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Ekológia (Bratislava) - Journal of the Institute of Landscape Ecology, Slovak Academy of Sciences Vol. 42, No. 1, p. 75–80, 2023

DOI:10.2478/eko-2023-0009

IS IT POSSIBLE TO INDICATE THE INFLUENCE OF MEDIEVAL SETTLEMENT ACTIVITIES ON FOREST PHYTOCOENOSES BY USING 400 m² GEOBIOCOENOLOGICAL PLOTS?

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Received: 26 May 2022 / **Accepted:** 31 January 2023

Abstract

Ondráček J., Štykar J.: Is it possible to indicate the influence of medieval settlement activities on forest phytocoenoses by using 400 m² geobiocoenological plots? Ekológia (Bratislava) Vol. 42, No. 1, p. 75–80, 2023.

Many abandoned villages in Central Europe are now covered with forest. These abandoned villages can be indicated by their different species composition compared to the surroundings. We were interested in whether these differences could be indicated by geobiocoenological plots (400 m²). Phytocoenological samples were taken from geobiocoenological plots located on the former buildings, in the village square and in gardens. Based on significant fidelity (Fisher's exact test at P = 0.05 significance level) and differential species coverage (ONE WAY ANOVA at P = 0.05 significance level), indicator species for the former buildings and former village square could be determined. The former buildings were indicated by species requiring higher soil nutrient content and higher pH, such as *Anemone ranunculoides* and *Stachys sylvatica*. The former village square site was indicated by species adapted to acid soils with less competitive abilities that could not compete on the more fertile soils of the former buildings, e.g. *Maianthemum bifolium* and *Dryopteris carthusiana*. Based on these results, it can be concluded that the influence of forest plant communities by medieval settlement activities can be phytoindicated using geobiocoenological plots of 400 m². This method can be applied especially in areas with acid soils, e.g. where there is a large difference in the amount of plant-available nutrients in the soil

Key words: non-destructive archaeology, phytoindication, land use history, abandoned villages, forest plant species composition.

Introduction

Many abandoned medieval villages are located in forests both in Central Europe (Mareš et al., 2013; Jaszczak et al., 2018; Latocha et al., 2019) and in the Czech Republic (Roubík, 1959; Nekuda, 1961; Simms, 1976). The study of abandoned villages and their vegetation has a long tradition in the Czech Republic (Roubík, 1959; Nekuda, 1961; Nová, Karlík, 2010).

In the area of these villages it is often possible to observe visible morphological features. The different species composition of the herb layer often indicates these morphological features (Gojda, 2004; Špulerová et al., 2011). Human influence on changes in the species composition of the forest understory is also often mentioned (Zhukov et al., 2019; Schulze, 2018; Hermy et al., 1999; Hermy, Verheyen, 2007; Honnay et al., 1999; Sciama et al., 2009; Wulf, 1997). Therefore, it is useful to use the indicative abilities of these plants to indicate earlier settlement activities (Kenderessy et al., 2020; Koerner et al., 1999).

Differences in the species composition of the herb layer can be identified when comparing the species composition in the village and its surroundings. The species composition was evaluated from villages that were abandoned in the 20th century (Hédl, 2004; Hejcman, Smrž, 2010; Nová, Karlík, 2010; Semelová et al., 2008; Vojta, 2007) and in the Middle Ages (Celka, 2011; Gallo et al., 2009; Hejcman et al., 2013), from Roman times (Dupouey et al., 2002) and even from prehistoric times (Lasaponara, Masini, 2007). Differences were also found in current and completed experiments with fertilization (Hejcman et al., 2007; Hrevušová et al., 2009; Spiegelberger et al., 2010).

The study area, including the abandoned village Kří, is located 40 km east of Prague and 10 km west of Poděbrady in the central part of the Czech Republic in the enclave of eolic sands and geobiocoenologically in the 2nd vegetation zone (Zlatník, 1976). The altitude of the location varies between 183 and 185 m above sea level. The average temperature is 8.9 °C and the annual precipitation is 559 mm. The soil type is cambisol and podzol. These soils are moist in spring and dry in summer. The study area is covered by (semi)natural mixed deciduous and pine forests. In these forests, human activities have reduced the species richness of the herb layer (Neuhauslová, Kolbek, 1982; Zlatník, 1976; Mikeska, 2006; Culek et al., 2013). The location of the village is shown in Fig. 1.

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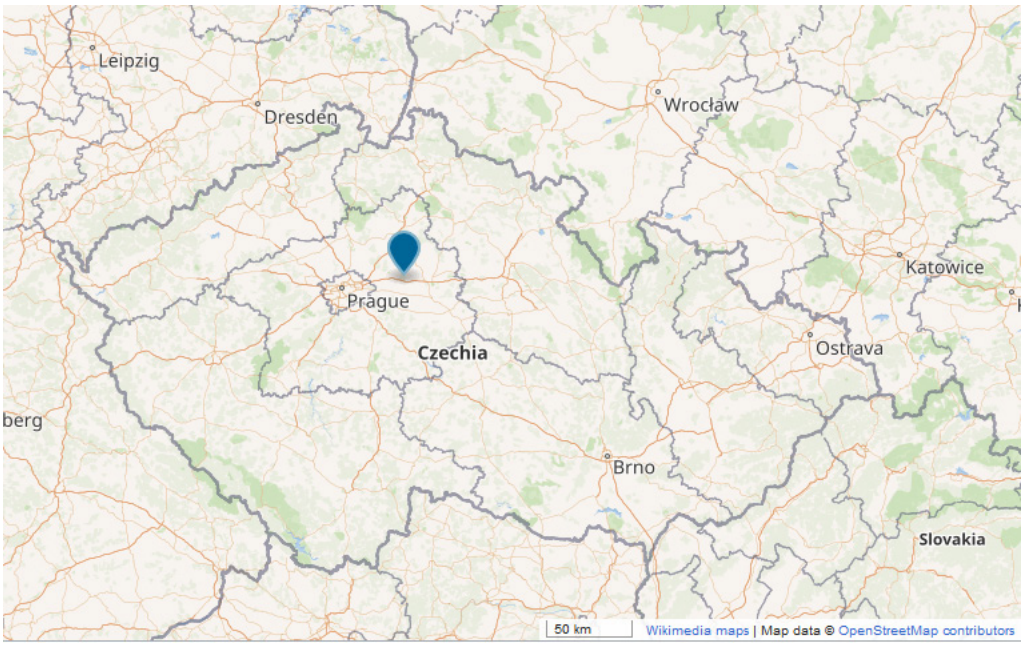


Fig. 1. The blue dot shows the location (Wikipedia, 2023).

The village was founded in a planned way with a regular rectangular village square, with a length of 800 m and a width of 80–100 m. Homesteads were built on both sides of the village square. There were 40 homesteads planned, but not more than 32 were built. Some parcels have never been inhabited. Moreover, some of these parcels were abandoned during the existence of the village (Klír, 2008). The existence of this village was approximately between 1357 and 1420.

In a previous study, diagnostic species for former buildings, courtyards and village square were determined on detailed plots of 4 m² (Hejcman et al., 2013). No indicator species were detected in the gardens. Former buildings were indicated by the presence of *Aegopodium podagraria*, *Alliaria petiolata*, *Allium oleraceum*, *Anemone nemorosa*, *A. ranunculoides*, *Brachypodium sylvaticum*, *Colchicum autumnale*, *Dactylis polygama*, *Galium aparine*, *Geranium robertianum*, *Impatiens parviflora*, *Lysimachia nummularia*, *Polygonatum odoratum*, *Primula veris*, *Stachys sylvatica*, *Vinca minor* and *Viola riviniana*. The indicator species for the village square were *Dryopteris carthusiana*, *Maianthemum bifolium*, *Molinia caerulea*, *Mycelis muralis*, *Poa angustifolia* and *Rubus idaeus*. The only indicator species of courtyards was *Agrostis capillaris*.

The aim of this study is to determine whether it is possible to indicate the influence of short-term settlement activities (about 60 years) on vegetation of phytocoenological plots of 400 m² (as used in geobiocoenology and forest typology) more than 500 years after the abandonment of the village. Finding out the possibilities of phytoindication is important for both archaeological and botanical practice.

Methods

In May and June, species of the forest herb layer were sampled on geobiocoenological plots with an area of 400 m². It was not possible to place the geobiocoenological plots separately in the courtyards because their size was too small. The courtyards and former buildings were therefore sampled together. Geobiocoenological plots in the former gardens and in the former village were also sampled.

In order to make the results comparablj with the previous research, the geobiocoenological plots were placed to include detailed plots of 4 m². In both cases, the same methodology of phytocoenological sampling was used.

Nomenclature was used according to Kubát et al. (2002). For each species, its percentage coverage was recorded. Subsequently, indicator species were determined based on fidelity. Fidelity and frequency of occurrence were assessed based on species presence/absence of data. Data were not transformed, whereas frequency and fidelity were calculated using Juice 7.0 software. Fidelity was calculated using the Phi coefficient (Sokal, Rohlf, 2001; Chytrý et al., 2002). Significant fidelity was tested by Fisher's exact test (P = 0.05) and presented as a synoptic table (Tichý, 2002).

Subsequently, the coverage data were statistically evaluated. Species coverage and species richness were evaluated in real percentage cover values without data transformation. The effect of settlement activities on species richness was tested by One Way ANOVA, and significant differences in species richness were tested using the Tukey HSD test. The coverage of diagnostic species on detailed and geobiocoenological plots was tested by Fisher's LSD test and presented in the form of a table.

Results

On 21 geobiocoenological plots, significant differences were found in all observed vegetation properties. A total of 68 herb species and 9 tree species were recorded.

Based on Fisher's exact test, indicator species for individual types of former settlement activities were determined on the

Table 1. Synoptic table of significant indicator species of individual types of settlement activities. The indicator species were sorted according to decreasing fidelity. Freq = frequency, fidel = fidelity, N = number of plots, n.s. = not significant. Frequency means the frequency of occurrence of a given species on the studied areas on a scale of 0-100.

Species	Geobiocenological plot						Detailed plot	
	Buildings		Village square		Gardens		Buildings	Village square
	freq.	fidel.	freq.	fidel.	freq.	fidel.	fidel.	fidel.
	(N = 9)		(N = 6)		(N = 6)		(N = 41)	(N = 20)
Vicia sepium	75	81.6					n.s.	
Colchicum autumnale	75	81.6					23.7	
Stachys silvatica	75	81.6					37.7	
Aegopodium podagraria	75	81.6					29.9	
Galium odoratum	75	81.6					n.s.	
Primula veris	62	72.5					36.6	
Myosotis palustris	62	72.5					n.s.	
Geum urganum	75	68.2	17				n.s.	
Alliraria petiolata	62	57.9	17				33.6	
Allium oleraceum	50	63.2					33	
Anemone ranunculoides	75	68.2	17				42.1	
Geranium robertianum	50	63.2					23.4	
Urtica dioica	75	57.3	17		17		n.s.	
Viola riviniana	88	59.1	50				35.7	
Polygonatum odoratum	88	68.1	33				23.7	
Glechoma hederaea	6	57.9	17				n.s.	
Galium aparine	38	53.5					23.4	
Impatiens parviflora	100	50	67		33		32.7	
Anemone nemorosa	100	50	83		17		25.7	
Vinca minor	75	47.8	50				27.3	
Lysimachia numularia	100	56.4	83				21.4	
Brachypodium sylvaticum	100	n.s.	83		33		39.2	
Dactylis polygama	88	n.s.	83		17		22.6	
Agrostis capillaris	25	n.s.					33.3	
Poa angustifolia			50	63.2				34.2
Maianthemum bifolium	25		83	69.2				38.6
Rubus idaeus	12		67	64.6				23.9
Dryopteris carthusiana	38		83	n.s.	50			19.9
Molinia caerulea	38		50	n.s.				34.2
Mycelis muralis	38		33	n.s.	17			30.1

geobiocoenological plots using the calculated fidelity in the Juice software (Table 1). The former buildings, including the area of former yards, were marked by species: *Anemone ranunculoides*, *A. nemorosa*, *Aegopodium podagraria*, *Brachypodium sylvaticum*, *Impatiens parviflora*, *Stachys sylvatica*, *Stellaria holostea*, *Vicia sepium* and *Viola riviniana*. The village square was indicated by species: *Maianthemum bifolium*, *Poa angustifolia* and *Rubus idaeus*. The gardens had no indicator species. Indicator species with their fidelity and frequency of occurrence are listed in synoptic Table 1.

Former settlement activities were mostly indicated by the same species of herbs on the detailed and geobiocoenological plots. In addition, the former buildings on the geobiocoenological plots were indicated by species *Galium odoratum*, *Geum urbanum*, *Myosotis palustris* and *Vicia sepium*. On the contrary, only in the detailed plots the species *Brachypodium sylvaticum* was an indicator of former buildings and the species *Agrostis capillaris* was an indicator species of former courtyards. In addition, *Molinia caerulea* and *Mycelis muralis* were the indicator species in the detailed plots at the village square.

Some indicator species of the herbaceous layer identified from the detailed plots had lower coverage in the geobiocoenological plots (e.g. *Anemone ranunculoides*) and others had slightly higher coverage (e.g. *Dryopteris carthusiana*) (Table 2).

On both the geobiocoenological and detailed plots, species richness was highest on the former buildings. Species richness was lower in the former village square compared to the former buildings. The lowest species richness of the herb layer was in the gardens. All former settlement activities were statistically different on the detailed plots (Fig. 2). Only gardens were significantly different from other settlement activities in terms of lower species richness on the geobiocoenological plots (Fig. 2) (Tukey HSD test).

Table 2. Coverage of indicative species of non-woody understory synusia of individual settlement activities. Table shows species data of cover indicator species of former settlement activities on geobiocenological and detailed plots. Mean values with standard error of the mean are presented. Land use types with the same letters (a) did not differ significantly (at the probability level $P = 0.05$).

Geobiocenological plots	**Buildings+courtyards**	**Village square**	**Gardens**
Species	($N = 9$)	($N = 6$)	($N = 6$)
Aegopodium podagraria	8.8b±3.5	0.02a±0.02	0.0a±0.0
Anemone nemorosa	18.9b±3.5	18.3b±4.6	3.3a±3.3
Anemone ranunculoides	6.5b±2.7	1.0b±1.0	0.0a±0.0
Carex acutiformis	1.8a±1.16	1.3a±0.8	7.83a±4.1
Dryopteris carthusiana	0.2a±0.1	14.5b±7.4	0.8a±0.6
Impatiens parviflora	38.7b±7.1	9.7a±5.4	0.1a±0.1
Maianthemum bifolium	0.67a±0.55	13.3b±3.1	0.0a±0.0
Stachys sylvatica	4.0b±1.0	0.02a±0.02	0.0a±0.0
Viola riviniana	2.9b±0.8	0.15a±0.1	0.0a±0.0
Detailed plots	**Buildings+courtyards**	**Village square**	**Gardens**
Species	($N = 55$)	($N = 20$)	($N = 12$)
Aegopodium podagraria	7.5b±2.0	0.05a±0.1	0.0a±0.0
Anemone nemorosa	16.6c±2.2	26.9b±4.9	1.7a±1.7
Anemone ranunculoides	6.9b±16	1.5a±1.5	0.0a±0.0
Carex acutiformis	0.8a±0.4	0.8a±0.6	6.7b±2.9
Dryopteris carthusiana	0.1a±0.1	3.25b±1.6	0.7a±0.4
Impatiens parviflora	18.3b±2.5	3.3a±1.6	0.0a±0.0
Maianthemum bifolium	0.2a±0.2	5.0±b1.7	0.1a±0.1
Stachys sylvatica	1.9b±0.6	0.05a±0.1	0.0a±0.0
Viola riviniana	1.0a±0.3	0.3a±0.2	0.0a±0.0

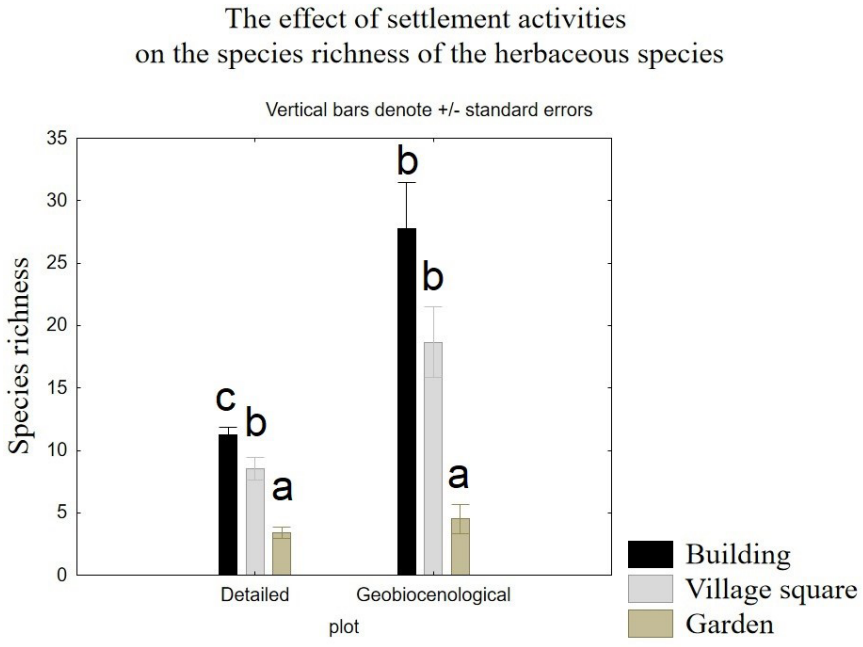


Fig. 2. The graphs show the influence of settlement activities on the current species richness of vascular plants in the original detailed and geobiocenological plots. In both cases, the plots of buildings also include courtyards. The bars represent the mean and the spreads shows the standard error of the mean (at the P = 0.05 probability level). Mean values with standard error of the mean are given. Land use types with the same letters (a) did not differ significantly (at the P = 0.05 probability level). The detailed plots all differed significantly from each other. On the geobiocenological plots, the buildings did not differ from the village square. The gardens differed from the buildings and the village square.

Discussion

Differences in vegetation are caused by large differences in the amount of nutrients in the soil. These differences are most evident in locations with nutrient-poor soils that also have an acid soil reaction. However, the soils on thw former buildings differed significantly from these soils. The buildings were constructed of heavy clay material rich in calcium. This very different soil material, probably from the wider surroundings of the village, affected the soil's ability to retain water and nutrients. The differences between anthropogenic and naturally occurring soils were so pronounced that they were visible to the naked eye from the soil samples taked (Hejcman et al., 2013).

The differences caused by earlier settlement are so significant that they are visible even on relatively large geobiocoenological plots. The results of many authors show that human settlement can cause long-term or irreversible changes in the species composition of the herb layer and the chemical properties of the soil (Dambrine et al., 2007; Asare et al., 2021).

When comparing detailed and geobiocoenological plots, the coverage of some indicator species was lower on the geobiocoenological plots (*Anemone ranunculoides*). However, species richness and coverage of indicator species remained significant on the geobiocoenological plots. The indicator species of former buildings had significantly lower coverage or were completely absent from other types of former settlement activity (e.g. *Primula veris*, *Stachys sylvatica*, etc.). These differences in vegetation cover were primarily due to differences in available plant nutrients in the soil as well as differences in the soil water regime. Species that are rare or absent in the landscape often grow on former buildings (Celka, 2011).

The merging of the former houses and courtyards within one geobiocoenological plot has led to an increase in the species richness of the herbs of these geobiocoenological plots. Thus, the former buildings had a significantly higher species richness compared to the surrounding area.

The higher species richness may have been due to the presence of nutrient-rich clays. These clays were particularly rich in Ca, P, K, Mg and Zn. Another reason for the higher species richness at the former buildings was differences in soil grain size. The clay material had a better water retention capacity compared to the surrounding sandy soils. Plants on the former buildings were therefore better supplied with water and nutrients. Plant stress caused by water and nutrient deficiencies was therefore eliminated or substantially reduced on the former buildings.

Similar conclusions were reached by Asare et al. (2021, when studying the chemical properties of soil at archaeological site . They found that the so-called „black archaeological soils" are so enriched with nutrients that the effect of these plant-accessible nutrients cannot be covered even by intensive fertilisation. For example, archaeologists have observed vegetation differences in the growth of winter wheat (*Triticum aestivum*), as well as in the growth of other crops (Gojda, Hejcman, 2012; Hejcman et al., 2011).

In principle, it can be said that the influence of past settlement activities was sufficiently indicated on the geobiocoenological plots by the same indicator species as on the detailed plots. It can be said that these tend to be herbaceous species with higher nutrient requirements and also nitrophilous species that could not grow successfully elsewhere in Kersko forest. The occurrence of these plants is therefore restricted to imported soils rich in calcium and other nutrients. The clay soils probably come from the wider surroundings of the village. Some authors have reached similar conclusions in other areas because the plants preferred sites on the archaeological site (Dambrine et al., 2007). Therefore it can be assumed that these plant species have occupied all the habitats that suit them over the last 600 years and have not spread further. The conclusions of the study lead me to agree with the authors' views that human settlement activity can lead to long-term or irreversible changes in vegetation composition and soil chemistry (Dambrine et al., 2007; Dupouey et al., 2002; Asare et al., 2021).

Conclusion

The main result of this study is that the soil properties influenced by the short-term medieval settlement activity, lasting only about 60 years, caused such significant differences in the species composition of the herb layer that these differences can still be observed even after 500 years on the geobiocoenological plots of 400 m^2.

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