sciendo

Ekológia (Bratislava) - Journal of the Institute of Landscape Ecology, Slovak Academy of Sciences Vol. 42, No. 3, p. 218–229, 2023

DOI:10.2478/eko-2023-0025

DEVELOPMENT OF FLOWER MEADOWS IN AN URBANIZED ENVIRONMENT

ZDENKA RÓZOVÁ[1], ANNA PÁSTOROVÁ ✉[1], GABRIEL KUCZMAN[2]

[1]Department of Ecology and Environmental Sciences, Faculty of Natural Sciences and Informatics, Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 949 01 Nitra, Slovak Republic; e-mail: anna.pastorova@ukf.sk
[2]Department of Garden and Landscape Architecture, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Tulipánová 7, 949 76 Nitra, Slovak Republic

✉ Corresponding author

Received: 30 May 2023 / **Accepted**: 27 June 2023

Abstract

Rózová Z., Pástorová A., Kuczman G.: Development of flower meadows in an urbanized environment. Ekológia (Bratislava), Vol. 42, No. 3, p. 218–229, 2023.

With increasing urbanization, it is necessary to create green infrastructure in cities and urban areas to improve not only the quality of life for residents, but also the health and sustainability of local ecosystems. One effective way to create green spaces is by establishing meadows filled with diverse plant species. These meadows can provide numerous benefits, such as aiding pollinator conservation, improving air and water quality, and increasing biodiversity. Therefore, creating these meadows is an important component of urban ecology. Seven types of flower meadow mixtures from a Czech company were sown in 12 plots within the Hliník Urban Park in Nové Zámky, Slovak Republic. The development of the vegetation and the impact of maintenance management and climatic factors were monitored during the vegetation period of 2021–2022, and the plots are still being monitored. The results of the flower meadow research in 2021 showed that improper maintenance and insufficient precipitation negatively influenced the vegetation's development. Grasses were most prevalent during the summer months, while legumes were more common in the spring months. The analysis of the plots revealed that four out of 12 plots were dominated by annuals and grasses, which were the most abundant throughout the entire vegetation period. In 2022, it was observed that grasses were most prevalent in May, legumes in June and July, and annuals occurred sporadically in all plots. Insufficient precipitation and high temperatures in 2022 created unfavorable conditions for the thriving of the flower meadow vegetation, resulting in a high proportion of opportunistic species. Due to the impact of stress factors, the vegetation in the plots dried up.

Key words: flower meadows, biodiversity, climate crisis, pollinators.

Introduction

While there is increasing recognition of the importance of urban green infrastructure for biodiversity (Rudd et al., 2002; Williams et al., 2014) and human well-being (Lovell, 2010; White et al., 2019) and the links between them (Carrus et al., 2015; Dallimer et al., 2012; Fuller et al., 2007, there is also increasing interest in the role of urban environments as habitats for wildlife, including species of conservation concern (Jeffries, Memmott, 2013; Godefroid, Koedam, 2007). These contemporary approaches to plant use are most often described as "naturalistic" and "ecological," associated with the term "natural garden" or "wildflower meadow" (Dunnet, Hitchmough, 2004; Jorgensen, Keenan, 2011).

As the world becomes increasingly urbanized, it is becoming more important than ever to incorporate green spaces into our cities and towns (James et al., 2009; Kabisch et al., 2015). Green spaces not only provide numerous benefits for human well-being, but also play a crucial role in supporting the health and sustainability of urban ecosystems. One effective way to create green spaces in urban environments is by establishing wildflower meadows using seed mixtures (Wu, 2014; Tallis et al., 2011; Díaz et al., 2006).

Wildflower meadows are diverse self-sustaining habitats that can be established on a variety of sites, from small patches of land to large expanses of green space. They can provide a range of benefits for both the environment and the people who live in urban areas. By creating a habitat for pollinators (Baldock et al., 2015), improving air and water quality, and increasing biodiversity, wildflower meadows have become an essential part of urban ecology (Baldock et al., 2015). These meadows provide a vital habitat for pollinators, such as bees, butterflies, and other insects. By establishing wildflower meadows in urban areas, we can help to support pollinator populations and improve the health of local ecosystems (Lerman, Warren, 2011). This type of stand also helps to improve air and water quality by absorbing pollutants and filtering rainwater. The diverse range of plant species found in wildflower meadows can absorb a wide range of pollutants, including nitrogen dioxide, carbon dioxide, and heavy metals, while the root systems of the plants can help to prevent soil erosion and improve soil quality (Davies et al., 2011; Duchamp, Winston, 2019).

Urban environments are often characterized by a lack of biodiversity, with many plant and animal species struggling to survive in the concrete jungle (Akbari et al., 2001). Wildflower

© The Author(s) 2023. This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/3.0/).

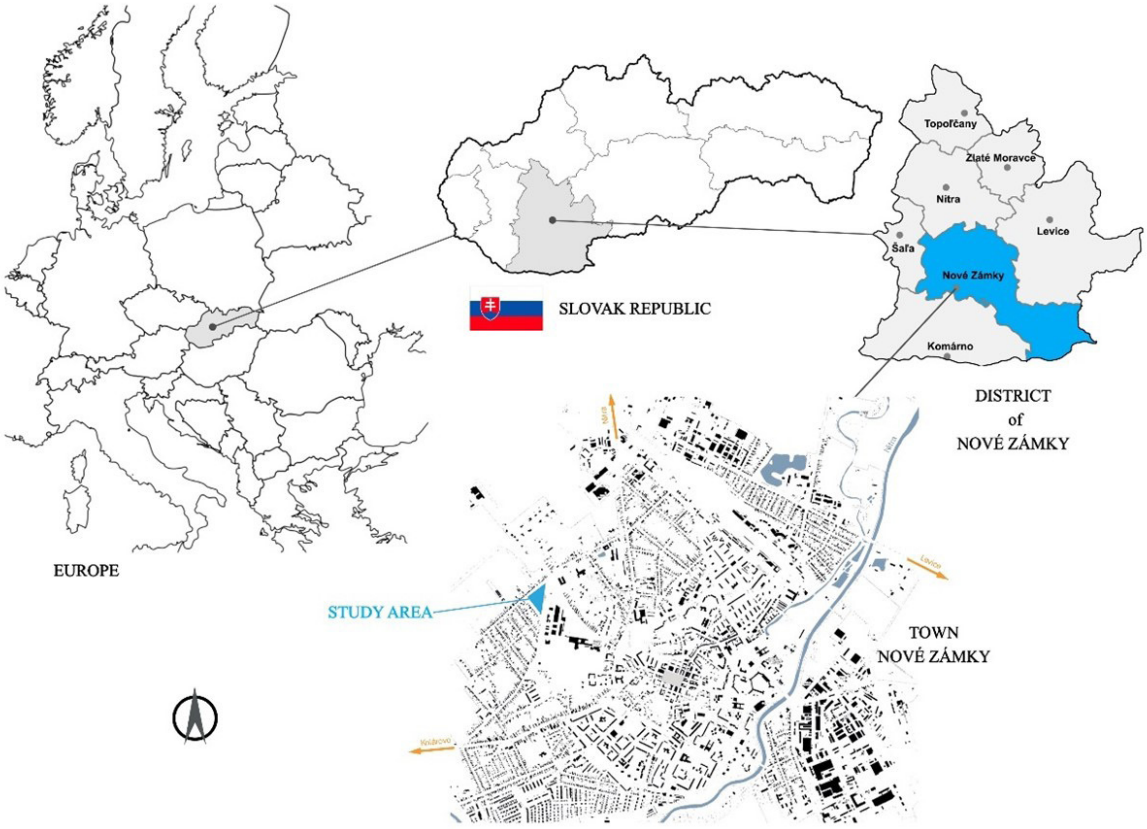


Fig. 1. Localization of the study area.

meadows provide a diverse range of habitats for plants and animals, helping to increase biodiversity and create a healthier, more resilient urban ecosystem (Francis, 2010; Lerman, Warren, 2011; Lu, Li, 2015; McPhearson et al., 2016).

Creating wildflower meadows using seed mixtures is a simple and effective way to bring green spaces to urban areas. Wildflower meadows have become an integral component of urban ecology due to their ability to provide a habitat for pollinators, enhance the quality of air and water, and promote biodiversity.

Material and methods

Background: establishment of artificially sown flower meadows

In cooperation with the municipal authority of Nové Zámky (Slovak Republic), we are involved in monitoring 12 plots established by grass–herbaceous commercial mixtures from direct sowing. The research plots are in the city park Park Hliník on Holuby Street in the city of Nové Zámky (Fig. 1). The city management decided to revitalize the city park with an emphasis on measures that would promote biodiversity enhancement in the urban area. The measures included the identification of areas that would fulfill different functions with the benefit of reducing the frequency of mowing. The development of the vegetation is influenced by management of maintenance of the flower meadows (FMs).

The concept, location, and size of the plots were designed by landscape architects Attila Tóth and Tomáš Pavelka (2019). Mixture selection and seeding implementation was carried out by Gabriel Kuczman and the implementation team (from GRANDIFLORA).

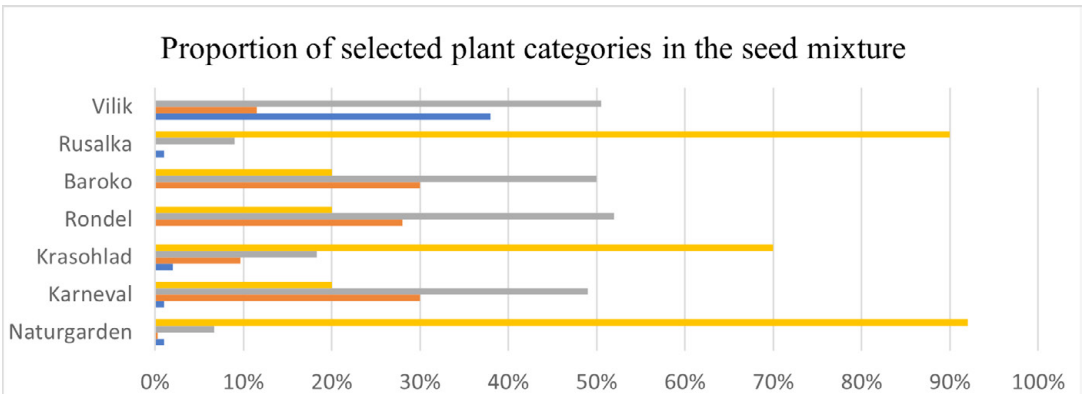
These plots were chosen because of the variety of mixes used and the number of plots per site. This site is surrounded by residential areas and visited frequently by local people.

The FM mixtures were sown using a sowing trolley into technically recultivated and herbicide (Roundup Classic PRO)-treated soil. The total area sown is 9900 m^2.

Seed mixture specification

The mixtures used for sowing were developed by a Czech company. Seven types of commercial mixtures were used for the seeding process (Figs 2, 3).

- Naturgarden mixture: plot NAT 1 (450 m2), NAT 2 (890 m2), NAT 3 (550 m2); suitable for enhancing biodiversity in gardens and small parks.
- Krasohled mixture: Plot KRAS 1 (350 m2), KRAS 2 (250 m2); ensures colorful vegetation by including attractive cultivated annuals in the first year after establishment Due to its esthetic appeal, it is suitable as an edge planting.
- Rusalka mixture: Plot RUS 1 (50 m2), RUS 2 (900 m2) grass–herbaceous mixture intended for undergrowth in deciduous or mixed parks and forest parks.



	Naturgarden	Karneval	Krasohlad	Rondel	Baroko	Rusalka	Vilik
Grasses	92%	20%	70%	20%	20%	90%	0%
Perennials	6,70%	49%	18,30%	52%	50%	9%	50,50%
Annuals	0,30%	30%	9,70%	28%	30%	0%	11,50%
Legumes	1%	1%	2%	0%	0%	1%	38%

Fig. 2. Proportion of selected plant categories (grasses, perennials, annuals, legumes) in the seed mixture by Agrostis Trávníky, s.r.o. (2023).

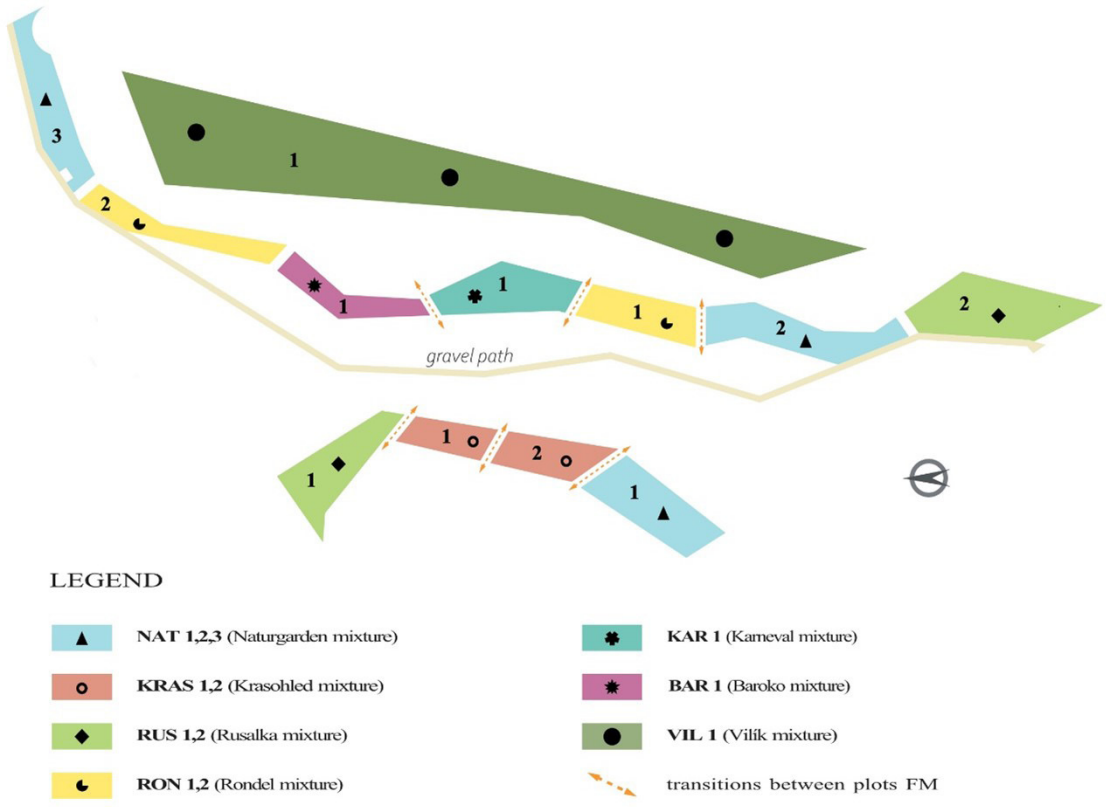


Fig. 3. Map of plots with sown seed mixtures.

Table 1. Maintenance management of FM plots in Nové Zámky during the vegetation period in 2021–2022.

Plots name	Year 2021			Year 2022		
	Mowing	Irrigation	Weed control	Mowing	Irrigation	Weed control
NAT 1	4 x	0 x	0 x	3 x	0 x	0 x
NAT 2	6 x	0 x	0 x	2 x	0 x	0 x
NAT 3	3 x	0 x	0 x	2 x	0 x	0 x
RUS 1	6 x	0 x	0 x	5 x	0 x	0 x
RUS 2	2 x	0 x	0 x	3 x	0 x	0 x
KRAS 1	1 x	0 x	0 x	1 x	0 x	0 x
KRAS2	1 x	0 x	0 x	1 x	0 x	0 x
BAR 1	1 x	0 x	0 x	1 x	0 x	0 x
KAR 1	1 x	1 x	0 x	1 x	0 x	0 x
RON 1	1 x	0 x	0 x	2 x	0 x	0 x
RON 2	0 x	0 x	0 x	1 x	0 x	0 x
VIL 1	1 x	1 x	0 x	3 x	0 x	0 x

- Rondel mixture: Plot RON 1 (400 m2), RON 2 (400 m2); highly impressive mixture with a higher proportion of annuals.
- Karneval mixture: Plot KAR 1 (530 m2); a visually attractive mixture already in the first year after establishment.
- Baroko mixture: Plot BAR 1 (330 m2); an attractive mixture suitable for use in parks and gardens.
- Vilik mixture: Plot VIL 1 (4300 m2); a productive mixture with no grass species present; a high proportion of legumes.

Management of FM maintenance

The germination period of plants is a critical phase for establishing annual seedings (the seed must not be allowed to dry out). Feunteun (2014), Kuťková et al. (2013), and Schmidt (2004) recommend irrigation during the emergence of species in artificially established meadows from direct sowings (during dry springs when natural precipitation is insufficient). The average amount of precipitation required for the growth of FMs is 25–30 mm per week (Greenlee, 2009). This step eliminates the occurrence of unwanted species and promotes density and coverage of the vegetation. Feunteun (2014) states that weeding of FM vegetation should be carried out 3–4 weeks after sowing. Appropriate mowing management is also important, not just irrigation. Russo and Steffan-Dewenter (2020) recommend mowing FM to a height of at least 25 cm using a scythe mower. Table 1 presents the maintenance management in the observed plots during the years 2021–2022. The maintenance management did not meet the conditions for healthy growth and development of FM.

Impact of climatic factors on FM development

Climatic factors such as air temperature, soil temperature, and precipitation influence seed germination and subsequent development of FM. The monitoring of climatic conditions was obtained from the Slovak Hydrometeorological Institute (SHMÚ) at the nearest meteorological station in Hurbanovo (SHMÚ, 2023), where daily data is recorded. Figures 4 and 5 depict the average monthly atmospheric precipitation and air temperature for each vegetation period from 2021 to 2022.

The aim of the research was to determine the factors influencing the development of artificially established wildflower meadows from commercial seed mixtures in an urbanized environment.

Analysis

Based on the field research conducted from May to August or October, one or two times per month in 2021 and 2022, we focused on monitoring the establishment and growth success of plant species categorized by the Czech company into plant type categories (G-grasses, P- perennials, A-annuals, L-legumes). The data were collected from four randomly selected squares with dimensions of 2×2 m. From these squares, the present plant species from the seeds were recorded into four categories: grasses, herbs, annuals, and legumes. Nominal measurement of species presence from the seed was used during data recording whether a particular species is present or absent. For a species to be recorded as "present," it had to be present in at least three out of the four squares. If it occurred in only two or fewer squares, it was recorded as "absent." Through nominal measurements, the percentage of development success for each category was determined over the course of 2 years.

Evaluation of FM development in relation to climatic factors and maintenance management

Considering the analytical data regarding the development of plant type categories and the maintenance management of FMs (specifically mowing, irrigation, and weed control), as well as atmospheric precipitation and air temperature in the respective months (SHMÚ, 2023), the impact of these factors on the development and existence of FMs was monitored directly at specific locations in the field.

Results

Through monitoring of four plant categories in the seed mixture (G- grasses, P- perennials, A- annuals, L- legumes), in which individual plant species were included by the Czech company (Fig.

2), we can determine the percentage of seeds that germinated reaching 100% quantity for each category present in the given mixture (Figs 4, 5). We do not include the Vilik mixture (VIL 1 plot) in the assessment. The seed did not germinate on the plot, and the plot was infested by ruderal weeds.

Analysis of plots with Naturgarden and Rusalka mixtures in 2021

By analyzing data from field research conducted in 2021, the following findings were obtained:

- NAT 1 plot (Naturgarden mixture).

In the months of May-October 2021
According to the research, the analysis of NAT 1 plot in May and June 2021 showed that the herb category was most prominent, decreasing from 42 to 38% in May and June, while grasses remained consistent at 81% in both months. Legumes maintained the same level of 16%, but perennials decreased from 42 to 38% in June and annuals decreased from 33 in May to 0% in June. In the summer month of July 2021, the most dominant categories on the NAT 1 plot were grasses (45%) and perennials (23%). Legumes accounted for 16%, while annuals were not present. In August, no research was conducted on the NAT 1 plot since no plant category from the seed mixture was observed on the site.

- NAT 2 plot (Naturgarden mixture).

In the months of May–October 2021
The research revealed that the dominant categories on the NAT 2 plot were legumes (83%) and grasses (81%) in May 2021. In June, legumes decreased to 33%, while perennials increased from 38 to 52%. There was no occurrence of annual flowers. In July, no categories from the seed mixture were present on the plot (Fig. 4).

- NAT 3 plot (Naturgarden mixture).

In the months of May–October 2021
The research revealed that the dominant categories on the NAT 3 plot in May 2021 were grasses (81%), legumes (66%), annual flowers (66%), and perennials (42%). From June to October 2021, none of these categories were present on the plot, and the research was not conducted further (Fig. 4).

- RUS 1 plot (Rusalka mixture).

In the months of May–October 2021
Based on the research, it can be observed that in May, June, and July 2021, the highest percentage of occurrence on the RUS 1 plot was represented by the legume category (100%), followed by grasses (86%) and perennials (20%). However, in August and subsequent months, none of the categories from the mixture were present on the plot. The plot's vegetation was not subjected to subsequent evaluation (Fig. 4).

- RUS 2 plot (Rusalka mixture).

This plot was not evaluated throughout the entire vegetation period as it ceased to exist at the beginning.

Evaluation of plots with Naturgarden and Rusalka mixtures in 2021

The evaluation of FM development in relation to the influence of climatic factors and maintenance management indicates that the growth of vegetation was negatively affected due to improperly executed mowing with more than five cuts during the vegetation period and a cutting height of only 5 cm. The low amount of precipitation during spring and summer months, with the highest average monthly value of 93.4 mm recorded in May and the lowest in June (with precipitation of 6 mm on June 12), had a negative impact on vegetation development following frequent mowing (Fig. 4). Drought conditions at the transition of the summer months June/July resulted in repetitive high daily temperatures exceeding 30 °C.

During the autumn months (September/October/November), the average monthly air temperatures dropped to around 11 °C. The highest precipitation was recorded in the second half of September, with 56.5 mm of rainfall. Despite the decrease in high temperatures, FM vegetation was unable to recover due to a persistent rainfall deficit. FM faced multiple stress factors that negatively affected plant growth and development. The meadows were not irrigated or cleared of debris, while the recommended amount of rainfall necessary for FM growth is 25–30 mm per week (such levels of rainfall were not achieved in any month of the vegetation period, as shown in Fig. 4). Grass species proved to be the most resilient, as they can adapt to drier conditions (Greenwood et al., 1994). Among the evaluated plots, NAT 1 showed the most favorable results, as it was assessed over the longest time (3 months). On the other hand, RUS 2 showed the least favorable results and was excluded from the evaluation.

Analysis of plots with Naturgarden and Rusalka Mixtures in 2022

The analysis of plots with Naturgarden and Rusalka mixtures in 2022 did not take place due to the disappearance of the plots in the previous vegetation period. Data collection was not possible.

Evaluation of plots with Naturgarden and Rusalka mixtures in 2022

The evaluation of FM plots in relation to the influence of climatic factors and maintenance management in 2022 revealed that the vegetation experienced a decline due to negative factors from the previous period. The effects of drought and frequent mowing weakened the vegetation and allowed the proliferation of undesirable plant species, which suppressed the original mixture species. Repeated extreme temperatures and drought in 2022 (Fig. 5) once again had a negative impact on plant growth and development, resulting in devastating consequences for the vegetation and its complete disappearance this year. The plot's vegetation was not subjected to subsequent evaluation.

Analysis of plots with Baroko, Karneval, Krasohled, and Rondel mixtures in 2021

By analyzing data from field research conducted in 2021, the following findings were revealed:

- BAR 1 plot (Baroko mixture).

In the months of May–October 2021

In May, there was a low representation of plant species and categories. In June, annual flowers (22%) and perennials (3%) were present, while other categories were not yet observed.

In July 2021, there was a change in the composition, with annual flowers increasing from 22% to 43%, grasses increasing to 37%, and perennials to 13%. Legumes were not observed. In August 2021, annual flowers had the highest percentage of occurrence on the site, reaching up to 70%, while perennials and grasses were present at over 50% (Fig. 4). Annuals continued to dominate in September and October 2021, accounting for 70% of the vegetation. Perennials and grasses remained at a similar level of around 50% throughout the year 2021.

- KAR 1 plot (Karneval mixture).

In the months of May, June, July, August, September, and October 2021

The research revealed that in May 2021, the highest percentage was represented by grasses (70%), followed by annuals (56%), while perennials and legumes accounted for approximately 33%. In June and July, the percentages increased for legumes, reaching 100%, and perennials, reaching 45%.

In August 2021, the highest occurrence was observed in the legume category (100%), followed by grasses (70%), annual flowers (68%), and perennials (45%). Similar levels of representation were achieved in September and October 2021 (Fig. 4).

- KRAS 1 plot (Krasohled mixture).

In the months of May–October 2021

The research showed that in May and June of 2021, the legume category (57%), followed by grasses (46%), perennials (37%), and annual flowers (26%), exhibited the highest percentages. In June, the percentage of annuals increased to 56%, while the other categories remained at the same level. In July, the percentage of annuals rose again to 67% (Fig. 4).

In August and September, the highest occurrence on the plot was observed in the annual flower category (67%), followed by legumes (57%), grasses (46%), and perennials (42%).

- KRAS 2 plot (Krasohled mixture).

In the months of May–October 2021

Based on the research, it can be observed that in May 2021, legumes (57%), followed by grasses (46%), perennials (39%), and annuals (37%), exhibited the highest percentage of occurrence. In June, the percentage of annuals increased to 63%, and in July, perennials reached 45% (Fig. 4).

In August and September 2021, the highest percentages of occurrence on the plot were recorded in the annuals category (67%), followed by legumes (57%), perennials (47%), and grasses (46%). In October 2021, none of these categories were present on the plot.

- RON 2 plot (Rondel mixture).

In the months of May–October 2021

The research showed that in May 2021, there was a low representation of species from the plant category types on the plot. In June 2021, the highest percentage of occurrence on the plot was observed in the annuals category (23%), followed by grasses (20%) and perennials (12%), with no legumes present in the mix. In July, the percentages of occurrence increased for annuals (62%), grasses (50%), and perennials (40%). In August 2021, the category of annuals showed the highest increase, reaching 81%, followed by perennials at 56% and grasses at 50%. In September and October, none of these categories were present on the plot (Fig. 4).

Evaluation of plots with Baroko, Karneval, Krasohled, and Rondel mixtures in 2021

The evaluation of FM development in relation to the influence of climatic factors and maintenance management revealed that the growth of vegetation was affected by low precipitation during the spring and summer months. The highest average monthly rainfall of 93.4 mm was recorded in May, while the lowest was recorded in June, with only 6 mm of rainfall recorded on June 12. This had a negative impact on the growth of vegetation. The recommended amount of rainfall necessary for optimal FM growth is between 25 and 30 mm per week. Drought conditions during the transition between the summer months of June and July resulted in recurring high daily temperatures exceeding 30 °C (Fig. 4). The coverage of FMs on all plots was not complete, as it was influenced by the amount of precipitation. For this type of vegetation, a monthly rainfall range of 25–75 mm is recommended (depending on the species composition), with rainfall evenly distributed rather than occurring in short and intense storms (American Meadows, 2023).

Within these plantations, a higher proportion of ruderal species was observed, which spread on the plots due to insufficient vegetation establishment. *Chenopodium album* L. and *Cirsium arvense* L. were particularly successful on the plots, indicating infertile soils. Both plants can thrive in various conditions, including poor soils and drier regions (Grime, 2006).

During the autumn months (September/October/November), the average monthly air temperatures dropped to around 11 °C. The highest precipitation was recorded in the second half of September (Fig. 4). The plots were not irrigated or cleared of weeds (Table 1). FMs were not mowed during the vegetation period. Stress factors such as inadequate rainfall, high air temperature, poor vegetation coverage, and lack of irrigation and weed control negatively influenced the growth and development of the vegetation.

Among the mentioned plots, KAR 1 performed the best, displaying intense flowering of various annual varieties and was evaluated for the longest period (6 months). On the other hand, despite abundant flowering, RON 1 was heavily infested with ruderal weeds.

Analysis of plots with Baroko, Karneval, Krasohled, and Rondel mixtures in 2022

By analyzing data from field research conducted in 2022, the following findings were obtained:

- BAR 1 plot (Baroko mixture).

In the months of May–August 2022

The research showed that on the BAR 1 plot in May and June

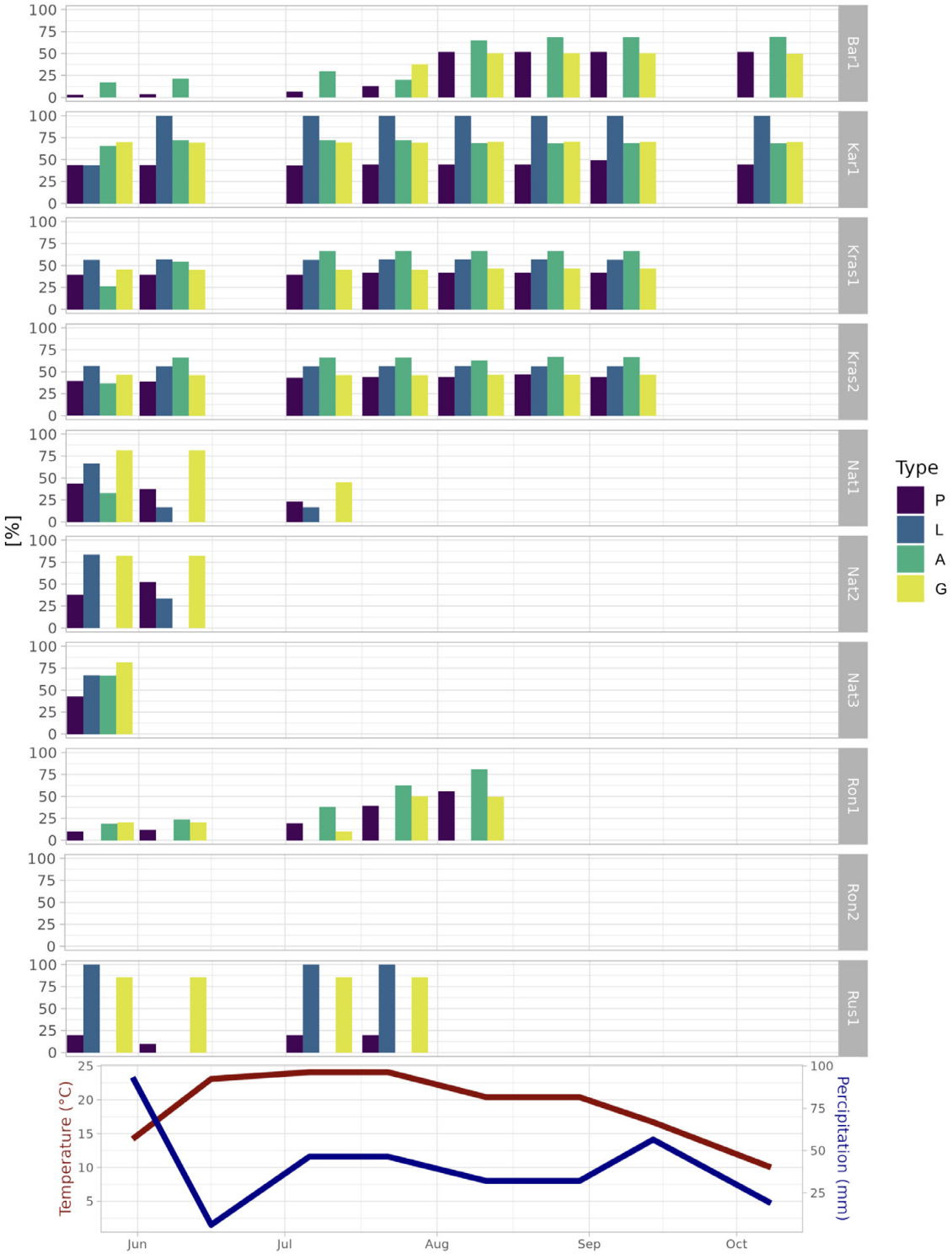


Fig. 4. The development of flower meadows during the vegetation period of 2021 and the influence of climatic factors on their growth.

2022, the category of grasses (50%), followed by perennials (39%) and annuals (17%) were the most dominant. The percentages of each category remained consistent throughout both months. However, in August 2022, none of these categories were observed on the plot (Fig. 5).

- KAR 1 plot (Karneval mixture).

In the months of May–August 2022
In May 2022, the grass category had the highest percentage of occurrence on the plot (70%), followed by legumes (66%), perennials (54%), and annuals (25%). In June, legumes increased to 100%, while grasses and perennials remained at approximately the same level and annuals increased to 43%. In July 2022, legumes reached the highest percentage of occurrence (100%), followed by grasses (70%), perennials (52%), and annuals (40%). Similarly, in August 2022 (Fig. 5), legumes had the highest percentage of occurrence (100%), followed by grasses (70%), perennials (52%), and annuals (40%). Due to vegetation withering and subsequent mowing, no research was conducted in September and October 2022.

- KRAS 1 plot (Krasohled mixture).

In the months of May–August 2022
The research showed that in May, June, and July of 2022, the legumes had the highest percentage of occurrence (71%), followed by grasses (53%), perennials (52%), and annuals (40%). In August 2022 (Fig. 5), the legumes still had the highest percentage of occurrence (71%), followed by grasses (53%), perennials (52%), and annuals (29%). Due to vegetation withering and subsequent mowing, no research was conducted in September and October 2022.

- KRAS 2 plot (Krasohled mixture).

In the months of May–August 2022
Based on the research findings, it can be concluded that in May, June, and July 2022 (Fig. 5), the categories of legumes (71%) and grasses (53%), followed by perennials (50%) and annuals (33%) exhibited the highest percentage of occurrence. In August, only annuals decreased to 25%. Due to vegetation withering and subsequent mowing, no research was conducted in September and October 2022.

- RON 1 plot (Rondel mixture).

In the months of May–August 2022
In May and June 2022 (approximately at the same level), the category of annual flowers exhibited the highest percentage of occurrence (62%), followed by annuals (60%) and grasses (50%), while legumes were not in the mix (Fig. 5). In July 2022, perennials increased to 56%, annuals decreased to 43%, and grasses remained unchanged. In August 2022, the category of perennials reached the highest percentage of occurrence (52%), followed by grasses (50%), and annuals decreased to 33%. Due to vegetation withering and subsequent mowing, no research was conducted in September and October 2022.

- RON 2 plot (Rondel mixture).

In the months of May–August 2022
In May, June, July, and August 2022 (Fig. 5), the category of perennials exhibited the highest percentage of occurrence (80%), followed by grasses (50%), while annuals accounted for only 14%. Legumes were not included in the mix. Due to vegetation withering and subsequent mowing, no research was conducted in September and October 2022.

Evaluation of plots with Baroko, Karneval, Krasohled, and Rondel mixtures in 2022

The evaluation of FM development in relation to the influence of climatic factors and maintenance management revealed that in 2022, the growth of vegetation was once again affected by low precipitation levels during the spring and summer months. In comparison to the previous year, the average monthly precipitation in April was 22.3 mm, whereas in 2021, it was 42 mm. In May, it was 32 mm, while in 2021, it was 93.4 mm. June 2022 had significantly higher rainfall, with a total precipitation of 78.7 mm during the month, compared to only one rainy day and 6 mm of precipitation in the previous year. However, the amount of rainfall was still insufficient for abundant growth and thriving of the vegetation.

During July and August, the intensity of precipitation remained low. The change occurred in September when the total precipitation reached 104.2 mm, nearly double the amount compared to 2021, when the monthly precipitation was 56.5 mm. High temperatures combined with insufficient rainfall resulted in weak development and growth of the vegetation. The recommended amount of precipitation necessary for optimal FM growth is 25–30 mm per week. Air temperatures in April and May were higher compared to the previous year in 2021. In the previous year, the average monthly temperature in April was 9 °C, whereas in 2022, it was 10 °C. In May 2021, the average monthly temperature was 14.2 °C, while in 2022, it rose to 18.2 °C. During the transition between the summer months of June and July, recurring high daily temperatures exceeding 30 °C caused drought. As a result, FM vegetation on all plots was not fully developed (Fig. 5).

In these vegetation areas, we observed a significantly higher proportion of invasive species that spread due to insufficient coverage of the vegetation. *Ch. album* L. and *Ci. arvense* L. thrived particularly well in the plots. FMs were not mowed during the vegetation period. Stress factors such as inadequate rainfall, high air temperature, poor vegetation coverage, and lack of irrigation and weed control, to which the vegetation was exposed during the vegetation period, negatively affected their growth and development. The vegetation dried up in August.

The BAR 1 plot consistently outperformed other plots, demonstrating robust floral growth and was the longest evaluated (4 months) during the vegetation period. Annuals such as *Zinnia elegans*, *Coreopsis tinctoria*, and other species were absent compared to the previous year, as their seeds did not survive the winter period. It is recommended to sow the seeds of these annuals in spring, when the soil temperature is stabilized without the risk of frost (Saarinen et al., 2011). Despite the initial prosperity, the BAR 1 plot gradually dried out due to inadequate rainfall, high air temperature, and lack of irrigation during the vegetation period, completely withering at the end of summer and autumn. Due to the high level of desiccation, all plots were mowed at the end of August, and further research was not conducted.

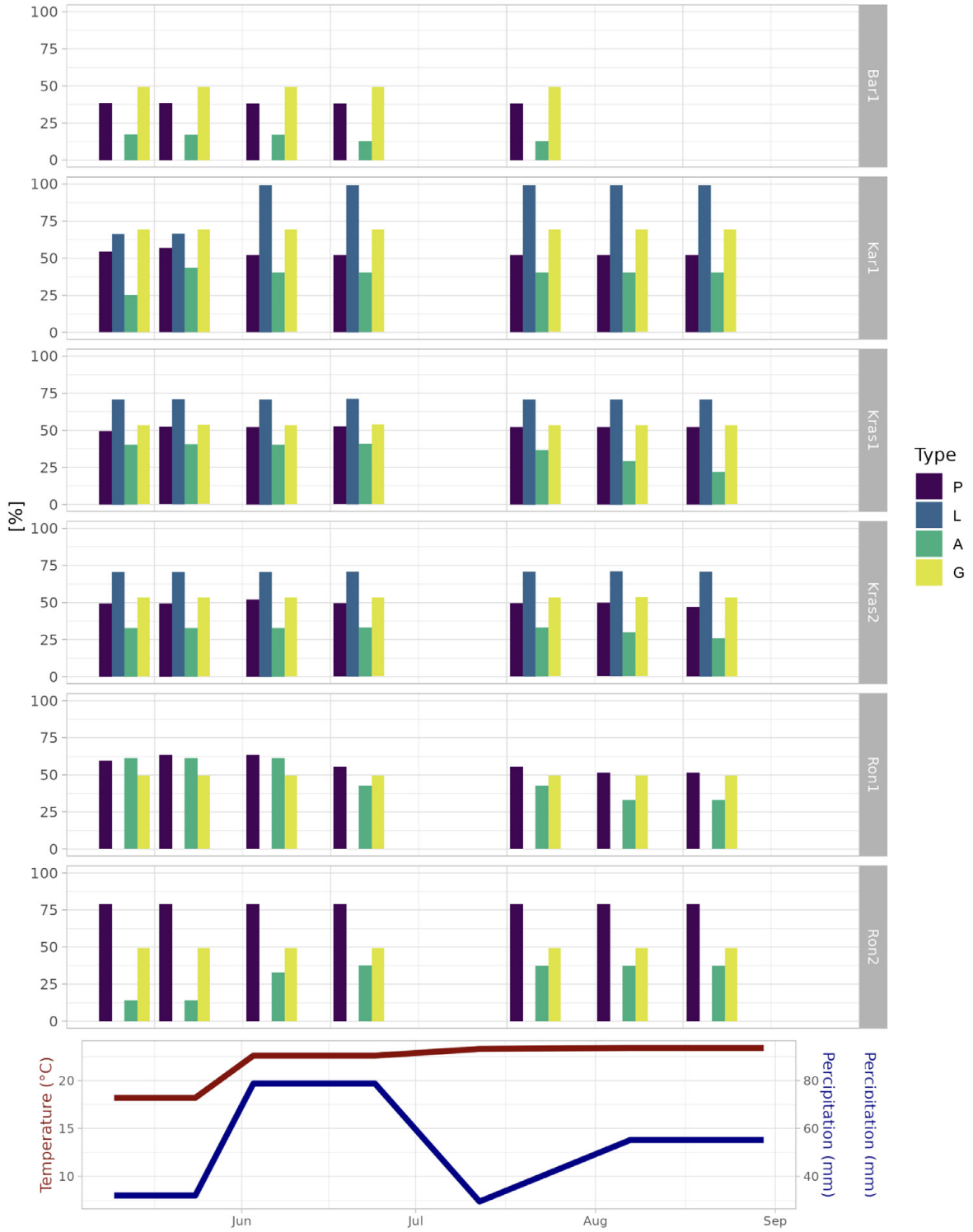


Fig. 5. The development of flower meadows during the vegetation period of 2022 and the influence of climatic factors on their growth.

Discussion

FMs in urbanized environments have important benefits for biodiversity conservation and ecological balance. Nowadays, when many cities are trying to improve the quality of life of their inhabitants, FMs represent an important means to achieve these goals. In addition to their esthetic benefits, FMs contribute to the conservation and enhancement of biodiversity in urban areas, which are often at a disadvantage compared to natural areas. They also help to improve air and soil quality in cities (Carreck, Williams, 1997).

FM vegetation creates conditions for the growth of a greater variety of plant species, which provide food for many insects and birds. As a result, they contribute to increasing biodiversity in urban areas where species numbers and abundance are often low. In addition, FMs can help to reduce the heat island in cities, thus contributing to the improvement of the microclimate (Pauleit et al., 2021; Keresztesová et al., 2014).

Improper management of mowing and irrigation of these meadows is a common problem in urban areas. Meadows are mowed to a low mowing height and several times during the growing season. This practice leads to a reduction in the number of flowers and, consequently, a decline in pollinators. Therefore, it is important to use maintenance management practices correctly in FMs to ensure their conservation and increase biodiversity (Pywell et al., 2002).

Our research showed that the plots of FMs NAT 1, NAT 2, NAT3, RUS 1, and RUS 2 have disappeared precisely due to failure to follow the correct mowing management practices. Excessive mowing has proven to be destructive to the vegetation cover of FMs, leading to a rapid decline in the total number of plant species and the subsequent loss of FM. This issue was also addressed by Russo and Steffan-Dewenter (2020), who stated that mowing FMs to a low cutting height and multiple times during the growing season is counterproductive for biodiversity conservation. Two mowings at a cutting height of at least 20 cm with a scythe mower are recommended. The approach provides higher numbers of flowering plants for pollinators, which are important for biodiversity conservation (Baldock et al., 2019; Pywell et al., 2011).

Fiedler et al. (2020) reported that proper management of mowing FMs significantly influences vegetation composition. The correct frequency and the correct intensity of mowing are essential for the maintenance and support of diverse plant species that form FM communities.

Another factor influencing the development of FMs is climate, including precipitation and air temperature. During the vegetation period in 2021 and 2022, insufficient rainfall and high atmospheric temperatures affected the growth of meadows. SHMÚ (2023) classified the conditions in these two years as extremely dry for our climatic zone. Globally, 2021 and 2022 were among the warmest years recorded in the history of climate and meteorology. Several regions also experienced extreme weather events, consistent with the scientific consensus that climate change increases the frequency and severity of such events (WMO & NOAA, 2023).

Our research confirms that plots where mowing was performed more than five times during the vegetation period, at a cutting height of 5 cm, resulted in the disappearance of FM vegetation.

Greenlee (2009) states that the average amount of rainfall required for the growth of FMs is 25–30 mm per week. In case of lower precipitation, the author recommends irrigation of these meadows to fulfill their functions and promote proper development. The lack of rainfall was evident even in the uncut plots of BAR 1, KAR 1, KRAS 1, KRAS 2, RON 1, and RON 2. The drought weakened the vegetation cover and created suitable conditions for the growth of ruderal plant species. The most successful ruderal species observed were *Chenopodium album* L. and *Cirsium arvense* L., present in all monitored areas.

In conclusion, FMs have significant contributions to biodiversity and ecological balance in urbanized environments. However, improper management of mowing and irrigation, as well as the influence of climate factors, can lead to a reduction in the number of flowers and subsequent decline of the vegetation cover. Proper maintenance management of FMs, including two mowings during the vegetation period at a cutting height of 20–30 cm, is crucial for their prosperity. With such management practices, FM communities become more resilient to adverse climate effects such as low rainfall and high air temperatures.

Conclusion

Based on the research conducted on the planted plots with Naturgarden and Rusalka seed mixtures in 2021, it is evident that the development of vegetation was negatively affected by inappropriate mowing practices and insufficient rainfall. Grasses were most abundant during the summer months on the NAT 1 plot, while legumes dominated in May on the NAT 2 plot and grasses prevailed on the NAT 3 plot. In the summer and autumn months, when the vegetation was completely mowed and dried, the plots were no longer evaluated. On the RUS 1 plot, legumes were most prevalent during the spring months. Grasses and perennials were absent during summer and autumn, resulting in disappearance of the vegetation. The RUS 2 plot became extinct early in the vegetation period. Therefore, it can be concluded that inadequate rainfall and improper maintenance management negatively impacted the development of vegetation on the research plots in 2021.

The analysis of the Baroko, Karneval, Krasohled, and Rondel mixtures revealed that annuals and grasses dominated on most of the plots throughout the vegetation period. Perennials and legumes were present in smaller quantities. Changes in plant composition were observed on all plots during the vegetation period, with the most significant changes occurring on the BAR 1 plot, where there was a substantial increase in the number of perennials and annuals in July and August. Despite abundant flowering of annual flowers, the RON 1 plot was infested with ruderal weeds.

In 2022, the research on the BAR 1, KAR 1, KRAS 1, KRAS 2, RON 1, and RON 2 plots showed that grasses were most prevalent in May on the BAR 1, KAR 1, and RON 1 plots. Legumes had the highest proportion on the KAR 1, KRAS 1, and KRAS 2 plots in June and July. Perennials were present on the KRAS 1, KRAS 2, and RON 1 plots in May and June. Annuals were present on all plots, with the highest percentage found on the KAR 1, KRAS 1, and KRAS 2 plots. The development of FM vegetation in 2022 was once again influenced by low rainfall during the spring

and summer months. Monthly rainfall totals were lower compared to the previous year, while air temperatures were higher. Insufficient rainfall and high temperatures created unfavorable conditions for the prosperity of vegetation, leading to poor vegetation cover and a high proportion of ruderal plants spreading across the plots. The combination of stressful factors such as low rainfall, high air temperatures, and inadequate maintenance management resulted in drying and extinction of the vegetation (which was not irrigated or weeded). Recommended amount of precipitation for the growth of wildflower meadows is 25–30 mm per week, but this level of rainfall was not achieved throughout the entire vegetation period. We recommend watering FMs, especially in the first weeks after sowing. The recommended mowing height is a minimum of 25 cm using a scythe mower, and it is important to follow this.

In conclusion, the growth of vegetation in the researched areas was adversely affected both in 2021 and 2022 due to insufficient rainfall, high atmospheric temperatures, and inadequate maintenance management practices (mowing, irrigation, weed control), which had a negative impact on the development of vegetation in the studied areas.

Acknowledgements

This work was supported by project VEGA 1/0706/20 Sustainable urban development in 21. Century – assessment of key factors, planning approaches, and environmental contexts.

References

Agrostis.cz. (2023). *Druhově pestré směsi*. https://www.agrostis.cz/katalog/druhove-pestre-smesi.

Akbari, H., Pomerantz, M. & Taha H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*, 70(3), 295–310. DOI: 10.1016/S0038-092X(00)00089-X.

American Meadows. (2023). *Wildflower Planting Guides*. https://www.americanmeadows.com/

Baldock, K.C.R., Goddard, M.A., Hicks, D.M., Kunin, W.E., Mitschunas, N., Morse, H., Osgathorpe, L.M., Potts, S.G., Robertson, K.M., Scott, A.V., Steniczenko, P.P.A., Stone, G.N., Vaugham, I.P. & Memmot J. (2019). A systems approach reveals urban pollinator hotspots and conservation opportunities. *Nature Ecology & Evolution*, 3(3), 363–373. DOI: 10.1038/s41559-018-0769-y.

Baldock, K.C., Goddard, M.A., Hicks, D.M., Kunin, W.E., Mitschunas, N., Osgathorpe, L. M. Stone, G. N. Robertson, K.M., Scott, A.V., Stone, G.N., Vaugham, I.P. & Memmot J. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proc. R. Soc. Biol. Sci. Ser. B*, 282(1803), 20142849. DOI: 10.1098/rspb.2014.2849.

Carreck, N.L. & Williams I.H. (1997). Observations on two urban flower meadows and their importance for bees (Hymenoptera: Apoidea). *Eur. J. Entomol.*, 94(2), 189–196.

Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F. & Salbitano F. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. *Landsc. Urban Plann.*, 134, 221–228. DOI: 10.1016/j.landurbplan.2014.10.022.

Dallimer, M., Irvine, K.N., Skinner, A.M., Davies, Z.G., Rouquette, J.R., Maltby, L.L., Warren, P.H., Armsworth, P.R. & Gaston K.J. (2012). Biodiversity and the feel-good factor: Understanding associations between self-reported human well-being and species richness. *BioScience*, 62(1), 47–55. DOI: 10.1525/bio.2012.62.1.9.

Davies, Z.G., Edmondson, J.L., Heinemeyer, A., Leake, J.R. & Gaston K.J. (2011). Mapping an urban ecosystem service: quantifying above-ground carbon storage at a city-wide scale. *J. Appl. Ecol.*, 48(5), 1125–1134. DOI: 10.1111/j.1365-2664.2011.02021.x.

Díaz, S., Fargione, J., Chapin III, F.S. & Tilman D. (2006). Biodiversity loss threatens human well-being. *PLoS Biology*, 4(8), e277. DOI: 10.1371/journal.pbio.0040277.

Duchamp, J.E. & Winston R.L. (2019). Using green roofs to reduce urban heat islands and improve water quality. *Environmental Science & Policy*, 100, 78–89.

Dunnett, N. & Hitchmough J. (2004). *The dynamic landscape: Design, ecology and management of naturalistic urban planting*. Taylor & Francis. DOI: 10.4324/9780203402870.

Feunteun, M. (2014). *Biologische Vielfalt im Herzen Ihrer Landschaftsgestaltung*. Tagungsband: Thüringer Garten- und Landschaftsbautag.

Fiedler, S., Monteiro, J.A., Hulvey, K.B., Standish, R.J., Perring, M.P. & Tietjen B. (2020). Restoration ecologists might not get what they want: Global change shifts trade-offs among ecosystem functions. *bioRxiv*. DOI: 10.1101/2020.12.21.423790.

Francis, R.A. (2010). *Urban wildlife habitats: a landscape perspective*. Cambridge University Press.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H. & Gaston K.J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, 3(4), 390–394. DOI: 10.1098/rsbl.2007.0149.

Godefroid, S. & Koedam N. (2007). Urban plant species patterns are highly driven by density and function of built-up areas. *Landsc. Ecol.*, 22(8), 1227–1239. DOI: 10.1007/s10980-007-9102-x.

Greenlee, J. (2009). *The American Meadow Garden: Creating a Natural Alternative to the Traditional Lawn*. Timber Press.

Greenwood, D.J., Zhang, K., Hilton, H.W. & Čatský J. (1994). The role of soil water in determining the growth of the grassland species Festuca rubra L. *Plant Soil*, 161(2), 215–227. DOI: 10.1007/BF00046464.

Grime, J.P. (2006). *Plant strategies, vegetation processes, and ecosystem properties*. John Wiley & Sons.James, P., Tzoulas, K., Adams, M.D., Barber, A., Box, J., Breuste, J., Elmqvist, T., Frith, M., Gordon, C.,

Greening, K.L., Handley, J., Haworth, S., Kazmierczak, A.E., Johnston, M., Korpela, K., Moretti, M., Niemelä, J., Pauleit, S., Roe, M.H., Sadler, J.P. & Thompson C.W. (2009). Towards an integrated understanding of green space in the European built environment. *Urban Forestry & Urban Greening,* 8(2), 65–75. DOI: 10.1016/j.ufug.2009.02.001.

Jeffries, D.L. & Memmott J. (2013). Floral resource availability and the pollinator community in a set-aside *Centaurium erythraea* population. *J. Insect Conserv.*, 17(6), 1165–1176.

Jorgensen, A. & Keenan R. (Eds.) (2011). *Urban Wildscapes*. Routledge. DOI: 10.4324/9780203807545.

Kabisch, N., Qureshi, S. & Haase D. (2015). Human-environment interactions in urban green spaces—A systematic review of contemporary issues and prospects for future research. *Environmental Impact Assessment Review*, 50, 25–34. DOI: 10.1016/j.eiar.2014.08.007.

Keresztesová, S., Klein, J. & Rózová Z. (2014). Evaluation of Microclimatic Data on Localities with Different Ratio of Vegetation in Urban Environment. *Ekológia (Bratislava)*, 33(4), 301–306. DOI: 10.2478/eko-2014-0028.

Kuťková, T., Klasová, K. & Feit O. (2013). Letničkové záhony z přímých výsevů ve veřejné zeleni města Strakonice - ověřování výsevní směsi a technologií zakládání. *Zahrada-park-krajina*, 23(speciální číslo), 66–72.

Lerman, S.B. & Warren P.S. (2011). The conservation value of residential yards: linking birds and people. *Ecol. Appl.*, 21(4), 1327–1339. DOI: 10.1890/10-0423.1.

Lovell, S.T. (2010). Multifunctional urban agriculture for sustainable land use planning in the United States. *Sustainability*, 2(8), 2499–2522. DOI: 10.3390/su2082499.

Lu, J.W. & Li C.H. (2015). Promoting urban biodiversity and improving urban ecosystem through creating wildflower meadows in Taiwan. *Ecological Engineering*, 75, 121–129.

McPhearson, T., Andersson, E., Elmqvist, T. & Frantzeskaki N. (2016). Resilience of and through urban ecosystem services. *Ecosystem Services*, 17, 1–3. DOI: 10.1016/j.ecoser.2014.07.012.

Pauleit, S., Sauerwein, M. & Breuste J. (2021). Urbanisation and its Challenges for Ecological Urban Development. In Urban Ecosystems (pp. 1–15). Berlin, Heidelberg: Springer. DOI: 10.1007/978-3-662-63279-6_1.

Pywell, R.F., Bullock, J.M., Hopkins, A., Walker, K.J. & Sparks T.H. (2002). Improving the management of grasslands for flower-visiting insects. *J. Appl. Ecol.*, 39(2), 321–337. DOI: 10.1046/j.1365-2664.2002.00706.x.

Pywell, R.F., Meek, W.R., Loxton, R.G., Nowakowski, M., Carvell, C. & Woodcock B.A. (2011). Ecological restoration on farmland can drive beneficial functional responses in plant and invertebrate communities. *Agric. Ecosyst. Environ.*, 140(1–2), 62–67. DOI: 10.1016/j.agee.2010.11.012.

Rudd, H., Vala, J. & Schaefer V. (2002). Importance of backyard habitat in a comprehensive biodiversity conservation strategy: a connectivity analysis of urban green spaces. *Restor. Ecol.*, 10(2), 368–375. DOI: 10.1046/j.1526-100X.2002.02041.x.

Russo, L. & Steffan-Dewenter I. (2020). Wild bee pollen preferences and wildflower planting for enhancing wild bees and ecosystem services in agricultural landscapes. *Insects,* 11(4), 226.

Saarinen, T., Lundell, R., Åström, H. & Hänninen H. (2011). Parental overwintering history affects the responses of Thlaspi arvense to warming winters in the North. Environmental and Experimental Botany, 72(3), 409–414. DOI: 10.1016/j.envexpbot.2011.02.012

Schmidt, C. (2004). Amerikanische Annuelenwiesen. *Gartenpraxis*, 30(4). SHMÚ (2023). Klimatické zmeny na Slovensku. https://www.shmu.sk/sk/?page=1613.

Tallis, M., Taylor, G., Sinnett, D. & Freer-Smith P. (2011). Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning*, 103(2), 129–138. DOI: 10.1016/j.landurbplan.2011.07.003.

White, M.P., Alcock, I., Grellier, J., Wheeler, B.W., Hartig, T., Warber, S.L., Bone, A., Depledge, M.H. & Fleming L.E. (2019). Spending at least 120 minutes a week in nature is associated with good health and wellbeing. *Scientific Reports*, 9, 7730. DOI: 10.1038/s41598-019-44097-3.

Williams, K.J., Joye, Y. & O'Brien L. (2014). *Biodiversity planning and design: Sustainable practices*. Routledge.

WMO & NOAA (2023). *State of the Climate: Global Analysis - Annual 2022.* National Oceanic and Atmospheric Administration. https://www.ncdc.noaa.gov/sotc/global/202213

Wu, J. (2014). Urban ecology and sustainability: the state-of-the-science and future directions. *Landsc. Urban Plann.*, 125, 209–221. DOI: 10.1016/j.landurbplan.2014.01.018.