EVALUATION OF VEGETATION ON LANDS WITH PHOTOVOLTAIC POWER PLANTS

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Abstract: The aim of this paper is to evaluate species structure of weeds on lands with photovoltaic power plant in Moravsky Krumlov. The observation was carried out on twelve test spots also under photovoltaic panels and between them. Vegetation was evaluated via phytocoenology relevé. The evaluation took three months (July, August, September) in 2013. The observation was statistically evaluated using DCA and CCA analysis. A total of 66 weed species were found on land with photovoltaic power plant. The largest coverage was noticed by species *Poa pratensis* L., *Lolium perenne* L., *Achillea millefolium* L. The most common specie between rows were: *Plantago major* L., *Achillea millefolium* L., *Cerastium holosteoides* Fr. The most occurring weed species under panels were: *Poa pratensis* L., *Lolium perenne* L., *Festuca rubra* L., *Agrostis capillaris* L., *Bromus tectorum* L.

Key Words: weeds, photovoltaic power plant, phytocoenology relevé

INTRODUCTION

A total radiant power of 180 000 TW reaches the earth's surface illuminated by the Sun. The power consumption of our entire civilization is only about 10 TW. A total offer of solar energy is more than sufficient and give the opportunity to replace all other sources (Murtinger et al. 2007).

A total of 87.6 TWh electricity was produced in the Czech Republic in 2012. The largest portion, namely 54% produced through coal power plants, 34.6% of the electricity have supplied nuclear power plants. Energy obtained from renewable sources is 9% (Energy Regulatory Authority 2014). Among the unique benefits of obtaining energy from the Sun is the fact that the Sun is an inexhaustible source of energy. Relatively low operating costs, easy operation, saving fossil fuels, nature is not polluted by emissions of SO_2, CO_2, NO_x and dust, long life solar cells, which is guaranteed for 15–20 years. Over this period efficiency of the device decreases, but the function can last up to 50 years (Information portal about solar energy 2014).

Turney and Fthenakis (2011) states that the obtaining of solar energy is environmentally more favorable than the traditional method, also with regard to land use and wildlife protection. Photovoltaic power plants are environment-friendly in all material aspects, negative effects are from an environmental perspective negligible. Less land per kWh is used in gaining energy from the Sun than from coal. According Tsoutsos et al. (2005), solar energy technology represents a tremendous environmental benefits compared to conventional energy sources. In addition, the energy from the Sun belongs to renewable natural resources. A major advantage is almost total absence of any emissions into the air and waste products. In other words, solar energy is considered to be almost totally clean and safe energy source. Significant fluctuations in radiation and diversity of intensity are a disadvantage of solar energy in particular areas, then there are high initial costs, devices operate only during the day, a large area is needed for the application of solar panels (Renewable energy sources 2014). Plant communities are formed on such a surface.

Plant community is a plant complex formed as a co-existence of species populations in a specific environment. In phytocoenology the choice of species and their populations is determined by the terms of the environment (Neuhäuslová-Novotná, Guth-Jarkovská 1980). According to Moravec (1994), the species composition of the community means both, qualitative species spectrum and quantitative representation of their populations. The number of species of a certain size, that are on the surface, provides basic information about species richness that depend on habitat conditions.

The aim of the study was to evaluate the composition of the vegetation growing on lands with photovoltaic power plants and assess selected environmental factors influencing vegetation.

MATERIAL AND METHODS

Characteristics of the area

Monitored vegetation is placed on land with photovoltaic power plant in Moravsky Krumlov. This city is located in the district of Znojmo in the South Moravia region and is situated between the Bohemian-Moravian Highlands and the Dyje-Svratka ravine. Black soils dominate near the Moravsky Krumlov area (Culek 1996).

This area belongs to the drier places of our country. We classify it into the warm climate T2, which is characterized by long, warm and dry summers, very short period of transition, warm spring and autumn, a short, warm and dry winter with very short duration of snow cover. The area of interest is situated at an altitude of 323–340 m.

There used to be a waste dump on most of the area, currently there is a photovoltaic power plant. This landfill has been successfully recultivated at the end of 2005. Part of the area was arable land and the rest was infertile land. Moravsky Krumlov city sold part of the lands to the SKI-TURIST-SPORT company in 2009. This company began with the construction of photovoltaic power plant and end in late 2009. This is a unique solar photovoltaic power plant, which in addition to traditional fixed panels uses an automatic rotating stands with a polar axis tracking of the Sun. Both-sided bifacial solar panels able to produce electricity with rear side of the solar panel was used to increase efficiency.

Methodology of evaluation of weed infestation and statistical processing

A number of 12 phytocoenological relevé were formed in June 2013. Each within an area of 9 m^2. Relevé 1 and 2 were located at the habitat, which was earlier arable land. Other relevé were located at habitat which was earlier barren land. Farmland classification of land parcels of both habitats is 23716. The evaluation was recorded in three terms (July, August, and September) in 2013. Coverage of each species was estimated in percentage. Czech and Latin names of each weed species were used according to Kubát (2002).

The obtained data were processed by multivariate analysis of ecological data segment analysis DCA (Detrended Correspondence Analysis) and canonical correspondence analysis CCA (Canonical Correspondence Analysis). A total number of 499 permutations were calculated in Monte-Carlo test. Collected data were processed by a computer program called Canoco 4.0 (Ter Braak 1998).

RESULTS AND DISCUSSION

A total of 66 plant species were identified on land of photovoltaic power plant. The average coverage of found species is shown in Table 1.

The obtained data about frequency and coverage of individual species were initially processed by the DCA analysis which determined the length of the gradient, and it was 4.089. Based on this calculation was for further processing selected canonical correspondence analysis CCA. Analysis CCA defines the spatial arrangement of plant species and selected environmental factors. This is subsequently graphically expressed by the ordination diagram. Weed species and different habitats are shown by points of different shape and color.

Influence of the original habitat on the frequency of species occurrence and coverage was according to the CCA analysis significant at the significance level $\alpha = 0.002$ for all canonical axes. The results are statistically highly significant. According to the ordination diagram (Figure 1) plant species can be divided into several groups.

The first group of species occurred more frequently on site, which was originally arable land: *Agrostis capillaris, Achillea millefolium, Amaranthus retroflexus, Apera spica-venti , Arrhenatherum elatius, Artemisia absinthium, Artemisia vulgaris, Bromus hordeaceus, Bromus tectorum, Capsella bursa-pastoris, Carduus acanthoides, Cichorium intybus, Convolvulus arvensis, Conyza canadensis,* *Dactylis glomerata, Descurainia sophia, Echium vulgare, Festuca rubra, Geranium pratense, Geranium robertianum, Hordeum murinum, Chenopodium album, Lamium purpureum, Logfia arvensis, Lolium perenne, Lotus corniculatus, Medicago lupulina, Phragmites australis, Plantago lanceolata, Plantago major, Poa pratensis, Polygonum aviculare, Potentilla reptans, Rumex acetosella, Rumex crispus, Silene vulgaris, Stellaria media, Symphytum officinale, Taraxacum officinale, Trifolium arvense, Trifolium pratense, Trifolium repens, Tripleurospermum inodorum, Urtica dioica, Vicia cracca* and *Viola arvensis.*

Table 1 Average coverage of identified weed species

Species	Abbreviations	The initial land use	
		Arable land	Others
Agrostis capillaris	*Agr capi*		3.70
Achillea millefolium	*Ach mill*	3.11	8.00
Amaranthus retroflexus	*Ama retro*		0.44
Anagallis arvensis	*Ana arve*	1.33	
Apera spica-venti	*Ape spic*	23.44	0.67
Arenaria serpyllifolia	*Are serp*	1.22	
Arrhenatherum elatius	*Arr elat*	3.22	0.37
Artemisia absinthium	*Art absi*	0.67	0.11
Artemisia vulgaris	*Art vulg*		1.85
Atriplex patula	*Atr patu*	0.33	
Berteroa incana	*Ber inca*	1.00	
Bromus hordeaceus	*Bro hord*		1.63
Bromus sterilis	*Bro ster*		5.19
Bromus tectorum	*Bro tect*	2.56	3.56
Calamagrostis epigejos	*Cal epig*	0.67	
Capsella bursa-pastoris	*Cap burs*	1.11	0.52
Carduus acanthoides	*Car acan*	2.33	1.89
Cerastium holosteoides	*Cer holo*	15.00	
Cerasus avium	*Cer aviu*		0.07
Cichorium intybus	*Cic inty*		0.63
Convolvulus arvensis	*Con arve*		0.70
Conyza canadensis	*Con cana*	0.78	1.30
Dactylis glomerata	*Dac glom*	1.00	2.15
Descurainia sophia	*Des soph*		0.33
Echium vulgare	*Ech vulg*		0.59
Elytrigia repens	*Ely repe*		1.11
Festuca rubra	*Fes rubr*	1.22	4.56
Geranium pratense	*Ger prat*		0.37
Geranium robertianum	*Ger robe*	1.67	0.22
Geum urbanum	*Geu urba*	0.33	
Hordeum murinum	*Hor muri*	2.22	1.04
Chenopodium album	*Che albu*		0.11
Inula conyzae	*Inu cony*	2.22	
Inula helenium	*Inu hele*	0.33	
Lamium purpureum	*Lam purp*	0.33	0.26
Logfia arvensis	*Log arve*	6.67	1.67
Lolium perenne	*Lol pere*	1.56	15.48
Lotus corniculatus	*Lot corn*		0.33

Malva neglecta	*Mal negl*	1.11	0.67
Medicago lupulina	*Med lupu*	5.11	0.93
Melilotus officinalis	*Mel offi*	0.33	
Papaver rhoeas	*Pap rhoe*	0.67	
Phragmites australis	*Phr aust*		0.63
Picris hieracioides	*Pic hier*	0.67	
Plantago lanceolata	*Pla lanc*	0.78	0.85
Plantago major	*Pla majo*	0.33	0.19
Poa pratensis	*Poa prat*	16.67	25.81
Poa trivialis	*Poa trivi*	2.00	
Polygonum aviculare	*Pol avic*	1.00	0.63
Polygonum convolvulus	*Pol conv*	0.44	
Potentilla reptans	*Pot rept*	0.56	3.26
Rumex acetosella	*Rum acet*		0.15
Rumex crispus	*Rum cris*	0.78	2.67
Silene vulgaris	*Sil vulg*		0.52
Stellaria media	*Ste medi*	0.33	0.26
Symphytum officinale	*Sym offic*		1.89
Taraxacum officinale	*Tar offi*	7.89	3.33
Trifolium arvense	*Tri arve*	0.33	0.33
Trifolium pratense	*Tri prat*	0.44	0.11
Trifolium repens	*Tri repe*	10.67	1.19
Tripleurospermum inodorum	*Tri inod*	3.56	0.56
Urtica dioica	*Urt dioi*		0.74
Verbascum densiflorum	*Ver dnes*		1.67
Veronica persica	*Ver pers*	1.33	
Vicia cracca	*Vic crac*		0.22
Viola arvensis	*Vio arve*	1.22	0.11

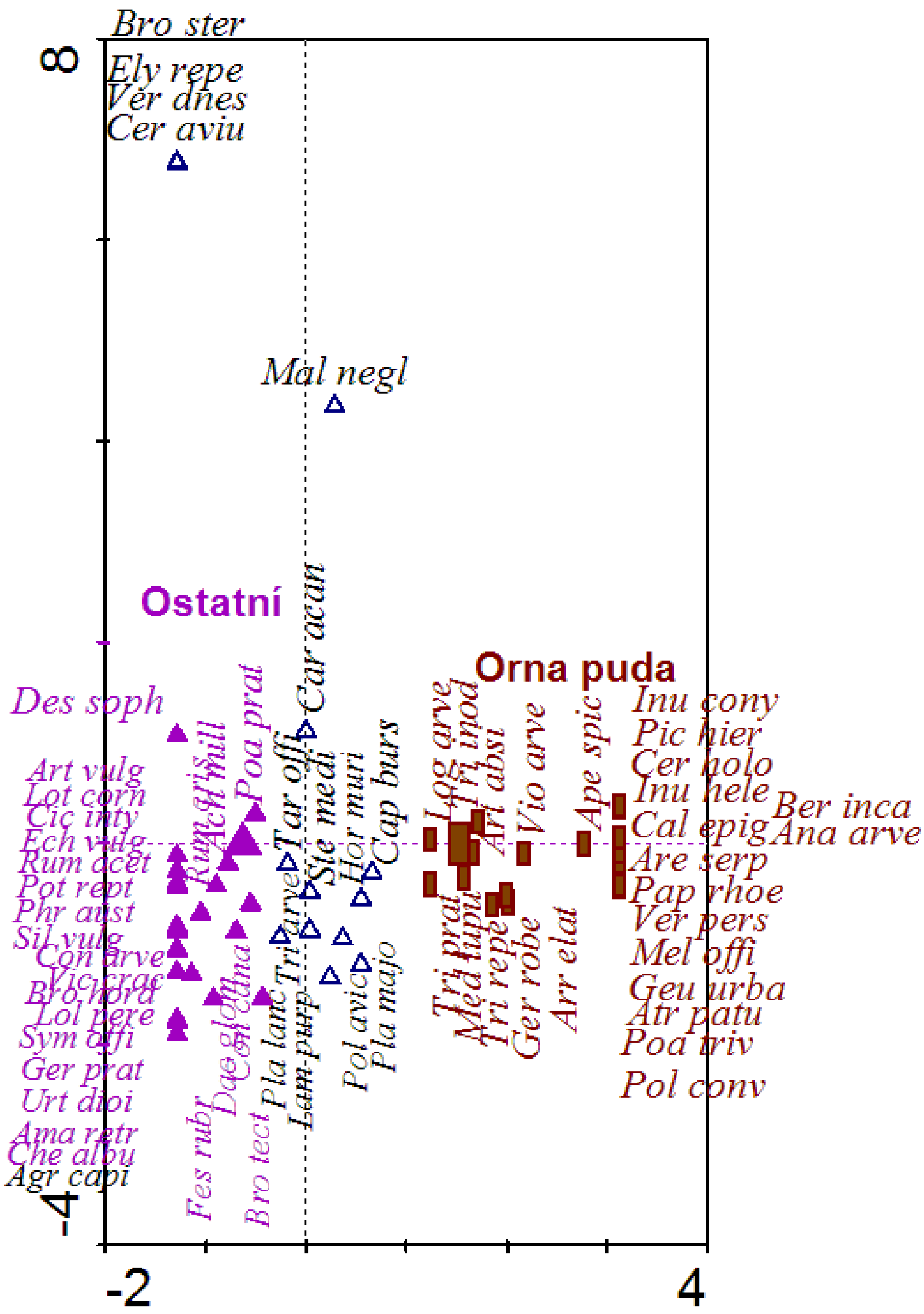
The second group of species occurred more frequently on spot that was originally recultivated and infertile land: *Achillea millefolium, Anagallis arvensis, Apera spica-venti , Arenaria serpyllifolia, Arrhenatherum elatius, Artemisia absinthium, Atriplex patula, Berteroa incana, Bromus tectorum, Calamagrostis epigejos, Capsella bursa-pastoris, Carduus acanthoides, Cerastium holosteoides, Conyza canadensis, Dactylis glomerata, Festuca rubra, Geranium robertianum, Geum urbanum, Hordeum murinum, Inula conyzae, Inula helenium, Lamium purpureum, Logfia arvensis, Medicago lupulina, Melilotus officinalis, Papaver rhoeas, Picris hieracioides, Plantago lanceolata, Plantago major, Poa pratensis, Poa trivialis, Polygonum aviculare, Polygonum convolvulus, Rumex crispus, Stellaria media, Taraxacum officinale, Trifolium arvense, Trifolium pratense, Trifolium repens, Tripleurospermum inodorum, Veronica persica Poir.* and *Viola arvensis.*

A third group was more influenced by another factor that this analysis does not include: *Bromus sterilis, Cerasus avium, Elytrigia repens, Malva neglecta* and *Verbascum densiflorum.*

The area of interest belongs to the warm areas and therefore is more likely to observe species which require drier conditions, such as *Silene vulgaris* and *Festuca rubra*. These species occurred mainly on sunny locations. Soils are sandy loam to loam sandy, which can be ideal for *Plantago major.*

The land is near the road, so we can assume a slight salinity of the soil, resistant species are for example *Agrostis stolonifera* and *Tripleurospermum inodorum*. The vegetation is trampled and grazed by cattle. Species as *Poa pratensis* and *Lolium perenne* are resistant. Species composition may be affect by not very instense grazing. Some species can be suppressed by kinds of cattle and there is possible subsequent expansion of other plant species. Cattle feces enrich the soil with nitrogen compounds, which could also support the emergence of nitrophilous species, such as *Geranium robertianum* or *Urtica dioica*. Plant species composition is more varied on reclaimed landfill. *Apera* *spica-venti*, *Cerastium holosteoides* and *Trifolium repens* were significantly represented on formerly cultivated sites.

Figure 1 Ordination diagram expressing the effect of habitat on the occurrence and coverage of found plant species



Legend: Habitat: Ostatní – original habitat has been recultivated/barren land, Orna puda – original habitat used to be arable land

CONCLUSION

Plant species that tolerate treading, have smaller stature and there is no high risk of expansion into neigh boring arable crops are welcome on the site of a photovoltaic power plant. One of these species is *Lolium perenne*. Negative ones for maintaining the photovoltaic power plant may be species, that are sturdy and significantly impair operating with photovoltaic panels or cause its shading. Species *Carduus acanthoides* i sone of them, plus it is detrimental to the digestive tract of sheeps.

The entire spectrum of plants has positive effects on the environment, ensures high biodiversity here, as well as ensures shelter for small mammals and is a source of pollen and nectar for pollinators. Negative species are expansive, which clearly extend to the surroundings.

Analysis of species composition on lands with photovoltaic power plants provide a very valuable and interesting insights. I suggest the continuation of research to assess the long-term development of vegetation.

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