Land Use Policy 100 (2021) 104937

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

A historical curiosity or a source of accurate spatial information on historical land use? The issue of accuracy of old cadastres in the example of Josephian Cadastre from the Habsburg Empire

Jindřich Frajer*, David Fiedor

Department of Geography, Palacký University Olomouc, Czech Republic

ARTICLE INFO

Keywords:
cadastral survey
historical landscape
historical GIS
Josephian Cadastre
Habsburg Empire

ABSTRACT

Scientific interest across the fields of historical landscape research and historical land use has grown in connection with the dynamic changes in the current landscape. Various historical sources are used for gathering information on historical land use and its reconstruction. These sources are then the subject matter of the research with respect not only to their contents but also to the quality and accuracy of the information presented. Our contribution deals with the issue of accuracy of old cadastres on the example of Josephian Cadastre which dates back to the Habsburg Empire at the end of the 18th century and which was made with the participation of laypeople (peasants) and with minimal technical equipment. We compared the results of field surveys from the Josephian Cadastre with the more recent Stabile Cadastre and using the GIS and methods of descriptive and inference statistics we evaluated the influence of individual factors on accuracy. The resulted average deviation of individual plots in Josephian Cadastre was 14.8% and depended mainly on the land use and slope of the plot. According to the results, we consider that data from this type of source could thus enrich the current known databases by data on long-term land use.

1. Introduction

Scientific interest across the fields of historical landscape research and its use has grown since the 1950s in connection with the significant dynamic changes in the current cultural landscape (Antrop, 2000, 2004) alongside the development of research methods. Substantial impact on the change in landscape character and its human use is caused by such phenomena as urbanization, industrialization, traffic system expansion, intensive agriculture as well as abandonment of farmland (Agnoletti, 2014; Antrop, 2004; Bastian et al., 2006). It is the changes in the use of landscape that are a key element and driver in the ongoing global environmental change (Gragson and Bolstad, 2006). Thus the study of changes in land use and land cover (LULC) may present underlying topics of both historical works emphasizing human interaction with the environment in the environmental history (Whyte, 1997) and scientific works focusing on the changes in the ecological parameters of landscape (Olah et al., 2009; Vellend et al., 2013). Interdisciplinary encounters of historical and natural sciences which complement each other with methods and data resources occur in the field of this research theme. This concerns the acquisition of terminology and quantitative methods of natural sciences in the case of environmental historians (Worster and Crosby, 1989) including geographic information systems (GIS) (Kingston, 2010; Knowles, 2008); in the case of natural sciences, this mainly concerns the use of a wide spectrum of historical sources which served the purposes of historians and archivists in the past and now enter purely scientific fields (e.g., Brázdil et al., 2005; Pecci, 2001; Trimble, 2008).

A popular information source within the historical LULC research is mostly historical topographic maps in various scales (Bender et al., 2005; Fuchs et al., 2015; Skaloš et al., 2012). These cartographic sources combined with modern GIS technologies seemingly left the shadow of archives and became important sources of historical spatial information (Balletti, 2006) which is easy to interpret and access due to growing archive digitization (Hartleib and Bobertz, 2017). In addition to old maps, there are many other sources for historical land use research (Yang et al., 2014). These include various official statistics and reports (Bičík et al., 2015), public surveys (Schulte and Mladenoff, 2001), and historical cadastres along with their written records of land ownership (Troll and Ostafin, 2016; Zaragozí et al., 2019) and taxation (Wei et al., 2015). The use of historical sources has thus become common part of "mainstream research" in the research of landscape changes (Vellend et al., 2013). However, it is essential, together with

* Corresponding author at: 17. listopadu 12, 7746 Olomouc, Czech Republic.
E-mail address: jindrich.frajer@upol.cz (J. Frajer).

https://doi.org/10.1016/j.landusepol.2020.104937
Received 26 November 2019; Received in revised form 7 April 2020; Accepted 17 July 2020

the information on the historical landscape provided by these sources, to critically view their accuracy, informativeness, and limits, and uncertainties introduced in their current processing and interpretations (Dahlström, 2008; Vuorela et al., 2002; Raška et al., 2014).

Leyk et al. (2005) used old maps to present three sources of uncertainty that could be demonstrated in the results of analyses of the historical change research LULC which necessitate consideration. First, it concerns the accuracy of historical maps themselves which were often elaborated on without the knowledge of geodesy and absent any united procedure (Balletti, 2006). A certain distortion also occurs during the processing of such resources (e.g., in GIS) (Baiocchi et al., 2013; Claeys Boùùaert et al., 2016; Pindozzi et al., 2016). The last point is the issue of combining current and historical data where an understanding and the significance of historical land use might not comply with current practices (Bender et al., 2005). Uncertainties and inaccuracies may then affect the results and interpretations of quantitative analyses of land use change that are often presented with a high degree of accuracy (Bender et al., 2005; Kopp et al., 2015; Skaloš and Emgstová, 2010). Similar issues are encountered when working with historical written sources whose unique historical landscape data might be more challenging to localize in space (Zaragozí et al., 2019). Therefore, it is necessary to cope with their information selectivity as well as the issues connected with their correct interpretation and processing (Woitschová, 2017). Working with this type of data, it is often necessary to know the historical context, language of the era, and paleography (Trpáková, 2009).

Our research focuses on the issue of accuracy of a written historical source which bears the information of historical land use—namely the Josephian Cadastre of the Habsburg Monarchy (particularly its part of the Bohemian Kingdom) at the end of the 18th century. Beside the more regional Milanese Cadastre (1718-1723) (Lisec and Navrátil, 2014), the Josephian cadastre can be considered as the first modern cadastre in the territory of the Habsburg Monarchy and can be seen as a unique record of the historical landscape. This potential in the study of landscape changes in historical perspectives has been presented in several studies (Láznička, 1959; Troll and Ostafin, 2016; Frajer, 2019).

2. Background of the Josephian Cadastre

The Josephian Cadastre, which emerged based on the imperial decree from April 1785, was the fifth cadastre established in the Bohemian Kingdom. It introduced a number of innovations in comparison to its predecessors including the First Land Registry (1654), the Second Land Registry (1684), the Theresian Cadastre (1748), and The Fourth Land Registry (1757) (Bičík et al., 2015) so that tax collections could be simplified and made more efficient. Emperor Joseph II ordered its realization following in the footsteps of his mother, Marie Therese, in her earlier attempts at tax collections. She was the first to tax not only peasants but also the nobles' land—it was declared in special declarations called Exaequatorium Domonicale that is outside the cadastre with a lower tax. The Josephian Cadastre unified the disproportion. All used land was taxed regardless of its owner. The new basic taxation unit was set to be the "Cadastral Municipality" and replaced the "manor." This created new tax administrative units which were not subject to nobility (Godsey, 2014), therefore avoiding the former hassle of deliberately undervaluing the plot area. The Josephian Cadastre gauged 60% more taxable land than the previous Theresian Cadastre (Roubík, 1954).

The cadastral areas were divided into several smaller areas (so-called topographical units) within the exactly demarcated borders of the cadastral municipalities, where the surveying of individual plots divided into basic categories according to their use took place for the first time in cadastral practice. Only infertile land without agricultural use were not evaluated, which was the forfeit for the speed at which the cadastral survey and gauging had occurred. Each survey was to be accomplished in the presence of an elected municipality committee in order to prevent a deliberate omission or underestimation while surveying the plot. Any attempts at fraud were fined and the proceeds of the fine were paid to the person who announced the discrepancy (Roubík, 1954). Joseph II put pressure on the hasty completion of the cadastre which also led to local farmers performing the gauging themselves although they had not been adequately taught to perform it. Engineers and professional surveyors were scarce and were only called to survey complex lands (i.e., water bodies, forests) in difficult or indented terrain (Pecka, 1985). Later, engineers were often employed by nobility who could pay them for their work.

Table 1
Areal units of the Josephian Cadastre.

Areal units *Josephian Cadastre*	*Current unit*
1 Austrian morgen (joch)	5754,64 m^2
1 Square fathom	3,5967 m^2
1 Square feet	0,0999 m^2

Source: Rameš (2005).

Technically, the surveys of individual plots were carried out with the participation of seven persons including an official, who recorded the results of surveys in the so-called Fasí book. The measuring tools were very simple and included officially approved and checked measuring rods and pegs together with measuring rope of the length of 10 Viennese fathoms (18.96 m) with special loops at each end which could hold the rods used to stretch the rope (Bumba, 2007). The basic areal unit was the Lower Austrian morgen (joch), which was further divided into square fathoms and square feet (Table 1). While the entire process was described in detail in the instructions elaborated in advanced, mistakes occurred during the gauging which resulted from inexperience and the use of new areal measuring units unknown to most of the inhabitants (the unit used in Bohemia at that time was called the korec, which was a complicated combined unit of area and volume). Land surveys also introduced the necessity to simplify the course of its borders and subsequent division of its area to regular geometrical shapes which facilitated the area calculations. Lay inhabitants had never encountered it before. Despite some partial issues, the Josephian Cadastre was completed in 1789, although it only remained valid until 1792 when Emperor Leopold I abolished its use under the pressure of disgruntled nobility (Roubík, 1954).

Despite its short existence, the Josephian Cadastre introduced novel elements to cadastral surveying. Most of all, it was a system of accurately demarcated cadastral municipalities which form the base of current cadastres of the countries of the original Habsburg Monarchy (Lisec and Navrátil, 2014). It accomplished the first surveys of all plots and their classification into finer categories according to their use, with the exception of uncultivated land. Unfortunately, the planned elaboration of detailed cadastral maps did not occur as the sketches from field surveys were unfit to create detailed cadastral maps (Boguszak and Císař, 1961). Thus scientists in the former Habsburg Monarchy countries mostly used the well-known Stabile (or Franciscan) Cadastre created between 1817–1860 following the Milan model which contains the list of plots as well as an extended map set in a detailed scale (Petek and Urbanc, 2004; Trpáková, 2009). It was elaborated based on modern geodetic surveys using schooled surveyors who accomplished it based on a dense trigonometric network (Lisec and Navrátil, 2014). The plot numbering of the Stabile Cadastre was completely new and the legacy of the Josephian Cadastre was reflected in the equal taxation and the cadastral municipality system.

3. Accuracy of Josephian Cadastre and aims of the study

One of the most important questions when using the Josephian Cadastre records is its accuracy and credibility, which may be distorted by the current view of the relatively primitive methodology of its cadastral survey, age, and the extensive participation of laypeople. While the current study proves that the data collected by experts and laypeople might not differ significantly (See et al., 2013), the differences in the 18th century were striking. Peasants participating in cadastral surveying may have lacked the necessary skills (e.g., reading and writing) used in surveying, which could have limited the effectiveness of the results. Low literacy rate among peasants were directly linked to their social status (Houston, 2014). The compulsory six-year school attendance was introduced in the Habsburg Monarchy in 1775 meaning that the lowest level of school only taught reading, writing, and the basics of arithmetic, while geometry (essential in surveying) was only taught on higher school levels (Bělina et al., 2001). The new areal units unknown to the inhabitants also presented complications (Roubík, 1954).

The issue of the accuracy of the data in the Josephian Cadastre was studied by Troll and Ostafin (2016) in their study of forest cover change in the Polish Carpathians; by Honc (1981) in an older work which studied the cadastral data from summaries for manor estates in Bohemia; and by Styś (1932), who studied Polish villages. All authors compared the results of the Josephian Cadastre with the Stabile Cadastre. However, the above-mentioned studies focused on the evaluation of the accuracy of aerial surveys in entire cadastral municipalities, not in the scale of individual plots. The aim of our study is to focus on the accuracy of survey in individual plots in the case study from central Bohemia (Czech Republic). The reference material used is also the data of the Stabile Cadastre which is considered sufficiently accurate in its surveys (Hendrych et al., 2013; Krčmářová and Jeleček, 2017; Pavelková et al., 2016). We follow several assumptions:

(1) the area of identical plots differs between the Josephian and the Stabile Cadastres due to the used method and the participation of laypeople;
(2) the land surveyed in the Josephian Cadastre by surveyors show smaller deviations in the survey;
(3) and the extent of the deviation is influenced by factors which might have hindered the field surveys—whether be it the complicated outline of the plot, the inclination of the plot, the use of the plot, or its area.

4. Data and Methods

Regarding the absence of maps for the Josephian Cadastre and the new number system of plots in the Stabile Cadastre, it was necessary to find a connecting element between both cadastres. It was accomplished in the area of interest through a set of regional maps of estates (or maps of manor) of the Žleby-Tupadly manor which belonged to the Auersperg family from the turn of the 18th and through the 19th century. Not only do these maps reflect the spatial layout of the plots at the start of the 19th century (i.e., approximately 15 years after the Josephian Cadastre was established) but also state the old numbers at each plot according to the numbers of the Josephian Cadastre. The maps were acquired and then scanned or photographed in detail at the State Regional Archives in Zámrsk. It was a set of 14 maps for individual mansions (Fig. 1). Most maps were probably created around 1817 in the scale of approximately 1:1510 by the engineer Johann Baptista Ziedler. The author of the map of the Žáky mansion from 1823 in the scale of 1:2200 is unknown. Unfortunately, more detailed data of these maps are unknown. Apart from the map of the Žáky mansion, the other maps do not show all the plots surrounding specific manors but only those belonging to the nobility or those rented out by the nobility. Thus, they create an interesting mosaic of connecting plots and loosely set enclaves of plots in an unmapped space (Fig. 2).

The plot data of the Josephian Cadastre were adopted from the original Fasí book of the Josephian Cadastre from 1789. The books were photographed at the National Archive in Prague and subsequently transliterated from the late medieval cursive font Kurrent (or German cursive).

The last source of the basic data was the maps of the Stabile Cadastre (in the scale of 1:2880), which were created for the area of interest in 1838. Their digital copies were acquired from the State Administration of Land Surveying and Cadastre (ČÚZK). The map sheets for individual municipalities were joined and geo-referenced in the ArcMap 10.6 software using the method of identical points and 1 st order polynomial transformation (affine) which is commonly used for such purposes (Dolejš and Forejt, 2019; Pereponova and Skaloš, 2019).

The plots from the Stabile Cadastre, which visually corresponded with the position and shape of the plots in the maps of the manor, were selected in the first stage. Subsequently, the course of plot boundaries in both map sources was checked in detail, and those plots for which it was impossible to prove that the shape and course of boundaries had not changed were excluded (Fig. 2). Those plots, which formed one area on the maps of the manor—within the Stabile Cadastre this area could be divided into more plots albeit within the same boundaries—were also kept. Additionally, this also included plots whose change in border could be unequivocally identified and reconstructed in the Stabile Cadastre.

A database was created from the selected sample of plots (n = 137) which was completed by the following attributes (Table 2). Firstly, the plot data stated in the Josephian Cadastre, such as the area, the participation of surveyors, aggregated categories of land use, may have influenced the manner and complexity of the surveys. The area of a plot in the maps of the Stabile Cadastre, the slope of the plot derived from the digital elevation model, and the quantitative indicators for the shape of the plot using simple contours of shapes were calculated in the environment of the GIS (Peura and Iivarinen, 1997), which are used as standards in Landscape Metrics (MacLean and Congalton, 2013). The Minimum Bounding Geometry tool in ArcGIS (ESRI, 2018) was used to calculate the area of circumscribed geometric objects for individual plots.

A comparison of the area of plots surveyed within the Josephian Cadastre and the Stabile Cadastre was impossible to be accomplished by absolute survey difference with respect to the various plot areas. Therefore, the deviation of survey (dm) was defined, which expresses the ratio of the absolute difference in the area of the plot according to the Josephian (Jc) and Stabile (Sc) Cadastres on the area stated by the Josephian Cadastre:

$$d_m = \frac{|Jc - Sc|}{Jc}$$

Mainly classical methods of descriptive and inference statistics were used in the processing of the obtained data. Specifically, the statistical hypotheses testing was used where the non-parametric methods was used with respect to the condition of data normality not being the Kruskal-Wallis test (hereinafter the K-W test). Correlation analysis was used to capture the met. The following were used: the Wilcoxon test; the Mann-Whitney two-sample test; and in the case of testing the hypothesis of compliance of more than two mean values, the relationship between the Josephian and Stabile Cadastre surveys and other characteristics (surveyor presence, terrain slope, border complexity, etc.). Multivariate regression analysis was applied in the explanation of the deviation variability. Some variables were transformed with respect to breaching the assumption of normality using classic transformations (i.e., using the extraction of a given variable and its logarithmization).

5. Results

The selected set comprised of 137 plots in total, which could be unambiguously identified and whose borders had remained unchanged since the introduction of the Josephian Cadastre after the creation of the Stabile Cadastre maps. The key issue and entry assumption for the purposes of further analyses was testing the hypothesis of mean value (median) compliance of the plot surveys of the Josephian and Stabile

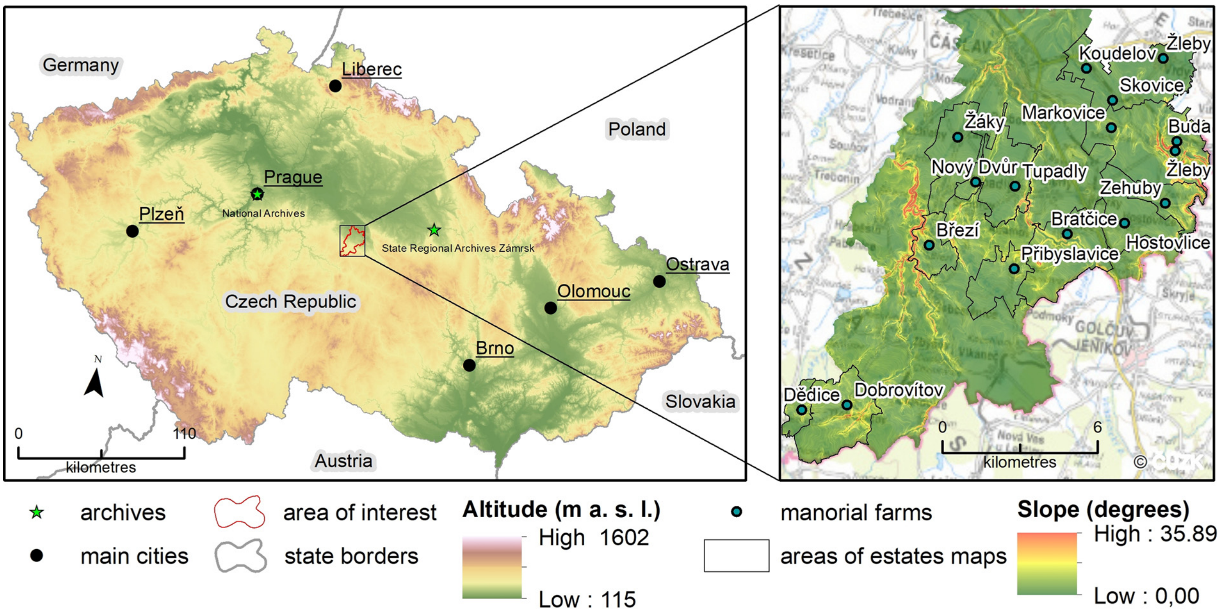

Fig. 1. Map of the area of interest in the geographical context of the Czech Republic (data sources: © State Administration of Land Surveying and Cadastre - ČÚZK; own processing).

Cadastres in the selected set of plots. This hypothesis was rejected at the significance level α = 0.05 by the paired Wilcoxon test (p = 0.00). The surveyed area of identical plots thus showed a significant statistical difference between the cadastres. This assumption allowed us to focus on other results including the deviations of plots with respect to their areas, the presence of a surveyor, and land use. Additionally, we created a model as part of the variability of the dependent variable (i.e., the deviation of survey).

5.1. Plot areas and their deviations

Most studied plots were not surveyed in the Josephian Cadastre by a surveyor (108), and as for the land use, the most frequent were the plots with arable land (85). These were the largest ones (88 thousand m^2 on average) although they have the highest absolute variability—see Table 3. The area of plots surveyed by surveyors shows altogether a smaller deviation (14.4%) than the plots surveyed by laypeople (14.9%). However, at a significance level of α = 0.05, the median deviation of the surveyed plots does not differ significantly from the median value of the plots surveyed by laypeople (Mann-Whitney U test; p-value = 0.28).

Comparing the plots in different categories of land use, the relatively least different are the areas with arable land (deviation of 9.7%), as opposed to the water bodies (28.5%) (Fig. 3). The K-W test was used to test the hypothesis of equality of median deviations of plots categorized according to land use. The null hypothesis was rejected and a statistically significant difference between variations of arable land and water bodies was found at the significance level α = 0.05 (p-value = 0.00). However, these were the ones most commonly surveyed by surveyors (Table 4).

As the individual categories of land use are clearly represented unevenly in the sample, we limit their focus on plots with arable land which clearly occur most in the sample (more than 62%). In case we only focus on comparing the deviations of plots with arable land surveyed by surveyors and those which had not been surveyed, we discover that there already exists a statistically significant difference on the level of significance α = 0.05 (Mann-Whitney U test; p-value = 0.01).

5.2. Correlation and regression analysis of survey deviations

The first step required the inclusion of several variables whose relation to the deviation of the plot survey according to the Josephian and Stabile Cadastre was investigated in the manner defined in the methods. Thus with respect to the theoretical part, the variables which represented four different phenomena were selected: the area of a plot (according to the Josephian Cadastre), the presence of a surveyor (a dichotomous variable), the plot slope (minimum, maximum, average, and variation coefficient), and the complexity of its outline (Para, Shape, Frac, Ampl, Conv).

The deviation between the plot survey in the Josephian and Stabile Cadastres is mostly linked (according to Spearman´s sequence correlation coefficient – see Table 5) with the plot survey in the Josephian Cadastre (-0.42). The larger the plot, the smaller the deviation. The relationship with the dichotomous variable surveyor was also characterized by indirect dependence (-0.27), which means that plots surveyed by surveyors show lower deviations. This finding is in accord with the previously presented result of hypothesis testing. Other variables significant on the level α = 0.05 were para (0.41), mean (0.29), and min (0.28), while all other variables were directly dependent (i.e., the higher the complexity [Para] or the slope [both mean and minimal], the higher the deviation of survey).

As the distribution of frequency of nearly all the studied variables is not normal, they were transformed so that the multi-dimensional regression analysis could be applied to explain the variability of survey deviation between the Josephian and Stabile Cadastres. The regression model was not further entered by the variables with strong intercorrelation as the resultant regression model would be highly compromised.

The resultant regression model explains the 29% variability of the dependent variable (deviation) and is as follows (the results are also shown in Table 6):

$$\sqrt{deviation} = 3.517 - 0.159 \times \sqrt{area} - 0.383 \times surveyor + 0.083 \times \ln ampl + 0.092 \times \ln slope_{min} + 0.005 \times slope_{varkoef}$$

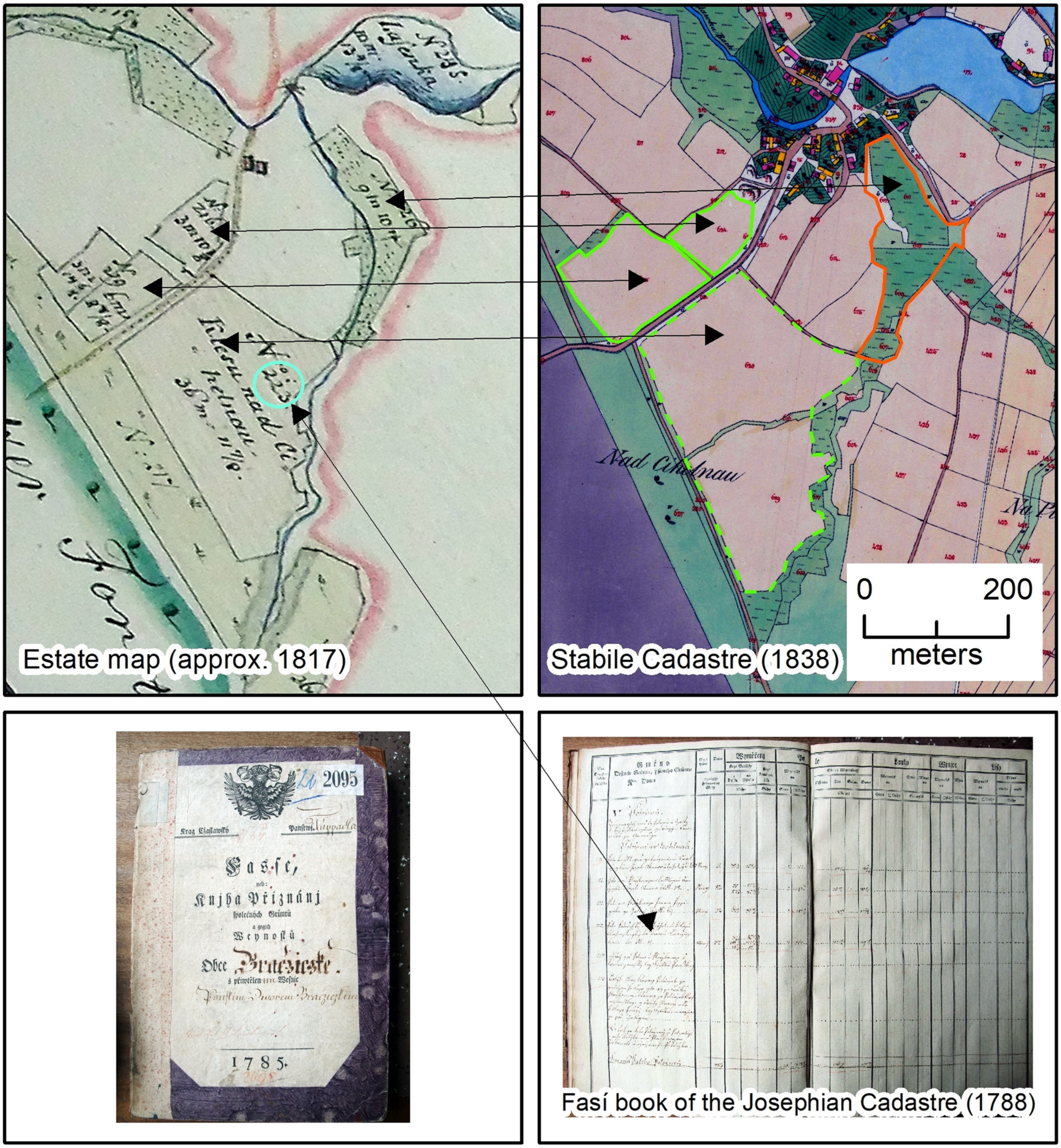

Fig. 2. Identification and selection of the plots from the estates and cadastral maps. Green line – direct identification (same plot), Green dashed line – original plot was divided into more plots within the original border, Red line – original plot was divided into more plots with changed borders. Pale green circle – identification of the cadastral plot in the Book of Fasí (Josephian Cadastre). (map sources: National Archives in Prague; State Regional Archives in Zámrsk; © ČÚZK; photo by authors).

6. Discussion

The results following from the assumptions established at the beginning of the research confirmed that difference in the area of identical plots in the Stabile Cadastre and Josef Cadastre is statistically significant. However, the total set of plots did not show statistical significance of participation of surveyors in the accuracy of their surveys. The area of the plots surveyed in Josephian Cadastre and Stabile Cadastre differed by 14.8% on average. This figure is higher in comparison with the results of previous studies—Troll and Ostafin (2016) state the deviation of 7%, Honc (1981) 13%, and Styś (1932) 8–12%. However, the mentioned studies worked with statistics from all cadastral or manorial units, and not individual plots. The results could then be influenced by the presence of unsurveyed plots within the Josephian Cadastre or the changes in borders of cadastral municipalities, which frequently occurred between individual cadastral surveys (Bičík et al., 2015; Frajer, 2019). Such circumstances might have smoothed out the deviations of the real surveys of individual plots. The following discussion chapters focus on those detailed factors which might have influenced the survey results of individual plots within the Josephian Cadastre as well as the methodological limitations of our study.

6.1. Insight of the results

A detailed analysis of the factors that may have contributed to the magnitude of the survey deviation showed that the most accurate

Table 2
Monitored attributes of the selected sample of plots.

attribut	source	record	note
Area in Josephian cadastre	Fasí books (1788-89)	square metres	unit conversion from Lower Austrian morgens and square fathoms
Land use category	Fasí books (1788-89)		
• *Arable land*			
• *Grassland (pastures, meadows)*			
• *Water areas (fishponds)*			
• *Other (forest, shrubs, fruit gardens)*			
Participation of surveyor	Fasí books (1788-89)	Yes/No	
Area in Stabile Cadastre	Imperial imprints of Stabile cadastre (1:2800)	square metres	measured in GIS
Slope	Digital elevation model (State Administration of Land Surveying and Cadastre)	degrees	Calculated in GIS; Basic interval of contours = 1 m, calculation grid = 5 x 5 m
• *minimum*		*degrees*	
• *maximum*		*degrees*	
• *mean*		*degrees*	
• *coeficient of variation*		*value*	
Shape of land parcels	Imperial imprints of Stabile cadastre (1:2800)	value	Calculated in GIS
• *Perimetr to area ratio (Para)*	$Para = \frac{p}{a}$		*(p) perimeter* *(a) parcel area*
• *Shape index (Shape)*	$Shape = \frac{p}{2\sqrt{\pi a}}$		*(p) perimeter* *(a) parcel area*
• *Fractal dimension (Frac)*	$Frac = \frac{2\ ln\ p}{ln\ a}$		*(p) perimeter* *(a) parcel area*
• *Convexity (Conv)*	$Conv = \frac{a_c - a}{a_c}$		*(a_c) area of the convex hull* *(a) parcel area*
• *Amplitude (Ampl)*	$Ampl = \frac{p - p_c}{p}$		*(p_c) perimeter of the convex hull* *(p) perimeter*

Source: Shape of land parcels - Demetriou et al. (2013); Brinkhoff et al. (1995).

surveys were accomplished in arable land and, on the other hand, the largest deviations were for water, which significantly distorted the overall results. Surveying the water bodies was a complicated process. Firstly, the irregular shape of the plot had to be simplified to a number of smaller geometrical shapes which were then surveyed (Fig. 4b). Furthermore, Roubík (1954) determined that many officials had difficulties calculating the new areal units using multiplications. Thus, the extent of the deviation may be given by the complexity of the survey as well as by details unknown to us of the cadastral survey itself.

The question arises whether the surveyors surveyed the area of the current shoreline or included littoral areas in the plot. Moreover, Darby (1986) states that the interpretations of instructions might have differed for different surveys by different surveying boards. The issue of the internal heterogeneity of similar historical surveys is also mentioned by Schulte and Mladenoff (2001). A similar situation arises in plots with woody vegetation (shrubs) where the deviation reached 22.6% on average. There could have occurred a problem with delimiting the plot itself (shrubs/meadow transitions) apart from technical problems related to visibility and movements of the surveyors. A larger sample of plots would be needed to carry out more in-depth analyses of the surveys of water bodies, shrubs, and forests. Surveying forests, especially in mountainous areas, presents a serious technical challenge. The surveyors who worked on the more current Stabile Cadastre encountered such a challenge (Petek and Urbanc, 2004).

If we only concentrate on arable land which was represented most widely in the studied set considering the general corn-growing focus of manorial farms in the 18th century (Semotanová, 1998), then the results show that surveyors were clearly more accurate in their surveys than the laypeople. However, both groups showed more inaccuracies in surveying sloped plots. Thus, it can be observed that the steeper the slope, the larger the deviation in the survey. This fact could be due to the more complex manner of surveying a plot—whose size was to be projected in a plane according to the instructions (Fig. 4a), which might have caused problems to many participants. The movement on sloped plots was also more difficult with the surveying tools.

A direct connection between the shape (complexity) of the plot and the deviation in the survey has not been proven, although it must be considered in the regression model. Here we encounter a more general issue of quantitative representation of the outline of a plot which shows a number of weaknesses (Demetriou et al., 2013). It was apparent with the indexes which dealt with the area of a plot. The PA index showed a strong negative correlation with the area of a plot and, as such, was absolutely unsuitable for assessing the deviation. In our analyses, the Ampl index proved to be of the best value, reflecting the complexity of the outline of a plot (Fig. 5). An alternative could be the new methods of surveying the shape and complexity of plots (Demetriou et al., 2013;

Table 3
Basic characteristics of plots according to the individual land use categories.

Plots	N	Area in Josephian Cadastre (m^2)					Deviation (%)				
		Mean	Median	Lower quartile	Upper quartile	Std.Dev.	Mean	Median	Q1	Q3	Std.Dev.
by surveyors	29	79 602	37 801	22 936	104 742	85 782	14.4	6.1	1.4	19.5	20.1
by laypeople	108	60 506	16 528	7 515	49 596	112 703	14.9	7.8	3.9	18.6	18.4
Arable land	85	88 390	37 010	13 077	104 742	126 391	9.7	6.0	1.7	12.7	11.7
Grassland (pastures, meadows)	20	35 573	18 694	10 254	29 066	59 120	20.0	10.8	4.9	28.2	21.1
Water areas (fishponds)	13	31 296	12 502	3 723	32 543	49 410	28.5	22.0	18.0	38.6	20.9
Other (forest, shrubs, fruit gardens)	19	11 136	8 812	3 420	13 121	11 166	22.6	10.9	5.2	25.6	29.7
Total	**137**	**64 548**	**21 202**	**8 398**	**60 830**	**107 563**	**14.8**	**7.8**	**2.9**	**19.0**	**18.7**

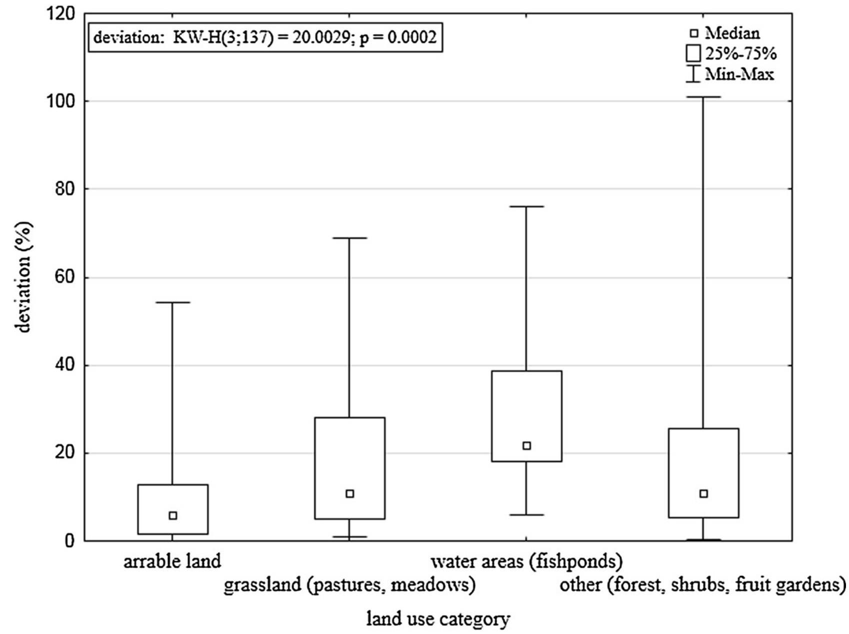

Fig. 3. Box plot expressing the deviation of individual land use categories in the Josephian Cadastre.

Table 4
Types of plots in the Josephian Cadastre according to the method of assessment.

Plots	Arrable land	Grassland (pastures, meadows)	Water areas (fishponds)	Other (forest, shrubs, fruit gardens)	Row
by laypeople	68	16	7	17	108
Column Percent	80.0	80.0	53.8	89.5	
by surveyors	17	4	6	2	29
Column Percent	20.0	20.0	46.2	10.5	
Count	85	20	13	19	137

Table 5
Spearman rank order correlation coeficients among selected attributes of plots. (For interpretation of the references to colour in this Table legend, the reader is referred to the web version of this article)

		Spearman's rho	1	2	3	4	5	6	7	8	9	10	11	12
1	Deviation		1.00	-0.42	-0.27	0.28	0.17	0.29	-0.09	0.41	0.14	0.16	-0.10	0.06
2	Area in Josephian Cadastre		-0.42	1.00	0.25	-0.61	-0.16	-0.45	0.33	-0.97	-0.06	-0.14	0.47	0.14
3	Surveyors		-0.27	0.25	1.00	-0.06	-0.03	-0.05	-0.04	-0.26	-0.10	-0.11	0.16	-0.03
4	Slope	min	0.28	-0.61	-0.06	1.00	0.46	0.71	-0.44	0.56	-0.05	0.01	-0.32	-0.09
5	Slope	max	0.17	-0.16	-0.03	0.46	1.00	0.89	0.38	0.16	-0.04	-0.03	0.05	0.07
6	Slope	mean	0.29	-0.45	-0.05	0.71	0.89	1.00	0.04	0.43	-0.03	0.01	-0.09	0.03
7	Slope	coeficient of variation	-0.09	0.33	-0.04	-0.44	0.38	0.04	1.00	-0.26	0.14	0.11	0.18	0.09
8	Shape of land parcels	para	0.41	-0.97	-0.26	0.56	0.16	0.43	-0.26	1.00	0.26	0.34	-0.38	0.00
9	Shape of land parcels	shape	0.14	-0.06	-0.10	-0.05	-0.04	-0.03	0.14	0.26	1.00	0.99	0.34	0.66
10	Shape of land parcels	frac	0.16	-0.14	-0.11	0.01	-0.03	0.01	0.11	0.34	0.99	1.00	0.30	0.64
11	Shape of land parcels	ampl	-0.10	0.47	0.16	-0.32	0.05	-0.09	0.18	-0.38	0.34	0.30	1.00	0.76
12	Shape of land parcels	conv	0.06	0.14	-0.03	-0.09	0.07	0.03	0.09	0.00	0.66	0.64	0.76	1.00

Note: Red color values means that these relations are statistically significant at the significance level of 0.05.

Kwinta and Gniadek, 2017), which, however, are considerably more complicated (cannot be simply calculated in GIS) and operated with parameters (e.g., number of vertex points) that cannot be applied with respect to the initial historical map sources as their original value is often unclear (the number of original boundary points differs from the number of clicks in GIS). However, the influence of the shape of the plot on its actual delimitation in historical cadastres has been proven by Forejt et al. (2018) and needs further attention.

6.2. *Limitations of the study*

As for interpreting the results, it is necessary to point out the limits given by the work itself with historical sources. Thus, in the sense of Leyk et al. (2005), we encountered the accuracy of the selected regional maps of estates and their selective plots or a possible generalization of their borders. A certain distortion might also have occurred while processing the maps of the Stabile Cadastre in GIS. In addition to the questionable surveys of water bodies, there is also the question of whether field paths or groves were considered part of the field in Josephian Cadastre, or whether they seemed useless and were not included in the cadastral survey. As stated by Darby (1986), it is a certain “gap” which can never be filled. This also relates to the question of how the learning effect and practice could be demonstrated with each new surveyed plot. Namely, the plots could be surveyed in any order

Table 6
Multivariate regression model for variable measurement deviation. (For interpretation of the references to colour in this Table legend, the reader is referred to the web version of this article)

N=69	R= 0.58558462 R^2= 0.34290935 Adjusted R^2= 0.29075929 F(5,63)=6.5754 p<.00006 Std.Error of estimate: 0.45940					
	b*	Std.Err.	b	Std.Err.	t(63)	p-value
Intercept			3.52	0.56	6.28	0.00
Sqrt of area in Josephian Cadastre	-0.42	0.14	-0.16	0.05	-3.12	0.00
Surveyors	-0.28	0.11	-0.38	0.15	-2.60	0.01
ln ampl	0.23	0.11	0.08	0.04	2.02	0.05
ln slope_min	0.21	0.14	0.09	0.06	1.48	0.14
slope_coeficient of variation	0.13	0.11	0.00	0.00	1.11	0.27

Note: In the end, only 69 plots entered the regression analysis, as 16 were discarded due to the missing ln ampl value. These are cases in which the ampl value has reached the value of zero (perimeter of convex was equal to perimeter) and the natural logarithm of zero is not defined. Red color values means that these relations are statistically significant at the significance level of 0.05.

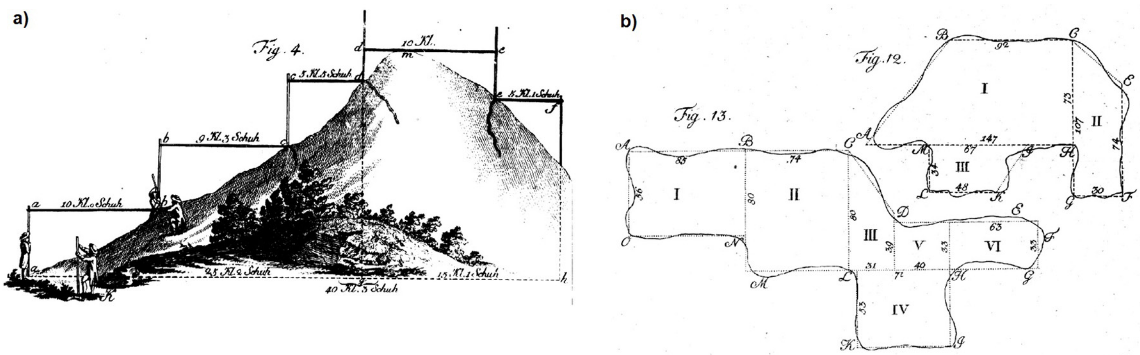

Fig. 4. Drawings from the original instructions of the Josephian Cadaster. Left –measuring distances in the hilly landscape, Right – simplification of the plot borders (Source: Talich ed. 2005 - Research Institute of Geodesy, Topography and Cartography, v.v.i.)

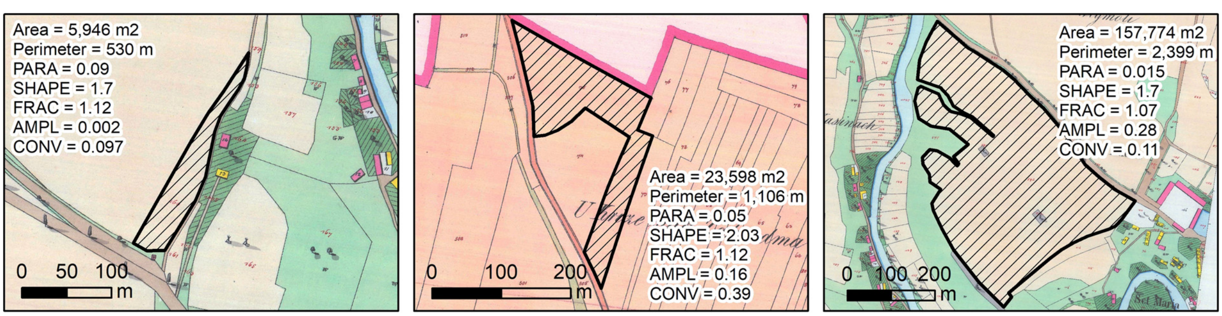

Fig. 5. Measuring complexity of the plots (data sources: © ČÚZK; own processing).

regardless of the order which they were listed in the Fasí books. This could be significant especially in the case of laypeople who had an opportunity to improve their skills during the survey as is evidenced in current studies dealing with the quality of crowdsourced data (See et al., 2013).

In order to answer more detailed questions about the accuracy of the Josephian Cadastre survey, it would be necessary to compare it with other case studies from areas with different physical-geographical conditions (mainly land use or slope). However, the realization of such research to the level of individual plots encounters the crucial question of finding the connecting elements between old and modern cadastres. In our case, these were the maps of estates which has survived in various archives selectively and their comprehensive summary and processing still wait to be completed (Tůmová, 2018).

It cannot be determined whether the determined deviation is small or large as the specific purpose always matters that the historical data are further used for. The situation can be compared with using the maps of the 1 st Military Survey created in the Habsburg Monarchy in the second half of the 18th century, also under the rule of Joseph II. These maps of medium scales were created in the absence of adequate cartographic procedures using military officers. They show poor geometry and we do not know their coordinate system among other necessary details (Podobnikar, 2009). In comparison to current maps, they show positional errors in the order of hundreds of meters (Frajer and Geletič, 2011). However, the quantitatively aimed studies devoted to the research of historical landscape and its use apply this source widely (see Petrovszki and Mészáros, 2010; Skaloš et al., 2011; Šantrůčková et al., 2017) as a source of valuable information on 18th century landscape (Podobnikar, 2009). From this point of view, the Josephian Cadastre can be considered not only as a source of unique information about the historical landscape but also of spatially accurate information.

7. Conclusion

The presented results suggest that the Josephian Cadastre from the 18th century, which was created in a trivial manner from today´s perspective, displays a relatively high accuracy in the survey. This is all the more surprising regarding the large number of laypeople who participated in the surveys. Applying statistical and GIS methods, we ascertained that the deviation in accuracy in surveying the individual plots is variable and closely related to the type of plots (fields, shrubs, water bodies) and its slope. However, we still register ambiguities regarding the real manners of surveying and delimitation of plots in the fields, which might help clarify some deviations. Here we follow from the conclusions of Kataoka (2013) and Prince (1959) that the accuracy of old cadastres or surveys may be surprising, although the understanding of the contemporary thinking and practices of the creators of the cadastre directly in the field may be complicated to interpret. Despite all these complications, it turns out that historical written sources like old cadastres can provide us with accurate spatial information on historical land use.

Funding acquisition

This work was supported by the internal grant of the Palacký University Olomouc no. IGA_PrF_2020_029, “Spatial analysis of selected environmental and social issues in urban and suburban areas”.

CRediT authorship contribution statement

Jindřich Frajer: Conceptualization, Methodology, Investigation, Writing - original draft, Visualization. **David Fiedor:** Methodology, Formal analysis, Data curation, Writing - original draft, Visualization.

References

Agnoletti, M., 2014. Rural landscape, nature conservation and culture: Some notes on research trends and management approaches from a (southern) European perspective. Landscape and Urban Planning 126, 66–73. https://doi.org/10.1016/j.landurbplan.2014.02.012.

Antrop, M., 2000. Background concepts for integrated landscape analysis. Agriculture, Ecosystems & Environment 77, 17–28. https://doi.org/10.1016/S0167-8809(99)00089-4.

Antrop, M., 2004. Landscape change and the urbanization process in Europe. Landscape and Urban Planning 67, 9–26. https://doi.org/10.1016/S0169-2046(03)00026-4.

Baiocchi, V., Lelo, K., Milone, M.V., Mormile, M., 2013. Accuracy of different georeferencing strategies on historical maps of Rome. Geographia Technica 1, 10–16.

Balletti, C., 2006. Georeference in the analysis of the geometric content of early maps. e-Perimetron 1, 32–39.

Bastian, O., Krönert, R., Lipský, Z., 2006. Landscape Diagnosis on Different Space and Time Scales – A Challenge for Landscape Planning. Landscape Ecology 21, 359–374. https://doi.org/10.1007/s10980-005-5224-1.

Bender, O., Boehmer, H.J., Jens, D., Schumacher, K.P., 2005. Analysis of land-use change in a sector of Upper Franconia (Bavaria, Germany) since 1850 using land register records. Landscape Ecology 20, 149–163. https://doi.org/10.1007/s10980-003-1506-7.

Bělina, P., Kaše, J., Kučera, J.P., 2001. Velké dějiny zemí Koruny české X.: 1740–1792 [Great history of Czech lands X.: 1740–1792]. Paseka, Praha 768 pp.

Bičík, I., Kupková, L., Jeleček, L., Kabrda, J., Štych, P., Janoušek, Z., Winklerová, J., 2015. Land use changes in the Czech Republic 1845–2010: socio-economic driving forces. Springer 215 pp.

Boguszak, F., Císař, J., 1961. Vývoj mapového zobrazení území Československé socialistické republiky III: Mapování a měření českých zemí od pol. 18. stol. do počátku 20. stol [Map development of the territory of the Czechoslovak Socialist Republic III: Mapping and measurement of the Czech lands since the mid-18th century until the beginning of the 20th century]. Ústřední správa geodézie a kartografie, Praha 80 pp.

Brázdil, R., Pfister, C., Wanner, H., von Storch, H., Luterbacher, J., 2005. Historical Climatology In Europe – The State Of The Art. Climatic Change 70, 363–430. https://doi.org/10.1007/s10584-005-5924-1.

Brinkhoff, T., Kriegel, H.S., Schneider, R., Braun, A., 1995. Measuring the complexity of polygonal objects. In: Bergougnoux, P., Makki, K., Pissinou, N. (Eds.), Proc. of the Third ACM International Workshop on Advances in Geographic Information Systems. Baltimore, Maryland, USA, December 1-2, ACM. pp. 109–117.

Bumba, J., 2007. České katastry od 11. do 21. století [Czech land registers from the 11th to the 21st century]. Grada Publishing a.s. 187 pp.

Claeys Boùùaert, M., De Baets, B., Vervust, S., Neutens, T., De Maeyer, P., Van de Weghe, N., 2016. Computation and visualisation of the accuracy of old maps using differential distortion analysis. International Journal of Geographical Information Science 30, 1255–1280. https://doi.org/10.1080/13658816.2015.1127377.

Dahlström, A., 2008. Grazing dynamics at different spatial and temporal scales: examples from the Swedish historical record a.d. 1620–1850. Vegetation History and Archaeobotany 17, 563–572. https://doi.org/10.1007/s00334-006-0087-1.

Darby, H.C., 1986. Domesday England. Cambridge University Press 416 pp.

Demetriou, D., Stillwell, J., See, L., 2013. A GIS-based shape index for land parcels. In: Hadjimitsis, D.G. (Ed.), First International Conference on Remote Sensing and Geoinformation of Environment (RSCy2013). SPIE - International Society For Optics and Photonics, Paphos-Cyprus. p. 748.

Dolejš, M., Forejt, M., 2019. Franziscean cadaster in landscape structure research: a systematic review. Questiones Geographicae 38, 131–144. https://doi.org/10.2478/quageo-2019-0013.

ESRI, 2018. ArcGIS Desktop. Environmental Systems Research Institute, Redlands, California.

Forejt, M., Dolejš, M., Raška, P., 2018. How reliable is my historical land-use reconstruction? Assessing uncertainties in old cadastral maps. Ecological Indicators 94, 237–245. https://doi.org/10.1016/j.ecolind.2018.06.053.

Frajer, J., 2019. Josefský katastr jako zdroj geografických informací o historické krajině [Josephian cadastre as a source of geographic information on historical landscapes]. Geografie 124, 315–340. https://doi.org/10.37040/geografie2019124030315.

Frajer, J., Geletič, J., 2011. Research of historical landscape by using old maps with focus to its positional accuracy. Dela 36, 49–67.

Fuchs, R., Verburg, P.H., Clevers, J., Herold, M., 2015. The potential of old maps and encyclopaedias for reconstructing historic European land cover/use change. Applied Geography 59, 43–55. https://doi.org/10.1016/j.apgeog.2015.02.013.

Godsey, W.D., 2014. Habsburg Government and Intermediary Authority under Joseph II (1780–90): The Estates of Lower Austria in Comparative Perspective. Central European History 46, 699–740. https://doi.org/10.1017/S0008938914000016.

Gragson, T.L., Bolstad, P.V., 2006. Land Use Legacies and the Future of Southern Appalachia. Society & Natural Resources 19, 175–190. https://doi.org/10.1080/08941920500394857.

Hartleib, J., Bobertz, B., 2017. New demands on old maps–An approach for estimating aspects of accuracy of old maps as basis for landscape development research. Coastline Changes of the Baltic Sea from South to East. Springer, pp. 257–270.

Hendrych, J., Storm, V., Pacini, N., 2013. The Value of an 1827 Cadastre Map in the Rehabilitation of Ecosystem Services in the Křemže Basin, Czech Republic. Landscape Research 38, 750–767. https://doi.org/10.1080/01426397.2013.794260.

Honc, J., 1981. Míra nepřesnosti josefského katastru z roku 1785 a plochy velkostatků v Čáslavském a Kouřímském kraji před r. 1848 [Inaccuracy of the Josephian Cadastre from 1785 and the Areas of Large Estates in the Čáslav and Kouřim Regions before 1848]. Listy genealogické a heraldické společnosti v Praze 8, 91–115.

Houston, R.A., 2014. Literacy in early modern Europe: Culture and education 1500–1800. Routledge 292 pp.

Kataoka, T., 2013. Historicogeographic Reconstruction of Okô-shinmachi, Tosa Province: Reexamination of Place Following a Market Town Based on the Chôsokabe Cadastral Books and Meiji Cadastres. Geographical review of Japan series A 86, 158–172. https://doi.org/10.4157/grj.86.158.

Kingston, R., 2010. Mind Over Matter? History and the spatial turn. Cultural and Social History 7, 111–121. https://doi.org/10.2752/147800410X477368.

Knowles, A.K., 2008. Placing history: how maps, spatial data, and GIS are changing historical scholarship. ESRI Press, Redlands, California 313 pp.

Kopp, J., Frajer, J., Pavelková, R., 2015. Driving forces of the development of suburban landscape–A case study of the Sulkov site west of Pilsen. Quaestiones Geographicae 34, 51–64. https://doi.org/10.1515/quageo-2015-0028.

Krčmářová, J., Jeleček, L., 2017. Czech traditional agroforestry: historic accounts and current status. Agroforestry Systems 91, 1087–1100. https://doi.org/10.1007/s10457-016-9985-0.

Kwinta, A., Gniadek, J., 2017. The description of parcel geometry and its application in terms of land consolidation planning. Computers and Electronics in Agriculture 136, 117–124. https://doi.org/10.1016/j.compag.2017.03.006.

Láznička, Z., 1959. Historické zprávy o erosi půdy v Brněnském kraji [Historical reports on soil erosion in the Brno region]. Sborník ČSSZ 64, 13–28.

Leyk, S., Boesch, R., Weibel, R., 2005. A Conceptual Framework for Uncertainty Investigation in Map-based Land Cover Change Modelling. Transactions in GIS 9, 291–322. https://doi.org/10.1111/j.1467-9671.2005.00220.x.

Lisec, A., Navrátil, G., 2014. The Austrian Land Cadastre: From the earliest beginnings to the modern land information system. Geodetski Vestnik 58, 482–516. https://doi.org/10.15292/geodetski-vestnik.2014.03.482-516.

MacLean, M.G., Congalton, R.G., 2013. PolyFrag: a vector-based program for computing landscape metrics. GIScience & Remote Sensing 50, 591–603. https://doi.org/10.1080/15481603.2013.856537.

Olah, B., Boltižiar, M., Gallay, I., 2009. Transformation of the Slovak cultural landscape since the 18th cent. and its recent trends. Journal of Landscape Ecology 2, 41–55. https://doi.org/10.2478/v10285-012-0018-z.

Pavelková, R., Frajer, J., Havlíček, M., Netopil, P., Rozkošný, M., David, V., Dzuráková, M., Šarapatka, B., 2016. Historical ponds of the Czech Republic: an example of the interpretation of historic maps. Journal of Maps 12, 551–559. https://doi.org/10.1080/17445647.2016.1203830.

Pecci, M., 2001. The Historical and Iconographic Research in the Reconstruction of the Variation of the Calderone Glacier: State of the Art and Perspective. In: Visconti, G., Beniston, M., Iannorelli, E.D., Barba, D. (Eds.), Global Change and Protected Areas. Springer. Dordrecht, Netherlands, pp. 505–512.

Pecka, K., 1985. Účast zeměměřičů na josefském katastru [Participation of surveyors in the Josephian Cadastre]. Historická geografie 24, 105–116.

Pereponova, A., Skaloš, J., 2019. Spatio-temporal dynamics of wood-pastures in lowland and highland landscapes across Czechia. Regional Environmental Change 19, 267–278. https://doi.org/10.1007/s10113-018-1404-9.

Petek, F., Urbanc, M., 2004. The Franziscean Land Cadastre as a Key to Understanding the 19th-century Cultural Landscape in Slovenia. Acta geographica Slovenica 44, 89–113. https://doi.org/10.3986/AGS44104.

Petrovszki, J., Mészáros, J., 2010. The Great Hungarian Plain in the sheets of the Habsburg military surveys and some historical maps—A case study of the Körös/Criş

Drainage Basin. Acta Geodaetica et Geophysica Hungarica 45, 56–63. https://doi.org/10.1556/AGeod.45.2010.1.9.
Peura, M., Iivarinen, J., 1997. Efficiency of simple shape descriptors. In: Arcelli, C., Cordella, L.P., Sanniti di Baja, G. (Eds.), Advances in visual form analysis. World Scientific, Capri-Italy, pp. 443–451.
Pindozzi, S., Cervelli, E., Capolupo, A., Okello, C., Boccia, L., 2016. Using historical maps to analyze two hundred years of land cover changes: case study of Sorrento peninsula (south Italy). Cartography and Geographic Information Science 43, 250–265. https://doi.org/10.1080/15230406.2015.1072736.
Podobnikar, T., 2009. Georeferencing and quality assessment of Josephian survey maps for the mountainous region in the Triglav National Park. Acta Geodaetica et Geophysica Hungarica 44, 49–66. https://doi.org/10.1556/AGeod.44.2009.1.6.
Prince, H.C., 1959. The tithe surveys of the mid-nineteenth Century. The Agriculture History Review 7, 14–26.
Rameš, V., 2005. Slovník pro historiky a návštěvníky archivů [Dictionary for historians and archives visitors]. Libri, Prague 432 pp.
Raška, P., Zábranský, V., Dubišar, J., Kadlec, A., Hrbáčová, A., Strnad, T., 2014. Documentary proxies and interdisciplinary research on historic geomorphologic hazards: a discussion of the current state from a central European perspective. Natural Hazards 70, 705–732. https://doi.org/10.1007/s11069-013-0839-z.
Roubík, F., 1954. Ke vzniku josefského katastru v Čechách v letech 1785–1789 [Notes to the foundation of the Josephian Cadastre in Bohemia in 1785-1789]. Sborník historický 2, 140–185.
See, L., Comber, A., Salk, C., Fritz, S., van der Velde, M., Perger, C., Schill, C., McCallum, I., Kraxner, F., Obersteiner, M., 2013. Comparing the quality of crowdsourced data contributed by expert and non-experts. PLoS ONE 8, 1–11. https://doi.org/10.1371/journal.pone.0069958.
Semotanová, E., 1998. Historická geografie českých zemí [Historical geography of the Czech lands]. Historický Ústav AV ČR, Praha 293 pp.
Schulte, L.A., Mladenoff, D.J., 2001. The Original US Public Land Survey Records: Their Use and Limitations in Reconstructing Presettlement Vegetation. Journal of Forestry 99, 5–10. https://doi.org/10.1093/jof/99.10.5.
Skaloš, J., Emgstová, B., 2010. Methodology for mapping non-forest wood elements using historic cadastral maps and aerial photographs as a basis for management. Journal of Environmental Management 91, 831–843. https://doi.org/10.1016/j.jenvman.2009.10.013.
Skaloš, J., Molnárová, K., Kottová, P., 2012. Land reforms reflected in the farming landscape in East Bohemia and in Southern Sweden – Two faces of modernisation. Applied Geography 35, 114–123. https://doi.org/10.1016/j.apgeog.2012.06.003.
Skaloš, J., Weber, M., Lipský, Z., Trpáková, I., Šantrůčková, M., Uhlířová, L., Kukla, P., 2011. Using old military survey maps and orthophotograph maps to analyse long-term land cover changes – Case study (Czech Republic). Applied Geography 31, 426–438. https://doi.org/10.1016/j.apgeog.2010.10.004.
Styś, W., 1932. Metryki gruntowe józefińskie i franciszkańskie jako źródła do historji gospodarczej Galicji [Josephian and Franciscan land records as sources for the history of the economy of Galicia]. Roczniki dziejów społecznych i gospodarczych 2, 57–92.
Šantrůčková, M., Demková, K., Weber, M., Lipský, Z., Dostálek, J., 2017. Long term changes in water areas and wetlands in an intensively farmed landscape: A case study from the Czech Republic. European Countryside 9, 132–144. https://doi.org/10.1515/euco-2017-0008.
Talich, M. (Ed.), 2005. Zeměměřictví a katastr IV. [Surveying and Cadastre IV.]. Výzkumný ústav geodetický, topografický a kartografický, Zdiby, Czech Republic.
Trimble, S.W., 2008. The use of historical data and artifacts in geomorphology. Progress in Physical Geography: Earth and Environment 32, 3–29. https://doi.org/10.1177/0309133308089495.
Troll, M., Ostafin, K., 2016. Use of late 18th and early 19th century cadastral data to estimate past forest cover change–a case study of Zawoja village. Prace Geograficzne 2016, 31–49.
Trpáková, I., 2009. The use of historical sources and their ecological interpretation in the course of almost two centuries–a literature review. Journal of Landscape Studies 2, 97–119.
Tůmová, M., 2018. Maps of estates in Bohemia as an example of an undervalued historical geographic source – research survey and examples of utilization. AUC Geographica 53, 238–251. https://doi.org/10.14712/23361980.2018.22.
Vellend, M., Brown, C.D., Kharouba, H.M., McCune, J.L., Myers-Smith, I.H., 2013. Historical ecology: Using unconventional data sources to test for effects of global environmental change. American Journal of Botany 100, 1294–1305. https://doi.org/10.3732/ajb.1200503.
Vuorela, N., Alho, P., Kalliola, R., 2002. Systematic assessment of maps as source information in landscape-change research. Landscape Research 27, 141–166. https://doi.org/10.1080/01426390220128631.
Wei, X., Ye, Y., Zhang, Q., Fang, X., 2015. Methods for cropland reconstruction based on gazetteers in the Qing Dynasty (1644–1911): A case study in Zhili province. China. Applied Geography 65, 82–92. https://doi.org/10.1016/j.apgeog.2015.11.002.
Whyte, I.D., 1997. Scotland's Society and Economy in Transition, c-1500–c-1760. Palgrave, London 167 pp.
Woitschová, K., 2017. Hidden treasures: Challenging traps of historical sources for environmental history. In: Vaz, E., de Melo, C.J., Costa Pinto, L.M. (Eds.), Environmetal history in the making, Volume I: Explaining. Springer, pp. 109–122.
Worster, D., Crosby, A.W., 1989. The Ends of the Earth: Perspectives on Modern Environmental History (Studies in Environment and History). Cambridge University Press, Cambridge 341 pp.
Yang, Y., Zhang, S., Yang, J., Chang, L., Bu, K., Xing, X., 2014. A review of historical reconstruction methods of land use/land cover. Journal of Geographical Sciences 24, 746–766. https://doi.org/10.1007/s11442-014-1117-z.
Zaragozí, B., Giménez-Font, P., Belda-Antolí, A., Ramón-Morte, A., 2019. A graph-based analysis for generating geographical context from a historical cadastre in Spain (17th and 18th centuries). Historical Methods: A Journal of Quantitative and Interdisciplinary History 52, 228–243. https://doi.org/10.1080/01615440.2019.1590269.