Grassing of Zone I in the Moravian Karst Protected Landscape Area

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The Moravský kras/Moravian Karst (central Moravia) is the most important karst area in the Czech Republic. In addition to underground karst phenomena, we can also find surface aboveground karst phenomena there, which include sinkholes and limestone pavements. All these karst phenomena are legally protected. The uniqueness of the area is also confirmed by the only internationally protected underground wetland in the Czech Republic, which is the Podzemní Punkva/Punkva Subterranean Stream Wetland of International Importance (Ramsar Site). The karst environment needs our protection, not only below the surface but also at ground level, from where nitrates and pesticides from intensively managed karst plateaus enter the underground areas. These substances pollute groundwater, which is used as a source of drinking water and harbours a lot of animals. Changes in management around the sinkholes and above the caves implemented in 2019 and 2020, resulted not only in positive shifts in the agricultural landscape, but they also significantly contributed to improving the quality of drip water that seeps down to the caves through the soil and rocks.

New declaration of the Moravský kras/Moravian Karst Protected Landscape Area

In April 2019, the Moravský kras/Moravian Karst Protected Landscape Area (PLA) was declared by Government of the Czech Republic Decree No. 83/2019 Gazette, making it the youngest PLA in the Czech Republic. In addition to the change in borders and new, more specified protective conditions, delimitation of nature protection zones also changed (Decree of the Ministry of the Environment of the Czech Republic No. 84/2019 Gazette). Protection zone I was delimited above the caves (100 m on each side) and around the sinkholes (30 m from a sinkhole edge). According to the Czech Geological Survey, the protection zone should prevent topsoil runoff from fields into sinkholes and seepage or soak of fertilizers and pesticides into caves. Historically, karst plateaus were farmed because there was flat terrain, unlike the steep cliffs and karst valleys. Karst plateaus are characterized by the occurrence of sinkholes, which used to be ploughed up to the edge and thus there was erosion into sinkholes. There are caves in some sinkholes, and topsoil containing fertilizers and pesticides went straight into the caves.

Figure 1 The area sown with alfalfa/lucerne grass mixture on the Harbeš Plateau. © Stanislav Koukal

Communication with farmers

Negotiations with farmers regarding the grassing of arable land in zone I began in 2017, when the Ministry of the Environment of the Czech Republic introduced the intention of a new declaration of the Moravský kras/Moravian Karst PLA to representatives of municipalities, affected large agricultural enterprises, and forest enterprises. During 2017 and 2018, a number of negotiations about the zoning proposal took place with farmers. Each farmer who had newly proposed arable land in zones I and II received a list of affected land parcels and map data. In addition to meetings with individual farmers, meetings and seminars were also held on the issue. Farmers did not submit any comments on the zoning proposal. After the declaration of the Moravský kras/Moravian Karst PLA, specific

steps leading to grassing were discussed, such as a geodetic survey of zone I, marking with stakes, composition of grass mixtures, and dates for grassing. In order to enable a gradual change of management in zones I and II, it was also agreed to submit applications for an exemption from Act 114/1992 Gazette on Nature Conservation and Landscape Protection, as amended later, for intensive farming and the application of fertilizers and biocides.

The change in management in zones I and II affected four large agricultural holdings and eleven private farmers. In the smaller zone II, it is a matter of excluding some pesticides with a long half-life (increased penetration into groundwater). For restrictions due to nature conservation (long-term exclusion of arable land from production), farmers are entitled to compensation for losses, which is determined by expert opinion.

Grassing Zone I

A total of 114 hectares of arable land was grassed. 11 hectares were grassed with Bromion subnational/regional grass mixture, sowing 20 kg/ha (90% grass, 16 species; 5% clover, 16 species; 5% herbs, 53 species), 64 ha with Živa species-enriched grass mixture, sowing 30 kg/ha (95% grasses, 10 species; 5% clover, 6 species), and 39 ha with alfalfa/lucerne grass mixture (70% alfalfa/lucerne; 30% grass, 3 species). The Nature Conservation Agency of the Czech Republic (NCA CR) contributed to the purchase of a regional and species-enriched grass mixture from the Landscape Management Programme. From the interim results of the NCA CR study entitled Monitoring of above-ground and soil biota of karst plateau grasslands in selected areas of Zones I and II of the Moravský kras/Moravian Karst PLA (implemented by Zemědělský výzkum, s.r.o/Agricultural Research Ltd. Troubsko, in cooperation with the Institute of Soil Biology of the Academy of Sciences of the Czech Republic České Budějovice, the Mendel University Brno, and the Masaryk University Brno), it is obvious that the areas with a species-enriched grass mixture sown in the spring were significantly weedy; after mowing, the weed species receded, and in the autumn the vegetation was already stratified. A total of 13 of the 16 sown species grew. The regional mixture showed slower vegetation development. Of the species sown, significantly fewer species germinated than in areas sown with a species-enriched mixture. A total of 7 species grew from the mixture. The reason is a high proportion of species with dormant seeds. Several rare and endangered plant species also appeared among flowering plants, such as the Night-flowering catchfly (*Silene noctiflora*), Field madder (*Sherardia arvensis*), Small bugloss (*Lycopsis arvensis*), Cut-leaved crane's bill (*Geranium dissectum*), and the Scarlet pimpernel (*Anagallis arvensis*).

Figure 2 Land surveying of Zone I by staff of the State Land Office. © Leoš Štefka

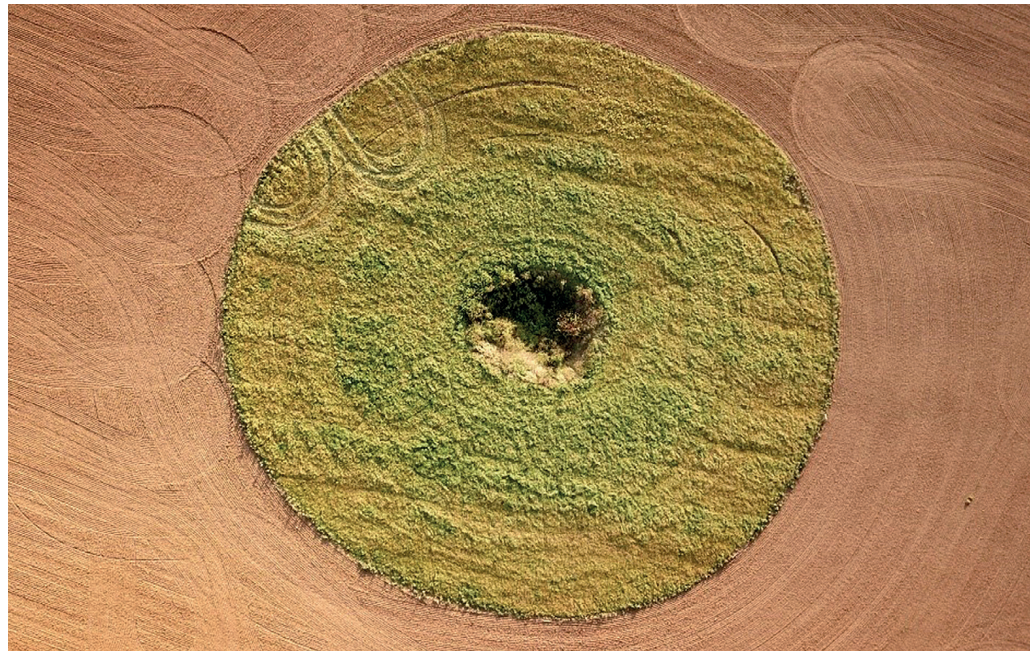

Figure 3 Grassed zone I around the sinkhole. © Stanislav Koukal

TACR TH03030178 project

Thanks to cooperation with the Research Institute of Plant Production, Public Research Institution, and ALS Czech Republic Certified Laboratories Ltd., within the TACR project "New methods of risk assessment of plant protection products against non-target organisms: Evaluation of xenobiotic soil load on organisms", the necessary information was obtained on soil pollution, active streams and, in particular, drip water in the Amatérská jeskyně/Amateurs Cave and the Harbeš Cave. This information significantly helped in negotiating with farmers and convincing the public about the importance of grassing zone I above the caves and around the sinkholes. This is a four-year project, which was launched in 2018. For three years now, monthly

Figure 4 Grassing the sinkhole at the municipality of Šošůvka in autumn 2019 and its state in summer 2020. © Leoš Štefka

sampling and analysis of soil and water samples for nitrate and pesticide concentrations has been underway in the north of the Moravský kras/Moravian Karst, where there was a change in management on karst plateaus. The obtained results will be further processed into a certified map of pesticide occurrence and will also serve as a model for the correct demarcation of the protection zone. The general objective of the project is to incorporate current approaches into the principles for evaluation and authorization of plant protection products.

Nitrate concentrations in the Amatérská jeskyně/Amateurs Cave have been around 115 mg/l on average since 2018, thus doubling the limit for drinking water. The highest nitrate concentration measured was in September 2018, when it reached 171 mg/l. The results of drip water analyses in the Harbeš Cave (under the Společňák Sinkhole) show high pollution, especially with nitrogenous substances and pesticides, nitrate concentrations average having been 140 mg/l. The highest nitrate concentration measured in the Harbeš Cave was in October 2019, when it reached 210 mg/l. The reduction of nitrogenous substances in drip water after the change of management has not yet had a significant effect. However, the measurement results show that nitrate concentrations in drip water under permanent grassland meet the public health limit for drinking water (50 mg/l). We expect that in 2021 there was also a gradual reduction of nitrate concentration under the newly grassed arable land as a result of reduction of agricultural activity in the area. Three-year monitoring of nitrates in drip water is shown in Fig. 1.

An important part of the TACR TH03030178 project is monitoring pesticides in the selected areas of Moravský kras/Moravian Karst PLA zones I and II, and monitoring the transfer of these substances from soil to drip water. The most significant pesticides found in the Harbeš Cave, which we encountered throughout the whole sampling period (2018–2020), mainly include triazine pesticides and their metabolites, chloridazon and its metabolites, chloroacetanilide pesticides and their metabolites, and azole pesticides and their common metabolite 1,2,4-triazole. The presence of the original active substances terbuthylazine, atrazine, metazachlor, epoxiconazole and others is no exception in this limestone area. Monitoring pesticides in drip water in the Harbeš Cave is shown in Fig. 2.

The levels of pesticides in drip water under arable land regularly exceeded the permitted limit for groundwater (0.5 µg/L). Concentrations of some individual pesticides and their metabolites exceeded the permitted limits several times. The “average” arable land sample in 2018 and 2019 contained 27 and for drip water 29 detectable pesticides and their metabolites. The change in management was significantly reflected in the reduction of concentrations of some pesticides and their metabolites. In the Harbeš Cave in 2020, there was a significant decrease in the total amount of pesticides measured and the absence of certain groups of pesticides, *e.g.* azole and amide pesticides, was also found there. Above all, there was a significant decrease in triazine pesticides and chloridazon metabolites. In the Amatérská jeskyně/Amateurs Cave, the total decreased to the 0.5 µg/L limit level. The pesticide totals in drip water in the Harbeš Cave and the Amatérská jeskyně/Amateurs Cave are shown in Fig. 3.

Figure 5 Grassing with a sub-national/regional and species-enriched grass mixture above the Amatérská jeskyně/Amateurs Cave. © Stanislav Koukal

Beneficial solution

Grassing above the caves and around the sinkholes has contributed not only to the protection of the karst underground and water from pollution, but also to differentiation in the agricultural landscape. Green islands on arable land

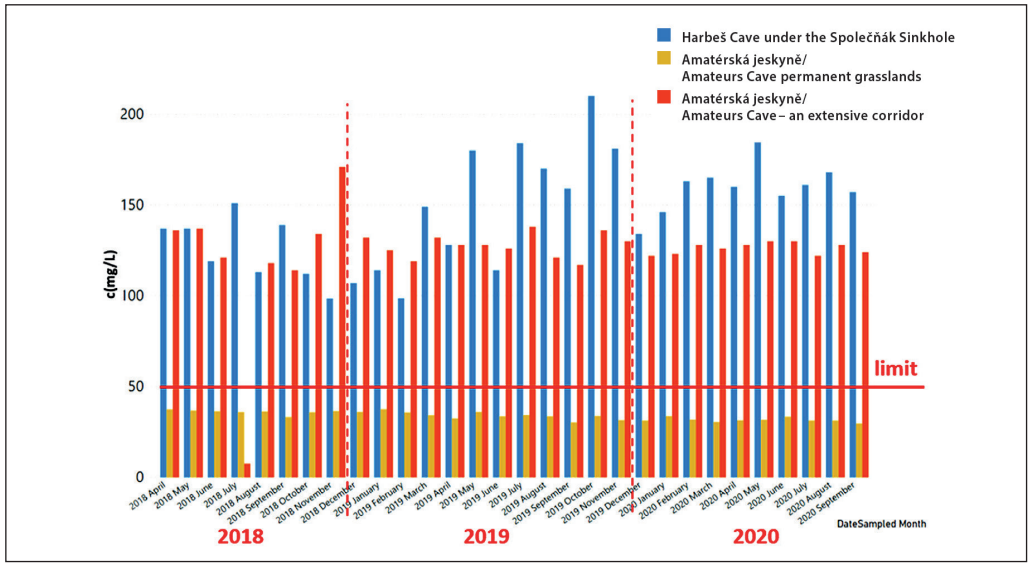

Figure 6 Monitoring nitrates in drip water in the Harbeš Cave and the Amaterská jeskyně/Amateurs Cave in 2018–2020. © Taťána Halešová

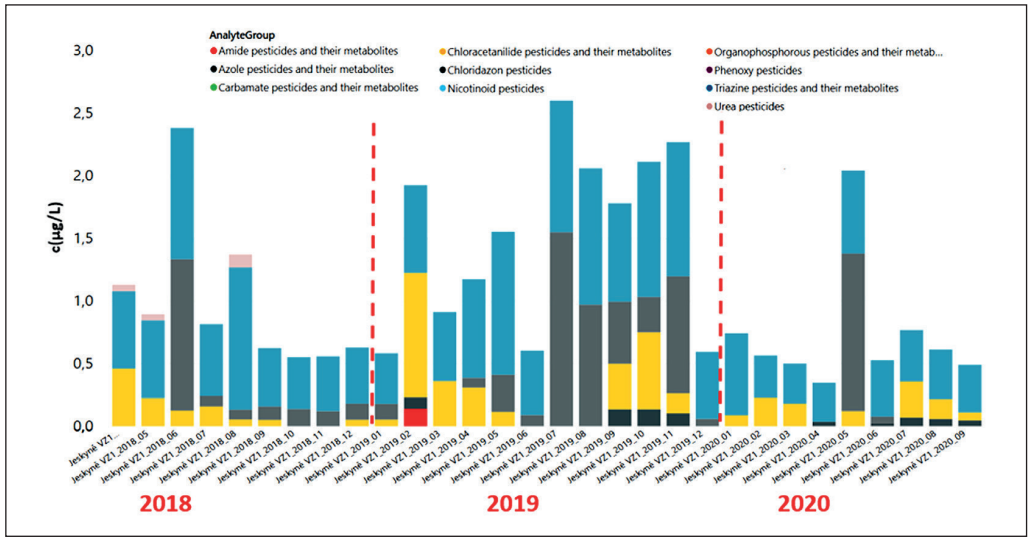

Figure 7 Monitoring pesticides in drip water in the Harbeš Cave in 2018–2020. © Taťána Halešová

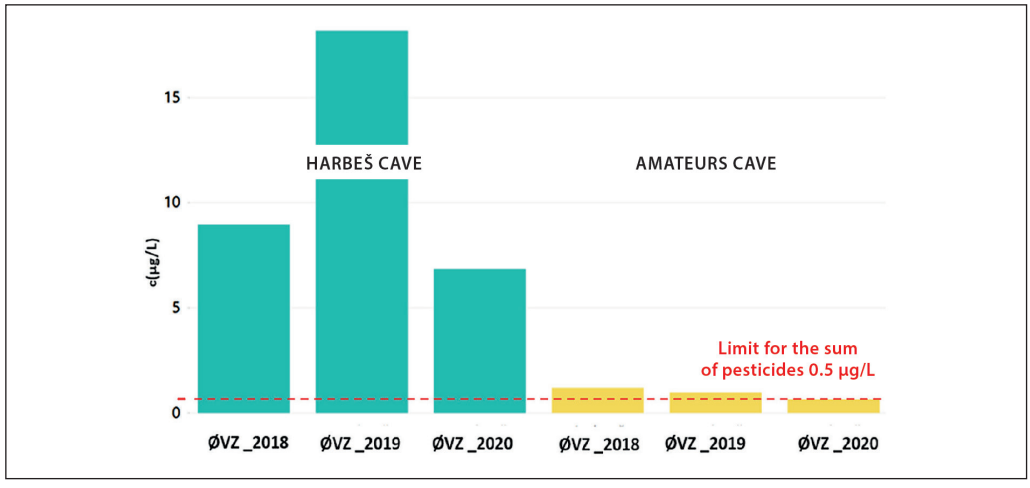

Figure 8 Average of the sum of pesticides in drip water (the Harbeš Cave and Amatérská jeskyně/Amateurs Cave) below arable land in 2018–2020. © Taťána Halešová

Figure 9 Collection of drip water in the Harbeš Cave. © Marie Kotyzová

have thus become home to many animals and various species of plants, including rare and endangered weed plants which have been irretrievably disappearing from farmland. We will gradually learn about the positive changes caused by grassing not only from the TACR TH03030178 project, but also from the four-year NCA CR study (popfk-043/73/20) "Monitoring of above-ground and soil biota of grasslands of karst plateaus in the selected areas of Moravský kras/Moravian Karst PLA zones I and II".

Acknowledgements

Grassing of zone I of the Moravský kras/Moravian Karst PLA would not be possible without the great cooperation from farmers in the Moravský kras/Moravian Karst PLA, support from colleagues at the Moravský kras/Moravian Karst PLA Administration, NCA CR South Moravia Regional Office and NCA CR's Headquarters, cooperation with the Moravský kras/Moravian Karst PLA rangers, Bílé Karpaty/White Carpathians Mts. PLA Administration, Institute of Plant Production, Public Research Institution, ALS Czech Republic Certified Laboratories Ltd., State Land Office in Blansko, Central Institute for Supervising and Testing in Agriculture Brno, State Agricultural Intervention Fund Blansko, Agrostis trávníky/Lawns Ltd., and all the others who have helped us to implement this great change in the agricultural landscape within the Landscape Protection Programme. ■