiversity and cultural landscapes using case studies from Scandinavia, Iberia and Oceania. Land Use Policy 36: 60-72.

Ceballosa, G., Ehrlich, P.R., Dirzob, R. 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. PNAS online early. https://doi.org/10.1073/pnas.1704949114

Kiehl, K., Kirmer, A., Donath, T.W., Rasran, L., Hölzel, N. 2010. Species introduction in restoration projects – Evaluation of different techniques for the establishment of semi-natural grasslands in Central and Northwestern Europe. Basic Appl. Ecol. 11, 285–299.

Kiehl, K., Kirmer, A., Jeschke, D., Tischew, S. 2014. Restoration of Species-Rich Field Margins and Fringe Communities by Seeding of Native Seed Mixtures, in: Guidelines for Native Seed Production and Grassland Restoration. Cambridge Scholars Publishing, pp. 246–275.

Kirmer, A., Rydgren, K., Tischew, S. 2018. Smart management is key for successful diversification of field margins in highly productive farmland. Agriculture, Ecosystems and Environment 251: 88-98.

Kirmer, A., Jeschke, D., Kiehl, K., Tischew, S. 2014. Praxisleitfaden zur Etablierung und Aufwertung von Säumen und Feldrainen. Eigenverlag Hochschule Anhalt, Bernburg. ISBN 978-3-86011-075-1.

Kirmer, A., Pfau, M., Mann, S., Schrödter, M., Tischew, S. 2016. Erfolgreiche Anlage mehrjähriger Blühstreifen durch Ansaat wildkräuterreicher Samenmischungen und standortangepasste Pflege. Natur und Landschaft 3: 109-118.

Kowarik, I. 2013. Cities and Wilderness: A New Perspective. International Journal of Wilderness 19: 32-36.

Kowarik, I., von der Lippe, M. 2018. Understanding plant species success across urban ecosystems – a framework to inform urban biodiversity conservation. Journal of Applied Ecology 55: 2354–2361.

Pimm, S.L., Clinton, N.J., Abell, R., Brooks, T., Gittleman, J.L., Joppa, L.N., Raven, P.H., Roberts, C.M., Sexton, J.O. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science 344: 1246752 doi: 10.1126/science.1246752

Schmidt, A. 2014. Bedeutung von mehrjährigen, artenreichen Blühstreifen und Feldrainen für Tagfalter und Widderchen - Fallbeispiele aus der Agrarlandschaft um Bernburg (Saale). Bachelor thesis Anhalt University of Applied Sciences.

Schmiede, R., Otte, A., Donath, T.W. 2012. Enhancing plant biodiversity in species-poor grassland through plant material transfer – the impact of sward disturbance. Appl. Veg. Sci. 15, 290–298.

Walker, K.J., Stevens, P.A., Stevens, D.P., Mountford, J.O., Manchester, S.J., Pywell, R.F. 2004. The restoration and re-creation of species-rich lowland grassland on land formerly managed for intensive agriculture in the UK. Biological Conservation, 119, 1-18.

Appendix

Wildflower strips on the Campus of the University of South Bohemia

Site characteristics	
Country	Czech Republic
Municipality	City of České Budějovice
Physical region	Ceskobudejovicka basin
Name of the site	Block trial Campus of University of South Bohemia
Geographical position	48° 58' 39,8" N, 14° 26' 49,6" E
Long-term yearly precipitation (1961-1990)	583 mm
Long-term average temperature (1961-1990)	8.2 °C
Height above sea level (m)	390
Exposition	plain
Shading	no
Length x wide (m)	4 x 4 m (4 repetition); 1,5 x 2 m (2 repetitions)
Geology	Loamy-sand
Soil type	-
Soil pH ($CaCl_2$)	-
Hydrological balance	dry
Nutrient status	-
Adjacent use	shrubs, cultivars, intensively cut grasslands
Former use of the site	shrubs, cultivars
Problematic species on the site	*Vicia hirsuta, Vicia villosa, Taraxacum* sect. *Ruderalia*

Trial characteristics	
Method	Scientific block trial
Site preparation	1 x digging before sowing
Seed mixture	62 wild plants from regional seed propagation (43 nectarous or host plants, 19 other forbs)
Sowing density	0.99 g/m²
Sowing method	Hand sowing
Sowing time	19. 10. 2016
Number of relevés (4 m x 4 m or 1,5 m x 2 m)	6
First-year management	3 times mowing (June, August, October) with the removal of biomass
Management since the second year	Mowing with the removal of biomass in mid-June and in November
Observation period	2017 - 2018
Specifics	Removal of *Vicia hirsuta, Vicia villosa, Taraxacum* sect. *Ruderalia* in June and July 2017 and 2018

Pictures

May 2018

End of June 2018

Floristic results

Observation year	2017	2018
Establishing rate (%)		
Whole variant (6 plots)	72.5	74.2
mean (n=6)	28.4	48.1
Total species number (6 plots)		
	117	95
Mean species number (n = 6)		
Sown nectarous or host plants	12.2	21.6
Sown other forbs	5.5	8.1
Spontaneous species (total)	24	16.5
of that graminoids	9	12
Mean cover (n = 6)		
Sown nectarous or host plants	3.0	43.6
Sown other forbs	5.4	7.0
Spontaneous species (total)	21.8	8.1
of that graminoids	0.4	4.9

Faunistic results

Observation year	2017	2018
Total species number		
Butterflies	2	4
Bees, wasps	7	35
Mean species number (n = 6)		
Butterflies	1	1.7
Bees, wasps	3.5	13.8
Total abundance		
Butterflies	3	6
Bees, wasps	9	126

Wildflower strips in the City Park Stromovka (České Budějovice)

Site characteristics

Country	Czech Republic
Municipality	City park of České Budějovice
Physical region	Ceskobudejovicka basin
Name of the site	Block trial city park Stromovka
Geographical position	48° 58' 39,8" N, 14° 26' 49,6" E
Long-term yearly precipitation (1961-1990)	583 mm
Long-term average temperature (1961-1990)	8,2 °C
Height above sea level (m)	384 – 387
Exposition	plain
Shading	no
Length x wide (m)	8 x 2 m (10 repetitions)
Geology	loamy sand
Soil type	-
Soil pH ($CaCl_2$)	-
Hydrological balance	mesic
Nutrient status	-
Adjacent use	intensively cut grasslands
Former use of the site	intensively cut grasslands
Problematic species on the site	*Rumex obtusifolius*

Trial characteristics

Method	Scientific block trial
Site preparation	1 x digging before sowing
Seed mixture	43 wild plants from regional seed propagation (27 nectarous or host plants, 16 other forbs)
Sowing density	0,75 g/m²
Sowing method	Hand sowing
Sowing time	17. 10. 2016, 11. 4. 2017
Number of relevés (8 m x 2 m)	10
First-year management	3 times mowing (June, August, October) with the removal of biomass
Management since the second year	Mowing with the removal of biomass in mid-June and in October
Observation period	2017 - 2018
Specifics	Removal of *Rumex obtusifolius* in June and July 2017 and 2018

Pictures

May 2018

Floristic results

Observation year	2017	2018
Establishing rate (%)		
Whole variant (6 plots)	58.1	90.7
mean (n=6)	33.5	57.9
Total species number (10 plots)		
	96	110
Mean species number (n = 10)		
Sown nectarous or host plants	10.5	15.3
Sown other forbs	3.9	8.6
Spontaneous species (total)	27.3	25.1
of that gramnoids	6	8.8
Mean cover (n =10)		
Sown nectarous or host plants	4.3	35.5
Sown other forbs	3.2	8.5
Spontaneous species (total)	48.1	77.6
of that gramnoids	19.5	55.6

Faunistic results

Observation year	2017	2018
Total species number		
Butterflies	8	7
Bees, wasps	12	52
Mean species number (n = 10)		
Butterflies	2.3	4
Bees, wasps	4	15.7
Total abundance		
Butterflies	17	81
Bees, wasps	26	154

Field margins close to the Campus Strenzfeld of Anhalt University of Applied Sciences

Site characteristics

Country	Germany
Federal state	Saxony-Anhalt
Municipality	City of Bernburg, Salzlandkreis
Physical region	Magdeburger Börde
Name of the site	Block trial Campus Strenzfeld
Geographical position	51° 49' 09,8" N, 11° 42' 19,5" E
Long-term yearly precipitation (1981-2010)	511 mm
Long-term average temperature (1981-2010)	9.7 °C
Height above sea level (m)	90 - 93
Exposition	-
Shading	no
Lenght x wide (m)	13x3-m², 5 repetitions (195 m² per variant)
Geology	Loess
Soil type	Chernosem
Soil pH ($CaCl_2$)	7.3 – 7.4
Hydrological balance	dry
Nutrient status (2010)	P(CAL) 10.0 – 12.6 mg/100 g soil; N_{ges} 0.23 – 0.29 %
Adjacent use	Arable land, field track
Former use of the site	Species-poor grass margin
Problematic species on the site	*Carduus acanthoides*

Trial characteristics

Method	Scientific block trial
Site preparation	1 x grubbing shortly before sowing
Seed mixture	49 wild species of plants from regional seed propagation (5 legumes, 39 other forbs, 5 grasses)
Sowing density	2.0 g/m²
Sowing method	Hand sowing, rolling after sowing
Sowing time	7 October 2010
Number of relevés (1 m x 8 m)	5 per variant
First-year management	mulching 1. June 2011 due to dry weather conditions; mowing with removal of biomass 29-31 August 2011
Management since the second year	Mowing with removal of biomass in mid-June
Observation period	2010 - 2017
Specifics	Removal of *Carduus acanthoides* in May und June 2012

Pictures

May 2014, mown mid-June since 2012

June 2017, mown mid-June since 2012

Floristic results

Observation year	2010 (before)	2011	2014	2017
Establishing rate (%)				
All plots (40 m²)	-	55.1	83.7	79.6
mean (8 m², n=5)	-	43.7	62.0	60.0
Total species number (all plots, 40 m²)				
	12	71	66	59
Mean species number (8 m², n = 5)				
Sown species (grasses)	1.0	2.2	3.4	3.0
Sown species (forbs)	1.4	19.2	27.0	26.4
Spontaneous species (grasses)	2.4	4.8	4.0	3.0
Spontaneous species (forbs)	2.8	17.0	8.2	5.8
Mean cover (8 m², n = 5)				
Sown species (grasses)	25	0.5	12.9	18.1
Sown species (forbs)	0.2	10.8	53.5	50.9
Spontaneous species (grasses)	29.7	38.1	14.6	7.3
Spontaneous species (forbs)	0.4	14.4	3.8	1.5

Faunistic results

Observation year	2013	2014	2017	2018
Species-rich field margins				
butterflies/burnet moths (total species numbers)	21	20	22	no data
Species-poor grass margins				
butterflies/burnet moths (total species numbers)	8	8	no data	no data