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MORAVIAN GEOGRAPHICAL REPORTS

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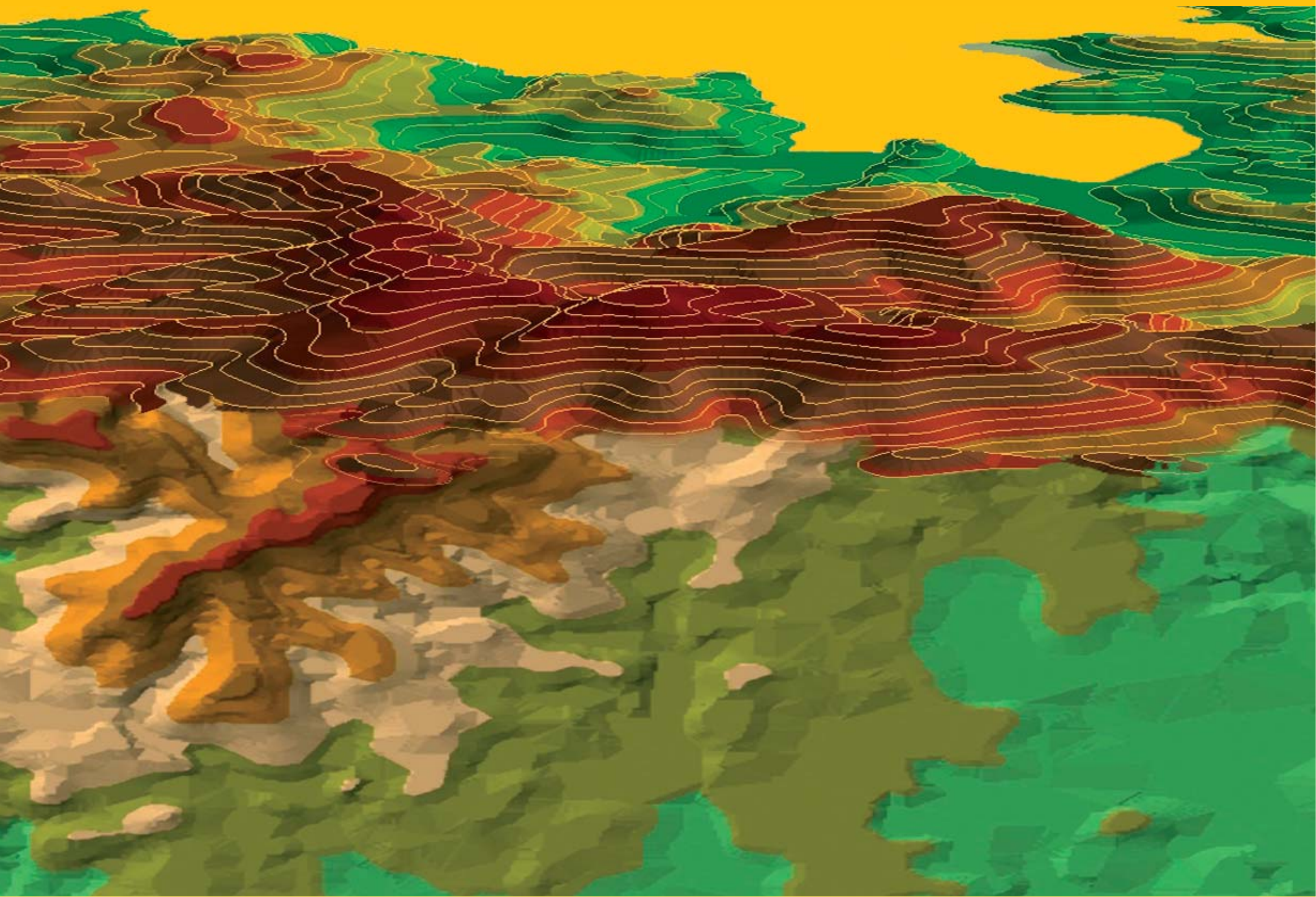

Fig. 6: An overgrowing orchard meadow near Brabschütz, Saxony (Photo: M. Forejt)

Fig. 7: Decaying wood in an orchard meadow near Niedergohlis, Saxony (Photo: M. Forejt)

Illustrations related to the paper by M. Forejt and R.-U. Syrbe

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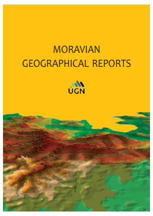

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Modelling walking accessibility: A case study of Ljubljana, Slovenia

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Abstract

Walkable access is recognised as one of the most important factors for deciding to walk instead of using other modes of transport. Distance has been less accurately taken into consideration in previous walking accessibility measures, however, as they are often based on an isotropic approach or on a fixed distance threshold. The objective of this paper is to present a method of modelling continuous walking accessibility to different amenities in a city, with an integrated network-based and distance-decay approach, applied to a case study of the city of Ljubljana, Slovenia. The approach is based on a web survey to obtain data on acceptable walking distances to different types of amenities. Several distance decay functions were analysed for each type of amenity from the cumulative frequency of responses. The best fitting functions were used to model the walking accessibility surfaces for individual amenities in the network, representing five domains (retail, services, recreation, education and transportation) and an overall walking accessibility index. Despite certain limitations and a further need to assess the validity of the methods, our distance-decay network-based approach is more accurate than the isotropic or even network-based modelling of walking distances in continuous or threshold approaches, as it enables the researcher to take into account the differences in propensities to walk to different amenities. The results can be used by city authorities and planners for implementing actions to improve walking accessibility in the most problematic areas.

Keywords: *walking, walking accessibility, distance decay, spatial interaction model, network analysis, Ljubljana, Slovenia*

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1. Introduction

Defining walking accessibility to different amenities in an urban area is an important task for city authorities and urban planners when they analyse existing accessibility, or when they develop and design land use and the built environment of urban areas (Yigitcanlar et al., 2004). Although walkability measures usually take into account numerous factors, ranging from street connectivity, density, diversity of land use and destinations, route characteristics and safety, to aesthetic qualities (Cerin et al., 2007; Maghelal and Capp, 2011), it seems that distance has somehow been underestimated or at least less accurately taken into consideration in those measures. So far, only Walk Score (https://www.walkscore.com/), an internationally recognised web-based walkability assessment tool, has addressed this issue more precisely, using a distance-decay approach – but with certain drawbacks, such as not taking into account differences in trip purposes.

The aim of this paper is to present a GIS-based method of modelling walking accessibility to different types of amenities. The purpose of the method is to integrate network-based and distance-decay approaches of modelling walking accessibility, and to take into account the potential differences in the propensity to walk between different trip purposes.

The method has been applied to a case study of the city of Ljubljana, Slovenia, for which information about intra-urban walking accessibility is lacking. Without such information it is difficult to monitor the goal of urban sustainability to which the city is committed (Vision of Ljubljana 2025, 2019).

The paper is structured as follows. Section 2 reviews the literature on the walkability concept and methods to assess walking accessibility. Material and methods are described in Section 3, including survey data acquisition, modelling distance decay functions, walking accessibility

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surfaces and indices. In Section 4, the empirical results on propensities to walk, calibrated distance-decay functions, and walking accessibility indices are presented. This is followed by a discussion of the results in Section 5 and conclusions in Section 6.

2. Theoretical background

The concept of walkability has been gaining increased attention by scholars, city authorities, social movements and initiatives, and urban planners in the last few decades. A walkable built environment has numerous positive effects on residents' well-being: it increases the number of walking trips (Cerin et al., 2007; Manaugh and El-Geneidy, 2011; Weinberger and Sweet, 2012) and thus enhances physical activity and health (Oishi et al., 2015; Rundle et al., 2016; Saelens et al., 2003); enhances life satisfaction (Cao, 2016; Jaśkiewicz and Besta, 2016, 2014); the level of social capital (Rogers et al., 2011); and residents' creativity (Oppezzo and Schwartz, 2014).

Among many walking needs, which range from feasibility to pleasurability (Alfonzo, 2005), good spatial accessibility from origins to destinations is found to be one of the most important, and it has been shown to influence the decision to walk over other transport modes (Boisjoly et al., 2018; Frank and Engelke, 2005; Giles-Corti et al., 2005; Giles-Corti and Donovan, 2002; Greenwald and Boarnet, 2001; Lund, 2003; Moudon et al., 2006; Owen et al., 2004; Reyer et al., 2014; Shriver, 1997). On the other hand, proximity is not necessarily the only factor (Giles-Corti et al., 2005) but can be secondary to individual and social environmental determinants (Giles-Corti and Donovan, 2002). In some cases, it is not even associated with walking (Cerin et al., 2007; Koohsari et al., 2013). Nevertheless, there has long been a general consensus that distance is an indispensable element of any type of accessibility (Hansen, 1959; Ingram, 1971), and walking accessibility is no exception in this regard (Forsyth, 2015).

With the widely-recognised importance of walkability for overall quality of urban life, there have been numerous attempts to develop methods and indices of walkability and walking accessibility, with objective GIS measures of the built environment being the most common (Brownson et al., 2009). It has been shown that objective measures have stronger associations with walking than subjective measures, such as self-reported perceptions of the environment (Hajna et al., 2013; Lin and Moudon, 2010). On the other hand, it is clear that objective measures have a high degree of variability (Brownson et al., 2009), and there is little agreement on theoretical and methodological assumptions for such measures (Cerin et al., 2007). Some scholars have urged the development of standardised measures of objective variables that can be replicated by other studies (Maghelal and Capp, 2011). Despite these limitations, GIS analyses can be widely used as a decision support tool for planning, enabling the rapid assessment of large areas (Ellis et al., 2016), or to understand the impact of the built environment on physical activities or modes of transportation (Lwin and Murayama, 2011; Tribby et al., 2015).

In the previous calculations of walkability scores, distance most often has been taken into consideration by using fixed distance thresholds, also called a pedestrian shed ratio (ped shed) or walkable catchment areas/buffers, mostly based on the concept of a reasonable walking distance (Frank et al., 2005; Kuzmyak et al., 2006; Lwin and Murayama, 2011; Porta and Renne, 2005; Witten et al., 2003). This method is very simple to use, but it has a number of drawbacks. Such measures are not necessarily based on precise findings of an acceptable, comfortable or desired walking distance, and they can mask within-buffer variations. Numerous studies have shown that the willingness to walk changes with distance (Iacono et al., 2010; Moudon et al., 2006; O'Sullivan and Morrall, 1996; Vasconcelos and Farias, 2012). At present, only Walk Score (https://www.walkscore.com/) has addressed this issue more precisely – with a special polynomial distance decay function – but without referring to existing research and also ignoring the fact that the propensity to walk regarding distance might also differ by trip purpose, as numerous studies have shown (Larsen et al., 2010; O'Sullivan and Morrall, 1996; Shriver, 1997; Yang and Diez-Roux, 2012). A similar approach, but with a simplified version of distance bands, was used by Reyer et al. (2014).

Although walkability indices in general are found to be a reliable and valid measure of estimating access to walkable amenities (Carr et al., 2010; Duncan et al., 2011), and have also performed quite well in describing pedestrian behaviours (Manaugh and El-Geneidy, 2011; Stockton et al., 2016; Weinberger and Sweet, 2012) or vehicle miles travelled (Kuzmyak et al., 2006), they have conceptual and computational limitations, as Vale et al. (2015) argued in their extensive review of operational measures of active accessibility. For example, they can be less accurate in certain areas (Koschinsky et al., 2017), partly because they can mask within-buffer variations (Gutiérrez et al., 2011), or if they use Euclidean distance instead of the street network (Kozina, 2010).

One of the most important concepts in urban, regional and transport geography is the concept of distance decay. Many researchers of spatial interactions, starting from Ravenstein (1885) and Stewart (1948), have shown that the intensity of interactions in space depends significantly on the distance between the pairs of considered locations (Taylor and Openshaw, 1975). Waldo Tobler condensed the role of the distance for interactions in geographic space in the 'First Law of Geography' (Tobler, 1970, p. 236): "Everything is related to everything else, but near things are more related than distant things." The concept has often been applied in gravity-based models and spatial analyses (e.g. Cheng and Bertolini, 2013; Fotheringham and Pitts, 1995; Drobne and Lakner, 2014; Halás and Klapka, 2015; Martínez and Viegas, 2013; Tiefelsdorf, 2003; Timmermans et al., 2003). It has been used as well in walking accessibility studies, where it evaluates the effect of distance in the walking trips of individuals (Giles-Corti et al., 2005; Giles-Corti and Donovan, 2002; Gutiérrez et al., 2011; Yang and Diez-Roux, 2012). Surprisingly perhaps, it has been employed very rarely for objective walkability and walk-score type measures in certain geographical areas. Among such measures, only the Walk Score has used this kind of approach to date – but with the above-mentioned limitations. A research question also remains: what is the best function of distance in gravity or potential models? In research to date, a cumulative Gaussian function has been considered as having the best fit for walking (Vale and Pereira, 2017).

3. Materials and methods

We suggest a network-based and distance-decay approach to modelling walking accessibility to different amenities in the urban environment in a geographical information systems (GIS) framework. The approach is applied to a case study of the city of Ljubljana: the largest city and the capital of Slovenia, with a population of 280,940, an area of 163.8 km^2 and a gross population density of 1,715.5 people/km^2 (Statistical Office of the Republic of Slovenia, 2018). The rationale in selecting this particular city as a case study is manifold. The city is acknowledged for its central position within the Slovenian urban system (Nared et al., 2017), its high quality of urban life (Tiran, 2016), diverse urban morphology and urban land use (Tiran et al., 2016), also as sustainability-oriented, compact and green (Nastran and Green, 2016; Žlender and Ward-Thompson, 2017). The city is also known for its activities in improving conditions for walking, and signing the International Charter for Walking (https://www.walk21.com/charter). On the other hand, little is known about its (intra-urban) walking accessibility, which is one of the key determinants for choosing walking as a transport mode (Owen et al., 2004).

The research design phase of the project can be summarised as follows (see Fig. 1):

a. data acquisition on the propensity to walk to different amenities in Ljubljana by using a web survey;
b. analysis of the frequency distributions of responses, according to distance intervals in a spreadsheet;
c. estimation of different distance decay functions for each type of amenity in software for technical calculations;
d. modelling the walking accessibility surfaces for each type of amenity by a network approach in GIS;
e. combining walking accessibility surfaces to obtain the overall walking accessibility surface in GIS;
f. analysis of the overall walking accessibility surface in GIS.

3.1 Survey

To obtain the subjective assessment of walking accessibility among Ljubljana residents, we conducted a web survey. The survey was performed between April and June 2014. The respondents were selected through non-probability sampling: the invitation and link to the survey was sent via a general invitation on mailing lists, forums and social media. A total of 663 respondents completed the survey. The sample was found to be representative regarding the demographic structure of the city population and its spatial distribution (according to area within the city), and dwelling type, with larger discrepancies only in a higher share of women and youth and a lower share of respondents living in single-family houses: see Table 1. Among the items in the

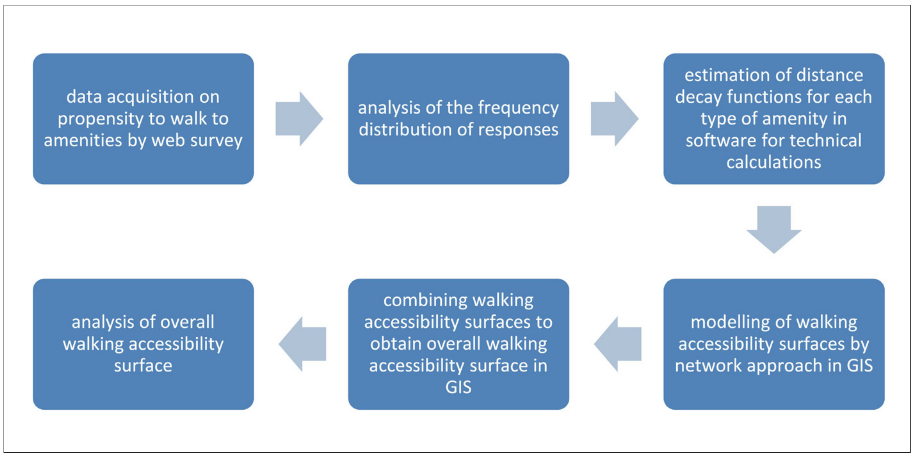

Fig. 1: Methodological steps used in the research design. Source: authors conceptualisation

Socio-demographic, dwelling type and locational attributes		**Share of respondents (%)**	**Actual share (%) in city population (2014)**
gender	male	36.3	47.8
	female	63.7	52.2
age	15–35	44.9	27.0
	36–45	18.6	14.5
	46–55	11.7	13.8
	56–65	14.6	13.3
	66 or more	10.2	17.6
dwelling type	single-family houses	27.9	41.4
	three- or more dwelling building	15.2	7.7
	multi-apartment building, tower block	56.9	50.8
location	Bežigrad	24.7	19.5
	Center	18.4	9.0
	Moste	14.4	25.9
	Šiška	19.8	24.3
	Vič-Rudnik	22.7	21.3

Tab. 1: Demographic and geographic characteristics of the respondents, compared to city population
Sources: authors' elaboration based on survey data

survey, acceptability of the distance to amenities by foot was questioned (e.g. "What distance from your home to 'selected amenities', do you perceive as still acceptable for walking?"). The range of the responses followed the assumption that everybody is prepared to walk at least 1 minute, but no more than 30 minutes. Hence, the responses offered were: up to 1 minute; up to 3 minutes; up to 5 minutes; up to 10 minutes; up to 15 minutes; up to 20 minutes; and up to 30 minutes.

In order to reduce the survey burden, respondents had to answer for only five selected amenities, which they had previously selected as the most important in terms of walking accessibility from their apartment. Overall, they were choosing between 14 types of amenities: grocery store, hypermarket, pharmacy, community health centre, post office, ATM, urban green space, playground, sports ground, cultural amenity, restaurant, nursery school, primary school and bus stop.

To test the potential differences on the subjective assessments of walking accessibility between population groups, we carried out Kruskal-Wallis tests.

3.2 Distance decay functions

To estimate distance decay functions to the analysed amenities in Ljubljana, we constructed the frequency distribution of responses and calculated the proportion of respondents who are prepared to walk to a certain amenity at a certain distance, estimating a general propensity or willingness to walk to amenities in terms of distance. The results for cultural centres and restaurants were excluded from the analysis, as distance to the nearest one is of minor importance compared to their offer, which can be decisive for the usage of the rest of the amenities, so we cannot assume that people are using them solely because of proximity. Therefore, 12 types of amenities were analysed, and different distance decay functions were estimated for each type of amenity to assess the propensity to walk, and for other distances as well. The parameters of the functions, the goodness of fit, as well as walking accessibility for each type of amenity, were calculated and modelled in Mathematica 10.3.

The distance decay functions were constructed as xy coordinate graphs, where the x axis showed the maximum time (in minutes) from the origin to the destination (to the nearest amenity in the consideration), while the y axis gave the relative cumulative frequency (probability) of amenity-distance interactions.

For each *k*-dataset, we calculated four different distance decay functions that expressed the influence of time-distance to the propensity to walk. The tested set of functions were used and suggested by Martínez and Viegas (2013), Halás et al. (2014) and Halás and Klapka (2015); see functions (1–4) below:

1. normalised power-exponential function

$$f(t) = \mathrm{e}^{-at^{b}}, \quad a, b > 0,$$

2. Box-Cox's function

$$f(t) = \mathrm{e}^{\frac{t^{a}-1}{a}b}, \quad a > 0,\ b < 0,$$

3. Tanner's function

$$f(t) = t^{a}e^{bt}, a > 0, b < 0,$$

4. Richards' function

$$f(t) = c + \frac{a-c}{\left(1+de^{-b(t-g)}\right)^{1/h}}\ , \quad a, b, c, d, g \in \mathcal{R}, h > 0$$

All four analysed functions can be considered to be flexible functions because all have two or more parameters. However, the most flexible function is Richards' function that has four parameters and is able to capture analysed data in detail.

The procedure of estimating parameters a, b, c, d, g, h was performed in Mathematica 10.3 using the least-square method, $\sum_{\mathrm{i}}(\mathrm{n}_{\mathrm{i}}^{\%} - \mathrm{f(t)})^2 = min$. For each function and for each *k*-dataset, standard errors of estimation, *SEE*, were calculated. Coefficients of determination, R^2, were calculated as $\mathrm{R}^2 = 1 - \mathrm{SS}_{\mathrm{res}} / \mathrm{SS}_{\mathrm{tot}}$, where $\mathrm{SS}_{\mathrm{res}} = \sum_{\mathrm{i}}(\mathrm{n}_{\mathrm{i}}^{\%} - \mathrm{f(t)})^2$, $\mathrm{SS}_{\mathrm{tot}} = \sum_{\mathrm{i}}(\mathrm{n}_{\mathrm{i}}^{\%} - \bar{\mathrm{n}}^{\%})^2$ and $\bar{\mathrm{n}}^{\%}$ is the average value of the relative cumulative frequency of propensity to walk. The best-fitting function was used to model the walking accessibility in the network.

3.3 Walking accessibility surfaces and indices

For each type of amenity, a separate walking accessibility surface was modelled using the best-fitting function for each amenity and network paths. Walking accessibility surfaces were calculated by our own Python code in ArcGIS 10.3.

Geo-referenced amenities were extracted from available official sources. Network paths were imported from the OpenStreetMap web site and corrected by digital orthophoto images and with the field surveys. For conversion of the propensity to walk expressed in minutes to distances in metres, a walking speed of 4.8 km/h (Transport for London, 2015) was selected. The walking accessibility surfaces for types of amenities were modelled by a 12.5-metre grid resolution.

The overall walking accessibility index was calculated by combining partial walking accessibility surfaces. The indices of walking accessibility were combined within their respective domain:

- retail: grocery store, hypermarket;
- services: pharmacy, community health centre, post office, ATM;
- recreation: urban green space, playground, sports ground;
- education: nursery school, primary school; and
- transportation: bus stop.

For each domain, the walking accessibility surface for corresponding amenities was calculated as an average of the propensity to walk to corresponding amenities. This categorisation is an adapted version of the basic human functions concept, which was introduced by Partzsch (1964) and later adopted by the Munich school of social geography (Ruppert, 1984) and widely used to comprehend patterns of human mobility. The original concept also includes work and housing and does not separate retail from services. Other dimensions were added in the development of the concept, like living in the community and disposal. In this paper, the analysis was limited to those amenities that have also been recognised as important in other housing and residential well-being studies (Allen, 2015; Bonaiuto et al., 2003; Kyttä et al., 2016).

In the last step, the overall walking accessibility surface for all domains of amenities was calculated as an non-weighted average of the input domains' walking accessibility surfaces, multiplied by 100. To compare the location of the amenities regarding their accessibility by foot with the spatial distribution of the population in the last step, we limited accessibility surfaces to the populated areas, defined with 100 m buffers around populated household addresses. For both aspects of the research – calculation of the overall walking accessibility surface, as well as its analysis according to the populated areas in the city of Ljubljana – the program ArcGIS 10.3 was used.

4. Results

4.1 Propensity to walk

Figure 2 shows the cumulative frequency of responses to walk to amenities at certain distances. It shows that the differences between amenities are the highest at 10 minutes. This can also be observed from the standard deviations in Table 2. At 3 minutes, the propensity to walk is still very high for all the amenities, while at 5 minutes, the differences start to increase and span from 95.8% (community health centre) to 67.0% (bus stop and playground). At 10 minutes, the range increases from 75.0% (primary school and community health centre) to 18.6% (bus stop). The profile then starts decreasing to very low differences at 30 minutes, where the propensity to walk to none of the amenities is over 5%. In general, respondents are less willing to walk to the playground, bus stop, grocery store and ATM. On the other hand, the willingness is generally the highest for walking to primary school and the community health centre.

The calculated average decrease of the propensity to walk with increasing the distance shows that the decrease is not linear: it is largest between 5 and 15 minutes, when it decreases by 64.5% (see Tab. 3). For seven amenities (hypermarket, pharmacy, community health centre, post office, urban green space, nursery and primary school), the greatest decrease is between 5 and 10 minutes; and for five amenities (grocery store, ATM, playground, sports ground and bus stop) it is between 10 and 15 minutes. Those intervals are therefore the most "critical" with respect to the respondents' decision to walk or not with respect to distance. The second largest decrease is outside of any of those intervals for only 3 amenities: for the community health centre (25.3% between 15 and 20 minutes), bus stop (26.9% between 3 and 5 minutes), and playground (22.0% between 3 and 5 minutes).

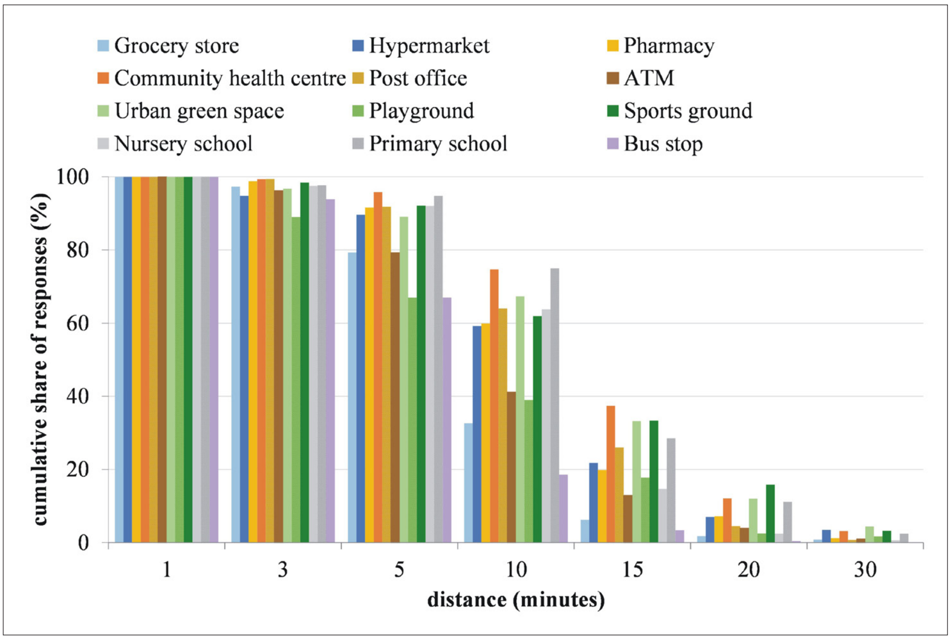

Fig. 2: Cumulative frequency of responses to walk to amenities
Source: authors' calculations from survey data

distance (minutes)	1	3	5	10	15	20	30
mean	99.9	96.6	85.8	54.8	21.2	6.7	1.8
standard deviation	0.0	2.9	10.2	17.7	10.9	5.0	1.4

Tab. 2: Standard deviation of the propensity to walk between amenities at certain distances
Source: authors' survey

distances (minutes)	1 to 3	3 to 5	5 to 10	10 to 15	15 to 20	20 to 30
average decrease	3.3	10.8	31.0	33.5	14.5	4.8

Tab. 3: Average decrease of the propensity to walk to amenities between distances
Source: authors' survey

The Kruskal-Wallis tests revealed only some expected statistical differences between population groups. The propensity to walk (average of responses in minutes) is statistically different only for gender, age, dwelling type, and location and for certain amenities. The significant differences are noted as follows:

- Gender
  - Urban green space ($\chi^2 = 11.319$; $df = 1$; $p = 0.001$)
  - Grocery store ($\chi^2 = 6.295$; $df = 1$; $p = 0.012$)
  - Post office ($\chi^2 = 5.748$; $df = 1$; $p = 0.017$)
  - Pharmacy ($\chi^2 = 4.680$; $df = 1$; $p = 0.012$)
- Age
  - Community health centre ($\chi^2 = 14.295$; $df = 4$; $p = 0.006$)
  - Post office ($\chi^2 = 9.988$; $df = 4$; $p = 0.041$)
- Dwelling type
  - Playground ($\chi^2 = 12.961$; $df = 2$; $p = 0.002$)
  - Bus stop ($\chi^2 = 11.039$; $df = 4$; $p = 0.004$)
  - Pharmacy ($\chi^2 = 6.475$; $df = 4$; $p = 0.039$)
- Location
  - Grocery store ($\chi^2 = 19.927$; $df =$; $p = 0.001$)
  - ATM ($\chi^2 = 13.340$; $df = 4$; $p = 0.010$)
  - Bus stop ($\chi^2 = 12.936$; $df = 4$; $p = 0.012$)
  - Post office ($\chi^2 = 10.456$; $df = 4$; $p = 0.033$)

The results show that differences are statistically significant for post office (3×, i.e. three times), bus stop (2×), grocery store (2×), pharmacy (2×), ATM (1×), urban green space (1×), playground (1×) and community health centre (1×). Although statistically significant, the differences are very small in most cases. An interesting finding is that women are prepared to walk far more than men (e.g. 11.4 minutes versus 9.6 minutes to urban green space). On the other hand, propensity to walk does not differ for nursery school, primary school, hypermarket and sports ground for any of the population groups. Therefore, we decided not to correct the sample nor to use any additional weighting of responses due to the non-probability sampling. For the same reason we did not estimate distance decay functions for each population subgroup, treating them as a single population.

4.2 Distance decay functions

Table 4 shows the coefficients of determination (R^2) for the analysed distance decay functions for the propensity to walk to the nearest amenity. Because the analysis was based on aggregated data (willingness to walk to specific amenity according to the classes of distance), all of the coefficients of determination for all analysed functions are very high. In spite of the fact that majority of the coefficients of determination for all analysed functions are very high and that the interpretation of Richards' function is difficult, we used Richards' function (4) for modelling purposes. For analysis purposes in general, however, it would be more convenient to use a simpler function with less parameters that gives comparable results (Halás and Klapka, 2015), e.g. the normalised power-exponential function (1). For these reasons, we show both results below. Tables 5 and 6 show the estimated parameters of the normalised power-exponential function (1) and, respectively, of Richards' function (4), for each type of amenity under consideration. A graphical representation of Richards' distance decay functions for different types of amenities is shown in Figure 3.

4.3 Walking accessibility indices

In Figures 4 and 5, the partial and final results of the modelling exercise are presented, which enabled us to make basic observations of the spatial distribution of amenities in the city. The results of the overall walking accessibility index indicate that the spatial distribution of the population fits very well with walking accessibility to amenities (see Fig. 6). If we interpret these data with the Walk Score classification, the majority (61.3%) of Ljubljana residents live in a "very walkable" environment (index between 70 and 89), while only 18.4% live in a "car-dependent" environment (index of 49 or less). We can conclude that Ljubljana, in general, is a city with a solid walking accessibility of the residential areas, with as expected, the highest in the centre and the lowest in the outskirts.

Such a spatial pattern can be explained by four main factors. The first is the general adoption of the neighbourhood unit concept in urban planning, based on examples from Nordic countries in the period of the largest city growth from the 1960s to the 1980s. The concept also

k	Amenity	normalised power-exponential function (1)	Box-Cox's function (2)	Tanner's function (3)	Richards' function (4)
1	Grocery store	0.9986	0.9987	0.9568	**0.9990**
2	Hypermarket	0.9978	0.9977	0.9668	**0.9999**
3	Pharmacy	0.9985	0.9985	0.9667	**0.9996**
4	Community health centre	0.9990	0.9990	0.9639	**0.9999**
5	Post office	**0.9996**	0.9996	0.9639	0.9994
6	ATM	0.9985	**0.9988**	0.9672	0.9987
7	Urban green space	0.9973	0.9972	0.9705	**0.9998**
8	Playground	0.9945	0.9956	0.9698	**0.9962**
9	Sports ground	0.9980	0.9983	0.9808	**0.9998**
10	Nursery school	0.9983	0.9983	0.9490	**0.9999**
11	Primary school	0.9952	0.9952	0.9545	**0.9990**
12	Bus stop	0.9972	0.9976	0.9420	**0.9999**

Tab. 4: Coefficients of determination (R^2) for distance decay functions for the propensity to walk to the nearest amenity (Notes: k = 1,2,…,12 is the type of amenity under consideration; the bolded number denotes the row maximum)
Source: authors' elaboration from survey data

k	Amenity	*SEE*	*R²*	*a*	*b*
1	Grocery store	0.016	0.999	0.005	2.382
2	Hypermarket	0.018	0.998	0.002	2.373
3	Pharmacy	0.016	0.998	0.001	2.620
4	Community health centre	0.013	0.999	4.2E-4	2.851
5	Post office	0.008	0.999	0.001	2.707
6	ATM	0.016	0.998	0.008	2.062
7	Urban green space	0.020	0.997	0.002	2.261
8	Playground	0.028	0.995	0.028	1.549
9	Sports ground	0.017	0.998	0.004	2.090
10	Nursery school	0.017	0.998	2.3E-4	3.312
11	Primary school	0.028	0.995	3.1E-4	3.023
12	Bus stop	0.022	0.997	0.009	2.261

Tab. 5: Parameters of normalised power-exponential distance decay function (1) for the propensity to walk to the nearest amenity in Ljubljana (Note: $f(t) = e^{([t^a - 1/a].b)}$; k = 1,2,…,12 is the type of amenity under consideration). Source: authors' elaboration

k	Amenity	*SEE*	*R²*	*a*	*b*	*c*	*d*	*g*	*h*
1	Grocery store	0.013	0.999	– 0.002	0.294	1.012	0.002	– 1.452	0.001
2	Hypermarket	0.003	0.999	0.035	0.383	1.065	3.663	9.059	1.629
3	Pharmacy	0.009	0.999	0.018	0.335	1.023	6.438	4.162	0.761
4	Community health centre	0.004	0.999	0.024	0.308	1.021	7.700	5.749	0.863
5	Post office	0.010	0.999	– 0.001	0.352	1.064	15.490	5.026	1.397
6	ATM	0.015	0.998	1.114	– 0.330	0.006	0.142	1.401	1.203
7	Urban green space	0.006	0.999	0.043	0.357	1.119	9.387	8.939	2.304
8	Playground	0.023	0.996	2.944	– 0.072	0.006	0.003	6.662	0.002
9	Sports ground	0.006	0.999	0.009	0.181	1.013	2.8E-5	1.232	5.9E-6
10	Nursery school	0.003	0.999	0.010	0.602	1.045	14.351	9.092	2.396
11	Primary school	0.013	0.999	0.034	0.353	0.991	6.078	5.572	0.612
12	Bus stop	0.005	0.999	1.004	– 1.453	– 0.008	0.078	1.799	5.570

Tab. 6: Parameters of Richards' distance decay function (4) for the propensity to walk to the nearest amenity in Ljubljana (Note: $f(t) = c + (a - c) / (1 + de^{-b(t-g)})^{1/h}$; k = 1,2,…,12 is the type of amenity under consideration) Source: authors' elaboration

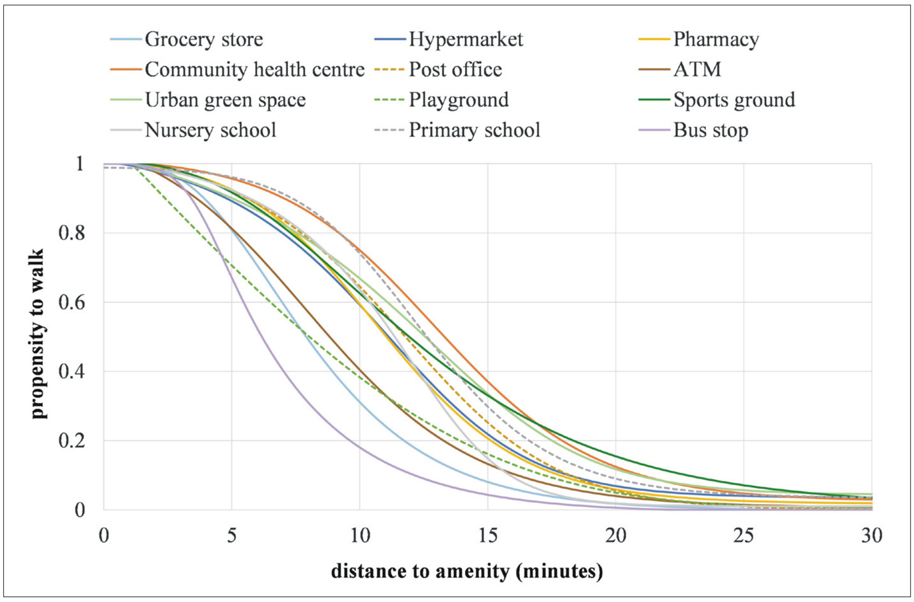

Fig. 3: Richards' distance decay functions for the propensity to walk to amenities in Ljubljana Source: authors´ calculations

emphasised the importance of locating the most important social infrastructure (grocery store, nursery school, primary school, playgrounds, bus stop) within the neighbourhood, including footpaths leading to them or locating the infrastructure at its edge within a walking distance, e.g. along the main artery road (Malešič, 2015). This explains the very high walking accessibility to most amenities in most of the city's territory: its centre and all main arteries along which most neighbourhoods with a majority of the population are located.

The second factor also relates to the urban planning system: in line with the concept of urban territorial cohesion and spatial justice, the spatial plans for Ljubljana have been supporting harmonious growth (Šašek Divjak, 2008), and the recent one also growth around the local centres (Municipality of Ljubljana, 2010). Consequently, those local centres are equipped with basic infrastructure, especially grocery stores, services and education facilities, providing good walking accessibility to them.

The third factor, which explains the dichotomy between centre and periphery, is the low population density and rural character of most of Ljubljana's outskirts. This is still very much visible in the built environment as the ground plan of former villages, which have been administratively merged into the town, remained almost intact (Tiran et al., 2016). There are very few urban amenities in those places, making

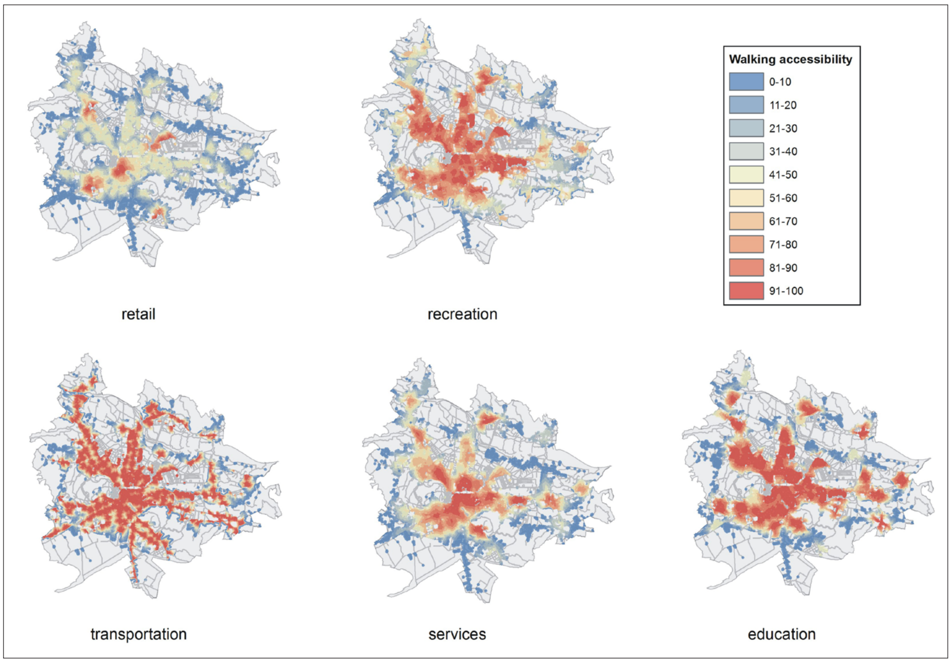

Fig. 4: Partial walking accessibility indices for each domain (retail, recreation, transportation, services, education) in the city of Ljubljana. Source: authors' calculations

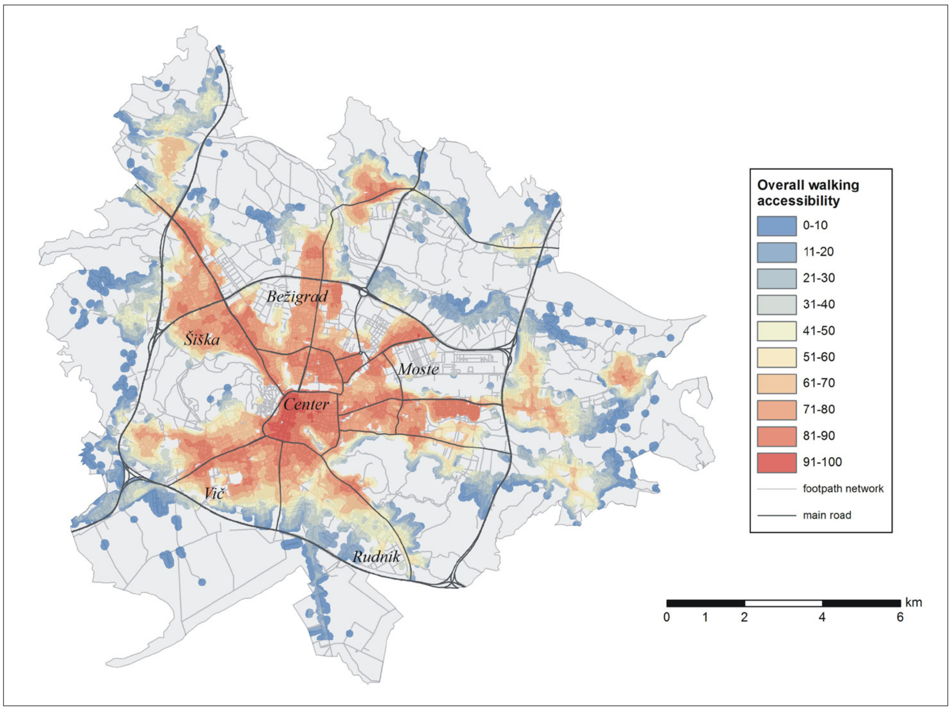

Fig. 5: Overall walking accessibility index in the city of Ljubljana. Source: authors' calculations

them almost non walkable and therefore car-dependent on the nearby local centres and shopping malls. The fourth factor also relates to the centre-periphery dichotomy. In the early 1990s in Ljubljana, spatial development was neglected because of prioritising macro-economic reforms at the national level. This led to the expansion of a dispersed or scattered residential and retail sprawl (Žlender and Ward Thompson, 2017), explaining the poorer walking accessibility on the outskirts.

5. Discussion

The main contribution of this paper is methodological in nature. The overall measure of accessibility can be described as a distance-based, location-based and gravity-based measure, calculated by the distance to the closest opportunity that integrates probabilistic methodology with the integration of a spatial interaction model, implemented in a GIS environment. The methodological approach applied here has numerous advantages over standard distance threshold methods. Firstly, being based on subjective assessments of walking distance makes this measure a better proxy of "real walking accessibility" than a rough estimation of walking distance, often used in measures of walkable access or in urban planning. Secondly, the method applies distance decay functions over the "standard" distance threshold approach, considering the fact that the propensity to walk changes over the distance in a non-linear manner. Thirdly, it takes into account the differences in the perceived walking distances between amenities, which we found to be significant. This is not an unexpected finding, as the trips to each amenity have their own specifics according to the frequency of visits, purpose, difficulty and other characteristics (e.g. waiting at the bus stop). Last but not least, the amenities are not weighted arbitrarily, such as for example in the Walk Score measure (despite claiming to refer to other studies), but rather groups them according to their respective functions to a human being. Although a more accurate weighting according to the importance of each amenity or frequency of visits was not applied, as in the study by Witten et al. (2003), this kind of approach probably better reflects the real needs of inhabitants rather than all amenities being treated equally.

We can also draw some theoretical contributions from the results of this study. One of them is that walking accessibility to the majority of amenities had the best fit with the Richards' function, which Martínez and Viegas (2013) also found suitable for accessibility assessment, especially for small distances. Our results also revealed that the largest decrease in propensity to walk is between 10 and 15 minutes (between 800 and 1,200 m) for most amenities, pointing to the distance band, where the use of a distance threshold is the most critical.

Nonetheless the methodology as presented also has its limitations. The survey was carried out using a non-representative sample, so its results cannot be used to assess the willingness to walk for the entire population of Ljubljana. Additionally, it is based on the assumption that people tend to visit the closest amenity and it does not take into account the variety of options in the vicinity and some types of amenities where variety is superior to proximity (e.g. bars or restaurants). Neither does the measure consider attributes such as quality, equipment or assortment. For example, the frequency of bus arrivals can be a very important factor for using public transport instead of a car, or when choosing between bus stops. The same argument applies to urban green areas, which differ considerably in size, equipment, aesthetic features and maintenance. As the study by Giles-Corti et al. (2005) revealed, such factors can also have an influence on the choice of walking and choice of one amenity over another. In our approach, the selection of the amenities within each type and domain can strongly influence the results: this aspect of our research should be carefully taken into consideration in future studies adopting a similar methodology. The subjective assessment of respondents, based on which the distance decay parameters were constructed, may also be biased, but this element cannot be known.

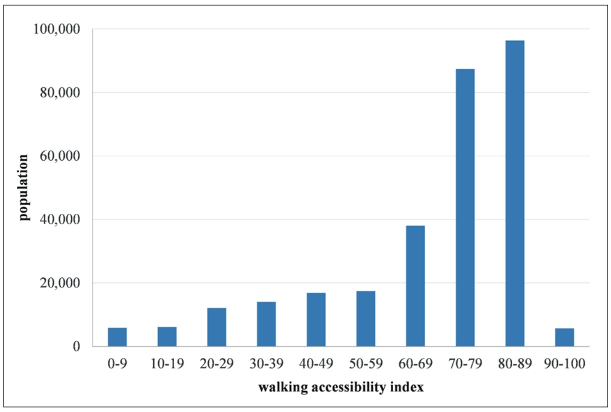

Fig. 6: Walking accessibility in the city of Ljubljana considering the distribution of the population
Source: authors' calculations

Despite the careful formation of the questions, informats' responses and distance decay functions may not truly reflect their actual propensity to walk. As studies show, people can have a biased perception about the true length of certain trips (Button et al., 2016; Hernández and Witter, 2015; Krizek et al., 2012; Lowrey, 1970; Säisä et al., 1986). It is also possible that their answers simply do not reflect the real willingness to walk, especially among people who predominantly use other transport modes, or that people were estimating actual distances to frequently used amenities and not whether they are prepared to actually overcome a reported distance. The results are also less accurate due to the edge effect, as we calculated only accessibility to amenities inside the city boundaries, not taking into account the amenities in neighbouring settlements. Another limitation is that the approach does not consider the differences in personal characteristics (Manaugh and El-Geneidy, 2011; Reyer et al., 2014; Shriver, 1997) or personal attitudes (Lund, 2003), which have been shown to be significant. In our analysis, we used aggregate flow data instead of pair-wise data, an approach that raises the risk of over-smoothing the heterogeneity of the real urban pedestrian flows. To obtain more accurate results, agent-based modelling (Badland et al., 2013) or dynamic location-based accessibility modelling (Järv et al., 2018), should be carried out.

6. Conclusions

The method of measuring walking accessibility to amenities, as presented above and applied to the city of Ljubljana, is one of only a few attempts to integrate a network-based and distance-decay approach for objective walk-score type measures in a specific geographical area. It is more accurate than most widely-used methods using a 'distance threshold'. It is based on subjective assessments of walking distance, accounting for the fact that the propensity to walk does not decrease linearly with distance. Moreover, it takes into account differences in the propensity to walk to different amenities and groups amenities according to their respective functions. In addition, it is relatively easy to apply. Testing the validity of the proposed measures in comparison to actual pedestrian behaviours and other walkability indices is needed. Future developments of the method should derive distance-decay functions taking into account the importance of domains and types of amenities, as well as other elements that influence walking accessibility. Such a measure could then be widely used to estimate the share of walking, assess the quality of the residential environment and applied in urban planning as a strategic or practical tool for locating amenities, as well as for the site-development process. Such a process could help to increase the physical activity of people and thus residential well-being. Nevertheless, these results should already be useful for Ljubljana's city authorities and planners for implementing actions to improve walking accessibility in the most problematic areas.

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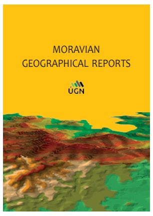

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The fate of socialist agricultural premises: To agricultural 'brownfields' and back again?

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Abstract

The variety of post-socialist agricultural transitions in four different rural regions located in South Bohemia (Czech Republic), with respect to the utilisation of the older premises, is subject to analysis in this article. A complete database was constructed, containing the identification of agricultural premises in 1989 and their use in 2004 and 2017. From 1989 to 2004, a number of agricultural brownfields emerged, and many sites had been utilised for non-agricultural purposes. After 2004, the acreage of agricultural brownfields was reduced and new land-use utilisation for housing and, especially other non-agricultural activities, significantly increased. The transition in the utilisation of pre-1989 agricultural premises is strongly influenced by the social and economic contexts in which particular sites are located. Proximity to an upper-level regional centre is of crucial importance for decisions with respect to how (and if) the site will be re-used. The peripheral location of the site also affects the level and the selection of options for the ways in which particular pre-1989 agricultural premises are used. In the case studies reported here, the marginality of particular regions is increased by their location in the border regions of outer peripheries, where the probability of the presence of agricultural brownfields and the probability of long-term abandonment of agricultural premises is higher. For the traditional developed countryside, we found a typical low level of the share of long-term agricultural brownfields. After 2004, the re-use of pre-1989 agricultural brownfields for agriculture was ascertained, which is complemented by their use for housing.

Keywords: *agricultural brownfields, transitional economies post-socialism, reuse, abandonment, South Bohemia, Czech Republic, Central and Eastern Europe*

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1. Introduction

Although the agriculture sector in the former Czechoslovakia was one of the most productive agricultural sectors in Central and Eastern European countries (CEE) during the 1980s (Bański, 2008), it was not able to compete with the production levels of the Western European agricultural production systems (Doucha and Divila, 2008) after the fall of the Iron Curtain in 1989. As a result, the agricultural sector of Czechoslovakia started to diminish but food consumption remained more or less the same, and a significant part of food consumption was covered by imports (Zagata, 2012). When the Czech Republic became a member of the EU in 2004, the Common Agricultural Policy was applied; however, tendencies to a reduction in the agricultural production system have persisted.

All of these changes significantly affected the Czech agricultural sector. Therefore, some reasons to widen our understanding of these changes in the countryside are required. As the Czech agricultural sector is weakening in the last decades, many abandoned or under-used agricultural premises are found. In order to comprehend what has happened to these premises since 1989, our research comprises a special interest in the variety of re-uses that have occurred in rural areas situated in different socio-cultural conditions.

2. Conceptual background and hypotheses

Until the beginning of 1990s, the "whole" life of rural settlements in the former Czechoslovakia had been closely linked to collective farms or the state farms that emerged in the 1950s during the process of collectivisation of agricultural land, with properties that were managed by the newly-established communist regime to take economic control over the agricultural sector and the countryside

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(Lindbloom, 2012). Collectivisation had resulted in the establishment of very large collective agricultural farms, that were incomparably larger than any other in the EU (with the exception of Slovakia), and made possible their industrialisation. Collective farming begun in the 1950s with the construction of large-scale premises such as cowsheds, intensive pig farms, intensive poultry farms, and operational buildings such as agricultural warehouses, machinery garages, stock houses, shop floors and office buildings (Svobodová and Věžník, 2009). Collectivisation completely changed the social dimensions of rural life and the premises of collective farms became not only a new physical dominant of Czechoslovakian villages, but also the new centres of rural settlements. Experiments in Czechoslovakian agricultural policy continued into the 1970s, when these farms were merged into even larger agricultural complexes, usually joined with facilities of small-scale industrial production.

The changes in the agricultural production system, after 1989 (with the market economy transition) and after 2004 (with EU membership), significantly affected the use of these earlier premises (Klusáček et al., 2013). While the transitions of the agricultural production systems after 1989 have already been studied intensively (Bičík and Jančák, 2005; Illner and Andrle, 1994; Jančák and Götz, 1997; Věžník and Bartošová, 2004), the changes to the utilisation of pre-1989 agricultural premises have not been of interest to researchers. Nevertheless, previous studies unequivocally show that the change of utilisation of these premises is important for a profound comprehension of the agricultural sector transition and for its effects, not only on agriculture but also on rural space (CzechInvest, 2008; Klusáček et al., 2013; Skála et al., 2013; Svobodová and Věžník, 2009).

In order to meet our main research objective, we identify agricultural transitions using the case of the present utilisation of pre-1989 agricultural premises in various types of countryside. South Bohemia was selected as a case study region representing various types of rural spaces. Hence, the type of rural space in selected areas of south Bohemia, is the leading factor for testing the changes in utilisation of pre-1989 agricultural premises between 1989 and 2017. In addition, we also researched areas bordering on pre-1989 agricultural premises that were not agricultural premises in 1989 but were such in 2004 and/or in 2017. In other words, we also focused on the expansion (or change) process of pre-1989 agricultural premises.

We have chosen two time periods: the first period is from 1989 (when the Iron Curtain fell and the transition was about to begin) to 2004 (when the Czech Republic became a member of the European Union): the second period from 2004 to 2017 takes in consideration the effects of the Common Agricultural Policy of the EU on the utilisation of pre-1989 agricultural premises. The pre-1989 agricultural premises are defined here as buildings and their intensively managed adjacent sites that were used by cooperative farms or state farms for agricultural purposes up to 1989.

The following seven statistical hypotheses will be tested:

- Hypothesis 1: We assume that the areas of pre-1989 agricultural premises differ among regions depending on the structure and intensity of agricultural activities, with respect to varying geographical conditions (e.g. Jančák and Götz, 1997).

Although agriculture is a rather "traditional" economic sector, it depends on market fluctuation dynamics (Bonfiglio et al., 2017). These changes might be theoretically expressed not only by a change in utilisation of the pre-1989 agricultural premises to 2004 or to 2017, but also by their demolition or spatial development outside the former area (Klusáček et al., 2013). So, we will focus also on development outside the areas' borders. To date, there is a lack of studies dedicated to this issue. Nevertheless, from our field research, we learned that expansions of pre-1989 agricultural premises are rare. Subvention schemes (Hrabák and Konečný, 2018), such as financial support, however, led to the growth of biogas plants and composting plants (Van der Horst et al., 2018) enlarging some of the pre-1989 agricultural premises, even though there is a general decline in agricultural activities (Bičík and Jančák, 2005).

- Hypothesis 2: The level of the spatial expansion of pre-1989 agricultural premises differs among individual regions and studied periods.

Changes in the utilisation of pre-1989 agricultural premises is more common than spatial expansion (Klusáček et al., 2013; Věžník et al., 2013). It was shown that those changes in utilisation are related to changes in the agricultural sector (Hrabák and Konečný, 2018).

- Hypothesis 3: The spatial extent of the studied types of new utilisation of pre-1989 agricultural premises differs between 2017 and 2004.
- Hypothesis 4: The spatial extent of the studied types of new utilisation of pre-1989 agricultural premises in 2004 as well as in 2017 differs among studied regions.
- Hypothesis 5: Change in the spatial extent of the studied types of new utilisation of pre-1989 agricultural premises from 2004 to 2017 differs among studied regions.

Regarding the life of rural communities, abandonment of agricultural premises and their following decline, presents probably the most substantial change leading to the abundance of typical agricultural brownfields (Klusáček et al., 2013; Skála et al., 2013). Agricultural brownfields are defined for our purposes as buildings and their intensively managed adjacent sites that had up to 1989 utilisation for agriculture and after 1989 were abandoned, i.e. without any use (Martinát et al., 2017). It is enormously difficult to find new uses for such sites that are not so attractively located (Frantál et al., 2015). Based on the above-mentioned ideas, there are two following hypotheses:

- Hypothesis 6: The regeneration of agricultural brownfields and their new uses differs for the period 2004–2017 among individual studied regions; and
- Hypothesis 7: The abundance of new agricultural brownfields after 2004 differs among individual studied regions.

3. Study area

The South Bohemian Region of the Czech Republic borders Austria and Germany (Popjaková and Blažek, 2015). The peripherality of the region is based on its history and the specifics of its economy. South Bohemia has always been known as one of the agricultural regions with a low population density and with a dominant number of small communities (70% of the communities in South Bohemia have less than 500 inhabitants), and with an above average percentage share of inhabitants employed in agriculture (see Fig. 1).

The South Bohemian Region has been selected for our analysis as it consists of a variety of countryside types (Perlín et al., 2010), thus, providing good opportunities to

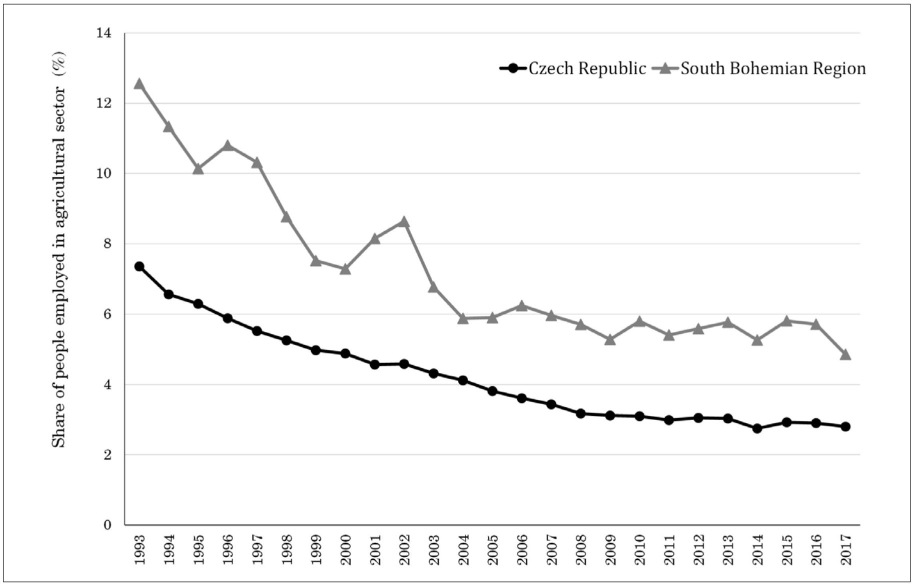

Fig. 1: Percentage share of people employed in the agricultural sector between 1993 and 2017
Source of data: Czech Statistical Office (2018); authors' elaboration.

compare the different trajectories of the development of pre-1989 agricultural premises. For this study, the areas of municipalities with extended powers called small districts (further, SDs) were selected. These districts were chosen as the spatial units closest to the "real" spatial organisation units of the Czech Republic (Klapka et al., 2016).

The SDs selected for the analyses had to meet the following criteria: they had to be located (1) in different districts; (2) not sharing a border with any other area under study; and (3) represent all types of countryside that have been detected in South Bohemia by Perlín and colleagues (2010). Using these criteria, the following four SDs were selected: České Budějovice, Blatná, Dačice, and Vimperk (Fig. 2).

České Budějovice SD is characterised as a 'developed' countryside (Perlín et al., 2010) surrounding the capital city of the South Bohemian Region – České Budějovice (Budweis). In the area of České Budějovice SD, no municipality is classified as peripheral according Kubeš and Kraft (2011). Blatná SD is a model region of the 'developing' countryside type, with well-established socio-economic connectivity within the region (Perlín et al., 2010). Blatná SD is formed by a majority of non-peripheral municipalities (Kubeš and Kraft, 2011). Vimperk SD is situated in the mountainous landscape of the Šumava Mountains. This region is classified as an 'intensively utilised' rural region for leisure and tourism (Perlín et al., 2010). More than half of the municipalities here are classified as peripheral, especially those municipalities situated at the border with Bavaria (Kubeš and Kraft, 2011). Finally, Dačice SD is characterised as a 'problematic recreational countryside' type with overall low level of rural development (Perlín et al., 2010). About half of the municipalities in this SD are classified as peripheral, especially municipalities along the border with Upper Austria (Kubeš and Kraft, 2011). A summary of the four types of selected SDs is presented in Table 1.

4. Data and methods

The map of pre-1989 agricultural properties (Krejčí et al., 2019) was used as the main source of data input to accomplish the aims of our study. The pre-1989 agricultural premises were identified on topographic maps of Czechoslovakia at the scale of 1:25,000 from the late 1980s

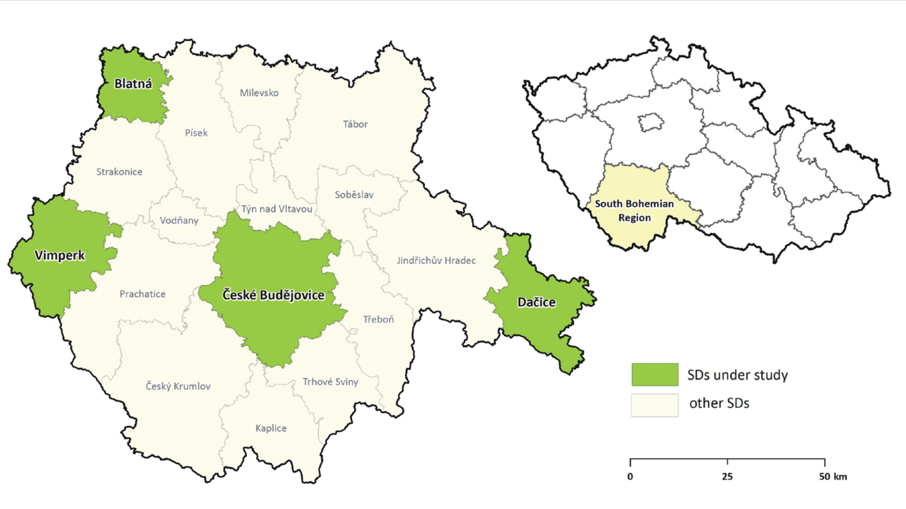

Fig. 2: Location of the four small districts selected in the South Bohemian Region
Source: authors' compilation based on ArcČR 500 data

Type of countryside	Selected SD
Developed countryside surrounding upper-regional centre	České Budějovice
Developing countryside with well-established socio-economic connectivity within the region	Blatná
Intensively utilised rural region for leisure and tourism	Vimperk
Problematic recreational countryside type with overall low level of rural development	Dačice

Tab. 1: Summary of the types of countryside under study as represented by selected SDs in the South Bohemian Region. Source: After Perlín et al. (2010)

and the first half of the 1990s. Pre-1989 agricultural premises were areas labelled in the maps as agricultural area, cowsheds, pig farms, poultry farms, haysheds, horticultural fields and stud farms. Black and white prints of aerial images from the early 1990s were used to draw the borders of those premises and to find potential other pre-1989 agricultural premises. Our four case study areas were sampled from this map.

Land-use data for the years 2004 and 2017 were gathered from free aerial images that cover the complete area of the Czech Republic. Two WMS services of The Czech Office for Surveying, Mapping and Cadastre (WMS – Ortophoto, WMS – Archival photo) were used. The images for 2004 were taken between 2003 and 2005; the images for 2017 were taken between 2016 and 2017. A final check of the aerial images was conducted using the panorama function that is freely accessible on the website application Mapy.cz. Thus, the categories of land-use for the years 2004 and 2017 are based on aerial images and are therefore relatively limited: listed below are the specific types of use in 2004 and 2017 of the pre-1989 agricultural premises:

- Agricultural utilisation (livestock breeding, storage of crop production and fodder, administration buildings, various water tanks, troughs and paved dung heaps, composting plants, biogas plants, agricultural storages, etc.), referred as “agri” in the graphs;
- Non-agricultural utilisation, utilisation for entrepreneurship but not agriculture (small craft production, industry, workhouses for repairing of agricultural mechanical machinery, scrapyards, non-agricultural storages, solar plants, sport grounds, etc.), referred as “non-agri” in the graphs;
- Housing, buildings used for permanent or recreational housing (buildings and their backgrounds), referred as “housing” in the graphs;
- Cultivated land (originally intensively cultivated land of agricultural farm that is currently ploughed, use as grazing or regularly mowed, including land that used be covered by buildings that were demolished), referred as “field” in the graphs; and
- No utilisation (abandoned premises, agricultural brownfields), referred as “brownfield” in the graphs.

For accuracy of the spatial data used, analyses of utilisation and changes in utilisation were conducted with a precision of 10 × 10 metres square. After the data preparation, statistical analyses were performed, so that individual hypotheses could be tested. Our hypotheses have been first re-defined as statistical null hypotheses and then tested. With respect to the nature of the analysed data (numbers of pixels of individual uses), chi-squared tests were used.

For testing Hypothesis 1 Pearson’s chi-squared test for the fit of a distribution was employed. We were observing the distribution of areas of agricultural premises in the four studied SDs against a theoretical distribution of areas corresponding to acreage of those SDs. This type of Pearson’s chi-squared test was also used for testing Hypothesis 2 in this case we tested the potential difference in the distribution of areas of enlarged agricultural premises in the four studied SDs against the even distribution corresponding to the acreage of those SDs (independently for 2004 and 2017). Pearson’s chi-squared test for the fit of a distribution was also employed to test Hypothesis 3 the distribution of frequencies of types of uses in 2017 was tested against a theoretical distribution that was represented by the distribution of frequencies of types for 2004. For testing Hypothesis 4 and Hypothesis 6, a Pearson’s chi-squared test for statistical independence was conducted. Hypothesis 7 could not be tested by a chi-squared test as there were too many null cell entries in the pivot table.

To enable the testing of Hypothesis 5, two approaches were applied. First, Cohen’s Kappa was calculated: this is a measure of agreement between two measured subjects that are often two classified maps (Viera and Garrett, 2005). It is similar to the Pearson correlation coefficient (Navrátilová et al., 2019). Based on this measure, the ratio of conformity for types of uses between two maps (two time horizons) of the same area, can be evaluated. A deeper view of this conformity, which is given by gains and losses of individual types of land-uses between 2004 and 2017, can be seen in a Mosaic plot, which is a graphical representation of multi-way contingency tables. It is commonly used in studies of land cover changes among land cover categories between two periods across several regions (Comber et al., 2016). It is a graph, in which its area is divided into rectangles having a proportional count of gains and losses for each land cover category in each region between two time periods (Navrátilová et al., 2019; SAS, 2017). The rectangles could be coloured – individual colours (in our case shades of red and green) represent the combination of variables being smaller (shades of red) or larger (shades of green) than an expected value under a model of proportionality and tested by standardised Pearson residuals (Comber et al., 2016). Hence, those rectangles with dark red and dark green colour are significant, because the main differences between real losses or gains and expected losses or gains are represented.

To enable a better reader orientation to the results, the data were graphically visualised either in proportional (percentage) scales or stated in absolute values. All calculations and the visualisation of the Mosaic plot were made by R software; other graphs were prepared in MS Excel.

5. Results

5.1 Distribution of agricultural premises in 1989

Acreages of pre-1989 agricultural premises (the shares of area were specifically 19% in Blatná SD, 44% in České Budějovice SD, 23% in Dačice SD, and 14% in Vimperk SD) were not consistent with the acreages of particular SDs (chi-squared = 7,846.8, df = 3, $p < 0.001$). In particular, Blatná SD had an acreage of pre-1989 agricultural premises extensively larger than expected according to the null model (150%). It means that 50% more agricultural premises (according to their acreage) could be found there than expected. A second region where specific details were found was Vimperk SD, where the acreage of agricultural premises in 1989 was just 56% of its theoretical extent (the acreage is equal to 70% of the acreage of the Blatná SD). In comparison, acreages of pre-1989 agricultural premises for both České Budějovice SD and Dačice SD are in line with the expected theoretical extent of the particular SDs.

5.2 Increase of the extent of agricultural premises up to 2004 and in the period of 2004–2017

There was an increase in the acreage of the original pre 1989 agricultural premises in the period 1989–2004, but it was only 207 ares (about 0.2% of the original acreage). In reality, one premise was extended in České Budějovice SD and one in Dačice SD. There were no increases in Blatná SD and Vimperk SD: this does not necessarily mean that development did not happen there but it was rather limited to the borders of the pre-1989 agricultural premises. The difference is statistically significant (chi-squared = 117.46, df = 3, $p < 0.001$). Up to 2017 an increase of the acreage of pre-1989 agricultural premises was detected in all four SDs. The detected overall increase is 5.88 ares, which is more than 6% of the original acreage of all pre-1989 agricultural premises (chi-squared = 5,319.64, df = 3, $p < 0.001$). Increases in the SDs of Vimperk (from 0 in 2004 to 162.9 in 2017), Dačice (from 92.7 to 319) and Blatná (from 0 to 87.8) are relatively comparable to one another, but a very large increase was detected in České Budějovice SD (from 112.8 in 2004 to 5,310.4 in 2017).

5.3 Utilisation of pre-1989 agricultural premises in years 2004 and 2017

More than one-quarter (28.2%) of the pre-1989 agricultural premises had lost their agricultural use by 2004 and more than one-third (35.2%) before 2017 (see Fig. 3). Almost one fifth (19.6%) of pre-1989 agricultural premises were classified as brownfields in 2004. Quite surprisingly, a decrease of agricultural brownfields (to 15.2%) was ascertained between 2004 and 2017. Non-agricultural use was detected for 7.4% of premises in 2004 and 15.2% in 2017. The areas of pre-1989 agricultural premises used for housing also increased between 2004 and 2017, as well as parts that were transformed into pastures, meadows and arable land. These changes are statistically highly significant (chi-squared = 21,053.00, df = 4, $p < 0.001$).

5.4 Differences in land-use of pre-1989 agricultural premises in 2004 and 2017 among the four studied SDs

Are there are any differences among the four studied regions in the use of pre-1989 agricultural premises separately for the years 2004 and 2017? We have found that the extent of individual types of re-uses varied significantly among these areas for both 2004 and 2017: year 2004: chi-squared = 3,627.01, df = 12, $p < 0.001$; year 2017: chi-squared = 3,123.68, df = 12, $p < 0.001$). In both studied time horizons, Dačice SD was identified as the most agricultural region: i.e. in this SD, the acreage of agricultural premises with contemporary (2004 and 2017) agricultural uses had the largest share of the original extent of pre-1989 agricultural premises (see Figs. 4 and 5).

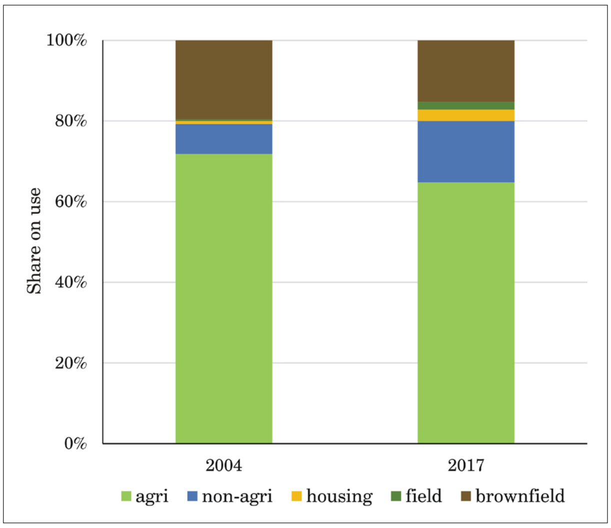

Fig. 3: The share of land-uses in 2004 and 2017 of pre-1989 agricultural premises for all four SDs
Source: authors' calculations

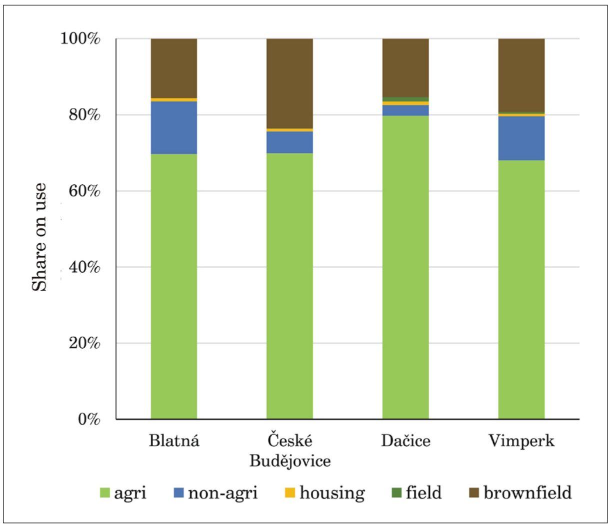

Fig. 4: The share of land-uses in 2004 on pre-1989 agricultural premises in the four study SDs
Source: authors´ calculations

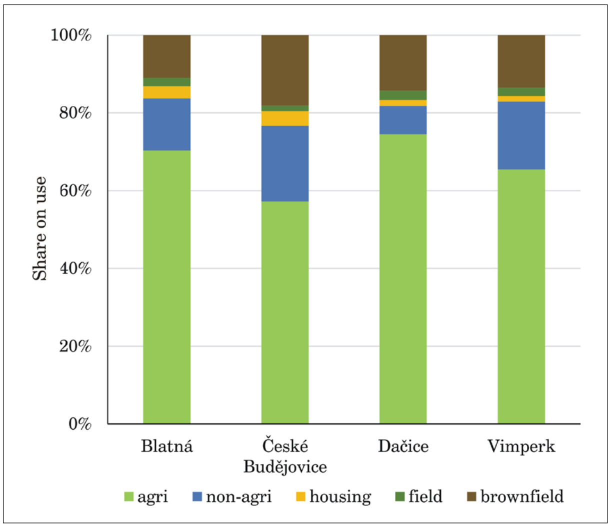

Fig. 5: The share of land-uses in 2017 on pre-1989 agricultural premises in the four study SDs
Source: authors' calculations

In contrast, in all four areas the area of agricultural brownfields was higher in 2004 than in 2017. For all four regions, the development of non-agricultural uses increased by 2017, but the most remarkable shift toward non-agricultural use can be found in the České Budějovice SD. A significant use for housing was detected in Blatná and České Budějovice SDs. With respect to the above-noted results, it is also interesting that only in Blatná SD was the level of agricultural use of pre-1989 agricultural premises the same in 2017 as in 2004.

5.5 Changes of land-use of agricultural premises in 2004 compared to 2017

Some conformity of the proportions between utilisations of pre-1989 agricultural premises in 2004 and 2017 was revealed by Cohen's Kappa (see Table 2). The results show that Blatná SD is the only region where a high stability of non-agricultural use in 2004 and 2017 was found (k = 0.88): only minor changes in utilisation as 'non-agricultural' were recorded between 2004 and 2017. On the other hand, agricultural use seems to be relatively stable in all study SDs (all values are higher than 0.61). If we compare the stability of utilisations of all types of uses of pre-1989 agricultural premises in the four study SDs between 2004 and 2017, the most stable is Dačice SD; on the other hand, the most dynamic development in land utilisation was found in České Budějovice SD.

The stability of utilisations of pre-1989 agricultural premises might also be illustrated by a multi-way contingent table, where gains and losses of individual types of utilisations among the four study SDs are expressed in a Mosaic plot (see Fig. 6). The Mosaic plot shows losses and gains across all five types of uses of pre-1989 agricultural premises and the four SDs between 2004 and 2017. Almost all changes among the types of uses and regions are different from expected values, i.e. Standardised Pearson residuals are greater than + 4.0 (dark green in the Mosaic plot) or smaller than − 4.0 (dark red in the Mosaic plot).

5.6 Structure of the transition of agricultural brownfields: 2004–2017

The areas of agricultural brownfields that were detected in 2004 and regenerated by 2017 significantly differs among individual regions (chi-squared = 2,440.18, df = 12, p < 0.001). The most remarkable result of this analysis lies in differences between the two rather urban SDs (Blatná and České Budějovice). In both cases, the abundance of agricultural brownfields from 2004 was substantially eliminated by 2017. In Blatná SD, such development was caused by a significant renewal of agricultural activities in the region (40% of agricultural brownfields from 2004 recorded agricultural use by 2017). On the other hand, in České Budějovice SD, the regeneration of agricultural brownfields was recorded for non-agricultural purposes.

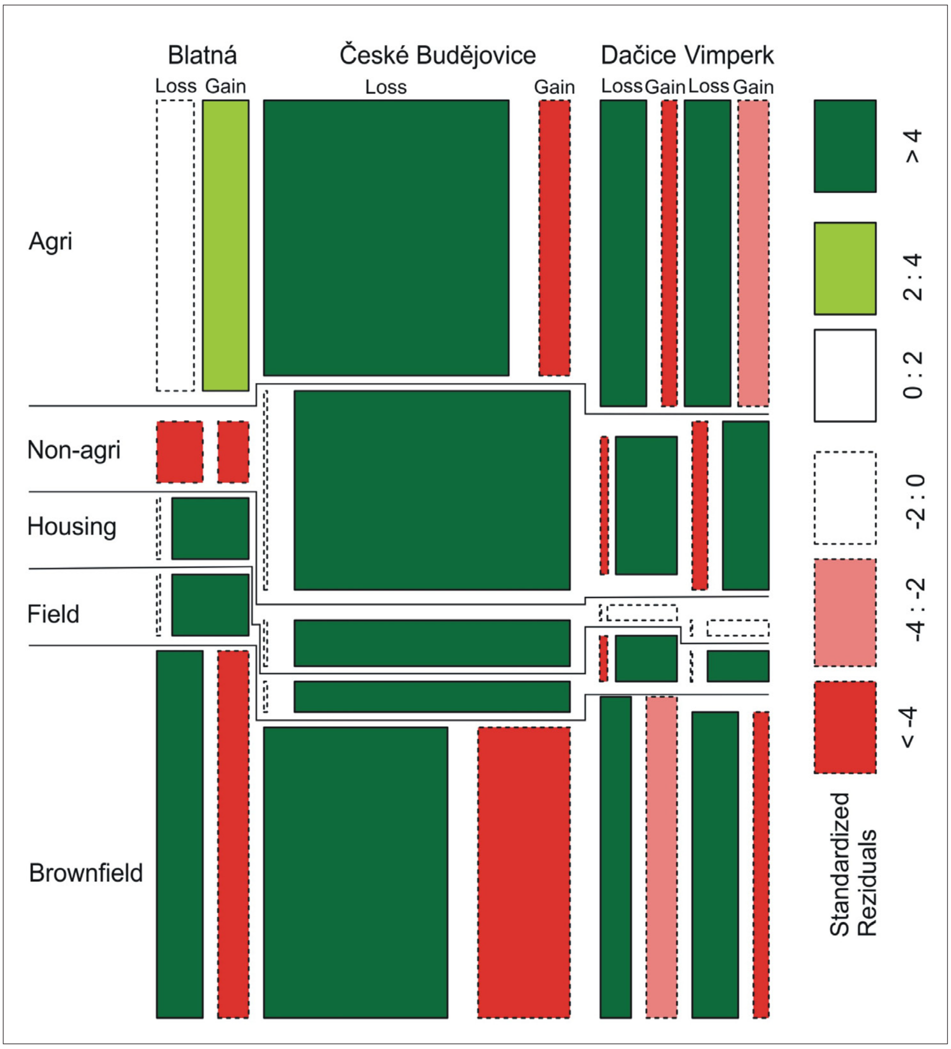

Fig. 6: Mosaic plot of the changes of all land-uses among all study SDs: 2004–2017
Source: authors' elaboration

Land cover	Blatná	ČB	Dačice	Vimperk
agri	0.71	0.61	0.70	0.66
brownfield	0.33	0.40	0.56	0.44
field	n.a.	0.40	0.59	0.34
housing	0.43	0.32	0.73	0.62
non-agri	0.88	0.40	0.47	0.66

Tab. 2: Cohen's Kappa for all studied types of land use and the four study SDs. Source: authors' calculations

In both SDs, we also discovered important agricultural brownfield regeneration for housing (in contrast to the other two SDs). In Dačice SD, 60% of agricultural brownfields from 2004 were registered as agricultural brownfields in 2017 (see Fig. 7); in other SDs, their acreage was reduced by more than one half (in Blatná SD, it is one third compared to the situation in 2004).

5.7 The structure of contemporary (2017) agricultural brownfields

Employing the Mosaic plot (see Fig. 6), we identified the occurrence of new brownfields during this period. The evaluation of the last hypothesis should answer our effort to comprehend the origin of agricultural brownfields in various study regions (unfortunately, the hypothesis cannot be tested due to many null cell entries in the measured values). In all four studied SDs, contemporary agricultural brownfields (in 2017) are represented by more than half of the agricultural brownfields already existing in 2004 (see Fig. 8). This phenomenon is particularly important in the peripheral SDs of Dačice and Vimperk, where almost two-thirds of the long-term agricultural brownfields are located. In Blatná SD, the occurrence of new brownfields is based on both agricultural and non-agricultural uses, whereas non-agricultural use does not generate any new brownfields in České Budějovice SD (in the period 2004–2017).

6. Discussion

There was no increase in the size of pre-1989 agricultural premises by 2004, which might be interpreted as a result of minimal investments in agriculture in this period (Bičík and Jančák, 2005; Jančák and Götz, 1997) and difficulties in the adoption by Czech agriculture to "western" trends (Nešpor, 2006). On the other hand, expansion of agricultural activities is remarkable after 2004, both in the number of enlarged agricultural premises and their total acreage. Both indicators are closely linked to the effects of the subvention system connected to support of energy transition, i.e. the generation of renewable energies by agriculture (Chodkowska-Miszczuk et al., 2019; Martinát et al., 2016; Van der Horst et al., 2018). A major increase of acreage is linked to the installation of large-scale on-ground photovoltaic power plants (an increase of 5.114 areas, thus, for example, some 87% of new areas of agricultural premises in České Budějovice SD). This increase of non-agricultural use is most frequently seen at the expense of arable land immediately attached to the original agricultural premises (Klusáček et al., 2014). Only in two cases (covering a total acreage of 245 ares), have we found that pre-1989 agricultural premises were demolished and a photovoltaic power plant was developed. The remainder of these areas are covered by buildings connected to the development of biogas stations that were built in all four SDs (Van der Horst et al., 2018). The generation of biogas that was massively supported by the government between 2008 and 2012 (Martinát et al., 2016), is clearly behind the expansion of pre-1989 agricultural premises.

The tendency in the reduction of agricultural use of the pre-1989 agricultural premises that can be noted by 2004, continued also after that year. On the other hand, a significant decrease of the acreages of agricultural brownfields between 2004 and 2017 is detectable, as well as an increase of acreages of agricultural premises that were transformed into non-agricultural use and housing. This development documents an increase of investment inflows into agricultural premises after 2004 (Pelucha et al., 2017; Věžník et al., 2013), as redevelopments for housing need large construction works and frequently also demolitions (Věžník and Konečný, 2011).

These outlined tendencies vary between individual study SDs, however. For example, housing development as a new use of agricultural premises is primarily linked to highly urbanised areas, such as the surroundings of the City of České Budějovice, the regional capital. It is obvious

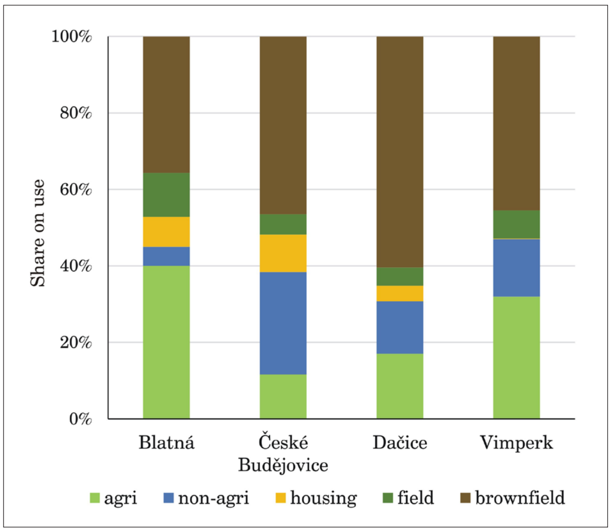

Fig. 7: The current use (in 2017) of agricultural brownfields existing in 2004
Source: authors' calculations

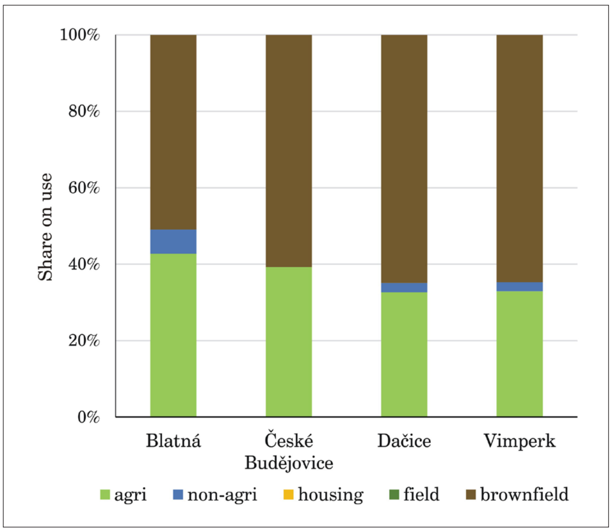

Fig. 8: The former use (in 2004) of brownfields identified in 2017.
Source: authors' calculations

that housing and general property prices are significantly higher compared to other regions, which enables higher investments for the re-establishment of various properties into housing (Kubeš and Kraft, 2011; Popjaková and Blažek, 2015). The same factors account for investments into other non-agricultural uses. Thus, the existence of an agglomeration centre significantly affects possibilities for new uses of agricultural premises (Skála et al., 2013), which is a phenomenon that is not existing in the peripheries (Klusáček et al., 2013). On the other hand, Blatná SD presents a very interesting case as the redevelopment of agricultural premises into housing and non-agricultural use there is comparable to České Budějovice SD. Similarly, a high ratio of agricultural use of former agricultural premises was detected in both SDs. This is in contrast to the development in Dačice SD, where there is a high ratio of agricultural use, minimal housing use, a low level of non-agricultural use and a relatively high share of agricultural brownfields. The use of pre-1989 agricultural premises in Vimperk SD is somewhere between the two extreme examples mentioned above. This might be interpreted as a result of general development of three various peripheral regions (Kubeš and Kraft, 2011; Perlín et al., 2010).

České Budějovice SD appears to have the character of high dynamic changes in the structure of utilisation of agricultural premises between 2004 and 2017. This is primarily linked to very high losses of agricultural use in this period, and also to a high ratio of conversions into housing and non-agricultural activities. This SD might be described as a typical development region, where constant and dynamic changes in space use are typical as a result of competition among particular utilisations (Haggett, 2001), as well as suburbanisation processes in this area (Popjaková and Blažek, 2015).

Blatná SD is typified by high gains in both housing and non-agricultural use but at the same time, by the stability of agricultural use. At the same time, surprisingly, the higher level of renewal of agricultural use of agricultural premises (the lost agricultural function by 2004 and becoming agricultural brownfields that time) was detected here. Such results might indicate that the region around Blatná is an example of a rural territory that is traditionally based on agriculture but simultaneously is capable of experiencing economic growth (Perlín et al., 2010), as well as being able to perform expected functions (de Roest et al., 2018). From this point of view, Vimperk and Dačice SDs are in a worse situation as they are located along the state border (with Bavaria and Upper Austria, respectively), and both are formed by outer peripheries with all the development problems connected to such locations (Klufová and Šulista, 2018). At the same time, it is clear that in Dačice SD, changes in utilisation of pre 1989 agricultural premises between 2004 and 2017 were at a minimal level. This confirms the characteristics of it being the type of the countryside that is rather problematic with respect to development (Perlín et al., 2010).

For the utilisation of pre-1989 agricultural premises, the largest dynamic is connected to the rise in the numbers of agricultural brownfields or to the end of their life cycle (the occurrence of new use), as these fundamentally affect the character of rural settlement (Klusáček et al., 2013). What might be interpreted as surprisingly good news is that in three of the four SDs (except Dačice SD), there has been a decrease in the acreage of brownfields to less than one half (for the period 2004–2017). The most significant renewed utilisation of agricultural premises is detectable in Blatná SD, where the majority of premises experienced the return of agricultural functions and housing. This result also demonstrates the development potential of this SD as a functional rural region. In comparison, České Budějovice SD recorded the highest detected utilisation of pre-1989 agricultural premises for non-agricultural use. To emphasise, we have not detected any increase of new brownfields in the agricultural premises that were utilised for non-agricultural use in 2004, in the following years. These results might serve as confirmation of the assumed impacts of the upper-regional urban centre (the City of České Budějovice) on agricultural transition in its surroundings (Lazzarini, 2018).

A significant renewal of agricultural functions was also revealed in Vimperk SD. This SD is situated in a less favourable mountainous region, focusing mostly on extensive livestock breeding. A very large share of permanent grasslands farmed under organic farming status can also be found here (Zagata et al., 2019). The most problematic situation is evident in Dačice SD, where for more than 60% of agricultural brownfields from 2004 no other new use has been found by 2017. This result also illustrates the non-developmental position of the district.

We are persuaded that, in all studied regions, the most concerning factor for future development are long-term brownfields, as they form more than half of all brownfields (in peripheral SDs, it is almost two thirds). These sites are not only abandoned but, as a result of long-term desolation, they are also neglected. Therefore, redevelopment of structures within these long-term brownfields is not usually possible and demolitions remain as the only solution. On the other hand, a renewal of agricultural brownfields by means of demolitions usually makes the regeneration projects even more expensive, which makes such efforts even more difficult and challenging (Klusáček et al., 2018; Kunc et al., 2018; Limasset et al., 2018), especially for developmentally weak regions.

7. Conclusions

Changes in the utilisation of the pre-1989 agricultural premises of former cooperative farms and state farms in the last three decades are dynamic and significantly affected by their location. Many agricultural brownfields were recorded by 2004 and many sites had been utilised for non-agricultural purposes. After 2004, the acreage of agricultural brownfields has been reduced and new utilisations for housing and other non-agricultural activities significantly increased. The transitions in the land uses of pre-1989 agricultural premises are heavily influenced by the social and economic environs of particular sites. Firstly, it seems that proximity to an upper-regional centre is of crucial importance for decisions of how (and if) the site will be newly re-used. Secondly, the peripheral location of a site also affects the level and the selection of options for how particular agricultural premises are used. In these four case studies, the marginality of particular regions is increased by their location in the border regions of outer peripheries, where the probabilities of the presence of agricultural brownfields and of the long-term abandonment of agricultural premises is higher. The agricultural use of these premises has a particular importance here but its use for housing is rather limited. For a traditional developed countryside, we have found a typical low level of the share of long-term agricultural brownfields, but after 2004, the re-use of agricultural brownfields for agriculture was ascertained, which is complemented by use for housing.

We believe that the results of our analyses complement existing knowledge on the spatial effects of agricultural transitions in various types of Czech rural regions after 1989. On the other hand, the limitations of this study have to be underlined, too. Four varying SDs in the South Bohemian Region were analysed, so that different development trajectories in the use of agricultural premises could be identified. Further research is needed so that the results of our analyses could be confirmed from other regions with varying social, economic and geographic conditions. Probably, researchers would obtain a very different picture if areas with good soil fertility were also analysed. In-depth probes on the types of regions of other CEE countries, where similar processes occurred in the last three decades, could be also useful for test purposes and to find out if our results possess general validity. In our opinion, the selection of time horizons for analyses (1989, 2004 and 2017) is justifiable, but surely, if other years were to be selected for analyses, more light could be shed on individual periods of the Czech and other CEE agricultural transitions.

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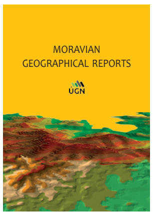

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The current status of orchard meadows in Central Europe: Multi-source area estimation in Saxony (Germany) and the Czech Republic

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Abstract

Orchard meadows are appreciated as an integrated land use of high cultural and biological value. While such meadows are typical habitats for temperate Europe, they experienced a decline in their total area during the second half of the 20th century, both in Western and Eastern Europe. In this contribution, we compare their current area and status in terms of semantics, law, public support in general, and the efficiency of public support in both Saxony and the Czech Republic. We estimated the area in Saxony on the basis of three public mapping projects. In the Czech Republic, where no recent mapping included orchard meadows as a specific land-use type, we carried out our own mapping. Hence, we mapped 124 randomly selected plots of 1 km^2. To cross-reference results from both countries, we used the pan-EU project LUCAS (Land Use/Cover Area frame Survey). According to various different sources, the orchard meadows cover 0.09–0.55% of Saxony and 0.01–0.72% of the Czech Republic. Interestingly, the results of the three mapping projects conducted in Saxony vary from each other. Although orchard meadows are supported by financial incentives of the respective governments in both countries, the Saxon approach concentrating more on individual activities (sanitation of old trees, planting, grassland management), seems more focused than the single measure practised in the Czech Republic. One key to a greater public awareness of the orchard meadow problematic can lie in the promotion of a simple expression referring to this specific landscape feature in Czech, similar to the phrase common in the German language: 'Streuobstwiese'. Our suggestion for the Czech language is: 'luční sad'.

Keywords: *Orchard meadow; Streuobst; LUCAS; agricultural policy; Germany; Czech Republic*

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1. Introduction

Orchard meadows are a phenomenon authentic to cultural landscapes in temperate Europe, spreading from the Atlantic coast (pré-verger in French) to Central Europe (Streuobstwiese in German) (Herzog, 1998). They are characterised by fruit trees with high stems, sparsely distributed on either mowed or grazed grassland. The fruit trees are ordinarily of many types and varieties and of various ages.

Orchard meadows have high ecological value as biotopes (Horak et al., 2013; Thiem and Bastian, 2014; Zillich-Olleck and Bauschmann, 1991). The fruit trees serve as a substitute habitat for birds (Kajtoch, 2017) and saproxylic beetles (Horak, 2014), while species-rich grasslands often grow underneath them (Žarnovičan et al., 2017). Due to the fact that orchard meadows generate a multitude of ecosystem services and maintain biodiversity, they are valuable elements of green infrastructure in both urban and rural areas. Orchard meadows are connected to traditional ecological knowledge (Žarnovičan, 2012), cultural ecosystem services such as recreation and education (Ohnesorge et al., 2015), and the preservation of gene banks for many local fruit tree varieties (Fischer, 2007). For regulating ecosystem services, orchard meadows provide pollination, climate regulation, flood mitigation, erosion control and water purification (Herzog, 1998). Orchard meadows both grace traditional rural landscapes (Thiem and Bastian, 2014) and can construct the green infrastructure of modern cities (Tóth and Timpe, 2017).

In contrast to the above-mentioned ecosystem service values, the decrease in the economic importance of orchard meadows is attributed to transformations in fruit supply

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chains. Specifically, there is an overall move to intensively managed orchards and the separation of integrated land uses into singular ones – fruit production in one place and arable land or grassland in another (Herzog, 1998). The fruit production of orchard meadows is perceived as one of the most vulnerable and important ecosystem services in the cultural landscape of the Swabian Alb (Plieninger et al., 2013).

This form of traditional agroforestry has been recently surpassed by modern agroforestry systems (Nerlich et al., 2013). Orchard meadows are mentioned as a threatened feature of traditional landscapes (Antrop, 2005). After the expansion of fruit trees during the 18th and 19th centuries and the peak of orchard meadows in the middle of the 20th century, numbers have declined throughout the second half of the 20th century in both democratic and socialist parts of Europe (Herzog, 1998). The decline of the total orchard meadow area was reported in eastern Germany as 37% in the period 1968–2008, which was the largest decrease among the studied types of 'trees outside forests' (other types discussed were hedgerows, isolated trees or woodlots: Plieninger et al, 2012). The decline was stronger in north-western Germany, with a 74% decrease from 1979 to 2009 (Umweltbundesamt, 2010, p. 89). A milder decrease (22%) was recorded in south-western Germany during a similar period (Plieninger et al., 2015b), and in some locations there was even an increase during the last century (Plieninger, 2012). Radical decline of the orchard meadows area was reported from central Slovakia between 1950 and 2010 (Hanušin and Lacika, 2018). The area of non-forest woody vegetation, including fruit trees and a number of individual features, declined in the second half of the 20th century in the hilly region of eastern Czech Republic (Demková and Lipský, 2015).

At present, orchard meadows are further threatened by agricultural intensification, urbanisation (Plieninger et al., 2015b), and the abandonment of undergrowth and tree management (Milton et al., 1997; Demková and Lipský, 2015). As described for the case of Slovakia, many orchard meadows are managed by the elderly, and thus the land maintenance in rural regions is threatened by the loss of traditional approaches and emigration of younger generations to urban regions (Špulerová et al., 2015; Žarnovičan, 2012).

Despite a certain level of public support for the managers of orchard meadows, it is not enough to guarantee a sustainable maintenance of current plots, and woefully insufficient for the establishment of new plots, as was shown in Lower Austria (Schönhart et al., 2011) and the Dresden area (Ewert, 2018). There have been measures proposed directly for improving orchard meadow policies, such as adding orchard meadows to the habitat list of Annex 1 (92/43/CEE Directive) (Kajtoch, 2017), or increasing premiums within the framework of the Agri-Environmental Policy (Schönhart et al., 2011). Some authors have suggested new management practices: for example, increasing harvest efficiency by shared mechanisation; providing an added value to the fruit by processing it (Schönhart et al., 2011); introducing the cultivation of energy crops in the understorey; and intensifying the processing of fruit into juices (Plieninger et al., 2013).

One problem with such measures is that many orchard meadow managers regard farming as a hobby, and they can be an inefficient target for agricultural subsidies since they often do not qualify for the minimum requirements of said subsidies (Ohnesorge et al., 2015). One general ambition, then, is to raise public awareness and connections to some regional identity, resulting in higher local fruit consumption and the successive creation of new orchard meadows (Rost, 2011).

To create good policy and strategies, it is necessary to know how important is the role that orchard meadows play in the landscape, beginning with how much area they cover. One estimate is that 10,500 km^2 of the European Union is occupied by grazed or intercropped areas with fruit, olive, and nut trees (den Herder et al., 2017). Another estimate, based on different sources from the end of the 20th century, comes to similar results, namely that 10,000 km^2 of Europe is covered by scattered fruit trees (Herzog, 1998). Den Herder et al. (2017) estimate there are 358 km^2 of grazed areas with fruit trees in Germany (0.1% of the total area), while Herzog (1998) states that there are 2,250–5,000 km^2 of orchard meadows in Germany, which amounts to 0.6–1.4% of the country's total area (note the difference between the objects under review). Germany's eastern neighbour, the Czech Republic, is said to have 72 km^2 of grazed orchards (0.09%: den Herder et al., 2017) or 93 km^2 of orchard meadows (0.12%: Herzog, 1998). Rapid declines are also evident here: in the first half of the 19th century, 0.64% of Bohemia (the historical territory: 2/3 of the present-day Czech Republic) was covered by agroforestry land with fruit trees (Krčmářová and Jeleček, 2017).

Several themes emerge as relevant for this paper. To accomplish better conservation and restoration of orchard meadows and to raise the appreciation of biodiversity and ecosystem services, a common terminology is required. Secondly, comparisons beyond European borders should give insights as to how this type of an ecosystem can be protected at an international scale, where subsidies already exist and what (EU) policy can do to maintain it. Finally, knowledge is needed about the precision of geo-data for this ecosystem type, about the available data to measure them and about their validity.

Therefore, the paper first clarifies the semantics of German and Czech terms, compares them and gives suggestions on how exactly to nominate this specific type of orchards in national debates. Second, the legal status and system of agricultural subsidies in both neighbouring countries are outlined. Third, we try to increase the precision of the estimated area of orchard meadows and their spatial distribution in the Czech Republic and Saxony, one federal state of Germany. The reason for choosing only one federal state in Germany is that Saxony has specific legal conditions in nature conservation, as well as completed unique land-use and vegetation mapping projects depicting orchard meadows. A similar approach is used for the Czech Republic and allows us to make a one-to-one comparison.

Previous studies had severe insufficiencies, namely den Herder et al. (2017), which took into account only those areas with fruit trees that are grazed, and Herzog (1998), which estimated the area based on non-explicit sources, for example relying on data from the Czech State Statistical Office despite orchard meadows not being explicitly recorded there. The present study is based on the multiple geodata approach. But first, we will discuss the current linguistic and legal status of orchard meadows in Saxony and the Czech Republic, and then we will continue to scrutinise orchard meadow support measures and estimate their efficiency.

2. Current status

2.1 Semantics

The English term 'orchard meadow' started to be used by researchers from German-speaking areas who were trying to find an equivalent for the word *Streuobstwiese*[1] (Ohnesorge et al., 2015; Schönhart et al., 2011; Steffan-Dewenter and Leschke, 2003). Another term we can encounter in English-language-based scientific literature is a 'traditional orchard', used in studies from Poland, Slovakia or the Czech Republic (Horak, 2014; Kajtoch, 2017; Špulerová et al., 2015; Žarnovičan et al., 2017). The most precise, but much longer, translation of *Streuobstwiese* is 'scattered fruit tree meadow' (Thiel et al., 2012).

Concerning the Czech language, there is the common word sad, which is equivalent to the English 'orchard'. It includes both intensively and extensively managed stands of fruit trees, which may also be ploughed. Expressions referring to extensively managed orchards are *extenzivní sad* and *vysokokmenný sad*[2]. In comparison to the German Streuobstwiese, these Czech expressions feel very professional, and they are used mostly by experts in conservation. There are also terms dividing orchards by the secondary use of the understorey, i.e. *polní sad* (when intercropped), *luční sad* (when mowed), or pastevní sad (when grazed). In Slovak, very similar to Czech, the term *sadová lúka*[3] is sometimes used (Žarnovičan, 2012) to refer to the orchard meadow concept in general.

2.2 Legal status – conservation

Orchard meadows are not listed as a protected habitat in Annex I of the Habitats Directive of the Council of the European Communities (Council of the European Communities, 1992), nor in Article 30 of the Federal Nature Conservation Act (BNatSchG, 2019), which is valid for Germany as a whole. Some German federal states, however, do list orchard meadows as nature conservation objects. The Saxon Nature Conservation Act (SächsNatSchG, 2018) mentions orchard meadows (*Streuobstwiese*) in the list of protected biotopes (§21 Art 1 No. 4), which means that any action that can lead to the destruction or damage of the biotope is forbidden (cf. BNatSchG, Art 30 No. 2). According to one commentary to the Saxon Nature Conservation Act (Göttlicher, 999), an orchard meadow must cover an area of 500 m^2 and must grow 10 trees at a minimum to qualify as a *Streuobstwiese*. The Czech Nature and Landscape Conservation Act (ZOPK, 2017) generally obliges all owners of trees to care for them. There is also an instance of 'remarkable tree', which ensures stricter protection, though this is used only in exceptional cases.

2.3 Public support

In both the Czech Republic and Saxony, specific measures supporting orchard meadows maintenance have been implemented. The Czech measure supported by the second pillar of the Common Agricultural Policy (CAP) for organic farming is called Krajinotvorný sad ('landscaping orchard'). Conditions to get this subsidy contain: growing high- or middle-stemmed trees to a minimum density of 50 trees per hectare (with a density greater than 100 trees/ha, a different program is more suitable). The trees must grow on once-a-year mowed or grazed grassland. Furthermore, farmers have to commit to work under the specified conditions for at least five consecutive years, and the trees have to be clipped at least once in the first four years after planting (Ministry of Agriculture of the Czech Republic, 2016). Together with basic and greening payments, each farmer, who is registered as an agricultural entrepreneur by the ministry of agriculture, can get approximately EUR 365/ha/year for managing the land in this way. There were 771 field blocks thusly supported, accounting for 1,009 ha (0.013% of the Czech Republic) in total, according to government statistics from January 2018 (Ministry of Agriculture of the Czech Republic, 2018).

Orchard meadows in Saxony are eligible for support from the program Richtlinie Natürliches Erbe ('Guidelines for Natural Heritage'). This program concerns, among other topics, the sanitation of old fruit trees and planting of new fruit trees. The first goal is supported by EUR 41 (easy conditions) or EUR 75 (hard conditions) per tree, with a minimum support for one project of EUR 500 (thus, a minimum of 7 trees per project in hard conditions). Following this, one newly planted tree is supported by EUR 68 with the same minimum sum per project (resulting in at least 8 new planted trees per project). Since 2014 when the program was established, 3,907 existing trees in 68 projects have been subsidised, an average of 58 trees per project (as of Spring, 2018). During the same period, 3,866 new trees were planted in 57 projects, an average of 68 trees per project. More than twenty (22) supported projects covered both planting and restoration, although it is unclear how much they contribute to the numbers mentioned above. Thus, we can roughly estimate that at least 100 plots in Saxony have been supported by the National Heritage program. The management of grasslands can be supported by a similar measure (Richtlinie Agrarumwelt- und Klimamaßnahmen).

Both in the Czech Republic and Saxony it is possible to request direct payment for grassland management within the first pillar of CAP. There are also other publicly- and privately-funded programs aimed at the planting of new fruit trees.

3. Methods

To estimate the total area of orchard meadows in Saxony and the Czech Republic, we used several existing datasets (their basic properties are shown in Tab. 1), one adjusted pan-EU data source, and researcher-mapped randomly selected plots. Other comparable data sources do not differentiate orchard meadows well enough: for example, the Corine Land Cover uses the class 2.2.2 (Fruit tree and berry plantations), which matches orchard meadows with the intensive type of plantations. Moreover, Corine Land Cover uses a minimum mapping unit of 25 ha, which is inappropriate to estimate the area of orchard meadows, with their typical small scale. Because each country has different types and the extent of data sources available, our approach differs for the different states, though it is cross-referenced with the use of the LUCAS (Land Use/Cover Area frame Survey) grid data.

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[1] *Streuen* = scatter, *Obst* = fruit, *Wiese* = meadow. Sometimes the word Streuobst is also used (Herzog, 1998; Tojnko et al., 2011), which includes intercropped orchards and such landscape elements as fruit alleys, etc.

[2] Direct translation to English: 'orchard with high-stemmed fruit trees'

[3] Direct translation to English: 'orchard meadow'

Country	Dataset	Years of origin	Min. registry unit (ha)
Saxony	SBK2	1996–2002	0.05
Saxony	BTLNK	2005	0.05
Saxony	ATKIS	2013–2016	1.00
Czech Republic	LPIS	2018	0.50
EU	LUCAS	2015	0.05

Tab. 1: Analysed data sets on orchard meadows
Sources: Selektive Biotopkartierung 2. Durchgang (SBK2) = Selective habitat mapping; Biotoptypen- und Landnutzungkartierung (BTLNK) = Mapping of biotope types and land use; Amtliches Topographisch-Kartographisches Informationsystem (ATKIS) = German digital topographic information system; LPIS – Land Parcel Identification System; LUCAS = Land Use / Cover Area frame Survey

3.1 Saxony

There were three independent projects conducted in Saxony, which mapped orchard meadows as spatially delimited patches.

Selective biotope mapping 'SBK' (Selektive Biotopkartierung = Mapping of selected biotopes; LfULG, 2002) in Saxony is thought to record all biotope types that are protected by federal and state nature conservation laws (BNatSchG, 2019; SächsNatSchG, 2018). SBK was used as bases for the administrative work of the nature conservation agency. The mapping was carried out on-site by experts, basing it on the already-existing BTLNK (see below). After completion of the first pass in 1994, a second pass 'SBK2' was carried out between 1996 and 2002. Since this second set was only partially revised by the third pass in 2006–2008, SBK2 provides the last available complete dataset. Since 2009 no revision has been carried out, so while the SBK data are very precise they are also potentially out of date. Because every biotope type was mapped and described in great detail to make a sophisticated data set, some smaller areas were described only as biotope complexes, such that an exact calculation of the real biotope area is rather difficult (Syrbe et al., 2018).

A complete aerial-covering biotope mapping 'BTLNK' (Biotoptypen- und Landnutzungkartierung = Mapping of biotope types and land use) based on colour-infrared aerial views was carried out in Saxony in the years 1992, 1993 and 2005. The recent data set is available from the Saxon Nature Conservation Agency (LfULG, 2005). The resulting digital biotope maps can be more precisely spatially analysed, but since they use remote sensing data, their precision is limited; in other words, shortcomings and confusion with other similar biotopes are an ever-present possibility.

The landscape model of the German digital topographic information system (ATKIS-Basis-DLM = Amtliches Topographisch- Kartographisches Informationsystem – Basis Digitales Landschaftsmodel; SGVSG, 2016) is updated separately by each federal state in Germany. The stage of project development varies among the German states. The classification system contains 190 object types. The minimum mapping unit for this system is 1 ha and therefore coarser than SBK2 and BTLNK (Tab. 1), and updates are carried out using aerial photography and more thematic details. Since then, the topographic data have been updated using high-resolution remote sensing data (SGVSG, 2016).

Based on these three projects, which spatially differ between each other, we constructed an intersection diagram expressing the probability for orchard meadow occurrence in Saxony. We assume that the probability of identifying orchard meadows is higher the higher the number of available data sources, particularly considering that newer sources tend to be more credible than the older ones.

3.2 Czech Republic

There is only one data source that spatially delimits orchard meadows in the Czech Republic, the Land Parcel Identification System (hereinafter LPIS). LPIS registers the land for which the discussed agricultural subsidies are provided. We took the field blocks with land use registered as 'landscaping orchard' as patches with a certain occurrence of orchard meadows. The minimum area of one field block is set to 0.5 ha.

Because these field blocks with 'landscaping orchard' land use refer only to orchard meadows registered for their organic management and receiving subsidies, we further estimated their area on the basis of our own mapping in randomly sampled squares of 1 km^2. We performed the whole analysis in ArcGIS 10.5.1 (ESRI). To assure that the squares would be equally spread across the country, we used the Create Fishnet tool to create squares of 25 km per side (an area of 625 km^2). Polygons smaller than 625 km^2 were created around the country border. In each polygon larger than 300 km^2 (i.e. approximately half of 625 km^2) we placed one sampling square. We used the Random points tool to randomly place points and the Graphic Buffer tool to build squares around the points. Using this procedure, we prepared 124 squares of 1 km^2 to be mapped. The sampling method was arbitrarily set up to give a coarse overview of the spatial distribution of orchard meadows throughout the Czech Republic.

We mapped the orchard meadows in the delimited squares on the basis of orthophoto maps provided as a web map service by the Czech Office for Surveying, Mapping and Cadastre (2016, 2017). We further used the Basic map of the Czech Republic to check for gardens and orchards for identifying patches with present fruit trees. We also used the tool Panorama at mapy.cz (the Czech equivalent to Google StreetView) to check the height of the trees and their undergrowth. Single field visits in three squares showed us that this approach is suitable (see photos on Fig. 1). The method used is comparable to one of the BTLNK and ATKIS sources which did not do on-site mapping, though we used additional sources to remote sensing. The definition used to identify orchard meadows comes from the Saxon Nature Conservation Act. We considered orchard meadows only of at least 500 m^2 in area size and with 10 or more high-stemmed trees scattered (approximately 20–200 trees/ha) across grassland undergrowth. A certain level of successive overgrowth was accepted.

Fig. 1: The appearance of visited orchard meadows in northern Czech Republic: Moderately managed orchard meadow situated between home gardens and a forest in the recreational settlement of Bukovec (top left); Overgrown orchard meadow situated not far from the village Krušovice near Rakovník (top right); Intensively managed orchard meadow near the centre of Zíchovec village (bottom left); Orchard meadow with old apple trees threatened by the construction of a bypass route, Krušovice village (bottom right). Photos: M. Forejt

3.3 Central European context

We further used the LUCAS grid database to compare and cross-reference the results obtained from the defined datasets from Saxony and the Czech Republic. The LUCAS database, purchased in 2015, is comprised of 273,153 field-surveyed and 66,604 photo-interpreted geo-referenced points (Eurostat, 2015). For each surveyed or photo-interpreted point, land use, land cover, and other data were recorded. It covers only the 28 member states of the EU, thus Switzerland and Lichtenstein, both of which are normally considered Central European countries, were not included. Previously, the database was used to estimate the extent of wood pastures (Plieninger et al., 2015a) and other various types of agroforestry (den Herder et al., 2017).

Both studies, when considering land with fruit trees, took into the account only land with grazing management, although orchard meadows (no matter if grazed or not) are generally considered a type of agroforestry (Nerlich et al., 2013). Here, we only selected points with fruit trees as primary land cover [LC1 (primary land cover) = B71–B75 (apple trees, pear trees, cherry trees, nuts trees and other fruit trees and berries)], and we further used orthophoto and LUCAS PhotoViewer to adjust photos from each site and to verify each point for fruit tree density, stem height, and grassland undergrowth.

We applied the same definition of orchard meadows as before, including the minimum area (500 m^2) and minimum number of trees (10). We performed this procedure for all Central European countries that are EU member states (Germany, Austria, Poland, Czech Republic, Slovakia, and Hungary). The share in area of one geographic unit was estimated by dividing the number of points matching the criteria by the number of all points for each state in the Central Europe region (den Herder et al., 2017).

4. Results

Table 2 presents geographical coverage of orchard meadows in the Czech Republic, Saxony, and other parts of Central Europe. Regarding to the LUCAS database, not all the fruit trees points are registered, but only those have been manually selected that doubtless represent orchard meadows with high-stem scattered trees. Relatively low values (compared to marginal distributions of orchard meadows and total acreage) are found in Hungary and Poland, while the relatively highest values are those from the Czech Republic and Slovakia. Detailed findings are presented in subsequent sections.

4.1 Saxony

According to the individual mapping projects, there are 44.1 km^2 (0.24% of Saxony's total area; SBK2), 61.5 km^2 (0.33%; BTLNK), or 15.8 km^2 (0.09%; ATKIS) of orchard meadows in Saxony (see Fig. 2). The minimum overlap between all projects is 6.1 km^2 (0.03% of Saxony). Areas where at least two of these mapping projects agree on the occurrence of orchard meadows amounts to 26 km^2 (0.14% of Saxony), while areas where at least one project shows the occurrence of an orchard meadow is 86.3 km^2 (the potential maximum area of orchard meadows without considering different mapping criteria; 0.47% of Saxony). The interpreted LUCAS database suggests even more, namely that 0.54% of all points in Saxony are orchard meadows. The mean patch size of one orchard meadow is highest according to ATKIS (1.8 ha), and more than three times smaller according to both BTLNK (0.54 ha) and SBK2 (0.46 ha).

Orchard meadows are concentrated in central Saxony (the districts of Leipzig, Mittelsachsen, Meißen, Sächsische Schweiz-Osterzgebirge, and Dresden) in a wide strip

Geographic unit	Dataset	km^2	%
Saxony	SBK2	44.1	0.24
	BTLNK	61.5	0.33
	ATKIS	15.8	0.09
	SBK2+BTLNK+ATKIS	6.1–86.3	0.03–0.47
	LUCAS	99.7	0.54
Czech Republic	LPIS	10.1	0.01
	Random squares	437.0	0.55
	LUCAS	566.0	0.72
Austria	LUCAS	360.6	0.43
Germany		1924.1	0.54
Hungary		180.0	0.19
Poland		623.2	0.20
Slovakia		356.0	0.73
Central Europe		4009.9	0.41

Tab. 2: Orchard meadow areas in Central Europe according to multiple sources.
Sources: Ministry of Agriculture of the Czech Republic (2018), Eurostat (2015), BKG (2016), LfULG (2002), and LfULG (2005); authors' survey

starting south of Dresden, spreading northwest to the town of Meißen and west between the cities of Leipzig and Chemnitz. Concerning landscape units, orchard meadows are concentrated in Mittelsächsisches Lösshügelland ('Central Saxon loess landscape') and Östliches Erzgebirgsvorland ('Eastern Ore Mountains foothills') (Mannsfeld and Syrbe, 2008). There is a significant difference between the spatial coverage of orchard meadows in the three mapping projects. In the southwestern part of Saxony, there is a relatively high share of mapped orchard meadows in the BTLNK dataset, while SBK2 reports large areas of mapped orchard meadows in the east and in the Meißen district (see Fig. 3).

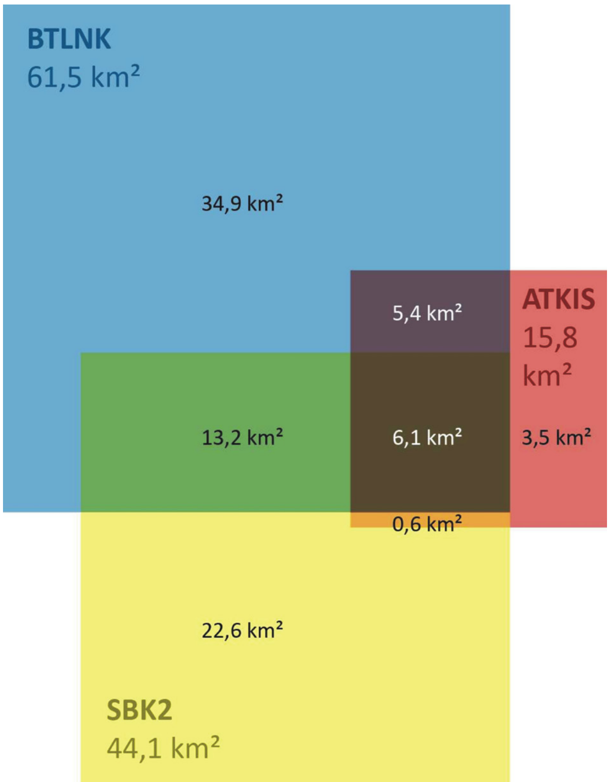

Fig. 2: Concordance in mapped orchard meadows in mapping projects in Saxony. Sources: BKG (2016), LfULG (2002), and LfULG (2005); authors' elaboration

4.2 Czech Republic

The LPIS system for registering land that receives agricultural subsidies, records 1,009 ha of orchard meadows (0.013% of the Czech Republic total area) in 771 field blocks in the Republic. They are mostly present in south-eastern, eastern and northern areas of the Czech Republic, where registered orchard meadows may reach up to 0.05% of the respective region's total area (see Fig. 4A). Concerning landscapes rather than administrative units, orchard meadow hot spots seem to occur in the Bílé Karpaty ('White Carpathians'), Ždánický les ('Zdanice Forest), Český ráj ('Bohemian Paradise'), and České středohoří ('Central Bohemian uplands') landscapes.

According to our digital mapping (Fig. 4B), 46 of the 124 mapped squares contained at least one patch of orchard meadow. Altogether we identified 68.7 ha of orchard meadows. The maximum orchard meadow share in one square was 12.8% (near the town of Kyjov), and the minimum share was 0%, which was true for 78 squares. 12 squares contained at least 1% of orchard meadows. Taking all the mapped squares together, we can calculate the average occurrence of orchard meadows in the Czech Republic as a 0.55% share of the country's total area. Again, there are apparent orchard meadows hot spots, especially eastern and partly in northern Czech Republic, and the south-western half of the Czech Republic does not show a high concentration of orchard meadows. One square, near the town of Rakovník, is a notable exception to this rule. Using the LUCAS database, we can estimate that 0.72% of the Czech Republic is occupied by orchard meadows.

4.3. Central Europe

In the context of Central Europe, the LUCAS database reveals that orchard meadows have the highest shares of land use in Slovakia (0.73%) and the Czech Republic (0.72%). The lowest shares, meanwhile, occur in Hungary (0.19%) and Poland (0.2%). Orchard meadows in Germany and Austria have average values (0.54% and 0.43%, respectively), which is due to very large areas with a very low density of points identified as orchard meadows (the Alps and North-German lowland).

Concerning the spatial distribution in Central Europe specifically (see Fig. 5), high concentrations of orchard meadows are found, not surprisingly, in Baden Württemberg, northern Bavaria, the Rhineland, eastern Saxony (all in Germany), in Steyerland (Austria), and the western Carpathians (western Slovakia, southern Poland, eastern Czech Republic), mostly between 100 m and 500 m above sea level (maximum at 1,135 m in the Alps in Austria).

Only very rare occurrences are found north of 52° latitude or in the whole of Hungary. Concerning our focal countries, low densities of orchard meadows are recorded in south-western Saxony and north-western and north-eastern Czech Republic (Fig. 5).

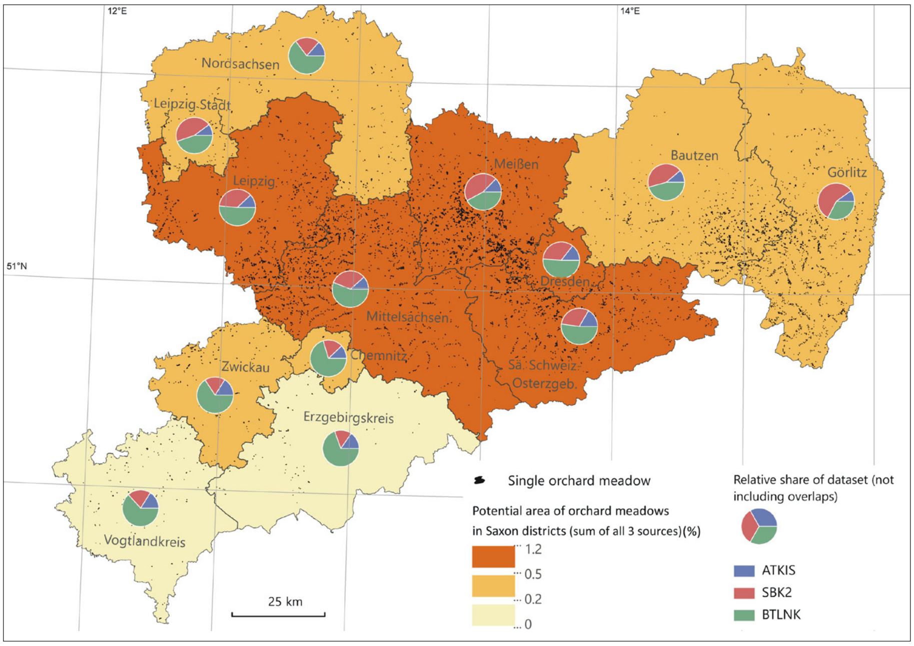

Fig. 3: Share of orchard meadows in Saxon administrative districts
Sources: BKG (2016), LfULG (2002), and LfULG (2005); authors' elaboration

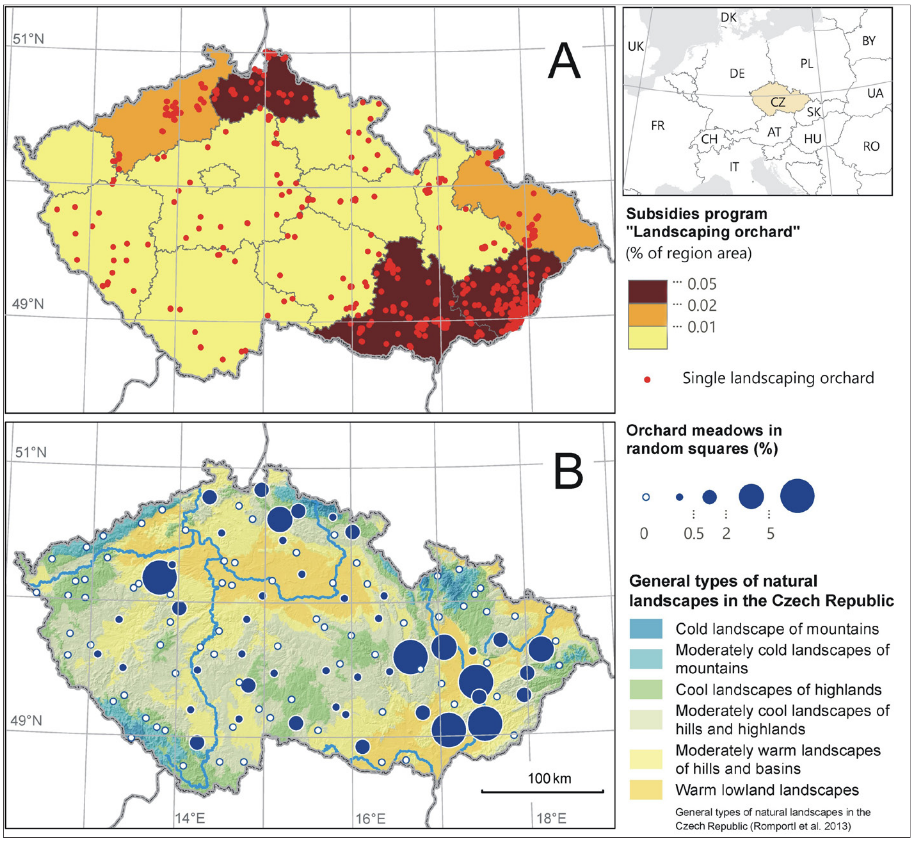

Fig. 4: The share of orchard meadows in the Czech Republic according to: A) LPIS (January, 2018); and B) authors' mapping based on aerial images (ČÚZK, 2016, 2017) and mapy.cz street view application. Sources: Ministry of Agriculture of the Czech Republic (2018), Romportl et al. (2013), authors' survey; authors' elaboration

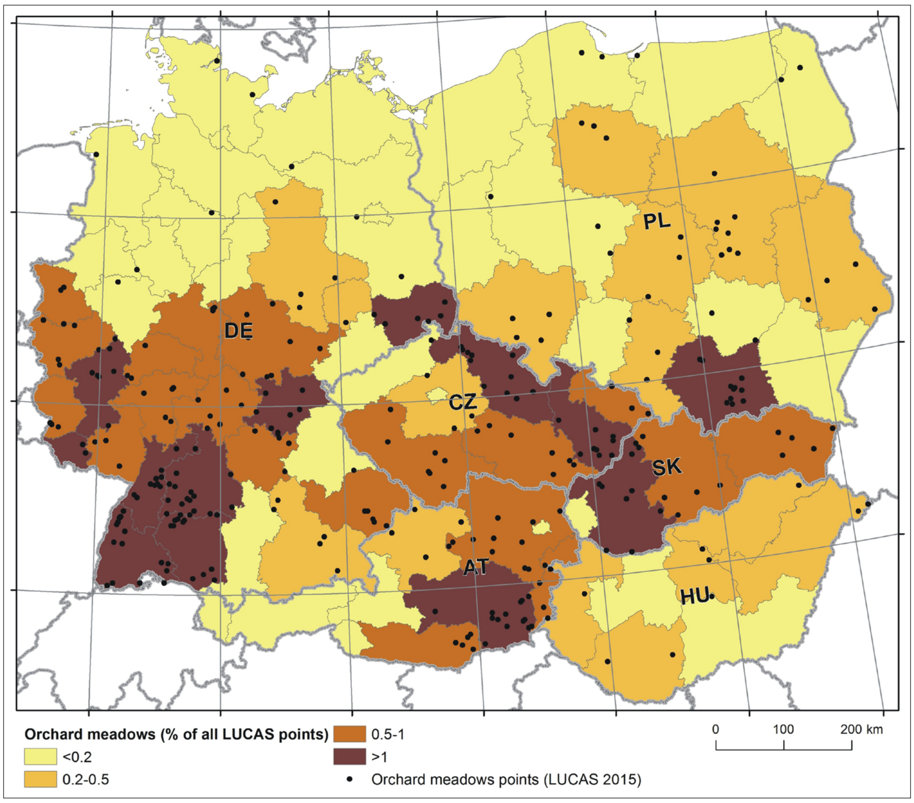

Fig. 5: Share of orchard meadows in Central European NUTS II units according to authors' verification of LUCAS points with fruit trees. Source: Eurostat (2015); authors' elaboration

Table 3 shows the share of points with interpreted orchard meadows in all mapping projects against the total point number of fruit trees. The highest values occur in Austria, Germany, and Slovakia, where orchard meadows make up about half of the fruit tree points. Lesser values are exhibited in the Czech Republic and very low shares are recorded in Poland and Hungary.

5. Discussion

Orchard meadows are a landscape feature typical for temperate Europe (Herzog, 1998). We used multiple geodata sources to estimate the area of orchard meadows and their spatial distribution in the Czech Republic and Saxony. Orchard meadows occupy a smaller share of the total area in Saxony than orchard meadows in the Czech Republic. This was confirmed by an additional source we used to cross-reference the results, the LUCAS grid database. In Saxony it is the central part of the territory that has the highest density of orchard meadows. South-eastern and northern Czech Republic are also characterised by high concentrations of orchard meadow plots. We do not consider the mapping of 124 random squares sized 1 km^2 each, however, to be a detailed orchard meadow distribution survey for Czech regions, rather we consider it to be an approximate localisation of large orchard meadow hot-spots.

Our study revises the previous area estimation of the total orchard meadow area in the Czech Republic. We estimate that the area is almost five times larger than the previous, often cited, estimate (Herzog, 1998). The present estimation suggests only a 15% decline since the mid- 19th century in Bohemia, which accounts for two thirds of the current area of the Czech Republic (Krčmářová and Jeleček, 2017).

According to LUCAS, the share of orchard meadows in Saxony is higher than what other data (SBK2, BTLNK, ATKIS, random squares own mapping) would leave us to believe. It is apparent that this widely-used source (den Herder et al., 2017; Plieninger et al., 2015a) overestimates the area of orchard meadows. Since only accessible points located lower than 1,200 m above sea level are included in the LUCAS dataset, the reason for the overestimation could be that orchard meadows are usually located in

Country	LC1 = fruit trees	Orchard meadows	Share OM/Fruit trees (%)
Austria	73	38	52.1
Czech Republic	121	41	33.9
Germany	273	144	52.7
Hungary	64	10	15.6
Poland	364	46	12.6
Slovakia	42	20	47.6

Tab. 3: Share of orchard meadows on all plots with fruit trees in Central Europe according to LUCAS and own visual evaluation of photos (Note: this is not share of orchard meadows to total area [cf. Tab. 2])
Source: Eurostat (2015); authors' elaboration

close proximity to villages and in rather hilly areas (Herzog, 1998). The area of land-uses with a similar spatial distribution (e.g. built-up area, gardens), is probably also overestimated, while land-uses typical for remote areas are underestimated in LUCAS. This important hypothesis should be tested in the future.

The LUCAS database, however, does give an overview and the possibility for comparison between several states and countries. When we compare different sources, especially in the cases of Saxon mapping projects, they agree only to a very small degree in the delimitation of orchard meadows. Such disagreement can be partly explained by the temporal extent of the mapping throughout the 20-year period (from 1996 to 2016). Another reason can be due to different mapping methods, as only SBK2 used on-site mapping, while ATKIS and BTLNK are based on remote sensing. Finally, orchard meadows are a transitional land use and the boundaries between them and the phenomena of gardens, intensive orchards, low-stemmed orchards, high-density fruit tree stands or young fruit tree stands, are very unclear. It presents a good example of the often difficult effort involved in putting landscape features into a single category (Dahlberg, 2015) or even of classifying landscapes (Wolski, 2016).

Regarding the share of orchard meadows among all fruit tree land cover in the LUCAS database, we can conclude that the largest proportions of orchard meadows per total fruit tree growing area are in Austria and Germany. We can also assume a high self-supply of fruit in these countries corresponding to the fact that orchard meadows in the Swabian Alb are often managed by hobby farmers (Ohnesorge et al., 2015). On the other hand, Poland, an important apple producer, has a low share of orchard meadows for the large amount of fruit trees growing in the country.

Considering public support in the two case study areas, one can apply a complex measure for the specific land use (Czech Republic) or separate measures for planting new trees, sanitation of old trees, and management of grasslands (Saxony). In the case of the Czech Republic, only 2% of orchard meadow areas (derived from the estimation based on our mapping of the 124 random squares – an average of 0.55%) receive subsidies designed for this land use in the 'landscaping orchard' program (10.1 km^2 in the country). Paradoxically, in the cases of orchard meadows which were mapped by us, not a single plot was subsidised by any means. The Saxon approach is not based on spatial delimitation, thus we cannot precisely estimate the share of supported orchard meadow areas. We can approximately estimate from data of the number of projects and trees that about 100 plots received support for the planting of young trees and/or the sanitation of old trees. If we take the data from BTLNK, namely the mean orchard meadow size of 0.54 ha and the total area of the orchard meadows of 61.5 km^2, we come to 54 supported hectares, which means that about 0.9% of orchard meadow areas are supported from the two programs. From the above-mentioned, it is apparent that the efficiency of public support towards orchard meadows is low in both Saxony and the Czech Republic.

Orchard meadows are land uses only partly covered by measures of CAP, even though they provide important ecosystem services. A similar case is the wood-pastures in Europe (Beaufoy, 2014; Jakobsson and Lindborg, 2015). This issue is discrepant with respect to the proclaimed intention of CAP to enhance the ecological functions of landscape. The presence of scattered trees on grassland (agroforestry) is considered to be an important climate change adaptation measure, yet as mentioned before, many orchard managers are hobby farmers (Ohnesorge et al., 2015), whose homesteads are not large enough to get public support. Since the orchard meadows are often managed by elderly people (Špulerová et al., 2015), there is a threat that traditional ecological knowledge connected with the care of fruit trees and fruit processing will fade away. Public awareness must be enhanced in both countries to attract younger people to adopt skills from people who still use them. If used, a more effective fruit production or new management practices such as cultivation of energy crops in the understorey, can lead to sustainability and the expansion of orchard meadows. (Schönhart et al., 2011; Plieninger et al., 2013).

One of the first steps to raise awareness of orchard meadows in the Czech Republic is to start using a specific term for the orchard meadows. Among landscape scientists, the term extenzivní sad ('extensive orchard') is used to describe orchard meadows as described above. If the same term were to be used by the general public, it could feel too professional and thus inappropriate. A better option could be luční sad ('meadowed orchard' or 'meadow orchard', where the meadow takes on a descriptive role). It seems important to use the word sad as a noun, rather than, for instance, the term sadová lúka ('orchard meadow', where sad is an adjective) as used in Slovakian research. The word luční (meadow-ish as a descriptor) specifies the type of orchard, sad being the only word used for an area of fruit production in an otherwise open landscape. The method of undergrowth management (whether pasture or mowing) could be deemed comparatively unimportant. Finally, the expression luční sad could be used as a label for products of orchard meadows, similar to the ways in which the word Streuobstwiese is used in relation to juices, jams, etc., in Germany.

6. Conclusion

Orchard meadows represent a landscape feature that is typical for temperate Europe: they provide a multitude of valuable ecosystem services. Based on the research presented in this study, both the Czech Republic and Saxony have high concentrations of orchard meadows in comparison with Central Europe in general. Orchard meadows cover more area in the Czech Republic than in Saxony, although they are protected by law only in Saxony, while the Czech language does not commonly use a distinctive term for orchard meadows let alone for them to be distinctly protected by the law. The information from recently available data sources differ too widely to set up a reliable monitoring program. In particular, data sources about orchard meadow coverage can differ. One estimation method differs from the other by almost 500% in Saxony (ATKIS – LUCAS) and by 7,200% in the Czech Republic (LPIS – LUCAS). The main problem with extracting orchard meadows from thematic maps or statistical data sets lies in the fact that they are a transitional landscape type, without consistent recognition. The highest densities of orchard meadows are located in parts of the Czech Republic and Saxony where biodiversity hotspots are also present. The orchard meadow is a type of traditional agroforestry with not only high historic heritage and recreational values, but also an ecosystem with potentially high resilience towards climate change due to their species and genetic diversity.

Some areas may even be called orchard meadow deserts, however – such as southwestern Czech Republic and the Ore Mountains – as these rather peripheral areas are regarded more for their touristic attractiveness, but they could benefit from a higher orchard meadow density.

The status of nature conservation differs essentially between the study areas. Whereas protection is directed to trees by the Czech legislation, in Saxony it is focused on the orchard meadow as a whole, which is not necessarily the case in the rest of Germany. Even though the latter approach of conservation seems to be more reasonable, regarding the share of orchard meadows on the whole area does not guarantee a higher quantity of this habitat type. Orchard meadows are subsidised from public budgets in both in Saxony and the Czech Republic, although with respect to the percentage of orchard meadows receiving such funds, the support cannot be really called efficient in either of them.

The high awareness of orchard meadows in Germany is generally highlighted by the well-known term (Streuobstwiese), which is frequently and successfully used, e.g. as a sales argument for fruits and juices produced in this sustainable manner. In Czech, a similar awareness could be raised by using the rather new expression luční sad, which feels ordinary and pleasant enough to get public appreciation. Since orchard meadows are often owned and maintained by elderly people, the threat of losing them in a long run must be countered by higher public attention and support. Policy agencies must find better solutions to protect these orchards in several areas, namely by improving the obvious small efficiencies of targetted subsidies and by enhancing overall data quality, so setting target values and their monitoring would be possible in future. We believe that the conservation and development of traditional knowledge connected with the orchard meadows can be raised by general interest, which is already partly being expressed by the activities of young and experienced farmers, NGOs, hobby clubs and public authorities.

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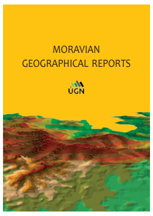

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A comparison of four approaches to river landscape delineation: The case of small watercourses in the Czech Republic

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Abstract

River landscapes represent key areas of great importance to human society as they perform many functions and provide valuable services. Traditionally, these areas have been perceived as geomorphological phenomena characterised by specific soil conditions, hydrological regimes and unique habitats. Due to the availability of detailed data, it is possible to perform a spatial delineation of river landscapes by interpreting these data using several different approaches. The results of these different approaches can vary considerably, since it is particularly challenging to define the river landscape along small watercourses for which the availability of suitable data is limited. The main aim of this study is to analyse the various methodological approaches that may be used to define the river landscapes of small streams, and to evaluate the efficiency of those approaches that can be applied in nature and landscape conservation. Two medium-sized catchments in the Czech Republic were selected as the study areas in order to ensure different natural conditions and degrees of anthropogenic pressure. As a result, an approach based on combining soil characteristics and topographic information is considered the most appropriate solution to delineate the river ecosystem.

Keywords: *floodplain delineation; small watercourses; river landscapes; Czech Republic*

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1. Introduction and theoretical background

River landscapes represent specific ecosystems, the existence of which are directly dependent on permanent or at least periodic contact with watercourses. These areas are beneficial to society for the wide range of functions and related services they provide. Geographically defined areas are broadly in line with the spatial extent of the area traditionally referred to as a floodplain (e.g. Lewin and Manton, 1975; Décamps et al., 1988; Hugett, 2003; Nardi et al., 2006; Kilianová et al., 2017). According to Tockner and Stanford (2002), river floodplains are defined as areas of low-lying land that are subject to inundation by lateral overflow water from rivers with which they are associated. Occasionally, floodplains are also referred to as valley bottoms (Williams et al., 2000, or Lindsay, 2003) and riparian areas or buffers (McGlynn and Seibert, 2003, or Katsuyama et al., 2005).

At present, however, the term 'riparian area' usually refers only to the sites closely adjacent to the riverbed that are covered by riparian vegetation (e.g. Dufour et al., 2019). The floodplain and river landscape areas, however, are not identical in terms of their spatial extent. The key difference between the two terms is the fact that a river landscape is defined on the basis of its actual functions (Štěrba et al., 2008): the main assumption is the actual presence of the watercourse in the landscape. By retaining water, river landscapes can buffer the effects of heavy rainfall and in this way protect economic activities and communities further downstream from flood damage. Many former natural river landscapes, however, are under increasing pressure from urban sprawl, infrastructure developments and agriculture. In Europe, up to 90% of river landscapes have been lost during the past centuries or are no longer able to serve as functioning natural ecosystems providing flood risk reduction and habitats favouring high biodiversity (EEA, 2016).

An important factor influencing the extent of river landscapes is primarily related to the anthropogenic activities that can alter local hydrological conditions, such as roads and railways, levees, flood walls and other line structures in the floodplain, thus limiting the natural functions of the

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ecosystem. Most river landscapes have been hydrologically disconnected from the riverbed by the construction of dykes and are currently often dominated by intense human use (Hein et al., 2016). According to Nilsson et al., 2005, Europe is the continent where the river landscapes are most affected by such kinds of human activities. Rinaldi et al. (2013) also noted that the habitat conditions in the remaining active floodplain areas have often been altered substantially by human impacts, such as river training, river damming, floodplain disconnection, aggradation, pollution by fertilisers and chemical contaminants, the introduction of invasive species or by intense forestry. The effects of floodplain management on the biodiversity of these unique ecosystems in several European countries were described by Schindler et al. (2016). The increasingly frequent and prolonged episodes of drought in Central Europe (e.g. Blauhut et al., 2016, or Kreibich et al., 2019) can also be perceived as one of the key variables influencing the extent of river landscapes due to decreased groundwater levels.

The basics of the "river landscape" concept first appeared in the late 1960s with the study of Leopold and Marchant (1968), who analysed the factors that formed the river landscape (then referred to as "riverscape"). Over time, the main object of study became the interactions between the different components of a river landscape, in the form of diverse patches. Energy and material flows between the patches in the river landscape environment were intensively studied through the "river continuum" concept (Vannote et al., 1980). The link between the watercourse and the surrounding area was considered the most significant and dynamic connection at that time (Amoros and Roux, 1988). The focus on solving spatial relationships in the landscape culminated with the development of the concept of habitat continuity (Ward, 1998), which received considerable attention in terrestrial landscape ecology. The contemporary understanding of a river landscape ecosystem in the Anglo–Saxon literature was developed much later, however, largely at the turn of the 21st century (e.g. Fausch et al., 2002; Ward et al., 2002; Wiens, 2002). Using this concept, the river landscape is defined as an inherently heterogeneous system, formed by a river and a background that intensively communicates with the surrounding environment.

The river ecosystem delineation process has been dealt with by a number of researchers in the past (such as Malanson, 1993; Ilhardt et al., 2000 and Winter, 2001), and more recently by Carbonneau et al., 2012, Nardi et al., 2013 and Rathjens et al., 2016. The availability of appropriate and accurate underlying data, however, has always played a key role because these data are reflected in the quality of the areas delineated. The most accurate data source currently available is detailed elevation information (Deshpande, 2013) acquired with remote sensing techniques.

Considering the factors discussed above (anthropogenic influences, drought episodes, etc.), river landscapes mainly located along small watercourses could be one of the most endangered components of present landscape structures, especially in lowland and agricultural areas. These small streams, despite their usual legislative insignificance, represent a crucial element in the hydrographic network in a landscape. One reason for their significance is their considerable share of the total length of the entire river network. For example, in the Czech Republic, the total length of all small streams is approximately 91,717 km (i.e. almost 85% of the total length of all rivers in the Czech Republic), according to the Czech Ministry of Agriculture (MoA, 2013). Small streams are those that are not considered to be "significant", according to a decree of the Czech Ministry of Agriculture. Small streams shape the nature of the runoff regime and they are important for the associated dynamics of water circulation in the landscape. The area that surrounds small watercourses and is characterised by the same attributes as the river landscape, may therefore be referred to as the "stream landscape". According to Štěrba et al. (2008), the area of these stream landscapes constitutes about 46% of the total area of the river landscapes in the Czech Republic, which is estimated at some 8,082 km^2 based on the documents available.

The methodological framework for defining river landscapes is one of the tools to be used in real-time decision-making processes in nature and landscape conservation. In Europe, the protection of river landscapes (or more precisely of floodplain areas as a key element of river landscapes) is encouraged, but not explicitly required by a number of international laws and regulations, i.e. the EU Water Framework Directive (2000/60/EC), the Floods Directive (2007/60/EC), the Habitat and Birds Directives (1992/43/EEC and 2009/147/EC), the EU 2020 Biodiversity Strategy, the Green Infrastructure initiative and the EU Climate Change Adaptation Strategy. In many cases, floodplains and river landscapes are also subject to national protection: for example, in the Czech Republic, these ecosystems are protected as a "significant landscape element" (by the Act on Nature and Landscape Protection No. 114/92 Coll.). For these reasons, it is justifiable to address the issue of defining river landscapes as an important and sensitive component of the current environment, especially with the aim of refining the identification process and increasing the efficiency of their delineation, which could help to develop better and more appropriate management of watercourses, as well as their immediate surroundings in the form of riparian habitats.

The main aim of this article is to analyse the possibilities of delimiting the river landscapes lining small watercourses (i.e. stream landscapes) by using existing background approaches. Further, we analysed the positive and negative aspects of four different approaches that are quite often used to address this issue. These approaches are:

i. the procedures based on soil cover type data (pedological approach);
ii. information about the river inundation area's spatial extent (hydrological approach);
iii. local topographical conditions (topographical approach); and
iv. the occurrence of specific habitats related to the water environment (geobotanical approach).

We paid particular attention to the accuracy of the delineation process based on resolution of the input data, and the potential application of each procedure.

2. Case study areas

The experimental delineation of the river landscapes was carried out on two small stream catchments, namely, the Borovský Stream basin (tributary of the Sázava river in the Bohemian–Moravian Highlands, in the central part of the Czech Republic) and the Košátecký Stream basin (tributary of the Elbe river at the town of Neratovice, approximately 30 km north of Prague). The exact locations of the areas of interest are shown on Figure 1. The selection of both catchments was designed to capture the widest range of natural conditions affecting the drainage processes in the landscape, the dynamics of river systems, and hence the extent of the area directly affected by the presence of the river. The second and equally important parameter taken into consideration when selecting the study areas was the degree and character of anthropogenic pressure to which the landscape structure is currently subjected. While the first mentioned natural conditions are the basic prerequisites for the formation of river landscapes, and thus influence the spatial pattern of these areas at the level of larger landscape structures (river basins or their parts), the anthropogenic influence primarily impacts the extent of the river landscape at the local level (the segment or reach of a watercourse). Anthropogenic activities most often limit the extent of river landscapes by significantly affecting the spatial pattern of the riverbed or the riparian zones, and by long- term interruption of the contact between the river and the surrounding landscape. The actual river landscape and its extent are the result of the interaction between the effects of human activities and the natural conditions specific to a particular place and time.

The Košátecký Stream basin, with a total area of 218.3 km^2, represents in its southern half the flat and fertile area in the Elbe river floodplain, where the river landscape of this small stream is very difficult to identify without a detailed (e.g. sedimentological) survey. The northern part of the catchment has a deep sandstone valley with a naturally narrow riverbed in almost the entire length of the segments studied. The Borovský Stream catchment (with an area of 72.7 km^2) is representative of basins with deeply incised valleys, a tectonically conditioned pattern, and with large dimensions in the lowland part.

These basins and their respective segments, are similar in character due to anthropogenic influences; however, they are different in their total extent. Our analysis focused only on the main watercourses of the two selected river basins, i.e. the Košátecký Stream, with a total length of 23.72 km, and the Borovský Stream, with a length of 17.11 km.

3. Methods and data for river landscape delineation

Based on the above-mentioned river landscape definitions, the key indicator for defining this specific ecosystem is the area where the environment is influenced by the presence of the watercourse, i.e. where the interaction between the water regime and the impacted environments take place. Several different methods can be used to locate the borderline between the terrestrial part of the river landscape and other types of landscape (see Tab. 1), but the most accurate and

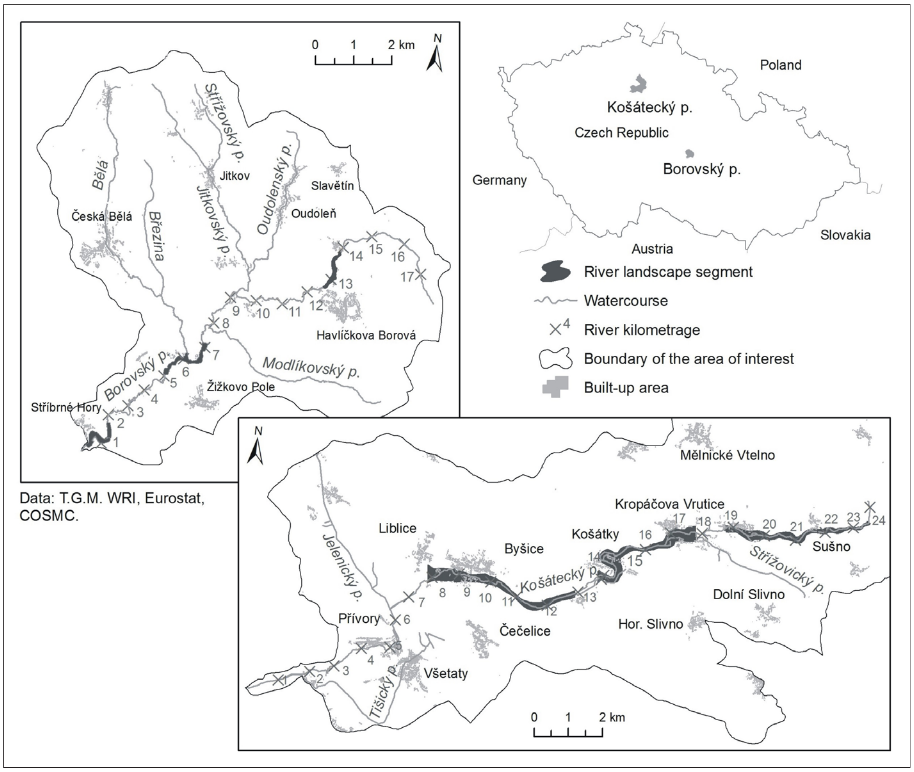

Fig. 1: Case study areas and their location within the Czech Republic
Source: authors' elaboration

Methodological approach	Delineation factors (methods) taken into account
Pedological (P)	Spatial extent of alluvial soils based on soil type terrain mapping
Hydrological (H)	Flood prone areas based on the methods of hydraulic and hydrological modelling
Topographical (T)	The flat areas of the same elevation as the riverbed edge where contact with the watercourse is ensured, based on the Fluvial Corridor (Valley Bottom) tool outputs
Geobotanical (G)	The areas adjacent to the watercourse where floodplain habitats occur, based on habitat mapping

Tab. 1: Overview of methodological approaches and the factors used for delineation of the river landscape
Source: authors' conceptualisation

reliable approach is based on an analysis of soil properties. Fluvisol ("Alluvial soil") is the most widespread soil type of river landscapes, formed by the erosion of sediments in the upland zone, and deposited in lowland areas or at sites with a flat valley floor in the transfer (piedmont) zone. Another soil type, which appears in abundance in river landscapes, is Gleysol, the formation of which is conditioned by the periodic repetition or permanent surplus of moisture in the shallow layers of the soil profile. A much less widespread soil type in the area of study is Phaeozem (Fluvi-gleyic Phaeozem according to The Food and Agriculture Organization of the United Nations (FAO, 1988)), in the form of deep semi-hydromorphic soils.

The spatial extent and precise location of hydromorphic soils can be determined by a detailed pedological survey. Additionally, accurate background data in the Czech Republic is provided by the system of Bonited Soil Ecological Units (BSEUs) mapping at a 1:5,000 scale. The present form of BSEUs is based on the maps of the Complex Soil Survey (CSS) realised in the former Czechoslovakia from the years 1961 to 1971 (and continuously updated to the present based on the Ministry of Agriculture Decree No. 327/1998). These maps, which are available only for agricultural land at scales of 1:5,000 or 1:10,000 depending on the particular location, represent a valuable and effective source for river landscape delineation in the vicinity of small streams. The CSS is based on a genetic and agronomic soil classification with the soil type as the base unit. The soil type is defined as the group of soils with the same stratigraphy of soil profile and with qualitatively identical geomorphological conditions (WAKPP, 2016).

We used the BSEU maps to define river landscapes within the areas of study. Since these maps only cover areas of agricultural land, however, we had to use other suitable data sources comparable to the BSEU in terms of their spatial resolution to identify the river landscapes in forested areas. The Forest Typological Maps (1:10,000), which contain information about the soil and humidity conditions of the studied sites, were considered the most suitable source of data for Central European conditions. Since these maps define forest types by combining the edificial, climatic, and phytosociological characteristics of the habitat, they were used to capture the optimal conditions for the existence of river and stream landscapes, including forest types specific to high groundwater levels and those affected by regular flooding (Chuman, 2008). Combining these two data sources, we were able to define the studied areas along a hydrographic network whose soil characteristics were formed mainly by local watercourses.

The second key approach used to define river landscapes is based on hydrological data taken from inundation maps that identify the river landscape and the floodplain on the basis of a 100-year flood area. It is theoretically possible to use other values, however: for example, Witner (1966) successfully studied the corresponding area of alluvial soils and floods with a return period of 50 years (i.e. 50-year flood). According to the hydrological approach, the delineation of the selected river landscapes is based on the flood-prone area borderlines, which in the Czech Republic is available through the Digital Base of Water Management Data (DIBAVOD) provided by the T. G. Masaryk Water Research Institute (TGM WRI, 2019). The floodplain borderlines (with repeat times of 5, 20, and 100 years) are derived from the highest water level in separate watercourse profiles during a given flood episode, while the altitude is determined by a hydraulic calculation. Compared to the pedological concept of river landscapes, the hydrological approach has a major advantage in that the reaction time is much shorter, and therefore possible changes in the spatial extent of the fluvial system can be captured from the available data. These changes occur easily; most often they are related to various anthropogenic impacts on the valley floor and nearby river channels (for example, construction of railway or road embankments, flood walls, etc.). The hydrological approach thus defines the actual spatial extent of the flood-prone areas. The only significant disadvantage may be the lack of data (i.e. the flood-prone areas' delineation) in the vicinity of small watercourses; however, in these cases it is possible to obtain the needed data using separate hydrological modelling tools.

When defining the river landscape area, the procedures of classical hydrological modelling can also be replaced by specialised software focused primarily on the topographic conception. An example of such specialised software is the "FluvialCorridor" tool (the outcomes are collectively referred to as the "topographic conception" of the river landscape), which was developed at the Institute of Ecology and the Environment in France (part of the CNRS infrastructure) in cooperation with universities in Lyon, France. This procedure is based on the methodological framework for the definition and characterisation of fluvial morphological shapes, consisting of primary data in large resolution (Alber and Piégay, 2011). In principle it is a geomorphometric delineation of river landscapes based on objectively defined topographic thresholds, which is further discussed by Clubb et al. (2017). This toolkit can be used for a variety of morphometric and spatial analyses. In particular, the "Valley Bottom" function defines river or stream landscapes on the basis of a digital elevation model (namely, the 5th generation DEM of the Czech Republic, provided by Czech office for surveying, mapping and cadastre (COSMC)). This function first provides information about the altitude of each river segment (at regular intervals), and then, based on the intersection of the relative altitude layer (user selectable) and the original DEM layer, it defines a territory that roughly corresponds to the river landscape area using a specific set of algorithms (Roux et al., 2015). Reportedly, the results of this software toolkit are only partially accurate but work well in cases of high river network density. With increasing demands for spatial resolution at the local level, their reliability decreases, and the results provided by the software need to be verified by performing field surveys.

In addition to the above-mentioned two approaches based on soil and hydrological data, the river landscape can be defined using other methods. An approach worth mentioning and one with a very long tradition in defining the river floodplain is based on combining the geological properties of the studied area with data on the geomorphological parameters of the terrain. According to Lewin (1978), floodplains (whose area roughly corresponds to the river landscape) represent sediment sinks or stores in which eroded and sorted sediments accumulate, are reworked, or indeed undergo biogenic or pedogenic processing for extended timespans. Nardi et al. (2006) consider floodplains as regions near stream channels, shaped by the accumulated effects of floods of varying magnitudes, and their associated geomorphological processes. Since this approach does not reflect the influence of current acting anthropogenic activities, and therefore differs from the definition of river landscapes, it is unsuitable for the delineation process.

The geobotanical view of the alluvial ecosystem is based on the assumption that watercourses largely affect the vegetation cover of their surroundings. Floodplains are often characterised by a mosaic of habitats differing in age, humidity, sediment properties and productivity – and by diversity, abundance, composition and succession state of biota (Geilen et al., 2004). Since this characteristic is also indirectly included in the definition of river landscapes, it offers the possibility of applying the geobotanical approach to define the studied phenomenon. The vegetation of a floodplain and a river landscape differs from the surrounding vegetation because of its adaptation to the frequent occurrence of floods and groundwater level fluctuations. Generally, the vegetation of a floodplain forms unique plant communities that do not occur in any other landscape type and are usually arranged in relation to the axis of the riverbed in a specific location. Gurnell and Petts (2002) highlighted the strong dependence of plant communities on the hydrological and geomorphological processes in floodplains. To define this type of landscape, the geobotanical and "landscape-ecological" approaches are based on alluvial habitat regionalisation, ecosystems, and communities of plants and animals, i.e., they are based on the actual vegetation structure, especially in the case of alluvial communities (Křížek et al., 2006).

Since anthropogenic activities have fundamentally altered the conditions for the presence of different plant and animal species, as well as the extent of the vegetation cover, however, this method of delineation of the river landscape is very difficult to realise in practice. Such a concept of floodplain (or river landscape) can only be applied to natural and nature-related segments of watercourses or areas where there is only minimum intensive farming (Chuman, 2008). From a practical viewpoint, the above-mentioned procedure has only limited applications in Czech conditions, as documented by the experimental delineation of the river landscape in the Košátecký Stream basin, based on data from the mapping of the NATURA 2000 habitats at the 1:10,000 scale (Nature Conservation Agency of the Czech Republic (NCA CR)). To define forest covers, we referred to the forest typological maps of the Forest Management Institute (FMI), available in the same spatial resolution. An overview of all the approaches used to define the river landscape in the selected study areas is shown in Table 2.

We applied these methodological approaches on eight independent watercourse reaches (see Tab. 3) in order to analyse the basic variables influencing the river landscape areas in the given conditions, to compare the achieved results, and to evaluate the potential of individual approaches and their applicability. While the pedological and hydrological approaches were applied to both studied watercourses throughout their length (from source area to mouth), the other methodological procedures (i.e. the topographical and the geobotanical) were applied only in three selected stream segments, with parameters typical for the upland, piedmont, and lowland zones (production, transfer and deposition areas, respectively).

4. Results

4.1. River landscape delineation based on the pedological and hydrological approaches

The width of the river landscape of the Borovský Stream in the Bohemian-Moravian Highlands varies significantly in its longitudinal profile from the headwater area to its mouth, with noticeable differences in the transfer and deposition zones. Both approaches were used to document the width variability of the river landscape and define the

Methodological approach	Data source (provider)	Data scale
Pedological (P)	Complex Soil Survey (BSEU) Forest Typological Maps (FMI)	1:5,000 1:10,000
Hydrological (H)	Maps of inundation areas (TGM WRI)	1:10,000
Topographical* (T)	DEM, 5th generation (COSMC)	mean altitude error 0.18/0.30 m**
Geobotanical (G)	NATURA 2000 habitat mapping (NCA CR) Forest Typological Maps (FMI)	1:10,000

*Tab. 2: Approaches and data sources used in river landscape delineation in the study areas (Notes: *This approach is based on application of the "Fluvial Corridor" Tool [Alber and Piégay, 2011]; ** In forest covered terrain)*
Source: authors' conceptualisation

Stream/segment localisation	Stream/segment length (km)	Stream kilometrage	Approach used to delineation
Borovský Stream/entire stream	17.88	0.00–16.61	P, H
Košátecký Stream/entire stream	24.21	0.00–23.56	
Borovský Stream/upland	1.14	12.71–13.85	P, H, T, B
Borovský Stream/piedmont	2.09	5.06–7.15	
Borovský Stream/lowland	1.54	0.22–1.76	
Košátecký Stream/upland	4.73	18.73–23.46	P, H, T, B
Košátecký Stream/piedmont	3.99	13.79–17.78	
Košátecký Stream/lowland	5.06	7.84–12.90	

Tab. 3: Selected characteristics of the studied stream segments and approaches used for river or stream landscape delineation (Notes: P = pedological; H = hydrological; T = topographical; and B = geobotanical approach)
Source: authors' elaboration

river ecosystem along the entire length of the Borovský Stream (see Fig. 2). The values in this figure showed the sudden increase of the average width of the hydrologically-defined river landscape in the river segment between km 11.00 and 10.00, which acts as the natural boundary between the upland zone of the streambed with lower width variability, and the lowland zone with much more significant fluctuations in the fluvial ecosystem. The main reason for this increase in the width of the river landscape is the presence of lateral valleys with several tributaries to the Borovský Stream (e.g. the Jitkovský Stream and a nameless tributary at km 9.92 of the river). The transfer zone in terms of sediment regime was relatively steady; in this part, erosion and accumulation stream segments often alternated, and they were usually only a few tens of metres long. This part of the streambed was typical for a deep valley with relatively steep slopes that limit the extent of the river landscape with an average width of 60 and 120 m in diameter. In the lowland zone, the span of the hydrologically-delineated river landscape increased due to the naturally increased aggradation activity of the stream, thus creating a flat floodplain (in some cases exceeding 200 m in width). The area of the hydrologically-conceived river landscape on the lowland segments is increased by the presence of valleys on the other side, often nameless drained streams. At the very end of the Borovský Stream valley, in the cadastral area of the village of Stříbrné Hory, the area affected by the watercourse is artificially limited due to a road embankment dividing the valley floor into two parts.

According to the pedological approach, the average width of the river landscape along the Borovský Stream had a somewhat lower variance than that provided by the hydrological concept (standard deviation = 40.426 metres; pedological approach: s.d. = 45.586 metres, hydrological concept). The pedological approach, however, had the advantage of providing data on the dynamic interchange of erosion and aggradation segments of the streambed. The upper boundary of the pedologically-defined river landscape area (i.e. km 14.30) included segments with a significant spatial extent of the fluvial ecosystem in the longitudinal profile, mostly due to the lithological and morphological features of the valley floor. In particular, the stream segment between km 13.50 and 12.50, in a widely open valley on the cadastral territory of the village of Havlíčkova Borová, developed a significant ecosystem (width of about 100 m) in the river landscape. Another large segment of the river landscape was located approximately between km 7.25 and 5.00. The main reason for the relatively sudden increase of the river landscape area in this location was the presence of a large number of tributaries (Jitkovský and Modlíkovský Stream, Bělá Stream, and also several unnamed, especially left-side, tributaries), contributing significantly to the transport and aggradation of sediments from the upland part. The last segment, which was an above-average developed area of the river landscape, was located near the mouth of the stream, in the cadastral territory of the village of Stříbrné Hory (km 1.40 to 0.50). Further, the Sázava River as a recipient of the Borovský Stream, had a significant impact, as the river can deposit entrained material and to some extent influence the spatial extent of the river ecosystem during high discharges in this location.

Significant anthropogenic impacts on the hydrographic network of the Košátecký Stream basin are a direct cause of the present form and spatial extent of the stream ecosystem and of other factors. These factors become apparent when comparing the genetically conceived concept of the river landscape (i.e., the pedological approach) with the concept derived purely from the topographical features of a relief and its relative elevation above the riverbed level (the hydrological approach, see Fig. 3). The hydrologically defined river landscape currently has its upper limit on the cadastral territory of the municipality of Kropáčova Vrutice (km 20.12) at a site with abundant springs only a few hundred metres behind the actual beginning of the permanent watercourse. In terms of the variability of the river landscape width, the difference in variability was not very noticeable; the standard width deviation in the pedologically-conceived river landscape was 262.80, and in the hydrological approach, it was 258.69. A high degree of variability was afforded by the existence of two segments, where the defined area reached significantly larger widths than at other sites. The stream segment between km 18.50 and 16.50 is a hydrologically-defined area due to the morphological features of the valley floor, which is much flatter, thus providing an intensive accumulation of sediment loads transported to the deep valley from the headwater area over a distance of more than 20 km. The second and much more extensive area of river landscape is the segment located approximately between km 8.20 and 6.00. This area, however, represents a specific case because the stream flows across the extensive lowlands formed by the Holocene sediments of the Elbe River. Principally, these are probably not the fluvial sediments of the Košátecký Stream. The lateral spatial extent of the pedologically-conceived river landscape was based on the interpolated boundary of a 100-year flood area, which may include the recent sediment storage area of the Košátecký Stream, which is active during major floods.

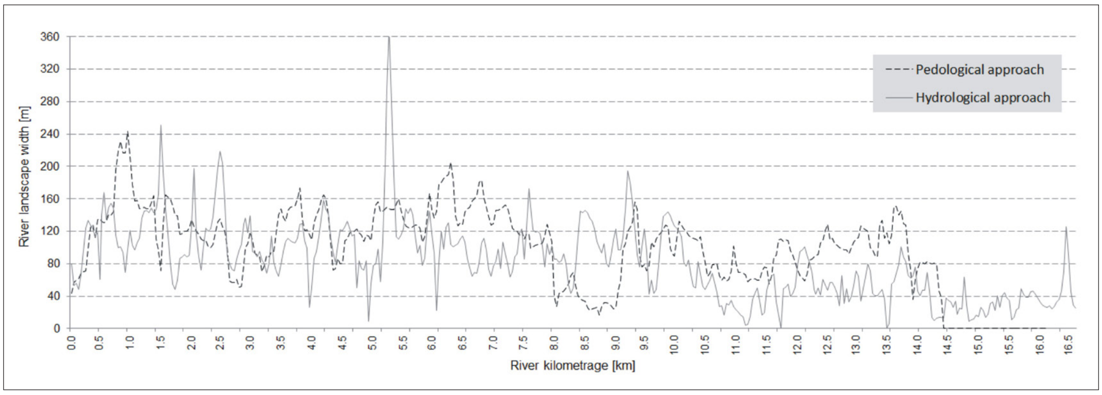

Fig. 2: The width of the river landscape according to the hydrological and pedological approaches delineated along the Borovský Stream, averaged in 50 m reaches. Source: authors' elaboration based on TGM WRI (2019) data

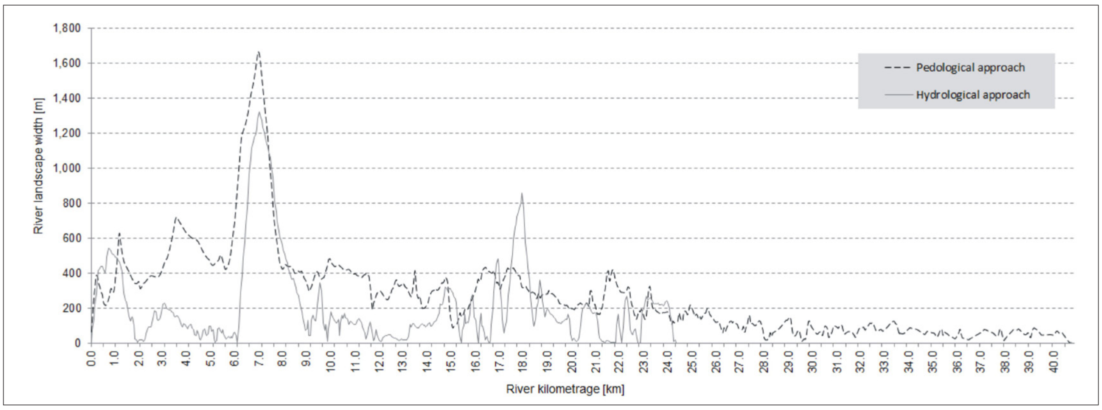

Fig. 3: The width of the river landscape according to the hydrological and pedological approaches delineated along the Košátecký Stream, averaged in 50 m reaches. Source: authors' elaboration based on TGM WRI (2019) data

In the hydrologically-defined area, a small increase in the segment near the mouth of the stream into the Elbe River was influenced by the floodplain area of the Elbe River. The total area of the studied river landscape in the given segment (roughly between km 2.00 and 0.00) was degraded, however, due to the presence of industrial anthropogenic forms of relief that affected the local topography. In comparison, the definition of river landscape based on soil properties only revealed a linear dependence in the form of a segment consisting of the Holocene fluvial sediments from the Elbe River; nonetheless, there was a continual extension of the river landscape area in the flow direction. This trend revealed the influence of local topographical conditions on the ongoing erosion–aggradation processes, and the character of the spatial distribution of accumulation areas along the stream.

4.2 Other approaches used to define the river landscape along small watercourses

For a more detailed assessment of the gradient of changes in the spatial extent of the river landscapes, we applied the above-mentioned methodological approaches on the representative segments of the Borovský and the Košátecký Stream. The selected stream segments were characterised by features typical for the upland, piedmont and lowland parts of a basin (e.g. hydrological or flood regime, erosion-accumulation capacity of the riverbed, or other natural conditions of the surrounding landscape). As shown in Figure 4, the gradient of changes in the longitudinal profile was not significant for the Borovský Stream ecosystem in the Bohemian-Moravian Highlands. This gradient was the effect of a permanent geological structure influencing the extent of the river landscape and did not allow a continuous increase from the upland to the mouth of the stream. Generally, the stream morphology reacted to these types of influences by extending its fluvial environment (part of the valley floor with active or passive contact with the stream) in the middle (piedmont) part of the river basin, where the erosion and aggradation segments often changed dynamically. In the lowland part, however, the stream tended to partially downsize. An important reason was the junction of several tributaries of the Borovský Stream in the transport zone of the catchment. In addition to the above-mentioned natural causes, anthropogenic activities in the landscape, concentrated mainly in the headwater part of the basin, also may have produced an increase in the spatial extent of the middle part of the river landscape (the stream segment located near the village of Macourov, see Fig. 5).

In the case of the Košátecký Stream, it is evident that the past natural geomorphic evolution of the watercourse made it possible to form a river (stream) landscape which was characterised by continuous expansion from the headwater area to the lowland part. Nowadays, the remains of this stream landscape can be identified using soil data (pedological approach). However, since the river basin is located in an intensively agriculturally exploited area, there have been significant human interventions into the local stream

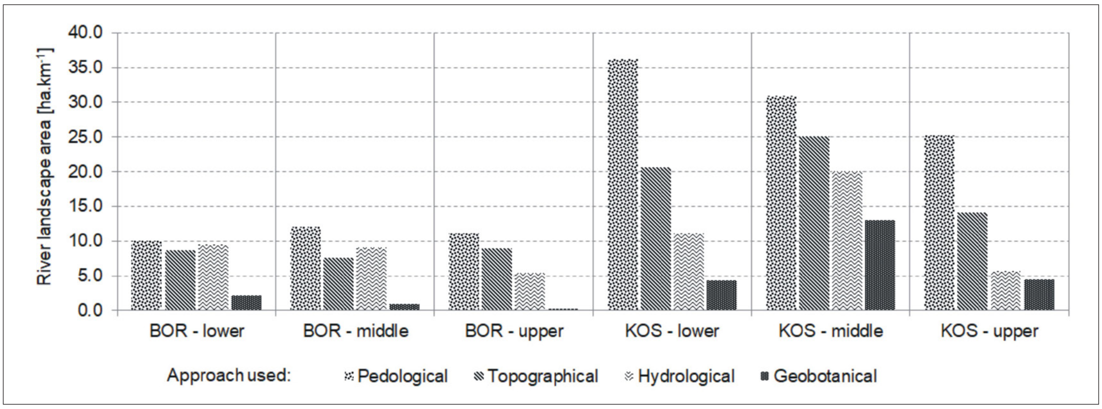

Fig. 4. The relative spatial extent of the river landscapes (for a segment of 1 km), delineated according to the selected approaches for three stream segments (upper, middle and lower segments) of the Borovský Stream (BOR) and Košátecký Stream (KOS). Source: authors' elaboration based on data from the following authorities: Research Institute for Soil and Water Conservation (RISWC), Czech Geological Survey (CGS), Czech office for surveying, mapping and cadastre (COSMC), T. G. Masaryk Water Research Institute (TGM WRI), and Nature Conservation Agency of the Czech Republic (NCA CR)

landscape, which were most significant in the upper and lower parts of the river basin. For this reason, now we can observe that the middle part of the stream (piedmont) and surrounding landscape is characterised by the relatively best preserved natural values. This is also reflected in the stream landscape area, which reaches its largest dimensions here according to the hydrological, topographical and geobotanical approach (Fig. 4), which responds more flexibly to changes in the landscape caused by current human activities.

The ecosystem of the Košátecký Stream riverbed was characterised by a gradual increase of the spatial extent from the headwater area to the middle part of the catchment. Conversely, the extent of the fluvial ecosystem in the lower stream was characterised by a slight decrease. This finding was observed in most of the methodological approaches applied, apart from the pedological concept. Regarding the change in the spatial extent of the river landscape, the highest increase was seen in the pedological delineation, whereby a defined area of over 180 ha occurred in the lower stream segment (around the village of Byšice, see Fig. 6). This result was very different from those obtained in the other approaches used. The main reason for this might be the occurrence of a deep and narrow valley bottom in the upper and middle part of the catchment, bounded by the slope foot positions. Further, the maximal limits of the river landscape do not provide much room for the uncertainty caused by the field mapping of the soil parameters at this site.

5. Discussion and conclusions

The outputs of the study, carried out at two small catchments in the Czech Republic, each with their own unique natural conditions and anthropogenic pressures, point to the validity of the aforementioned fact across the whole range of factors shaping the river (or stream) landscape. Differences between the tested approaches are apparent both in the case of the natural ("close to nature") status of the river network and adjacent landscape, as well as in basins influenced by human activity. By applying several approaches to define the landscape phenomenon at model sites, the results showed the relation of the extent of the area on its specific location within the stream catchment. The extent of the scattering of values increased from the headwater areas (respective sites near the upper limit of the river landscape) to the lower parts of the catchments. There

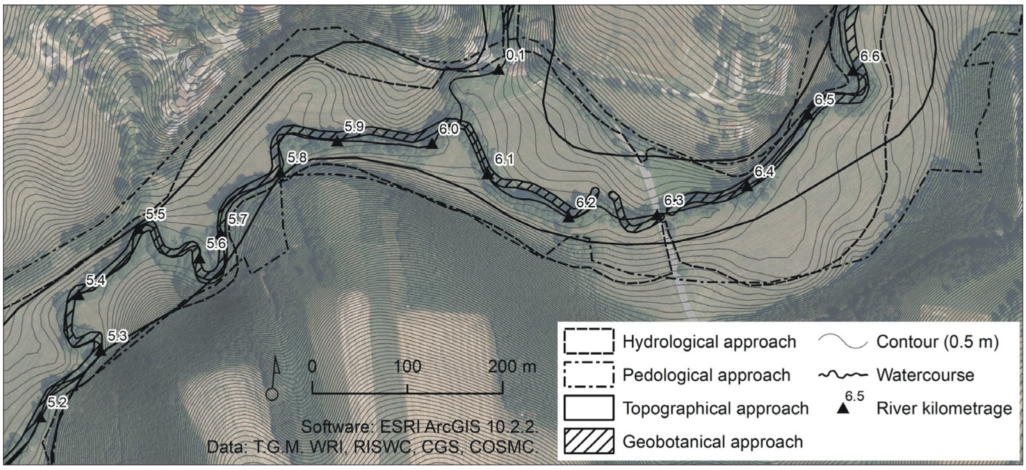

Fig. 5: The approaches used in river landscape delineation applied to a selected segment of the Borovský Stream (middle part of the catchment near the village of Macourov)
Source: authors' elaboration

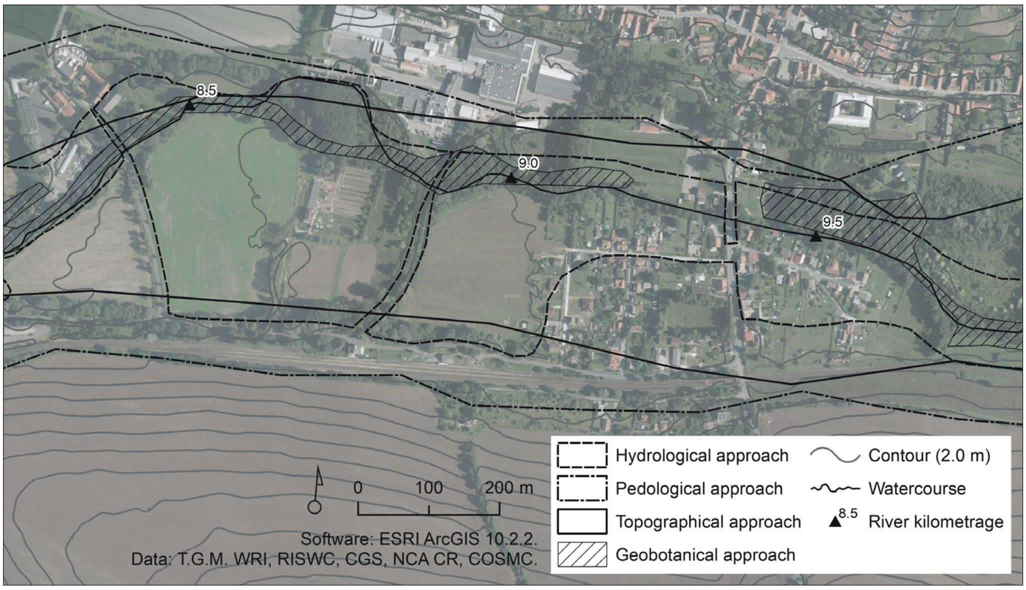

Fig. 6: The approaches used in river landscape delineation applied on a selected segment of the Košátecký Stream (lower part of the catchment near Byšice village)
Source: authors' elaboration

were significantly greater differences between individual concepts identified at lower segments of the watercourses, flowing through large flats with huge sedimentary layers, and usually formed by the recipient's activities. For example, the difference between the pedological and hydrological approaches in relation to the lower part of the Košátecký Stream amounted to 25 hectares of land per 1 km of the riverbed. Significant differences could be observed, especially between the approaches that considered the relief genesis (i.e. the pedological concept and partially the geobotanical concept), and the concepts based only on the morphometric parameters of the terrain and its relative elevation above the riverbed level (i.e. the hydrological and the topographical concepts).

Although the results of the hydrological and topographical approaches for the selected stream segments were in some cases very different, there were no hypothetical differences, since both approaches are based on similar principles of field delimitation. In this study, however, the topographical approach was experimentally implemented using the "FluvialCorridor" extension ("Valley Bottom" tool), which was designed for the automated delineation of fluvial areas along watercourses. This approach produced accurate results only at sites with a rugged topography and a clearly definable spatial extent of the valley bottom. The probability of error increases in flat terrain and such a situation occurred in the Košátecký Stream basin. Consequently, significant differences could occur between the topographical and hydrological concepts in all the studied stream segments. Since the authors of the tool (Roux et al., 2015) are aware of the deficiencies, the algorithm for automated delimitation is being further developed and refined. The tool is gradually expanding and being applied to various model territories (e.g. Demarchi et al., 2016). The authors of other software that can be used to delineate river landscape, e.g., the "Valley Bottom Extraction Tool" (Gilbert et al., 2016), are trying to eliminate the potential errors connected to river landscape delineation.

In this study, the river landscape was experimentally delineated following the geobotanical approach, but its application achieved significantly undervalued results compared to the other methods. The reason is that both locations studied represent a cultural landscape where the structure and size of each habitat type is strongly influenced by anthropogenic activities. The extent of discrete fragments of habitats bound to a fluvial environment is limited by the use of the surrounding landscape. For this reason, in the current Central European landscape, the geobotanical concept may be applied only to legally protected areas. An alternative to the geobotanical procedure to determine the extent of the inundation areas may be the method based on the analysis of the normalised differential vegetation index (NDVI), proposed by Powell et al. (2014). This method is applicable only to specific environments, however, optimally after a flood episode, within the inundation areas.

All the methods used for the delineation of river landscapes and their positives and negatives related to the application to small streams, are summarised in the SWOT analysis shown in Table 4, identifying strengths, weaknesses, opportunities, and threats related to each approach. The results of our study also showed that the largest extent in all the selected stream segments was the river (stream) landscape defined according to its soil characteristics. Considerable overestimation compared to other approaches was apparent in intensively cultivated landscapes, i.e. the headwater area of the Borovský Stream catchment and the lower part of the Košátecký Stream catchment (see Figs. 2 and 3). These areas are typical in flat terrain where relatively large inundations exceeding the area of the current floodplain may have occurred in the past; thus, the data may correspond to the real area of the hydromorphic soils. With regard to the definition of river landscapes, the area thus defined must necessarily include sites which do not meet this characteristic because they do not have permanent or at least periodic contact with the current riverbed. Lowland areas with flat terrain

Approach used	Strengths	Weaknesses	Opportunities	Threats
P	Higher resolution of analogue data, availability of underlying data	Demands on processing of analogue data, lower accuracy of digital data, the need to use multiple data sources (agricultural/ forest land)	Possibility of further data refinement by field survey (soil probes)	Use of inaccurate data in digital form
H	Higher data resolution	Unavailability of data for small streams, demands on the input data for modelling, defining inaccuracy in flat terrain	Opportunity to add data based on hydrological modelling even for small streams	Time limited data validity
T	Availability of analogue as well as digital underlying materials, the possibility of rapid processing, very high accuracy	Inaccurate delineation in flat terrain	Ability to use very accurate data (LIDAR), the possibility of automation	Misinterpretation of data, temporary data validity
B	Higher resolution of underlying materials in analogue and digital form	Difficult accessibility of data, unavailability for the whole territory of the Czech Republic	Possibility to refine/create data by field survey	Misinterpretation of data during field survey, time limited data validity

Tab. 4: SWOT analysis of individual approaches used to delineate the fluvial ecosystem in terms of their efficiency and complexity (Note: P = Pedological; H = Hydrological; T = Topographical; B = Geobotanical approach. The grey colour range of each column indicates the weight of the factors in the analysis [the more intense the color, the greater the weight of the identified factors])
Source: authors' elaboration

and minimal elevation above the riverbed edge can be the most problematic in terms of river or stream landscape delineation.

In areas with more rugged relief and in an urban environment, the most accurate approach to define a river landscape is the method based on topographical data, which was confirmed in the two analysed areas and corresponds also to the conclusions of other authors: e.g. Deshpande 2013; Notebaert and Piégay, 2013. Moreover, our study confirms the fact that this is especially due to the accuracy of the data and its availability for small watercourses, which remains the key factor affecting the accurate definition of the river landscape.

The results show that the various concepts of a fluvial ecosystem lining a small watercourse can vary considerably in terms of its extension and spatial distribution within the basin. Traditionally, among the most commonly used approaches is the hydrogeomorphic floodplain delineation method, which is a GIS-based approach linking a simplified inundation method with the geomorphic properties of the stream network and hydrologic characteristics of a flood event (e.g. Nardi et al., 2006). The floodplain or river landscape definition on the basis of the digital elevation model has generally received a lot of attention (i.e., Noman et al., 2003; Charrier and Li, 2012; Deshpande, 2013), as it was a method based on relatively easily accessible data and, at the same time, sufficient accuracy of the outputs. Moreover, the increasing global availability of high-accuracy DEMs or DTMs (Digital Terrain Models) derived from earth observation technology (e.g., satellite, aerial or drones), offers new opportunities for advancing large-scale floodplain mapping (Nardi et al., 2018). Current and relatively accurate information on the area of great river floodplains can be obtained on the basis of elevation data processed by a fast geo-spatial tool for floodplain mapping (GFPLAIN 250m, see Nardi et al., 2019), but this tool is only suitable for large river systems.

In order to determine the extent of a river (stream) landscape along small watercourses, however, it is necessary to use other data sources, especially soil cover data, which will increase the accuracy of the delimitation. The main contribution of this article lies in a comparison of four different approaches to delimiting a river (stream) landscape in terms of its applicability to small watercourses, whose ecosystems are a very important part of the landscape structure and perform a wide range of ecosystem functions and services.

GIS modeling techniques, based on the existence of an accurate digital terrain model, are increasingly being used to define river landscapes. Considerable attention is paid to this method because it is relatively easy to define, without the need for any field surveys. In general, using the correct and sufficiently comprehensive GIS tools (preferably fully integrated 2-D hydrologic and hydraulic modeling) can achieve relatively accurate results by this procedure, but it is still recommended to verify the validity of the resulting data by field surveys. The other delineation methods presented in this article are used much less frequently, mainly because of their time-consuming requirements; however, especially in the case of the pedological approach, it is a very precise method by which it is possible to identify sites clearly recently affected by a river.

Although the issues discussed in the article were applied to small catchment areas in the Czech Republic and the data used were "country-unique", it can be assumed that the conclusions regarding the applicability of different approaches to delineating the river landscapes and their accuracy can be used at a global scale, i.e., at the international river basin or hydrogeological region levels. It can be stated that most of the knowledge gained by the SWOT analysis is generally valid outside the Czech Republic as well, and that the conclusions can be applied, especially in practice, for the purpose of delineating the river landscape as a territory subject to the protection of natural value in terms of conservation.

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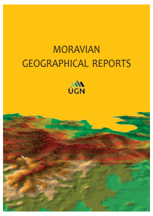

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Exploring citizen science in post-socialist space: Uncovering its hidden character in the Czech Republic

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Abstract

Citizen science is a relatively new phenomenon in the Czech Republic and currently a general overview of existing citizen science projects is not available. This presents the challenge to uncover the 'hidden' citizen science landscapes. The main objective of this paper is to explore the (public) representation of citizen science (CS) projects and to describe their heterogeneity. The study aims to answer the question of what type of projects in the Czech Republic meet the definition of citizen science. Based on a specific methodological data-base search approach, we compiled a set of CS projects (N = 73). During the classification process, two general citizen science categories were identified. The first group (N = 46) consists of "pure" CS projects with a prevalence towards the natural sciences, principally ornithology, and thus corresponding to general European trends. Citizens usually participate in such research in the form of data collection and basic interpretation, and a high level of cooperation between academia and NGOs was detected. The second group of "potential" CS projects (N = 27) entails various forms of public participation in general, frequently coordinated by NGOs. Based on these results, we discuss the position of citizen science in the Czech Republic, including socially-oriented citizen science. Further research is strongly encouraged to achieve a more in-depth insight into this social phenomenon.

Keywords: *citizen science, participation science, nongovernmental organisations, academia, public engagement, natural sciences, social sciences, Czech Republic*

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1. Introduction

Citizen science is usually explained by various authors as an engagement of citizens, enthusiastic amateurs or non-scientists, in scientific research through various forms and levels of participation and during various stages of the research work (e.g. Bonney et al., 2009; Silvertown, 2009; Dickinson et al., 2012; Shirk et al., 2012; Haklay, 2013). Traditionally, the domain of citizen science lies in natural and environmental sciences, where collecting a vast amount of data by volunteers is welcome, effective and facilitative (e.g. Cohn, 2008; Cooper et al., 2007; Miller-Rushing, Primack and Bonney, 2012). Social sciences and humanities research projects have recently come to the fore, calling for better cooperation with citizen science, stressing the potential of the democratisation of scientific knowledge (Wannemacher et al., 2018), and promoting political decision-making processes involving the environment and health (Kullenberg and Kasperowski, 2016), and the empowerment of grass-roots initiatives to conduct research (Mahr et al., 2018).

As in other post-socialist Central and Eastern European (CEE) countries, the Czech Republic has experienced different temporalities in the conceptualisation and societal acceptance of citizen science. The primarily exploratory character of our study shows that the proper term "citizen science" or "participatory science" (in the Czech language often translated as "občanská věda") is not frequently used in the country, despite evidence of citizen science-related practices taking place. This difference is often seen as an "allochronic delay" (Bevernage, 2016) beyond "normal" developments in Western countries. Instead of this geopolitically uneven interpretation, we prefer one based on the different meanings of citizen science in post-socialist space. Citizen science in post-socialist countries appears to be veiled by a certain "invisibility", further specified by the Hungarian researcher Bálint Balázs (2019) as "...invisibility of citizen science practices in the non-Western countries. In many central European countries, even the term is not recognised. This apparent division in the performance of

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citizen science between Eastern and Western countries reflects an unequal knowledge production." In contrast to Western countries, social sciences in the former socialist Czechoslovakia suffered from a dominance of the positivist approach and a negligible application of qualitative methods, particularly with respect to participatory research (Konopásek, 1999). Even 30 years later, participatory research or citizen science in the fields of human geography and environmental studies remains a largely marginal methodological approach.

Various scientific papers dealing with citizen science have recently been published (mostly in Czech) in the Czech Republic: a study researching dragonflies used a citizen science approach (Ožana et al., 2019); similarly, a text on ornithological research (Diblíková et al., 2019); and several papers exploring the concept of GeoParticipation, which is (in some respects) closely connected to citizen science (e. g. Pánek et al., 2017). Most other contributions fall within the sphere of grey and/or popular literature. A growing number of articles popularising Czech citizen science have recently appeared in social media, popular journals, and the daily press (e. g. Vesmír, Botanika, Idnes). Paradoxically, one of the best reviews of citizen science in the Czech Republic to date is a Bachelor's thesis by a library and information science student (Kalmárová, 2015). In general, librarians and information scientists are among the most active supporters of citizen science, and strongly encourage the role of public libraries as vital public institutions supporting education, research and information exchange (Černý, 2016).

In the field of geographical research, but also in urban planning and regional development, some prospects for future research can be seen in the various forms of participation in geographical research (GeoParticipation), especially in using research techniques of emotional mapping, which has been recently developed and applied in several towns in the Czech Republic (Pánek and Pászto, 2016; Pánek, 2017). The debates about citizen science and its role in social and geographical research can enrich discussions about sustainable spatial development in post-socialist space, especially in the sense of introducing non-hierarchical relations between researchers and for those who participate in research and are striving for change [i.e. the Critical Geography imperative] (Osman, 2013).

Based on this introduction, we can summarise that citizen science is a relatively new phenomenon in the Czech Republic, one which is not integrated into existing institutional structures and hence results in uncoordinated management, with no overviews of existing citizen science projects. The authors of this paper have endeavoured to uncover or reveal the hidden citizen science landscapes in the Czech Republic with their two primary research objectives: (i) to "Describe the heterogeneity of CS projects in the Czech Republic"; and (ii) to answer the general question: "What types of projects meet the definition of citizen science in the Czech Republic?"

2. Conceptualisations and definitions of citizen science

2.1 Principal definitions of citizen science

As previously stated, the engagement of the public in the research process is a key aspect and at the same time a condition of what is usually regarded as citizen science. Various typologies and scales of citizen science have been formulated according to the level of public engagement (e. g. Haklay, 2013; Shirk et al., 2012).

For the purposes of this study, we utilised the classification of public engagement proposed by Haklay (2013), which is closely related to geographical research, especially in the field of GeoParticipation or Volunteered Geographical Information (see, e.g. Goodchild, 2007). Haklay (2013) identifies four basic levels of citizen science from low-level participation to high-level participation, usually designated graphically in the form of a "ladder". On the bottom level is crowdsourcing, as basic data collection mostly through desk-top analysis or by simple field methods, followed by distributed intelligence as more intensive participation of the public in the first stages of the research process, which usually requires additional work and basic interpretation of the collected data. The third level, called participatory science, is perceived rather as a partnership: more in-depth cooperation between scientists and the public in selected stages of the research process, which starts with the elaboration of research questions and ends with data analysis. Extreme citizen science almost dismisses the science/citizen divisions and encompasses an entire range of mostly bottom-up research, which responds to community needs and is aimed at improvement or even societal change. In later studies, Haklay (2018) has enlarged his focus on participation with other dimensions, reflecting the development of a knowledge society, creating a combination matrix of four blocks (ranging from a [low level of knowledge/low engagement] to a [high level of knowledge/high engagement]).

Traditionally, the thematic classification of CS projects goes hand-in-hand with scientific classification, based primarily on a natural/social science divide. Besides the level of participation, the proportion of projects between natural and social sciences in this field can be evaluated. Some interesting findings concerning the conceptualisation and varying position of citizen science in different scientific disciplines have been indicated by Kullenberg and Kasperowski (2016). In the largest group, which is mainly composed of the natural sciences, citizen science serves mostly as a methodology for data collection and processing, which corresponds to other similar studies, such as Bhattacharjee (2005), Anderson (2013), Gosling et al. (2016), and Silvertown (2009). A second group, according to Kullenberg and Kasperowski (2016), consists of geographic information research, and citizens are perceived as participants in research, collecting geographic data. Contrary to this conceptualisation, Parrish et al. (2019) stress that involving citizens in CS projects can go beyond collecting and analysing scientific data.

Even if citizen science does not represent a typical approach in the social sciences, according to Ryan et al. (2018) there are some specific participatory approaches such as community-based participatory research (CBPR) and participatory action research (PAR), which generally correspond with social science research. Social scientists understand citizen science differently from natural scientists through a lens of the democratisation of scientific knowledge production, as stressed by Mahr et al. (2018). Kimura and Kinchi (2016) perceive social citizen science as a process in the democratisation of society, and see the potential to open up science institutions, policymakers, and other stakeholders to more democratic public participation.

The principal idea of both the social sciences and the humanities in relation to the citizen science concept, is the empowerment of relationships between science and society and in filling the gap between local communities and other stakeholders in the face of environmental or social challenges (Mahr et al., 2018; Ryan et al., 2018; Wannemacher et al., 2018; Joy et al., 2011).

Ethical aspects connected with social science research are raised and discussed by Purdam (2014), who uses the term "social citizen science" and renews the idea of "emancipatory social science". Using the example of a research study mapping begging, she points out that observations of humans, together with data collection, implies serious questions of research ethics and opens up sensitive issues, such as privacy, embarrassment and intimacy.

To summarise, public (citizen) participation in general – the involvement of the public in decision-making and planning processes, as well as community development – is a key principle of modern democracy and constitutes great potential for further utilisation in citizen science. Based on the preceding discussion, there appears to be a slightly different meaning of citizen science in the natural and social sciences. In the natural sciences, citizens usually help scientists to conduct research and serve more or less as adjuncts or field assistants, whereas social scientists provide a different view of public participation. First, social scientists have already identified numerous approaches encompassing public participation, such as community-based research and participatory action research (utilised in geography as GeoParticipation or Volunteered Geographical Information), so renaming this successfully established terminology as citizen science could be misleading. Second, the participation of citizens in social science research is more "radical": it contributes to societal changes and the reframing of society, and citizens tend to be viewed as reflexive partners. Finally, a rather mechanical application of citizen science methods in the social sciences could generate serious ethical questions concerning privacy and other sensitive issues.

2.2 Geographical context of the study: The hidden landscapes of Czech citizen science

To map the Czech citizen science landscape, we identified and investigated three potential sources of recruitment for citizen science in the Czech Republic. The first is from traditional hobby and amateur organisations, the second from social movements and bottom-up initiatives, while the last one consists of the application of participatory methods in social research.

2.2.1 Traditional engagements of amateurs in society and science

There is a long tradition (in many countries, as well as in the Czech Republic) of various amateur civic associations, evolving from the late 19th century, in the fields of nature protection, beekeeping, entomology, ornithology, librarianship, hunting and gardening, etc. (e. g. Tóth et al., 2018). Based on principles of voluntary engagement and self-organisation, enthusiasm and interest in a particular topic, these associations provide a fertile base for cooperation with scientists (some scientists may also be their members), especially due to strong organisation and more or less massive membership (ranging from thousands to hundreds of thousands of members). Members also actively exchange information and periodically publish their own professional journals (e.g. ornithologists, hunters, conservationists, beekeepers, etc.).

According to Diblíková et al. (2013, 2019), scientists usually regard the role of these amateurs as highly beneficial for the collection of geographically-scattered data about selected species (plants, animals, birds, insects, etc.). Others appreciate the possibility of longer-term research, replacing their own lack of research capacities, for example, in water quality monitoring (Fabšičová, Fránková and Šumberová, 2017) or in the observation of phenological changes in nature during and after the vegetation season (Dušková, 2019). Thus, ornithologists help to monitor and protect birds (Diblíková et al., 2019), hunters observe field birds and forest animals, conservationists count endangered species and old varieties of fruit trees, amateur meteorologists track weather, etc. Moreover, they can propose their own research problems and work on many projects. Most importantly, in the event of a crisis, they are able to act to protect their rights or the perceived rights of the subjects of their interests. In general, their work is supported and promoted (for example, through financial donations) by the public (Krajhanzl et al., 2015; Krajhanzl, Chabada and Svobodová, 2018; Tóth et al., 2018).

2.2.2 The rise of social and environmental movements

Unlike these traditional hobby and amateur organisations, activities of a more confrontational nature (especially in the field of social and environmental justice) were suppressed during the socialist era (Vaněk, 1996). Since the 1980s and 1990s, social and environmental movements have begun to partake in and reshape Czech society, exhibiting collaborative as well as confrontational attitudes towards the establishment (Fagin, 2000; Vaněk, 1996; Císař, 2008). Undoubtedly, all these societal trends have also influenced science, both natural and social, and contributed to challenging their functions in a changing world.

Among the most successful environmental organisations are Hnutí DUHA [Friends of the Earth Czech Republic] (environmental issues and small-scale farming), Arnika and Děti Země [Children of the Earth] (environmental pollution and transport), and Frank Bold (law and environmental counselling). Several foundations (Partnerství [Czech Environmental Partnership Foundation], and Veronica) support civic society and sustainable development projects, frequently based on participatory principles.

Finally, there is a strong stream of environmental education adhering to the principles of education for sustainable development and inquiry-based education. This includes numerous active organisations and educational centres. Most of these are scattered across the regions, and at the state level are connected through the Pavučina [Network of Environmental Education Centres in the Czech Republic].

The potential for mutual scientific cooperation with actively engaged citizens, whether as individuals or united in various civic associations, is perceived as one of the pillars of civil society, as stressed in the publication: "Science and nongovernmental organisations: experiences, possibilities, inspiration" (Čada, Ptáčková and Stöckelová, 2009). In this book, Zelený kruh [Green Circle], as a coalition of Czech non-governmental environmental organisations, explores potential ways of science – NGO collaboration, mentioning many foreign examples, such as community-based research, science coffees, etc. Various forms of public participation and engagement have been continually developed and applied in the processes of community development, participatory urban planning, nature protection, and solving various social and environmental issues, partly based on productive citizen – NGO – science cooperation or in active civic life (Kroupa and Mansfeldová, 2006; Krajhanzl et al., 2015; Krajhanzl, Chabada and Svobodová, 2018).

2.2.3 Application of participation methods in social and, specifically, geographical research

Geoparticipation, also referred as participatory GIS and public participation GIS (abbreviated as PGIS), emphasises the connection between citizens, spatial science, (new) technologies and public engagement (see e.g. Thompson, 2016). Spatial planning using advanced GIS technologies could greatly benefit from public engagement. Tools for incorporating laypersons into public agendas vary from basic forms of collecting data (such as crowdsourcing), through "fix-my-street" applications (such as Járókelő: see Marietta, 2016) to designing urban space and facilities (Pánek et al., 2014, 2017). Most of the geoparticipatory approaches (there is also a decision support tool for selecting the optimal participatory mapping method – see Pánek, 2015) involve the basic principles of citizen science. The scale of usability covers all forms of research areas/fields that could be widely used (from the geographical point of view).

Most of the cases classified as "geoparticipation" use GIS technologies. A good example is the OpenStreetMap (OSM) project, in which people edit a freely available map to obtain the most detailed and accurate map in the world. In some cases, OSM could serve for purely humanitarian purposes (Trojan, 2015) where participation is the main role. OSM has become one of the most used cartographic backgrounds in other geoparticipatory projects. Czech involvement in geoparticipation is quite high (compared to the situation worldwide). Geoparticipation has been used in many projects and often combined with mental mapping (Pánek, 2016). All of these volunteer activities covered by geoparticipation create a lot of useful data for further research and contribute to increasing information and knowledge in the field (Sui, Elwood and Goodchild, 2013).

2.3 Existing attempts to map or analyse the landscapes of CS projects

Despite the continuing increase in citizen science theory and practice, associated with the growing citizen science literature, overviews and analyses of existing CS projects with a specific geographical focus are quite rare. There are various reviews of the literature in citizen science, such as that by Follett and Strezov (2015), but one of the most comprehensive works is the meta-analysis by Kullenberg and Kasperowski (2016). In addition to a common finding of the growing number of studies related to citizen science, they analysed the distribution of work by scientific disciplines. The highest number of articles was found in biology and conservation research (specifically, the Web of Science shows the highest occurrence of terms such as ecology, environmental studies, geography, environmental science, and biodiversity conservation with respect to citizen science).

Another content analysis of CS projects was conducted by Ferran-Ferrer (2015), again with respect to the distribution of academic disciplines: this author similarly revealed that the arts, humanities and social science disciplines were almost non-existent. Interestingly, this contribution also points out that projects in the field of natural and physical sciences are fostered by a top-down approach and receive more financing from EU funds.

Some reviews do focus on collecting and analysing existing literature sources in a specific area, however, and describe, for example, volunteer environmental monitoring and how it influenced the participants who took part in the research (Stepenuck and Green, 2015). These authors found that the participants mainly expressed positive effects, such as increased personal knowledge and community awareness, changing attitudes and behaviours, the building of social capital and even beliefs in influencing change in natural resource management and policy. Although similar studies serve as useful insights into citizen science, they do not provide a satisfactory geographical picture of citizen science projects.

To assist in mapping the landscape of CS projects covering a given geographical area, many national and international collections or inventories of CS projects have been compiled in order to raise public awareness of projects and to popularise the phenomenon, or to advertise the possibility of participation. Just a few of most popular are SciStarter, CitSci, Ala Bio Collect (Atlas of Living Australia). A thematic mapping of projects dealing with citizen science and smart cities in Europe was carried out by Craglia and Granell (2014), although their study only enumerates and describes selected projects, without any further analysis.

A highly relevant source and inspiration for this study is an example of a citizen science investigation carried out on European-level on-line research conducted in 2016 by Hecker, Garbe and Bonn (2018). These authors conducted the first large-scale exploratory survey among CS project coordinators (N = 174), studying various aspects of the citizen science landscapes of Europe. They received the highest number of responses from Germany (34), followed by the UK (33) and Austria (25). Only three responses came from the Czech Republic and one from Slovakia, while other CEE countries showed similar numbers: Slovenia (1), Poland (3), Lithuania (1) and Estonia (3).

In terms of general research areas, Hecker, Garbe and Bonn detected the prevalence of the life sciences (75.7%), with the second-highest frequency among the humanities and social sciences (11%), followed by natural science (7.5%) and engineering (5.8%). The distribution of scientific disciplines was as follows: ecology (27.2%); environmental sciences (22.5%); biology (15.6%); and zoology (15.6%). More socially-oriented disciplines, such as sociology (4%), transport (2.9%) and geography (2.9%), occupied 5–7th positions. Some interesting findings are related to the coordination of CS projects, which show the dominance of academia in leadership: almost one half of the surveyed projects were coordinated by a scientific organisation (45%), followed by educational organisations (14%) and NGOs (11%).

Another research initiative, even though primarily focused on environmental policy, is the report for the European Commission (Bio Innovation Service, 2018). More than 500 European CS projects were collected and analysed according to their contribution to Sustainable Development Goals (SDGs) and in relation to environmental policy (United Nations, 2019). The geographical distribution of CS projects was of interest: highest in the UK, France and Spain, but quite low in CEE countries. The findings show the dominance of NGOs' leadership (41%), followed by academia (29%), government (12%), mixed consortiums (11%) and private companies (3%).

The main environmental domains of CS projects in this report focused on nature and biodiversity (69%), mostly through monitoring or the occasional reporting of species occurrences, while other natural resources (air, water, land) were only represented at 3% to 7%. Environmental risks and health contributed only 1% each. In the case of the SDGs, the highest contribution was to nature conservation (water and terrestrial) in contrast to those SDGs focusing on socio-economic and community aspects (poverty, gender, food, water, sustainable energy, sustainable cities, etc.).

These studies present at least two analytically interesting findings. First, there is a clear over-representation of research from Western countries while, on the other hand, a significant under-representation of research from post-socialist countries. Second, all the research findings confirm the strong dominance of the use of citizen science in natural science disciplines over its use in social science disciplines.

3. Methodological approach

3.1 Step-by-step search for CS projects

Citizen science is a relatively new phenomenon in the Czech Republic, and it has not been integrated into existing institutional structures, so that there is no coordinating management or overview of current citizen science projects. In order to address our research goals, it was necessary to create our own database of CS projects. Since no such database has existed until now, a purely inductive method was adopted.

The search for CS projects in the Czech Republic took place from August 2018 to February 2019 and consisted of several steps. Firstly, we searched for projects within the scientific literature. The terms Citizen Science, Participatory Science, Participatory Mapping, Participation, GeoParticipation in combination with the Czech Republic, Czechia, Bohemia, Moravia and Silesia in English and Czech languages, were subject to search. The next step was a similar search for information on public web-sites through the Google and Google Scholar full-text search engine, in general, complemented by several secondary information sources, such as the Národní uložiště šedé literatury [National Repository of Grey Literature], the Souborný katalog Národní knihovny [Union Catalogue of the Czech Republic] (CASLIN), and Centrální evidence projektů [Central Evidence of Scientific Projects]. Web pages of the Czech Academy of Sciences were also explored, such as all universities and the research institutions of the Czech Academy of Sciences, and especially those universities with a geographical orientation. Third, the web pages of selected non-governmental organisations enabled us to obtain a preliminary insight into the issue. Finally, the personal knowledge and contacts of all members of the authors' team were used. All six co-authors turned to partners in their social networks and specialist scientific communities, NGOs, public institutions and supporters of citizen science, asking whether they knew of a project with a scientific focus that involved the general public. The data obtained from these three levels of inductive search became the bases for a database of participatory-based projects, which included 82 unique cases.

3.2 Database creation and its limitations

The database created in this way, however, has a number of limitations that need to be highlighted before proceeding with further analysis.

3.2.1 Limitation 1: The scope of the search was affected by subjectivity

The origin of the database was heavily influenced by the subjectivity of the authors' collective associations, especially their affiliation to certain scientific communities and the extent of their social networks. From the point of view of specialisation, the database is influenced by the easier search of citizen science projects in the fields of the authors' collective. These include social geography, physical geography, natural and environmental studies, cartography and geoinformatics. A lower representation of projects outside the scope of the authors' team cannot, therefore, signify only the absence of projects in these disciplines but rather point to the specificity of the creation of this database.

3.2.2 Limitation 2: Social networks of the authors' team

The authors are well aware that their social networks cover universities, research institutions, educational institutions, specialist scientific communities and non-profit organisations. To a much lesser extent, they cover the private sector, self-government and state administration. The integration of participatory methods in the decision-making processes of Czech municipalities (participatory budgets, participatory planning, participatory mapping) has been increasing in recent years, which in some cases can be used creatively to generate new scientific knowledge. We are aware of these developments, but they are not primarily designed as citizen science, and so they were not included in this database. The effect of this limitation is thus seen in the fact that the citizen science projects in this database are more strongly connected to research and educational organisations than to other organisations.

3.2.3 Limitation 3: Projects using participatory principles do not directly imply citizen science

Thirdly, the database is limited by the fact that it includes projects that met some aspects of public participation in general, but it does not necessarily cover the entire definition of citizen science projects. In other words, the 82 projects included in the original database are not directly citizen science projects, but rather projects using (geo)participatory principles. This may cause difficulties in interpretation because it is not possible to generalise findings or conclusions to the overall situation of citizen science in the Czech Republic. The compiled database is the first in the Czech Republic, it is incomplete and, therefore, necessarily includes selected citizen science projects. For this reason, the goal of this article was formulated in such a manner that it does not aspire to describe the complete set of citizen science projects in the Czech Republic, but rather to describe the heterogeneity of CS projects in the Czech Republic or to better capture the variety of forms in which citizen science has manifested itself in this specific post-socialist context.

3.3 The classification and analysis process of CS projects

The database was analysed in several successive steps. Firstly, we excluded projects that did not meet even the most broadly-conceived definitions of citizen science, as discussed above, or were not primarily linked to the territory of the Czech Republic. Thus, global projects such as Wikipedia and OpenStreetMap, or projects from Slovakia, which were partially implemented in the Czech Republic, were removed. In total, nine projects were excluded at this stage; hence, only 73 unique projects entered into the next phase of the analysis. These procedures were driven by the need to cope with the relatively large heterogeneity of citizen science definitions. The whole database was split into two parts: the first part – socially-oriented projects complying with a relatively strict definition of citizen science; and the second part, using a more open definition. The first part of the database – "pure" citizen science – was defined according to Haklay (2013) and contained 46 unique projects; the second part – "potential" citizen science – was classified more generally and contained 27 unique projects (see Fig. 1). In the final stage of the analysis, both parts were analysed separately.

For both groups, we applied a general classification schema and described all CS projects using these categories: title, general description, aim of the project, main coordinator, stakeholder(s), the geographical scope of the project, contact information and start year of the project (if detected). In the thematic classification of the projects, however, we used a diverse approach for each group.

The first part of the database was further analysed according to Haklay's (2013, 2018) levels of participation, and was classified into the following categories of citizen science: crowdsourcing; distributed knowledge; participatory; and extreme. The thematic scope of pure CS projects was classified according to a comprehensive international classification recommended by OECD (OECD, 2015). We mainly utilised the first two levels of classification, which we slightly simplified and adjusted for the purpose of our database. The primary level of classification is based on six primary research areas. The secondary level identifies 42 potential specific research fields within the disciplines. The third level serves as complementary and includes 44 variations of pre-selected detailed research topics to obtain a comprehensive picture of CS projects.

The second part of the database serves primarily to describe the potential for citizen science (N = 27), which can be identified in a number of projects, but which is not yet fully developed into citizen science. For classification purposes, we used somewhat simplified themes at two levels. The first level included six primary research areas, the same as for the first group. The second level used simplified themes such as the environment, librarianship, public space, gardening, transport, safety, waste, animal protection, food, fix my street and historical heritage. Both parts, however, do meet the stated goals and respond to the research question: "What type of projects meet the definition of citizen science in the Czech Republic?".

4. Results

4.1 Geographical distribution of pure CS projects

The spatial distribution of CS projects in the Czech Republic, according to the address of the main project coordinators, is presented in Figure 2. The highest number of projects is closely related to larger towns such as Prague and Brno, where universities, public and academic institutions are located. In one case with more principal coordinators, the partnership was again between Brno and Prague. Quite interestingly, local projects are usually operated by local (or smaller) universities, particularly in case of Volunteered Geographic Information.

Another level of cartographic representation addresses the territorial scope of the project. Most of the defined projects covered the whole of the Czech Republic, while several projects had a limited local scope due to the specificity of their research. For example, earthquake monitoring is bound to Western Bohemia due to the prevalence of this natural phenomenon in that part of the country (with several insignificant exceptions elsewhere). On the other hand, only a few projects were oriented to a wider scope and collected data from Europe or all around the world. All of these latter projects were located either in or close to Prague.

4.2 Scientific classification of pure CS projects

Based on our database of 46 citizen science projects, we detected the following distribution, represented in Figure 3. A clear majority of projects represented natural sciences (80%) as the primary research area, followed by the social sciences (9%) and agriculture (4%). The other three research areas (engineering, medicine, and humanities) are each represented by one case only.

These results, which show the predominance of natural and life sciences, correspond strongly with similar research on CS projects, such as Hecker, Garbe, and Bonn (2018), or the literature review by Kullenberg and Kasperowski (2016).

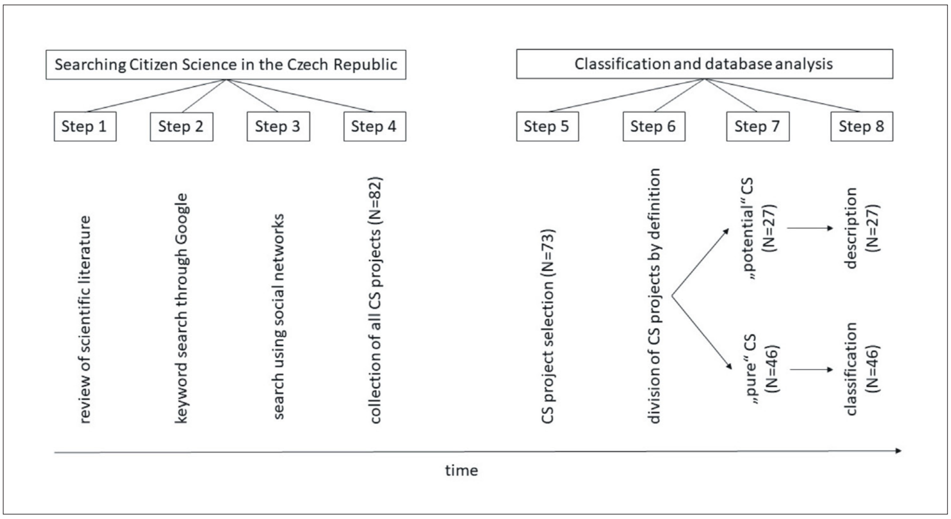

Fig. 1: Phases of investigation, classification and database analysis process.
Source: authors' elaboration

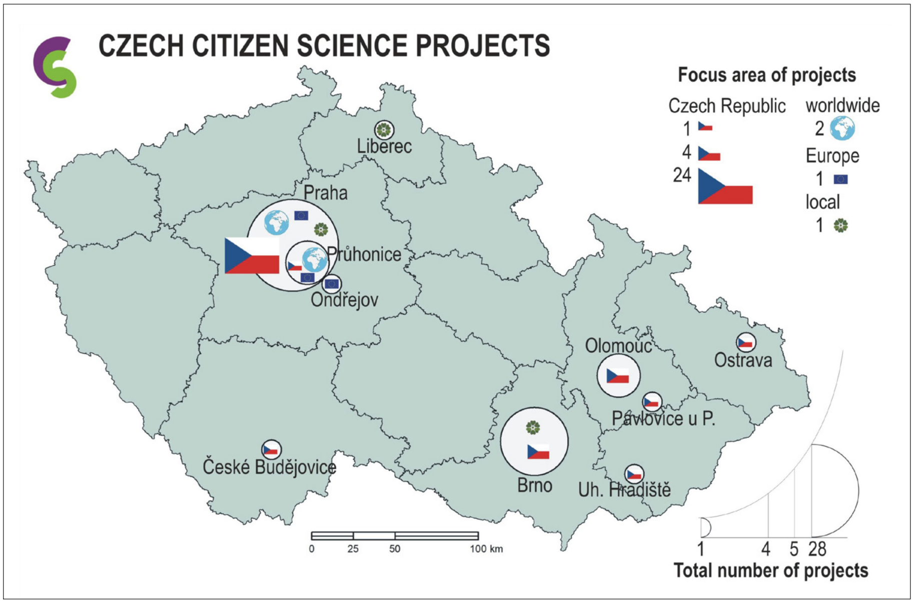

Fig. 2: Spatial distribution of pure CS projects
Source: authors' research

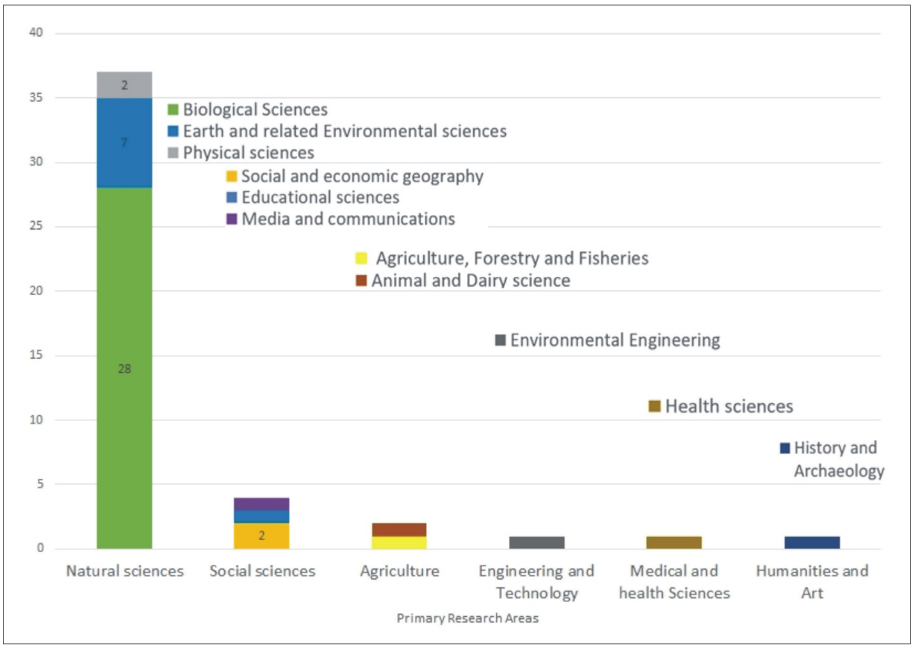

Fig. 3: Distribution of research areas (column descriptors) and research fields (legend) of citizen science projects in the Czech Republic. Source: authors' research

The second level classification revealed a more detailed distribution of research disciplines. Again, the highest prevalence is in biological sciences (28 cases), followed by earth and environmental sciences (7). No other research discipline was represented by more than two cases.

An even more detailed breakdown of research topics clearly shows the dominance of the biological sciences. We counted ornithology in 16 cases, followed by zoology (4), biology and conservation (3), education (3), hydrology (3), meteorology (3), urban studies (2), entomology (2) and botany (2). Other research topics are each represented by one case only.

4.3 Coordination and cooperation in pure CS projects

As for the coordination and supervision (both self and mutually coordinated) of citizen science activities, academia

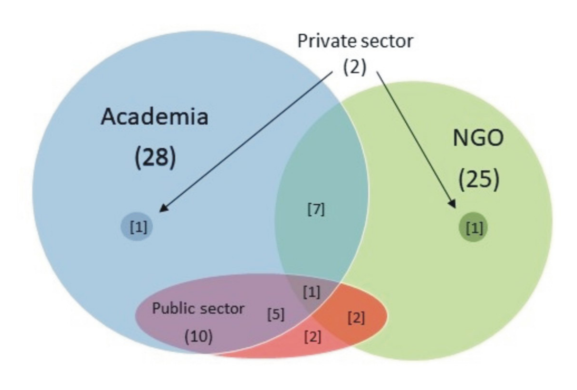

Fig. 4: Coordination of CS projects in the Czech Republic
Source: authors' research

(28) and NGOs (25) are responsible for most of the projects. The public sector (10) and, in particular, the private sector (2) play a lesser role in Czech CS projects.

The relationships presented in Figure 4 show the self-coordinated and mutually-coordinated citizen science initiatives in the Czech Republic, according to the type of stakeholder. The numbers in round brackets represent the total amount of initiatives per stakeholder. The numbers in square brackets show the extent of mutually-cooperative citizen science initiatives among stakeholders.

In more detail, we detected equal self-coordination either by Academia or NGOs, each stakeholder leads 14 CS projects (altogether represents 60% of all 46 CS projects), followed by public sector (only 2 cases), private sector does not individually leads no project. Mutual leadership between academia and NGO (7 projects) or academia and public sector (5 projects) shows quite satisfactory evidence of cooperation between stakeholders. Moreover, we revealed unique example of three party cooperation (NGO + public sector + academia). The relatively high level of cooperation between NGOs and academia indicates that academic organisations recognise the useful role of the non-profit sector. It values its connection to practice on the one hand, but also the willingness for public-science cooperation from the side of NGOs, as previously expressed by the Zelený kruh [Green Circle] (Čada, Ptáčková, and Stöckelová, 2009), which currently connects 27 NGOs. Moreover, these results contradict the relatively low evidence of NGO – science cooperation from recent European research of CS projects (Hecker, Garbe and Bonn, 2018), which showed the dominance of academia in leadership (45%), followed by educational organisations (14%), and with only 11% of projects led by non-governmental organisations.

4.4 Level of public participation in pure CS projects

An important aspect of CS projects is the level of public participation. Following Haklay's (2013) classification, we derived the following distribution of participation with respect to the Czech specific environment. Level IV of extreme citizen participation, based on mutual cooperation from the beginning and an open exploratory process, is represented by one unique case from the medical and health sciences with a strongly interdisciplinary character. The Level III of participatory science, characterised as mutual cooperation between various stakeholders, including scientists, was found in two projects (1 social science, 1 natural science).

Level II of distributed intelligence, in comparison, is widely represented in 35 cases, predominantly by the natural sciences (30), agriculture (2), social sciences (1), humanities and arts (1), and engineering and technology (1). This interpretation primarily corresponds to the natural sciences and monitoring in the field that requires advanced knowledge, time and some level of data interpretation. These efforts are required, for example, for the observation of the phenological phases of plants during the vegetation season, for meteorological monitoring, for observation of changes in bee colonies, for monitoring of plants and animals, for water quality and the environment. Finally, the Level I crowdsourcing includes various forms of simple data collection and reporting and was represented by 8 projects: the natural sciences (6) and social sciences (2). These activities mainly concern obtaining information and locations for special maps (e.g. animal accidents, the simple enumeration of single bird species occurrence, the location of events/objects, etc.). Table 1 briefly describes several representative examples of each level.

Level	Sum	Primary research area	Example		
			Name	Description	Coordinator
IV	1	Medical and health science1	Library for Brno without barriers	A highly interdisciplinary project based on a participatory process from the initial stage, which involves various stakeholders from policymakers, academia, the public, and NGOs. The aim of the project is to collect experience and know-how from participants to approach various aspects of disability from a community point of view. The project wants to institutionalise a new scientific discipline of disability studies.	Public institution
III	2	Natural sciences, social sciences	Action Frog	The project is based on cooperation between volunteers, NGOs, public institutions and scientists. Volunteers and conservationists indicate risk areas for frogs during spring migration and contribute to rescue actions. They also provide valuable scientific evidence and fight for better protection of this endangered species.	NGO
II	35	Agriculture, natural sciences, social sciences, humanities and arts	InterDrought	The project deals with monitoring and resolving agricultural drought. Scientists gather additional data from more than 100 active reporters/farmers that are used to monitor and evaluate the impact of agricultural drought on soil, yields, etc.	Academia
I	8	Social sciences, natural sciences	Emotional mapping	Recording of emotions that emerge in relation to specific places in an urban setting. Acquired data serves urban planning needs and applications, as well as further scientific analysis.	Academia

Tab. 1: Levels of public participation (Notes: [1] Medical science indicates the relation of the disability issue with medicine although the project is also connected to social science. Due to interdisciplinarity, is difficult to strictly indicate the primary research area. Translation: Knihovna pro bezbariérové Brno [Library for Brno without barriers], Akce Žába [Action Frog] InterSucho [InterDrought], Pocitové mapy [Emotional Mapping]. Source: authors' research

4.5 Evolution of pure CS projects over time

Finally, we analysed the duration of Czech citizen science projects. The first CS project was initiated in 1954 (Český Hydrometeorologický ústav) [Czech Hydrometeorological Institute], volunteer meteo-station service) and other long-lasting projects are also historically linked to the natural sciences, particularly ornithology. In Figure 5, we can clearly observe an extremely large increase in CS projects in the new millennium (since 2005 in particular), which corresponds to the recent expansion of information technologies and mobile applications. Most of the projects have been constantly running since their initiation. Only six projects appeared to be inactive in 2019, which probably indicates they have been terminated. One of those projects is in the stage of preparation and will be launched in 2020.

We can explain the long tradition of CS projects in the Czech Republic by the long-term history of various amateur associations and popular volunteer observation of the natural environment that provides vast amounts of valuable scientific data, leading to high-quality scientific outputs (e.g. Diblíková et al., 2013, 2019). Besides the long duration of these projects (especially ornithology and meteorology), another reason could be a need for non-conflictual social activities during the socialist regime (Vaněk, 1996; Tóth et al., 2018). On the other hand, most recent projects result from international cooperation, where a foreign project is adopted and adapted for the Czech environment.

4.6 The "potential" of potential CS projects

The 27 projects outside of the "pure" CS projects, i.e. those that did not meet any aspect of pure CS project definition but did represent some potential for further elaboration, are discussed in this section. In terms of a stricter definition of citizen science (Haklay, 2013), these were primarily first-level projects known as crowdsourcing, i.e. projects where public participation is realised through data collection. What connects most of these projects is that they do not designate themselves as CS projects, and they do not aspire to 'pass on' the results of their work outside their own community.

The main mission of these projects is to form or maintain a community and its environment, social environment or cultural heritage. If the results of their work are used for something, it is only for the purposes of the community, and perhaps for local or regional administrations. Their goal is not to perform or participate in science but to care for their own community. This character of these CS projects corresponds with the "more or less intensive public engagement" with NGOs (Krajhanzl et al., 2015; Krajhanzl, Chabada and Svobodová, 2018).

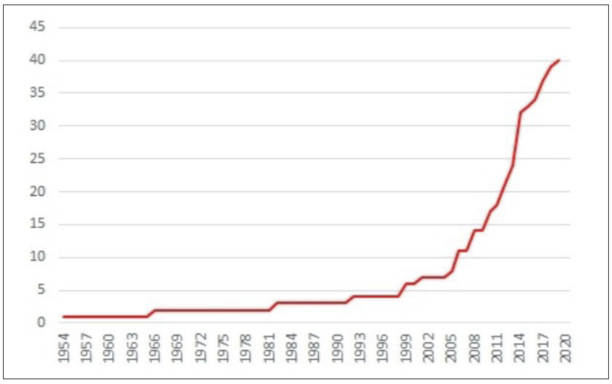

Fig. 5: Pure CS projects in the Czech Republic (1954–2019). Source: authors' research

In terms of coordination, there was a prevalence of the non-governmental sector (16 cases), followed by public institutions (7 cases), with a low representation of the private sector (3) and academia (1). This indicates a significant flourishing of civil society and the non-profit sector, which goes hand in hand with highly evolved social and environmental movements. These findings show that public engagement has already overcome previous difficulties in civil society development, as described by several authors after the breakup of the socialist regime (Fagin, 2000; Vaněk, 1996; Císař, 2008).

Although these projects do not meet the strict definition of "pure" CS projects, they can satisfy the less stringent definitions of socially-focused authors (Joy et al., 2011; Purdam, 2014; Kimura and Kinchi, 2016; Mahr et al., 2018) and namely geoparticipation (Pánek et al., 2014; 2017; Pánek, 2016). In this context, it is interesting that while natural sciences dominate the set of "pure" CS projects, this is not the case for "potential" CS projects: 16 of which can be described as closer to the social sciences (see Tab. 2).

In terms of the thematic focus of "potential" projects, the largest group relates to social geography, such as transport, safety, and quality of the urban environment, "fix-my-street" or preservation of historical heritage and other issues connected to urban planning or community, which represents nearly half (16) of all potential CS projects. These projects usually focus on improving various forms of mobility, problem fixing and enhancing public space. The second largest group is constituted by projects dealing with ecology, sustainability and care for nature and the environment (8). These are projects that map various sources of air pollution, heat in city islands, places of sorted waste or bio-waste, protected areas, etc. The agricultural (or gardening issue) is represented by three examples. A short summary of all topics is provided in Table 2.

5. Discussion and concluding remarks

As previously mentioned, this project did not aspire to provide a complete set of CS projects in the Czech Republic. The exploratory character of the study, using several step-searching methodologies, facilitated the process of uncovering the hidden citizen science landscape and its heterogeneity. This exploratory phase enabled us to compile our own database of more than 70 CS projects, and further to distinguish between "pure" CS projects (N = 46) and "potential" CS projects (N = 27). Thus, in answering the general research question: "What types of projects meet the definition of citizen science in the Czech Republic?", we found nearly 50 cases of pure CS projects, which more or less corresponded to established citizen science definitions.

To fulfill the general goal of the study to "Describe the heterogeneity of CS projects in the Czech Republic", we continued with a further analysis of CS projects in the database. The first dataset was analysed in more depth, while for the second group we used shorter summaries. This does not mean that the second group is "second-rate" or "worse". On the contrary, it is of particular analytical interest when it shows us the limits of universally understood definitions of citizen science. Moreover, the division between these two groups is not strict and the boundary is very thin.

We did not discover any significant differences in terms of general understandings and conceptualisations of citizen science in the Czech environment, compared to similar research in other countries, such as Hecker, Garbe and

Primary research area	Topics	Sum	Example		
			Name	Description	Coordinator
Social sciences	Transport Safety Waste Management Fix My Street Historical Heritage	16	Pedestrians for themselves	A web portal that seeks to improve the environment, ensure traffic safety, promote sustainable mobility and increase the accountability of citizens and public institutions regarding these issues. It enables community prioritisation of collected incentives by simply "liking".	NGO
Natural sciences	Care for the environment and nature Animal protection Quality of public space	8	Ecomap: your eco-friendly navigation	Mapping of various eco-objects. The main categories are Eco Consumer, Waste, Nature, Organisation, Objects, etc. (specifically green shopping, farmers markets, waste separation, protected areas, wells).	NGO
Agriculture	Gardening Food	3	Gengel	Efforts to preserve old, regional, family and similar varieties of agricultural plants as a common cultural heritage. Gengel offers these varieties to the public so that they can become acquainted with them, cultivate them, use their fruits, share seeds and care for their future destiny.	NGO

Tab. 2: Examples of potential CS projects (Notes: Translation: Chodci sobě [Pedestrians for themselves], Ekomapa: vaše ekologická navigace [Ecomap: your eco-friendly navigation]). Source: authors' research

Bonn (2018) or the literature review by Kullenberg and Kasperowski (2016). We note only a different temporality in citizen science monitoring. Proper fully evaluated evidence is still missing, however, such that this study is the first step in remedying this gap in our understanding of the phenomena.

Our investigation has indicated a prevalence of the natural sciences (80%) as the primary research area, followed by social sciences (9%) and agriculture (4%). The highest proportion of projects was linked with ornithological research and indicated a long tradition of working amateur associations. The results are similar to the findings of Hecker, Garbe and Bonn, (2018) and the Bio Innovation Service (2018), indicating the predominance of nature and biodiversity monitoring. In addition, the prevalence of crowdsourcing or distributive intelligence is in accordance with similar research elsewhere (Haklay, 2013). In opposition to other similar research (Hecker, Garbe and Bonn, 2018), however, but in accordance with the results of the Bio Innovation Service (2018), we discovered a high level of NGO coordination in the Czech Republic.

An interesting finding revealing the heterogeneity and diversity of CS projects was recorded by the comparison of pure and potential CS projects. While the first ("pure") group is more linked to the natural sciences and citizens mainly help by increasing scientific evidence (Kullenberg and Kasperowski, 2016), potential CS projects are closer to the general idea of participation and community work, and aim to improve public space or the environment, or rather social science objectives (Joy et al., 2011; Purdam, 2014; Kimura and Kinchi, 2016; Mahr et al., 2018) and are related to the "democratisation" process in science (Mahr et al., 2018). It is clear that, in the Czech Republic, the social sciences have a significantly higher occurrence among the "potential" CS projects than among the "pure" CS projects. While the natural sciences are more involved in implemented CS projects, the social sciences are more represented among potential CS projects. This implies a significant question: "Why are the social sciences less represented in the dataset of pure CS projects?". The question remains, moreover, as to whether this is as a result of the slower penetration of citizen science into the social sciences, or, conversely, of an inappropriate definition for CS, which mainly fits the natural sciences. Regardless, it is clear that citizen science in the Czech Republic has a different meaning for the social sciences than for the natural sciences. While natural sciences understand citizen science as a fundamental tool for building a relationship between scientists and the public, social sciences do not feel this need, as they are always linked to society through their subject of interest.

Social science "makes" science with people about people, is not dependent on complete datasets, and finally, more often uses qualitative methodologies that make it appropriate for even small data sets. The key question then is not: "Why are the social sciences less represented in the group of pure CS projects?", but rather: "What could be the benefit of citizen science for the social sciences?". Kingsley Purdam (2014) uses an example of "citizen social science" to answer this question. He offers examples of blogs and websites where people can share their experiences (e.g., sexual harassment) or observation by trained citizen scientists of their daily activities or everyday trips (identifying begging). Purdam himself defines a fairly comprehensive list of disadvantages (the need for training citizen scientists, limited validity checks, the difficulty of obtaining demographic data, the different terms and language used by citizen scientists, the very limited depth of collected data, the ethical problem of collecting data on other people, etc.) that do not show the use of citizen science in the social sciences in a particularly good light (Purdam, 2014, pp. 383–385).

In contrast, we note that social science has already the tools created for this purpose (field records, field diaries, diary records, activity travel-diaries, etc.). Other authors have attempted to answer this question by looking for examples in the collaboration between citizen science and Science and Technology Studies (STS). According to their examples, however, STS does not understand citizen science as a natural science, i.e. as a tool for achieving "other" results. Instead, STS understands citizen science as a subject for research, in which they essentially do not participate but merely critically evaluate it (Mahr et al., 2018; When et al., 2015).

Our answer to this question is, therefore, quite different. In agreement with Bálint Balázs (2019) and his concept of "invisible citizen science", we are addressing "hidden" citizen social science in two distinct ways: firstly, citizen social science in the Czech Republic was hidden in post-socialist space; and, secondly, it has been hidden by the demands of the natural sciences. Social sciences need and also use citizen science, but for other purposes than the natural sciences. Therefore, the form of citizen science in the social sciences cannot match the definition of pure citizen science projects, so its occurrence is under-represented in this part of our database. One of the most analytically interesting results of our research is actually our response to the question: "How to make citizen social science more visible in post-socialist space?".

Our answer to this question is twofold. The first concealment is the invisibility of citizen science, as Balázs (2019) points out. In this sense, further mapping of CS projects in individual CEE countries is helpful, especially when very little evidence of CS projects from these countries was indicated in most of the international studies or repositories (Bio Innovation Service, 2018; Hecker, Garbe and Bonn, 2018). Our study points out that the reality of a CS project in the CEE geographical region might be different or even distorted from how it is presented. First, a lower representation of a non-English CS project might be caused by language barriers, appositely mentioned in the study provided by Bio Innovation Service (2018). Second, the lower internal and subsequent international activity of the mentioned countries is monitored, as indicated by Hecker, Garbe and Bonn (2018), as a small number of responses. To rearrange this imbalance, more intensive international cooperation with non-English speaking countries and especially CEE countries is needed.

The second concealment is given by the desire to universally define citizen science for all sciences based on the needs of only the natural sciences. The solution to this concealment outside the definition and vice versa, is to increase the visibility of citizen social science in society by (i) abandoning the idea of a common definition of citizen science for all sciences, and (ii) allowing different definitions of citizen science for different sciences. In other words, to apply a more open and heterogeneous approach, as Niewöhner (2016) suggests. In practice, this may mean some or all of the following approaches: focusing on participation that is not limited to data collection; selecting citizen scientists intentionally, not randomly; a greater use of self-research approaches (autobiography, auto-ethnography, etc.); and finally, selecting different thematic areas of research (such as community emancipation, forms of resistance or organised disobedience, research on mental health, loneliness, stigmatisation, etc.).

Above all, another potential avenue for the future might be to extend the definition of citizen science to include organisational, administrative and genuinely community-based ways of participation, as presented in the section above on "potential" citizen science projects. This means embracing projects whose primary objective is not to "generate scientific knowledge" but to "generate knowledge useful for the community" (participation in a variety of administrations, management, coordination – flood management, water management, waste management, defect management, barrier management, etc.). Such projects would then be part and parcel of modern Critical Geography.

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Data accessibility

The data that support the findings of this study are available from the authors, with a further detailed expression of interest in their use as well as a reasonable request.

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Český Hydrometeorologický ústav [Czech Hydrometeorological Institute]: http://portal.chmi.cz/

Chodci sobě [Pedestrians for themselves]: https://www.chodcisobe.cz/

Czech Academy of Sciences: http://www.avcr.cz/en/

Děti Země [Children of the Earth]: https://detizeme.cz/

Ekomapa: vaše ekologická navigace [Ecomap: your eco-friendly navigation]: https://www.veronica.cz/ekomapa#

Frank Bold: https://frankbold.org/

Gengel: http://gengel.cz/

Hnutí DUHA [Friends of the Earth Czech Republic]: http://www.hnutiduha.cz/

InterSucho [InterDrought]: https://www.intersucho.cz

Knihovna pro bezbariérové Brno [Library for Brno without barriers]: https://www.kjm.cz/knihovna-pro-bezbarierove-brno

Nadace Partnerství [Environmental Partnership Foundation]: https://www.nadacepartnerstvi.cz/

Nadace Veronica: https://nadace.veronica.cz/

Národní uložiště šedé literatury [National Repository of Grey Literature]: https://nusl.cz/?language=en

Pavučina [Network of Environmental Education Centres in the Czech Republic]: http://www.pavucina-sev.cz/rubrika/77-ENGLISH/index.htm

Pocitové mapy [Emotional Mapping]: https://www.pocitovemapy.cz

Souborný katalog České republiky [Union Catalogue of the Czech Republic (CASLIN)]: https://aleph.nkp.cz/F/?func=file&file_name=find-b&local_base=skc&CON_LNG=ENG

Zelený kruh [Green Circle]: http://www.zelenykruh.cz/en/

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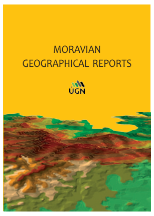

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Citizen science as a new approach in Geography and beyond: Review and reflections

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Abstract

Issues related to the evolving role of citizen science and open science are reviewed and discussed in this article. We focus on the changing approaches to science, research and development related to the turn to openness and transparency, which has made science more open and inclusive, even for non-researchers. Reproducible and collaborative research, which is driven by the open access principles, involves citizens in many research fields. The article shows how international support is pushing citizen science forward, and how citizens' involvement is becoming more important. A basic scientometric analysis (based on the Web of Science Core Collection as the source of peer reviewed articles) provides a first insight into the diffusion of the citizen science concept in the field of Geography, mapping the growth of citizen science articles over time, the spectrum of geographical journals that publish them, and their citation rate compared to other scientific disciplines. The authors also discuss future challenges of citizen science and its potential, which for the time being seems to be not fully utilized in some fields, including geographical research.

Keywords: *citizen science; open science; open-access; neo-geography; scientometric analysis*

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1. Open science as an impetus for the citizens

How scientific research is conducted has evolved over many centuries. Amongst several transitions, significant changes have taken place with respect to research methods, openness and the interactions of science and society. Since the 17th century, when the prestige of noble patrons caused scientists to perform their research in secrecy, scientists have found ways to collaborate and disclose their results and to obtain acknowledgements for their work (David, 2007). Despite the fact that this has led to a rich culture of journals and the foundations of copyright, it restricted access by society at large. With the evolution of scientific societies during the 19th century, however, we can see a movement taking place towards a more 'open' science through public domain thinking and the open access paradigm of the second half of the 20th century (Green, 2017).

The concept of open science can be interpreted in many ways, depending on how the word 'open' is understood and whether this refers to the process, means, results, etc. of science. A rather comprehensive definition is provided by Foster (2016: 1), who describes "open science as the movement to make scientific research, data and dissemination accessible to all levels of an inquiring society".

Although Foster's definition implies an inclusion of process arrangements in open science, the Foster taxonomy puts these at a higher level, i.e., Responsible Research and Innovation, under which label we can find Open Science, Education, Governance, Gender Policy, Ethics and Public Engagement (Participatory research, Citizen science, etc) (cf. Foster, 2016). Several initiatives have started to let organisations stimulate open science in practice, on

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[1] see https://osf.io

[2] https://www.openscience.nl

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a national level (e.g., US Open Science Framework[1], Dutch Open Science Platform[2], and at the international level (e.g., the EU Open Science Policy Platform[3]).

Obviously, in recent years, information and communication technologies have opened up ways for collaboration and sharing research data in many new ways. Not only have tools such as mobile communication and online services become available for collaborative research, but the web has made science more digestible for society at large. On the other hand, it has also forced scientists to adapt their processes of knowledge creation and dissemination to an environment with peer-researchers and software-based services, in which they have less control (Bartling and Friesike, 2014). Moreover, the myriad of communication channels, including social media, is facilitating an unprecedented outreach, but at the same time causes a publication abundance in which quality metrics are not always easily set (see e.g., Mirowski, 2018; Gadermaier et al., 2018; Specht and Lewandowski, 2018).

2. Open access, reproducible and collaborative research

An important condition for the open science movement lies in open access to research materials, which can be achieved through open access journals and self-archiving. Besides the articles and findings themselves, the open data symbolizing common outputs from the citizen science projects are very important. Whereas scientific articles published under the open access principle are useful mainly for other researchers, scientific data published as open data could also be valuable for public administration/government, citizens conducting their own research, media, etc. Public open data without any subjective comments might be more unbiased than articles with conclusions published as open access: in this case, we need to point out some abuse of open access by predatory journals, see for example, Sorokowski, 2017 or Fell, 2019. The importance of open access, however, is a key aspect of the process of opening science.

Fundamental to clear open access rulings is the availability of licencing schemes. With the advent of open source software, license options are made available that support the reuse of the software code. With respect to open content in general, a simple but effective scheme has been developed through the realm of the Creative Commons, which can be applied to a variety of content types, such as research data, images and publications (Frieseke, 2014). In addition to accessing research materials, scientists should be able to verify existing research results in order to reuse them and innovate. For this purpose, the FAIR guiding principles (Findable, Accessible, Interoperable, Reusable) have been established (Wilkinson et al., 2016), serving to enhance the reliability and reproducibility of research.

Whereas the open science movement and stimuli from funding agencies are leading to scientists' collaboration in project research consortia, the engagement of non-academics in the knowledge creation process is growing (Dickinson et al., 2012) and can be attributed to the open science movement. Such engagement can range from a single contribution of measurement to active participation in the scientific process (Haklay, 2013). Hecker et al. (2018) state that citizen science practitioners have an acute awareness about the societal relevance of their participation. This provides a great opportunity for scientists to put their research into a societal context.

Although there are some concerns about open science, such as quality control issues, platform domination by larger technology players and publishers (Mirowski, 2018), there are developments that take open science a step further, such as open data policies and new interoperable representations of knowledge (Albagli et al., 2015). An important task for all researchers is to educate the new open scientists on topics of quality, reusability and responsibility.

3. Towards citizen science

Citizen science appears to be a new term but it is actually a relatively old practice (see e.g., Eitzel, et al., 2017). The term itself incorporates diverse forms of cooperation and interaction among volunteers from the public, carried out in order to benefit society and the environment. Although this term was not adequately established in the scientific literature until the 1990s (Bonney et al., 2009), similar interactions had existed long before. One of the typical fields in which citizens participated substantially to scientific research is astronomy, where amateur astronomers collectively observed a variety of celestial objects and phenomena (Mims, 1999). For such activities, the term citizen science created a new framework and offered specified definitions and contents for already existing phenomena, conducted mostly with the help of modern information technologies. Some examples of these trends can be seen as: from simply collecting data about bird strikes around 1880 (Droege, 2007) to advanced odour sensing, for example via the D-NOSES project[4] funded by the European Union's Horizon 2020 Science with & for Society (SwafS)[5] call. Opening science, accessing modern technologies and raising public awareness, are critical factors for empowering citizen scientists and academics.

Many things have changed since the end of the 20th century. Opening science led to the increased engagement of citizens, as well as thoughtful acceptance of data sets coming from public participation in research. If we compare articles using public participation – in any format of its meaning, from collecting data and serving people as sensors, to public participation in research design and outputs analyses – from the past decades to the present, papers increasingly rely on the participation of citizen scientists (Follet and Strezov, 2015; Kullenberg and Kasperowski, 2016). This trend holds valid especially for natural and environmental sciences (Theobaldt et al., 2015), and applies to a large degree to research projects that require large amounts of data. The resulting data sets are usually published as well, for example, as an appendix to the original article, as downloadable files or in easliy-accessible databases. Notably, the integration of citizen science principles into modern (open) science has been spearheaded by ornithologists (see for example, the activities of the Cornell Lab of Ornithology in US[6], or the Czech Ornithologists Society[7] in the Czech

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[3] https://ec.europa.eu/research/openscience/

[4] https://dnoses.eu/

[5] https://ec.europa.eu/research/swafs/index.cfm

[6] https://www.birds.cornell.edu/citizenscience/

[7] https://www.birdlife.cz/en/

context). Bird watching has become a global phenomenon, where thousands of people are observing birds and helping scientists in research in this bio-geographical field (Devictor et al., 2010).

The movement of empowering citizen scientists appeared to have progressed faster in the European "western countries" compared to Central and Eastern European countries. More details for the Czech case are provided by one of the papers in this issue (Duží et al., 2019). The uneven production of knowledge with citizen scientists were also described by Irwin (1995). This "delay" does not mean that citizen science does not exist in those countries – it is just less visible (see the research conducted, for example, by Balint Balazs for Central and Eastern European countries, or the activities conducted by the Czech Academy of Sciences in its Institute of Botany[8] and Institute of Geonics[9]). Such empowerment is boosted by technological development. Technologies have increased the options for citizen science in enabling people to participate in more and more research fields. Technologies enable, among other aspects, the social sciences to carry out citizen science activities. A good example comes from the history of fine art, where digitalisations of the personal papers and letters of British-born émigré artists enabled the development of an online transcription tool (hosted in the Zooniverse platform[10]). In this case, volunteers could study and transcribe the digital archives. The popularity of Zooniverse itself – along with other platforms serving as repositories for citizen science projects, such as SciStarter or the Atlas of Living Australia – is strongly connected to the ubiquitous Internet connections and growing market of mobile technologies. Global repositories and platforms attract both researchers and citizens to connect mutually. As a natural outcome, one witnesses countless combinations of open science principles, new technologies and citizen science approaches, which lead to valuable projects based on building instruments to gather data for their own experiments (Baden et al., 2015). These activities are reinforced by continuing movements that are related to open software and open hardware, such as 3D printing (Pearce, 2012).

While the number of public participants in science and citizen science-based projects is increasing (despite the fact that many of them do not have long term engagement), the initiatives dealing with national and global coordination of public participation in research is becoming more critical. Leading organizations such as the American Citizen Science Association (CSA)[11], the Australian Citizen Science Association (ACSA)[12], the European Citizen Science Association (ECSA)[13], and several national and regional associations are proposing knowledge exchange, increased interoperability and improved standardization (for example, the 10 principles of Citizen Science made by ECSA (ESCA, 2015). These activities continuously help to improve the society-science-policy interface.

4. Citizen science in Europe – cooperation, networking and research

The major and traditional European-level support for citizen science originated from the EU-funded science and society programs, such as SwafS call (see footnote 5) and in the earlier FP7 and current Horizon 2020 programmes. Some examples are CitieS-Health[14] (on urban pollution), D-NOSES[15] (on odour pollution control), WeObserve[16] (on environmental monitoring), Doing It Together Science (DITOs)[17] (on active involvement of citizens in citizen science), LandSense[18] (on the use of satellite imagery for environmental decision making), GroundTruth2.0[19] (on sustainable implementation of citizen observatories), and EU-Citizen.Science[20] (tasked to set up a European Citizen Science Platform). Successful citizen science proposals have also appeared in related projects, such as the Collaborative Awareness Platforms (CAPs, examples include Making Sense[21], and CAPTOR[22]), and most recently also in the area of open science and the European Open Science Cloud (EOSC)[23].

In terms of application areas, citizen science already feeds particularly into environment-related policy (Bio Innovation Service, 2018), e.g., LIFE[24]. It is not only carried out in projects (as in the LIFE program) but also contributes scientific evidence to policy making, as for example, for farmland and agricultural birds, and marine litter. A recent study (Bio Innovation Service, 2018) identified more than 500 citizen science projects that are related to environmental policy (see also the data catalogue[25] and Citizen Science Explorer[26] offered by the European Commission's Joint Research Centre (JRC). Efforts are underway to increase policy relevance and impact (Schade et al., 2017a). The promotion of the wider use

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[8] https://www.ibot.cas.cz/en/public-relations/citizen-science/

[9] http://www.citizenscience.cz/

[10] https://www.zooniverse.org/

[11] https://www.citizenscience.org/

[12] https://citizenscience.org.au/

[13] https://ecsa.citizen-science.net/

[14] http://citieshealth.eu/

[15] https://dnoses.eu/

[16] https://www.weobserve.eu/

[17] http://togetherscience.eu/

[18] https://landsense.eu/

[19] https://gt20.eu/

[20] http://eu-citizen.science/

[21] http://making-sense.eu/

[22] https://www.captor-project.eu

[23] https://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud#

[24] https://ec.europa.eu/easme/en/life

[25] https://data.jrc.ec.europa.eu/

[26] https://ec-jrc.github.io/citsci-explorer/

of citizen science to complement environmental reporting is one of ten actions which the European Commission has adopted to achieve this goal[27]. Wider discussions related to citizen science data are, for example, supported by a recently published community page[28], hosted also by the JRC.

An important development has been the initiation (in 2014) and the subsequent evolution of ECSA, which is also supported by the EU. In addition to being a network of researchers, ECSA actively supports project initiatives and the development of the ideas behind open science. ECSA cooperates with the US-based CSA, and with ACSA.

In relation to citizen science, several projects have fostered cooperation in the field of volunteered geo-information generation (often abbreviated as VGI). In current participative research, VGI plays a major role (Sui et al., 2012). Some examples of the EU efforts in fostering VGI within citizen science are the COST Action IC1203 – ENERGIC[29] (European Network Exploring Research into Geospatial Information Crowdsourcing: software and methodologies for harnessing geographic information from the crowd), and COST Action project TD1202 – Mapping and the Citizen Sensor[30]. Each project resulted in the publication of a book, covering the research performed, (see, respectively, Capineri et al., 2016 and Foody et al., 2017). Currently, a cross-cutting COST Action on citizen science[31] (CA15212) aims to integrate a wide spectrum of stakeholders to employ citizen science for social innovation and socio-ecological transition. This will be performed in six working groups, which cover aspects of the scientific quality of citizen science, synergies with education, the society-science-policy interface, the role of citizen science for civil society, data standardization and interoperability and other cross-cutting relevant topics. Other COST actions involve more specialised fields, such as COST Action Alien-CSI (CA17122): Increasing understanding of alien species through citizen science[32].

As an emerging topic, many European national initiatives recognized the importance of a consolidated central portal. Thus, application portals have been set up over the last 15 years: notably in Austria[33], Germany[34], Spain[35], Belgium[36], The Netherlands[37], and the Czech Republic[38]. These mechanisms stimulate citizens to observe and learn and often result in data and mobile apps. Though many of these are very useful within each project, the challenge is to make them reusable across project initiatives and reproducible in the sense of open science (Schade et al., 2017b).

5. Citizen science and Geography

Kerski (2015) has emphasized that new converging global trends, including geoawareness, geoenablement, geotechnologies, citizen science and storytelling – all have the potential to offer geography world-wide attention (from education and society) that may be unprecedented in the history of the discipline. Issues which have been central to Geography are now part of the global consciousness, and many tools and data sets that were formerly used and examined only by geographers and other earth and environmental scientists, are now in the hands of the general public (Kerski, 2015: 14). The term "neo-geography" (see Turner, who championed the term in 2006) has also been implicated in this context (see e.g., Wilson and Graham, 2013; Leszczynski, 2014).

In an empirical investigation, we found (as of November 30, 2019) that the Web of Science (WOS) Core Collection included 2,870 articles that included "citizen science" in the Topic category (i.e., the title, abstract, author keywords, and/or keywords plus). Journals covered in the Geography category (according to the WOS classification) have published to date a total of 88 of these articles, which is slightly more than 3% of all articles on citizen science in the WOS database (see Fig. 1).

We realise that such a selection and subsequent analysis has clear limitations, because we have used the "basic search" method without applying any extra inclusion and/or exclusion criteria, as used by some previous studies (Follett and Strezov, 2015; Kullenberg and Kasperowski, 2016). As a result, some papers could have been omitted because they do not use the exact term "citizen science", even though they could be dealing with some kind of citizen science research while containing related terms, such as for example, volunteered geographic information, neo-geography, or citizen geography. This issue is linked to the prevalent problem of multiple meanings of the concept itself, and the use of alternative terms within different scientific disciplines and geopolitical contexts (see e.g., Eitzel, et al., 2017). Our aim here, however, was not to conduct a precise scientometric analysis but to provide a first insight into the diffusion of the citizen science concept in the field of Geography. The results presented below are based on an analysis excluding articles published during 2019, because this year was not complete at the time of writing this paper.

The first article published in a geographical journal that included "citizen science" in its content (specifically in the author's keywords) was "Building capacity for environmental management: Local knowledge and rehabilitation on the Gippsland Red Gum Plains" (Measham, 2007, in the Australian Geographer). Geography is still among the top ten scientific disciplines (according to the WOS categorization) dealing with citizen science, even though the share of geographic journals in publishing citizen science articles has been quite volatile over recent years (see Fig. 2). According to an earlier study by Kullenberg and Kasperowski (2016),

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[27] https://ec.europa.eu/environment/legal/reporting/fc_actions_en.htm

[28] https://ec.europa.eu/jrc/communities/en/community/citizensdata

[29] http://vgibox.eu/

[30] https://www.cost.eu/publications/mapping-and-the-citizen-sensor/

[31] https://cs-eu.net/

[32] https://alien-csi.eu/

[33] https://www.citizen-science.at/

[34] http://www.citizen-science-germany.de/

[35] https://natusfera.gbif.es/?locale=en

[36] https://www.scivil.be/en

[37] https://waag.org/en

[38] http://www.citizenscience.cz/

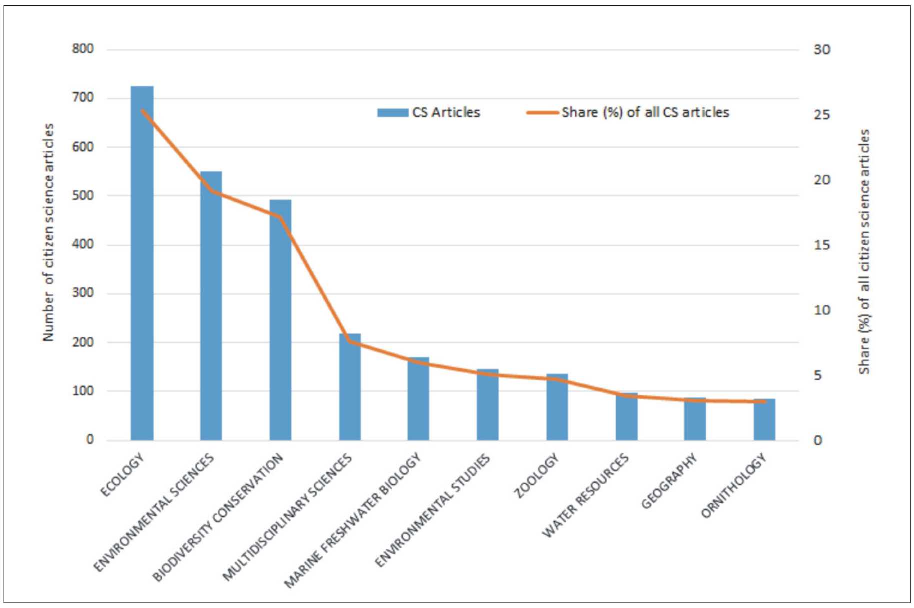

Fig. 1: The number of "citizen science" articles and the proportion of all citizen science articles according to Web of Science categories as of November 30, 2019 (Note: The graph includes only the top ten categories)
Source: authors' elaboration based on WOS/Clarivate Analytics data (2019)

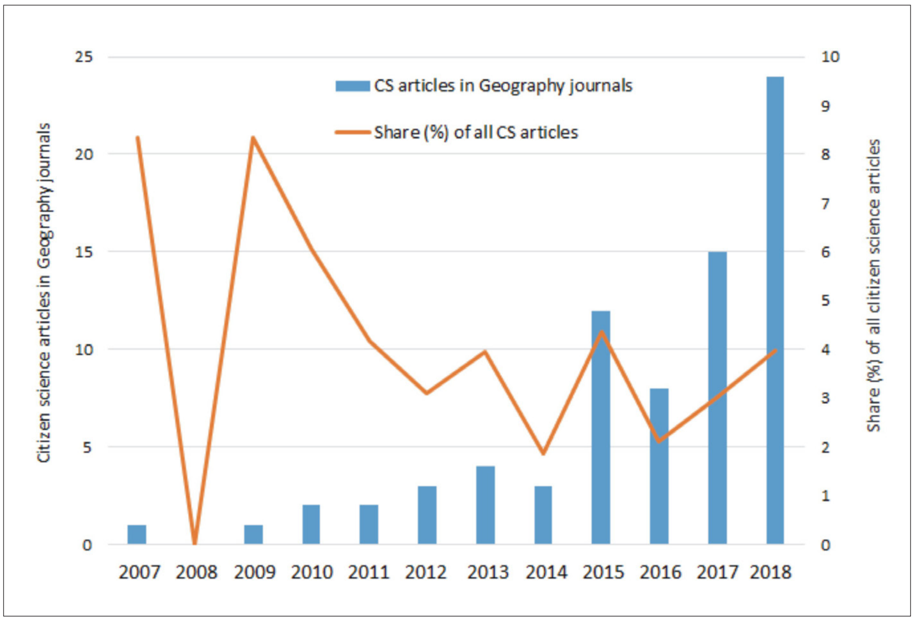

Fig. 2: The number of citizen science articles in Geography journals and the share of all citizen science articles for the category according to Web of Science categories (2007–2018)
Source: authors' elaboration based on WOS/Clarivate Analytics data

Geography was equal in third place among disciplines in the number of published citizen science articles (after Ecology and Environmental Sciences), but it has been overtaken in recent years by Biodiversity Conservation, Marine Freshwater Biology, Zoology and Water Resources categories. The articles in geographical journals, however, show a similar trend to the articles in other scientific disciplines, in that research on methodology, the quality and reliability of data and validation techniques, preceded the rise of the publications on empirical research outcomes based on citizen science methods (see Follett and Strezov, 2015).

It may seem that Geography does not fully utilize its potential for publishing citizen science research at this time (see e.g., Connors, Lei and Kelly, 2012), or that geographical journals are not so open to this type of article and/or that authors prefer publishing in journals in other fields or use different publishing models (Follett and Strezov, 2015). Another interpretation may be that geographers use different terminology.

A basic analysis of authors' keywords used in citizen science articles in geographical journals revealed that "crowdsourcing" and "volunteered geographic information" (VGI) are among the most frequent keywords (see Fig. 3) – and, in fact, these two terms are generally more widespread in geographic journals than the "citizen science" term. As emphasized by Cooper et al. (2017), the concepts of volunteered geographic information, crowdsourcing, neo-geography and citizen science are sometimes confused with

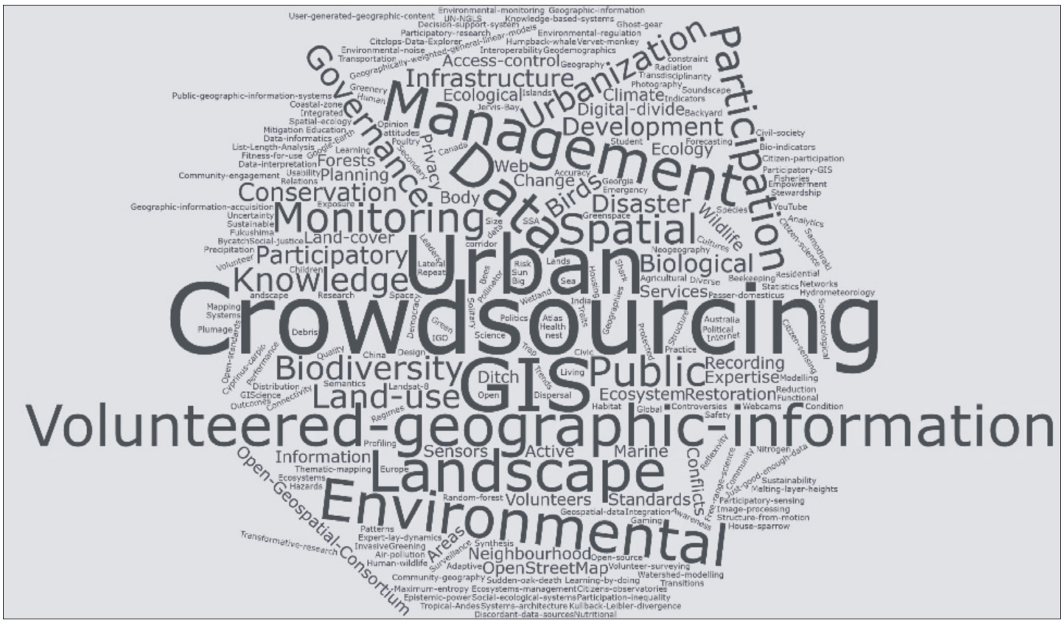

Fig. 3: A collage (word-cloud) of the most frequent authors' keywords assigned to citizen science papers in Geography journals. Source: data from WOS / Clarivate Analytics (2019); authors' elaboration using Free Wordcloud generator (www.wordclouds.com)

one another – even though each of these concepts has unique characteristics and even though they can overlap. Cooper and colleagues (2017) provide some practical examples of citizen science that are neither neo-geography, VGI, nor crowdsourcing, and examples of neo-geography that are neither VGI nor citizen science.

Nevertheless, the use of the citizen science approach relies on a wider acceptance of this method by the scientific community and academic journals. Gadermaier et al. (2018) outlined five factors that influence the probability of publication using citizen science data in open-accessed peer-reviewed scientific journals. These factors include: (i) funding to cover publication costs; (ii) quality, quantity and scientific novelty of the data; (iii) recommendations to acknowledge the contributions of citizen scientists in scientific, peer-reviewed publications; (iv) citizen scientists' preference for the hands-on experience over the product (publication); and (v) bias among scientists for certain data sources and scientific jargon (Gadermaier et al., 2018: 1). Citizen science papers to date have been published in a total of 33 geographical journals, the largest proportion for the journal Landscape and Urban Planning (see Tab. 1).

One third of all papers have been published as open-access (including the first and the third most cited papers), and the open-access papers have slightly higher average citations per article (14.5) than not open-accessed articles (12.5). It may be interesting to compare the average citations of citizen science papers in Geography journals with other categories (for the same range of publication years): the average citations of citizen science articles in Ecology journals is 22.4; 19.9 in Environmental Sciences; 17.7 in Multidisciplinary Sciences; 14.4 in Environmental Studies; (only) 10.5 in Marine Freshwater Biology; 6.8 in Zoology; and 6.2 in Ornithology. The citation rate seems to reflect the more specialised focus of a specific discipline. The top ten most cited papers on citizen science in Geography journals are listed in Table 2.

With respect to the overall share of countries in publishing citizen science research in Geography, authors from the USA (participating in 28 articles), UK (23 articles), Australia (9 articles) and Germany (8 articles) are most represented. Authors from Austria and Canada authored and/or co-authored four articles, and authors from other countries presented in the chart (see Figure 4) participated on two

Rank	Journal	Publisher	No. of articles
1	Landscape and Urban Planning	Elsevier, Netherlands	16
2	International Journal of Spatial Data Infrastructures Research*	European Commission, Italy	7
3	Transactions in GIS	Wiley, USA	7
4	Annals of the American Association of Geographers	Taylor & Francis Ltd, England	6
5	International Journal of Geographical Information Science	Taylor & Francis Ltd, England	5
6	Applied Geography	Elsevier Sci Ltd, England	4
7	Cartography and Geographic Information Science	Taylor & Francis Inc, USA	4
8	Computers Environment and Urban Systems	Elsevier Sci Ltd, England	4
9	Earth Systems Data and Models	American Geophysical Union	4
10	Global Environmental Change	Elsevier Sci Ltd, England	4

*Tab. 1: The top 10 source journals in Geography for citizen science articles (*Journal covered in the Emerging Sources Citation Index). Source: authors' elaboration based on WOS / Clarivate Analytics data (2019)*

or three articles. The category "others" includes authors from other eight countries (Bolivia, Brazil, Czech Republic, Denmark, Finland, Greece, Japan and Nigeria) who participated in one article.

As examples of 'good practice' in the citizen science approach in the field of Geography we could list several projects (see Tab. 3). Some of the projects redefined the geographical field – as an example, OpenStreetMap brings a new look to map creation and usage in real time, including many derivatives from the original cartographic basemaps (Haklay and Weber, 2008).

Another global community-driven project, FreshWater Watch led by the Earthwatch Institute, has engaged over 9,000 volunteers in collecting 20,000 water samples

Rank	Article	Total citations
1	Ahern, J. et al. (2014): The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. Landscape and Urban Planning, 125: 254–259.	114
2	Connors, J. P. et al. (2012): Citizen science in the age of neo-geography: Utilizing volunteered geographic information for environmental monitoring. Annals of the Association of American Geographers, 102(6): 1267–1289.	69
3	Foody, G. M., et al. (2013): Assessing the accuracy of volunteered geographic information arising from multiple contributors to an internet based collaborative project. Transactions in GIS, 17(6): 847–860.	64
4	Newman, G., et al. (2010): User-friendly web mapping: lessons from a citizen science website. International Journal of Geographical Information Science, 24(12): 1851–1869.	57
5	Strohbach, M. W. et al. (2013): Are small greening areas enhancing bird diversity? Insights from community-driven greening projects in Boston. Landscape and Urban Planning, 114: 69–79.	46
6	Robinson, L. M. et al. (2015): Rapid assessment of an ocean warming hotspot reveals "high" confidence in potential species' range extensions. Global Environmental Change, 31: 28–37.	45
7	Johnson, M. F. et al. (2014): Network environmentalism: Citizen scientists as agents for environmental advocacy. Global Environmental Change, 29: 235–245.	44
8	Lawrence, A. (2009): The first cuckoo in winter: phenology, recording, credibility and meaning in Britain. Global Environmental Change, 19(2): 173–179.	38
9	Johnson, B. A., Iizuka, K. (2016): Integrating OpenStreetMap crowdsourced data and Landsat time-series imagery for rapid land use/land cover (LULC) mapping: Case study of the Laguna de Bay area of the Philippines. Applied Geography, 67: 140–149.	34
10	Bruce, E., et al. (2014): Distribution patterns of migrating humpback whales (Megaptera novaeangliae) in Jervis Bay, Australia: A spatial analysis using geographical citizen science data. Applied Geography, 54: 83–95.	28

Tab. 2: The top 10 cited citizen science articles in Geography journals
Source: authors' elaboration based on WOS / Clarivate Analytics data (2019)

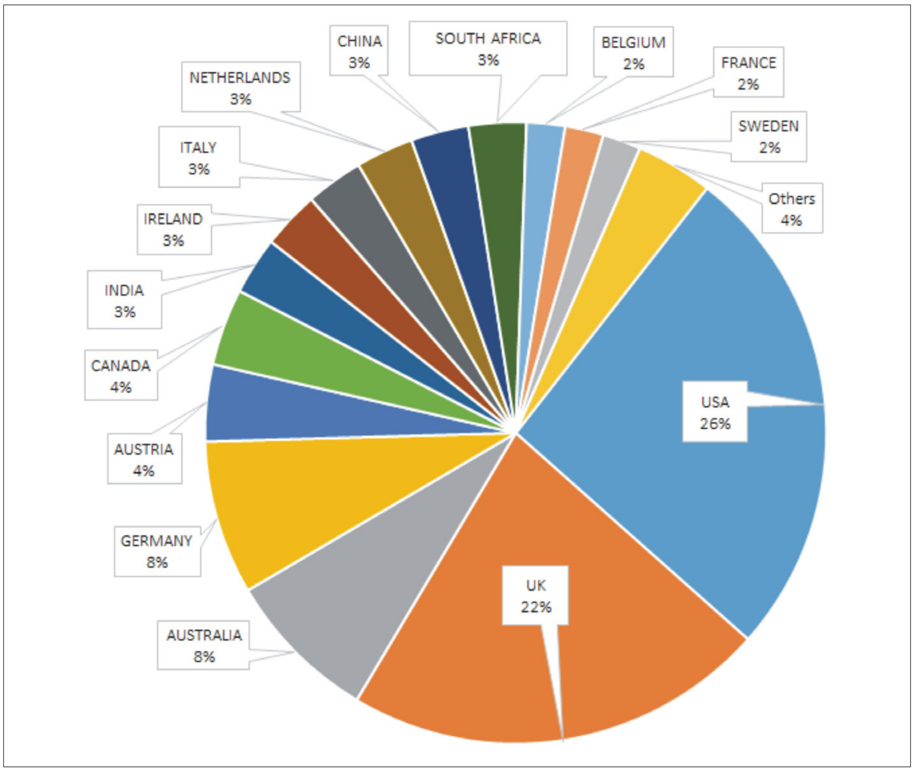

Fig. 4: Share of authors of citizen science articles in Geography journals according to authors' affiliation.
Source: authors' elaboration based on WOS/Clarivate Analytics data (2019)

since 2013 (Bio Innovation Service, 2018). Data collected in this project complement environmental agency monitoring efforts by filling in gaps in spatial and temporal coverage and water body types (Hadj-Hammou et al., 2017). More random examples from the citizen science databases can be found in Table 3.

6. Current trends and challenges in citizen science

Across the globe – and especially in Europe – citizen science is applied at different geographic scales, covering a vibrant and ever-expanding set of thematic domains. At the same time that we witness the emerging diversity of approaches, citizen science has also become increasingly recognized, and the interest in applying citizen science solutions continue to emerge from many different fields of science, society and government. This interest might go as far as assuming that citizen science could be the golden solution to resolve the challenges of post-normal science and post-truth politics. While this evolving landscape and acknowledgement leads to new opportunities of transferring knowledge between geographic regions and across stakeholders, it also challenges methods and tools to manage expectations, and to avoid reinventions, the duplication of funding, or potential miss-use due to over-excitement and missing guidance and capacities.

To meet these new challenges, there is an ongoing movement to establish a dense network of citizen science associations and partnerships. National coordination is paired with continental and even global structures. In addition to the above-mentioned examples at the national and European level, support is also provided by the Citizen Science Global Partnership[39].

Further, organisations such as the Global Biodiversity Information Facility (GBIF)[40] help coordinate the citizen science community in addressing biodiversity-related matters at the international level. Given that citizen science associations are established in Asia and Africa, too, this network of networks provides a solid ground for knowledge sharing and well-coordinated activities across the entire planet.

Regardless, it remains crucial to see how the regional and national networks, in particular, will respond to the diverse societal, economic and environmental needs, and how they will adopt citizen science in their respective cultural and governmental settings. Particular care will have to be taken in recognising the conditions under which a citizen science activity succeeded in one country (or even one city), and to understand which mechanisms can be applied elsewhere.

At present, discussions on what might qualify as 'citizen science' very much depend on parameters such as the nature of participatory culture, trust in governments and available funding. A significant challenge will be the re-use of shared knowledge and its adoption in a way that suits local contexts. The evolution of citizen science to fit (or possibly innovate) existing knowledge structures and markets will be very different depending on geographic location – in Japan, for example, compared to Ecuador or Sweden (or more regionally in Nairobi, Kenya). It remains to be seen how citizen science will grow and in what ways it will evolve in different parts of the world. In order to better understand these effects and support the future evolution of citizen science, it will be essential to advance the methods and tools to assess the impacts of citizen science on society (individuals and communities), science, governmental policy and the economy.

Regardless of local and regional diversities, the citizen science community has come a long way in achieving technical and semantic interoperability. Especially in the area of biodiversity research and geospatial information, good progress could be made in close collaborations with Biodiversity Information Standards (TDWG)[41] and the Open Geospatial Consortium (OGC)[42], respectively. Nevertheless, although guidance and recommendations become available, the exploitation of the material for different citizen science user groups remains to be improved. The same condition holds for useful, useable and used standards-based tools. Whereas this challenge might be more controlled within one thematic area (e.g., biodiversity), it becomes more challenging when cross-cutting topics – such as situations where the management and processing of geographic information – are considered.

Project name	**Goal / Task**
Narrative Atlas	Connect, Collaborate and Create Solutions for the SDGs
GLOBE Observer: Trees	Observe trees to understand changes in biomass and effects on the carbon cycle
GLOBE Observer: Land Cover	Photograph and classify land cover and share the data with NASA
The National Map Corps	Update and verify man-made structures data for the USGS
Raspberry Shake	Monitor Earth motion and seismic activity around the globe
Hush City	To empower people to identify and evaluate quiet areas in cities
Landslide Reporter	Build open global landslide data for science and decision-making
ISeeChange	Connecting communities to investigate weather and climate change
Stream Selfie	Map streams across the country and start testing the waters
City Nature Challenge	Document urban biodiversity

Tab. 3: Examples of projects from the "Geography" category on SciStarter.com
Source: authors' elaboration based on SciStarter.com data (as of November 30, 2019)

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[39] http://citizenscienceglobal.org/

[40] https://www.gbif.org/

[41] https://www.tdwg.org/

[42] https://www.opengeospatial.org/

This is primarily due to the diversity and potentially large extent of projects to which these standards could apply. We still lack an effective and efficient way to not only disseminate related information but also to support the community in the use of standards – which all too often require some highly specific skills and capacities, even to digest the essential requirements.

A further important area for improvement considers data management and processing – especially when it comes to private data. A milestone was reached on the 25th of May 2018, when the European Union's General Data Protection Regulation (GDPR)[43] came into force. As an essential part of a broader data protection framework, this globally recognized legal act protects and empowers all EU citizens' data privacy, and it also inspired similar discussions outside the EU. This still very recent regulation – with very few legal cases supporting its interpretation – also challenges the citizen science community because it requests clarity and security for treating information, which is indeed very often collected and processed as part of citizen science activities (Berti Suman and Pierce, 2018). Again, guidance and tools remain rare – or at least they are rarely distributed across citizen science projects.

Last but not least, the re-gained interest in Artificial Intelligence (AI) indicates both a future direction and challenge to citizen science. Paired with the unprecedented data collection of humans and machines, as well as the power of new technologies, the interest in AI has a revival in a social-technical setting that could be hardly predicted when AI was born in the 1970s. The potential blends of human cognitive capabilities with machine learning and reasoning – when sensibly combined – promise to be powerful in creating new insights and scientific knowledge. Citizens are likely to be involved in several of these emerging new scientific endeavours. Apart from overall ethical considerations, issues related to the internal workings of algorithms, the transparent use of personal data, and the possible implications of algorithmic biases are most challenging for future citizen science actions.

All of the positive implications coming from citizen science to recent research approaches, however, should be seen with limitations coming from the different natures of scientific disciplines. As examples, we could point to limited usage of citizen science in medical research, in research covering ethical issues, in environmental risk assessments, in genetically modified crops research, etc.

7. Conclusions

Citizen science has become an emerging topic among methodological approaches in many research fields. Despite the fact that the practice is very old, the term itself figures in methodological frames more frequently in recent decades. This could be more related to the opening of science, as mentioned by some authors (see e.g. Dörler and Heigl, 2019). Keeping in mind that open science represents also negative phenomena (such as predatory journals), we would consider it as an enabling factor to engage people for scientific activities.

Throughout the world the number of citizen science approaches is increasing – this has led to more coordination of the initiatives and several associations were founded. Under the framework of global partnership and networking, many research projects dealing with citizen science issues, whether researching citizen science as such, or using citizen science as a key tool to address a specific problem in various research projects.

Geography as a discipline, albeit with an old tradition, also deals with citizen science. We investigated the occurrence of citizen science in the articles covered by the largest scientific database – WOS. Aware of the limitations associated with the searching methods, our research showed that citizen science in Geography is not fully utilized. Its potential, however, is very high, as can be seen from the number of geographical projects using citizen science as a research approach (including flagship geographical projects such as OpenStreetMap).

Turning to the outputs from citizen science activities, we should also point to the great advantages of collected open data, not only for research but also for policy making, as well as education, etc. As an example, in an OpenStreetMap project, many cities produce their own maps (touristic maps, traffic maps, cycling maps, etc.) based on a freely available database of this spatial data source. Furthermore, data from observing nature (in many ways) can be utilized for biodiversity conservation, etc.

A number of issues related to citizen science have not been discussed in this article. We mentioned only briefly the limited usage of citizen science in some fields (e.g., medical research), but we also did not broadly discuss data quality issues and did not fully touch other aspects of citizen science like citizen motivations, the changing role of educational systems under the open science umbrella, etc. Our reflections in this paper, however, should point to an emerging topic, which needs further discussion with respect to its full adaptation in standard research approaches.

Acknowledgements

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Fig. 7: Meanders in a well-developed and functional river landscape of the Borovský Stream, near Havlíčkova Borová village, on the border of the transfer and accumulation zone (Photo: authors)

Fig. 8: Central part of the Košátecký Stream catchment (dried up here due to anthropogenic influence) in a site with heavily degraded river landscape where restoration of the riverbed and riparian habitats was realized in winter 2011/2012 (Photo: authors)

Illustrations related to the paper by J. Jakubínský et al.

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