

DISCLOSURE OF HISTORICAL SPATIAL AND STATISTICAL DATA OF DISTRICTS IN CZECHIA IN A GIS ENVIRONMENT

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ABSTRACT

This article presents a methodology for the creation and reconstruction of historical borders of chosen spatial units, especially political and judicial districts in Czechia for the specific years of population censuses within a GIS environment. Since an ethnic, language, demographic, social and cultural composition of a population is one of the main features of national and regional identity, the main objective of the article is to introduce a new method for the creation of spatial-statistical databases which will make these historical data sources accessible to both experts and the public for general use. For this purpose, district borders from 1921, 1930, (1947), 1950, 1961, 1970, 1991, 2001 and 2011, which represent the years of the population censuses in Czechia, were digitized. Our method is based mainly on historical maps, which correspond with the censuses' statistical datasets. The proposed methodology for the creation of GIS layers (digitalization, geo-referencing, vectorization, accuracy assessment, and spatial identification), their connection with censuses' statistical data (creation of spatial codes), metadata creation, and web publication is described in this article along with examples of some of the difficulties encountered during the process. We also bring attention to several case studies of problematic areas where the reconstruction of borders was particularly complicated. Finally, spatial and statistical data in the format of ESRI shapefile and ESRI Geodatabase offer possibilities for retrospective analyses of quantitative data to current researchers from a range of scientific disciplines. Files in both formats are publicly available at www.historickygis.cz.

Keywords: administrative borders; historical GIS; districts; Czechia; historical cartography

1. Introduction

One of the most important elements involved in the existence of a distinct national and regional identity has been development of demographic, social, and cultural composition of population. A unique source of a wide range of data on this composition was completed primarily due to a long tradition of population censuses, which on our territory spans of over 300 years¹. Since the mid-19th century, population data have been acquired periodically at regular 10-year intervals through the Population Censuses (censuses)². Since the establishment of Czechoslovakia, the censuses took place in 1921, 1930, (1946/47)³, 1950, 1961, 1970, 1980, 1991, 2001 and 2011. However, these historically and thematically rich sources of information are currently not being fully utilised, mainly due to a limited accessibility of data, their incompleteness, or damage done to the paper originals over time. Example of such damage were extensive floods in 2002 which destroyed a number of original publications kept at the library of the Czech Statistical Office in Karlín. Valuable historical population data are therefore rarely used for research across the range of scientific disciplines,

but instead remain in old statistical repositories of selected institutions⁴ and in private collections. In light of the reorientation of the focus of geographic research during the period of transformation (see e.g. Hampl, Dostál and Drbohlav 2007), which now focuses on the investigation of the mechanisms of socio-spatial differentiation, more and more attention is being paid to the development trends and causal mechanisms of social phenomena (see e.g. Semotanová and Chromý 2012; Svoboda, Přidalová and Ouředníček 2014). The inclusion of a large spectrum of spatial and statistical data is therefore becoming not only an appropriate, but often an outright necessary element of such research effort.

The article is one of the outputs of the multidisciplinary project called "Disclosure of Historic Spatial and Statistical Data in GIS Environment". The project has been developed as part of the Program of Applied Research and Development of National and Cultural Identity (NAKI) commenced at the Faculty of Science of the Charles University in Prague (2012–2015). The contribution aims to introduce and to discuss the methodology of disclosure of

¹ Since 1869 in form of regular, nationwide population censuses with relatively stable 10-year periodicity.

² Portfolio of surveyed data, as well as the name of censuses itself, have been throughout the history subjects of frequent changes.

³ Due to the rush period just after the World War II, the census 1946/47 was organized in irregular and incomplete form.

⁴ Over the course of the research which prompted this article, the authors have identified a number of valuable publications which are predominantly located (frequently only as a singular exemplar) in repositories and libraries of the Charles University in Prague, the Czech Statistical Office (CZSO), or the Czech Office for Surveying, Mapping and Cadastre (ČÚZK). However, the efforts to locate data sources which would help to provide a complete (as complete as possible, at least) picture were joined by over 20 addressed institutions.

historical spatial and statistical data in the environment of geographic information systems (GIS). The methodology was proposed in such a way that it should be possible to reproduce, albeit in a perhaps slightly adjusted form, by a range of both domestic and international users in further research concerned with the accessibility of valuable historical spatial and statistical data. We are aware that, for a variety of reasons, it is not currently possible to achieve full digitalization and public availability of all relevant historical data sources. However, we believe that a creation of a unified methodological framework can contribute for it and aid in research efforts interested in the investigation of historical events and processes.

Throughout the attempts at increasing availability of historical sources which provide valuable information on the causal and developmental mechanisms of current processes, several research concepts have proven their particular usefulness. On a theoretical level, we follow research in historical demography and cartography, historical GIS application, and, especially, mapping techniques of the Chicago School (Musil 1991; Gregory and Ell 2007; Ouředníček et al. 2009; Semotanová 2009). The outputs of our research complement the recently published Landscape Atlas of the Czech Republic (Hrnčiarová et al. 2009) offering a complex documentation of the natural and social components of Czech landscape and the Atlas of Socio-spatial Differentiation of the Czech Republic (Ouředníček, Temelová and Pospíšilová 2011), which explores the changes in spatial distribution of selected social and economic phenomena since 1991. A similar emphasis on the accessibility of historical data, retrospective analysis, and acknowledgement of developmental trends during an assessment of the character and intensity of land use changes can be attributed to Bičík et al. (2010) and their Database of Long-term Land Use Changes in Czechia. In regards to methodological approaches to utilization of historical and contemporary population data, this article shares some features with certain international web portals. For example, the internet portal of the US population census (census.gov; see U.S. Census Bureau 2011), which not only provides access to its data, but also allows them to be used interactively for the creation of variously themed online maps, serves as a great inspiration in this case. Domestically, the issue of historical borders and the utility of historical population censuses have recently been explored by Kučera and Kučerová (2009) or Semotanová (2009). However, none of the aforementioned works make use of the GIS software, although modelling of historical spatial data within this framework could make cartographic visualisation and the analysis of historical data significantly more convenient.

The recent rise in interest in the preservation and application of historically valuable data sources is primarily associated with the Program of Applied Research and Development of National and Cultural Identity (NAKI) provided by the Czech Ministry of Culture. Within this

program, two similarly oriented research projects have recently been elaborated. One of them aims to propose methodology for discovering and accessibility of old maps, plans, atlases and globes (DF11P01OVV021), while the other deals with technologies which could increase the accessibility of the Czech Republic's official map archives (DF11P01OVV003). Both projects attempt to preserve old maps through a digitalization of their content. However, the digital information is kept in raster format only, and is not converted into a vector format which would enable the creation of new maps with historical data. A shift towards the GIS vector outputs of selected historical borders data is apparent in the recent work of Burda, Janoušek and Chromý (2014). However, the authors were not interested in the reconstruction of historical borders relevant for the individual years for which census data are available. Instead, they produced layers representing years 1930 and 1950, when significant changes in administrative borders occurred. Burda et al. (2014) adjusted the shape and course of the borders to the current GIS cadastral layer (from 2010), from which their creation of the borders went out. For this reason, as the authors mention, "... this is not a reconstruction of an accurate historical border, or of its exact course" (Burda et al. 2014, p. 54). As a point of difference from this approach, we attempted to reconstruct the shape and course of historical borders of administrative units as accurately as possible in respect to the specific census years and available map data sources for both – district units (e.g. political, judicial and post-1960 districts; *okres*) in the case of the entire country and cadastral units (*katastrální území*) and census tracts (*urbanistický obvod*) in the case of Prague.

In the article, we first investigate the changing historical delimitation of spatial administrative units, which significantly affected the development of statistical territorial units used in the population censuses. The central section of the article discusses the methodology of reconstructing the historical borders of these spatial units in GIS and their interaction with population data. Though we used the ArcGIS 10.1 (Esri ©) software the described methodology is applicable in general. We focus on the digitalization of state, regional, and district borders existing on the territory of the Czechia during 1921–2011, as well as corresponding borders of municipal districts, cadastral units, and (later) census tracts on the territory of Prague. We pay particular attention to selection of appropriate map sources in available archives, elaboration of a suitable methodology of converting these data into GIS and their connecting with information obtained through population censuses, and the incorporation of census data into a database. All of these steps improve the accessibility of historical spatial data and enable the creation of historically themed specialised maps, as well as a prospective publication of the Historical Population Atlas of the Czech Lands. These outputs, as well as a new internet map portal (www.historickygis.cz) established over

the course of the project, will contribute to an increased usage of these “new” historical spatial and statistical data in public, academic, and educational spheres. Finally, we include three case studies, for which the reconstruction of historical borders involved particular difficulties associated with significant changes of borders throughout the observed period.

2. Development of the Czech districts from 1850 to 2011

Reconstruction of spatial datasets of district borders in Czechia related to the years of the census (in a period of 1921–2011) needs to discuss historical development of the analysed spatial units. The delimitation of districts had its origins in the reform of the spatial administration in 1849, which abolished the feudalism as an administrative system and replaced feudal fiefdoms with political and judicial districts (Růžková et al. 2006; Čáp 2009). Further administrative changes took place during the 20th century, which also impacted on the delimitation of districts for particular census years. We therefore summarize the most important administrative reforms which took place since 1849 and affected the use of districts as statistical units.

The Imperial Edict no. 295/1849 separated political and judicial administration (starting from January 1, 1850). Political districts, made similar in both their area and population size (Janák 1987), became the primary units of state administration below the level of Czech historical lands (Bohemia, Moravia and Silesia) and regions. Total of 79 political districts (not including Prague) were established in Bohemia, 25 in Moravia, and 7 districts were created in Silesia. Judicial administration devolved some of its powers to newly founded regional and district courts (with specifically delimited judicial districts). Consequently, 207 judicial districts were delimited in Bohemia (excluding Prague as a city with special status), 78 in Moravia and 22 in Silesia (Mleziva 2010). These judicial districts also became elementary territorial units (Čáp 2009). The establishment of judicial districts respected historical and geographic borders while maintaining comparable population numbers in individual districts (Jeřábek 2000). Alongside judicial districts, the new system also recognized statutory cities which initially comprised only the capital of Prague, but later came to include Brno, Opava, and even later also Liberec (Mleziva 2010). Regions, such as higher spatial units were only established in Bohemia (7 + Prague) and Moravia (2)⁵, while the borders of regional authorities corresponded with borders of regions as official territorial units.

The separation of political and judicial administration was temporarily suspended in 1855⁶, when every judicial district also assumed the responsibilities of their political counterparts (Jeřábek 2000). Then, 208 new administrative units emerged in Bohemia, 76 in Moravia, and 22 in Silesia (Janák 1987; Čáp 2009). The number of regions in Bohemia increased to 13 (excluding Prague), reached 6 in Moravia and 1 region emerged in Silesia (Jeřábek 2000). Act no. 44/1868 once again separated judicial and political districts. With minor exceptions, the delimitation of judicial districts followed the set up established in 1850 and over the next few years, their number had risen as a result of further divisions of original districts (Čáp 2009). Political districts were newly delimited (Mleziva 2010) – 89 were established in Bohemia, 30 in Moravia, and 7 in Silesia (Janák 1987; Jeřábek 2000). Their numbers also continued to grow along with the population of the country (Růžková et al. 2006). The year 1868 brought about a second significant administrative change – the abolishment of regions as territorial units⁷.

A reform of the territorial and administrative system which would create counties (named *župa*) and discontinue the use of political districts was attempted in 1920 (Mleziva 2010). However, the administrative changes never materialised, since Act no. 126/1920 affected merely territorial units, wherefore counties (*župa*) never acquired any administrative functions. Czech historical lands were divided into the capital city of Prague, 15 counties (*župa*), and 330 judicial districts (226 in Bohemia, 81 in Moravia, and 23 in Silesia) (Mleziva 2010). The division into political districts was based on the state before 1918 (Semotanová 2013). Růžická et al. (2006) account for 159 political districts between years 1921 and 1927. An administrative reform was enacted in 1928 (Mleziva 2010) under Act no. 125/1927 (Růžková et al. 2006). By this act, Czech historical lands regained their position as the highest level administrative units. Silesia had revoked its status of historical land and Czech lands were divided into Bohemia and Moravia-Silesia (Jeřábek 2000). The law also completely eliminated counties (*župa*; see Mleziva 2010). Bohemia became comprised of 103 political and 228 judicial districts, while Moravia-Silesia included 45 political and 106 judicial districts (Dostál and Kára 1992; Jeřábek 2000). During the 1921 population census, the spatial organisation of civil administration was not fully established and the 1920 law on the establishment of counties was still in effect. For this reason, the results of the first post-war census were calculated according to these counties (CZSO 2013a). The statistics also operated with political district and judicial districts (CZSO 2013a). At the time of the Population Census (on February 15, 1921) the territory of Czechia was divided

⁵ From a legal perspective, Silesia was not considered to be a separate region, since it was not administered by a regional president but by a Land governor (see more on the administrative division in Janák 1987).

⁶ Unlike administrative changes, territorial reorganizations took place already in 1854 (Mleziva 2010).

⁷ Regional offices had been already disestablished in 1860–1862 (Janák 1987).

into 328 judicial districts (Prague as a single district) and 152 political districts, while 330 judicial and 151 political districts existed in the country during the next census (December 1, 1930) (see Table 1).

The system of judicial and political districts preserved its function until 1949. However, between 1930 and 1949, the numbers of districts of individual types experienced considerable changes as the outcome of the annexation of border regions specified by the Munich Agreement. The period after 1945 and the return of occupied territories to Czechoslovakia saw (with some exceptions) the restoration of the state of affairs valid in September 30th 1938. Czech historical lands were re-parcelled into districts on the basis of a presidential decree from October 27, 1945 (Semotanová 2013) – Bohemia was partitioned into 110 administrative and 223 judicial districts, while Moravia-Silesia featured 44 administrative and 103 judicial districts. In light of significant changes which had occurred during and after the war, the census of 1950 was preceded by a post-war listing of inhabitants which took place in 1947 (May 22) and collected data representing 162 districts.

In 1949, based on Act 280/1948 abandoned historical lands (*země*) as administrative units and re-introduced regions (*kraj*). Czech historical lands were partitioned into 13 regions (8 in Bohemia and 5 in Moravia and Silesia) (Burda 2010). By Decree 3/1949 326 former judicial districts were replaced by 180 new districts which served as territorial units, as well as areas of competence of national district committees (*národní výbor*) and district courts (Mleziva 2010). The first post-war census took place on March 1, 1950, and collected data for 193 units.

While year 1960 did not bring any systemic changes of the administrative set up, it did, however, witness a territorial reform. Act 36/1960 abolished a majority of existing districts and replaced them with 75 new districts (Jeleček 2000), and also reduced the number of regions from 13 to 7 (Burda 2010). Prague became the 76th district and 8th region (Růžková et al. 2006). This division is also considered to be insensitive towards historical and geographic borders of concerned territories (Mleziva 2010). This territorial order of things remained in place for the next 30 years. The Population and Housing Censuses in 1961 (March 1), 1970 (December 1) and 1980 (November 1) all operated with 76 districts.

The administrative system remained unchanged even after 1989, and the Czech Statistical Office used 76 districts when publishing the outputs of the 1991 census. Act 347/1997 on higher territorial self-governing units established territorial units as replacements for the previously existing regions since 2000 (January 1). However, the partition into regions continues to be relevant to this day and some institutions (such as courts) are organized in accordance with it (Pospíšilová and Šimon 2011). District of Jeseník was created in 1996 (through a separation from the larger Šumperk district), wherefore the 2001 census operates with 77 districts. In 2003, in line with

Act 320/2002, districts as administrative units were abolished and their responsibilities were mostly taken over by municipalities with extended power (*obec s rozšířenou působností, ORP*). However, districts continue to be used as territorial and statistical units. For this reason, the 2011 census once again presents its findings as subdivided for 77 districts.

Tab. 1 Number of units recognized in the outputs of Population censuses in Czechia.

Year of the census	Judicial districts	Political districts	Districts
1921	328	152	–
1930	330	151	–
1946/1947	–	–	162
1950	–	–	193
1961	–	–	76
1970	–	–	76
1980	–	–	76
1991	–	–	76
2001	–	–	77
2011	–	–	77

Source: Czech Statistical Office, based on the statistical data

3. Methodology for the creation of historical borders in GIS

3.1 Preparation of map records

A successful reconstruction of administrative borders of selected territorial units used in census publications rests upon a thorough initial research. This research involved the procurement of all map records with vital information on the administrative delimitation and partition of the territory of present-day Czechia in the time periods corresponding with official population censuses (see Table 1). A wide multidisciplinary collaboration joined by over 20 addressed institutions helped to secure approximately 70 valuable maps of the Czechia and an equivalent amount of maps and plans of the city of Prague⁸. This archive work fulfilled the fundamental criteria of usefulness – a depiction of judicial or political districts – or, ideally which feature territorial units of a lower scale level (in this instance primarily cadastral units).

The final selection of maps (Table 2) was guided by two elementary criteria: (i) the year in which the map was published must be as close to the year of the census as possible; (ii) maps include administrative borders which constitute the basis of selected GIS layer. The borders of districts (judicial, political, and administrative) were

⁸ A detailed list of maps with their citation references and photographic documentation is available on request in the central data point of the Urban and Regional Laboratory research group.

Tab. 2 List of map records used for a transfer of spatial data into GIS.

Name of Map Record	Scale	Format	Provider	Time of Depiction	Author
III. Military Mapping	1 : 75,000	raster	ČÚZK	1927	Ministry of the Interior – Geographic Department
Synoptic map of cadastral areas: Bohemia/Moravia-Silesia	1 : 144,000 / 1 : 115,200	raster	ČÚZK	1936	Ministry of Finance – Reproduction Department
Synoptic map of cadastral areas: Bohemia/Moravia-Silesia	1 : 200,000	raster	ČÚZK	1947	Ministry of Finance – Reproduction Department
Synoptic map of territorial organization by February 1, 1949	1 : 200,000	raster	ČÚZK	1949	Ministry of Finance – Reproduction Department
Map of administrative subdivision of the ČSR	1 : 200,000	raster	ČÚZK	1960	Central Bureau of Geodesy and Cartography
Map of administrative subdivision of the ČSR	1 : 200,000	raster	ČÚZK	1971–1973	Czech Geodetic and Cartographic Office
Map of administrative subdivision of the ČSR	1 : 200,000	raster	ČÚZK	1980–1982	Czech Geodetic and Cartographic Office
okr96g1s.shp	x	SHP	CZSO (Census 1991)	1991	Czech Statistical Office
okresy_201102.shp	x	SHP	CZSO (Census 2001)	2001	Czech Statistical Office
okres.shp	x	SHP	CZSO (Census 2011)	2011	Czech Statistical Office

Sources: explained in the table itself; adjusted and organised by authors

searched for the case of maps depicting the territory of Czechia. Subsequent geo-referencing and vectorization of these data revealed that a successful utilization of data source (on the level of districts) is dependent on the maps' inclusion of lower scale units' borders – cadastral units (*katastrální území*), in this instance. It is because cadastral units are the oldest relatively stable administrative units which allow for a successful delimitation of district borders. Another important criterion for map selection was to keep relatively unified scale throughout the entire time series of maps selected for particular year of censuses. Readability and completeness of administrative borders across the entire map also served as an important criterion for selection, as did the completeness of the coverage of the studied area, while a general clarity and physical condition of the map acted as supporting criteria.

Map records pertinent to the censuses of 1991, 2001, and 2011 were obtained differently from the rest, since their source data were provided by the Czech Statistical office (CZSO). For years 2001 and 2011, complete digital datasets (shp layers) for the level of basic settlement units (*základní sídelní jednotka*) were provided by the CZSO, which can be used for creation of all higher-level administrative or technical units. The administrative borders reflected the scale level of municipalities in 1991 had also been previously determined and adjusted by the URR-lab on the basis of vector layers provided by the CZSO. Source data for all censuses had therefore already been digitally recoded into a GIS polygon layer with an associated database of district codes.

Digital vector layers on individual censuses taking place before 1991 had to be created with a comparable level of precision and in similar quality on the basis of

above listed contemporary maps (see Table 2). Information from paper maps had to be digitized, geo-referenced, recoded into GIS vector polygon layers and connected with the database of statistical information obtained through individual censuses (see e.g. Robinson et al. 1995; Kolář 1997; Dobrovolný 1998; Tuček 1998; Doubrava 2005; Antoš 2006; Harvey 2008; Kraak and Ormeling 2010; Cajthaml 2007, 2012). Special attention was paid to the process of map scanning, both in terms of the appropriate raster resolution⁹ necessary for correct geo-referencing and vectorization, but also in regards to the potentially fragile nature of materials with great historical value.

3.2 Georeferencing and vectorization

The ArcGIS 10.1 software (Esri©) environment was used for georeferencing and vectorization. The scanned map sheets were georeferenced in the GIS environment¹⁰. The georeferencing was based on a vector layer of census tracts from the 2001 census (supplied by the CZSO) in the .shp format using the JTSK coordinate system. The JTSK coordinate system is used for all final data layers.

⁹ Scans of source maps were made in the 300 dpi resolution in the tif format. Due to limitations imposed on the borrowing of certain items, we sometimes used the scanning services available at respective institutions. Large-scale scanners had to be used in the case of maps exceeding the A3 format. Therefore, individual map sheets were always scanned as a compact unit in order to avoid distortions potentially caused by splicing. For other technical specifications, see Ouředníček et al. (2014a, b) or webpage www.historickygis.cz.

¹⁰ Using ESRI ArcGIS, version 10.1.

Its selection was also inspired by its utilisation in respect to historical maps (e.g. Doubrava 2005; Cajthaml and Krejčí 2008). Unified transformation method – 1st order polynomial (affine) transformation based on a sufficient number of control points was used for all map inputs (e.g. Dobrovolný 1998; Doubrava 2005). Control points were equally distributed across the entire transformed raster and their amount was derived from the spatial deformation of the raster input in order to achieve the highest level of accuracy during the transformation. The Nearest Neighbour calculation method was used for resampling.

The precision of georeferencing (using root mean square error) for map at the scale of 1 : 200,000, which formed the basis of the dataset, was established at 100 metres (0.5 mm at map's scale). In certain cases, it proved impossible to maintain this level of maximum quadratic deviation, especially due to deformations of the source scan. The highest deviation value reached 167 metres.

As has been mentioned earlier, the vectorization was based on a vector polygon layer of basic settlement units from 2001 (further only as *zsj_2001*) provided by the CZSO in the .shp format. This layer was subsequently manually edited over the georeferenced raster maps from years close to the census years (see Table 2). Where the border lines provided by *zsj_2001* vector layer aligned with district borders displayed by the source maps, these were left unchanged. Where they diverged, the *zsj_2001* vector layer was edited in accordance with the borders depicted by the source maps. While attempting to identify appropriate catchment areas, it proved expedient to make use of contemporary administrative maps which depict territorial borders of even smaller units than districts (cadastres, in this instance), especially in the case of the earlier censuses. The original polygons were edited using the Editor tool (functions of Topology, Trace, Move Vertex, Input Vertex, Delete Vertex) in order to fit the borders specified in the source maps capturing individual census periods. During this step, we created the .shp layer of “modified areas” (problem areas). This modified *zsj_2001* layer was then aggregated into judicial or political districts (or new districts and regions in censuses since 1961). Alongside this aggregation, a database emerged of places with problematic combination of judicial districts into political districts. This difficulty primarily pertains to Moravia and Silesia in the first half of the 20th century (for more information, see e.g. Gawrecká 2004).

Vector layers for the period of 1921–1980 were created independently of each other by a modification of the original *zsj_2001* layer in the .shp format. A significant number of district borders (cadastres at district borders) had an identical course over the entire period of 1921–2001. These borders were therefore displayed identically across all layers. However, borders which had undergone change were vectorised independently according to source maps corresponding with the individual census years. This caused divergence in the courses of concerned

border lines across different time horizons, which needed to be identified. These layers were topologically revised and edited in order to eliminate gaps or overlaps. This approach ensured the preservation of a unified topology (Kraak and Ormeling 2010; Allen and Coffey 2011) of the entire dataset. Spatial identification of the individual GIS layers and a consistent level of generalisation across the entire set of layers were achieved by the use of a unified vectorization source (which was edited over the raster maps from individual census years), by control of the changes in the shape and course of administrative borders across the specific timeframes, and by final topological adjustment. Subsequently, all layers were assessed for accuracy by a comparison of the location of 24 randomly selected points (scattered across the image in regular intervals) in the original raster and in the resultant vector layer.

The recommended scale for the publication of map outputs is derived from the scales of raster sources used for the vectorization of areas with changed administrative borders and from the level of detail provided by the *zsj_2001* vector layer. Recommended scales, as well as the amount of units featured in each layer, and accuracy (deviation) recorded for the individual layers are included in the metadata files, which are integrated into the .shp and .gdb layers. The layers in both forms are freely accessible for download at webpage www.historickygis.cz.

3.3 Spatial identification of individual layers of district borders

Due to a limited availability of suitable map records most of our source maps do not exactly correspond with the specific years of the censuses. Therefore, a perfect link between spatial and statistical data could not be achieved in this form. For this reason, the resulting layers of districts had to be verified through a variety of methods. Discrepancies and disproportionalities found in the vector layers were identified and categorised according to their cause of origin. This categorisation also predetermines the method of their modification.

The first category of discrepancies emerged in the unedited areas of the original *zsj_2001* layer. It involved lines (from *zsj_2001* layer) whose shape was identical in the case of source maps, but their position was slightly shifted in one direction or another. This deviation was caused by the existing RMS error as verified by a careful measurement of the extent of this displacement (the difference in their location between the source map and the *zsj_2001* vector layer). If this distance fulfilled the criteria set by the maximum permissible deviation of the RMS error, the 2001 borders were left in place, because this GIS layer offers greater spatial accuracy than the scanned source maps.

The second type of discrepancy emerged in association with border lines running alongside dynamic physical-geographic elements, such as river meanders. Since

the goal of layer creation was to present the most accurate spatial layers corresponding with the shape and extent of territorial units relevant for the censuses years, the original zsj_2001 layer was modified (vectorised) in accordance with the course of river meanders depicted in the source map.

The third kind of spatial discrepancy was brought about by historical changes of state borders. Although the period after 1920s had seen no radical territorial change, several discrepancies which reflected changes to the state borders were identified. These changes were verified in relevant documents (e.g. borders operate; *hraniční operát*) and the resulting layers were adjusted based to these archive documents.

The fourth type of discrepancy was directly caused by the differences between the year portrayed by the source map and the date of the census we assigned it to. The final modifications of the source layers, which mostly streamlined them with the number of units used in the census records, were conducted with the assistance of smaller-scale maps which presented information directly tied to the census in question, or of the legislative documents recording territorial changes in the given period. For example, in the case of the 1980 census, we made use of an atlas which was specifically published to accompany the outputs of the census (*Atlas ze sčítání 1980*, resp. 1984). Similar publication or their map-based attachments (at various scales) were used in the case of other census years as well.

3.4 Joining the vector layers with the statistical database

In order to join the created shp/gdb layers with the original statistical data provided by the population censuses, it was necessary to create identification codes for individual territorial units across the census years. Due to frequent changes to the numbers of spatial units during the observed period, a desire for a user-friendly (e.g. in terms of adding custom content) interface lead us towards the creation of a dual coding system.

(i) Coding system for district units existing in 1961–2011 is based on the codes of territorial district units used in the 1991 census which are, at least partially available electronically. The coding system features a six-digit unit code, which is composed of first two digits representing the year of the census, followed by numerical designation of a region (second pair of digits), and a third pair of digits specifying the district's designation within the region.

(ii) Coding system for district units existing in 1921–1950 is based on layers of territorial units recognised by the CZSO and derived from the Historical Lexicon of Municipalities (see Růžková et al. 2006) and its attachments in the form of shp layers. These layers were created by a modification of a layer founded on the Register of statistical districts (RSO) from 2001. The JOIN function in the GIS was used to link this data through the use of territorial units' centroids. This system employs numerical

codes with 1–3 digits (1–514) adopted from electoral statistics and their numbering of judicial districts¹¹. This three digit code was supplemented with a two digit designation of the census year in order to ensure that identically designated territories can be distinguished if more than one spatial layer is used at once (for example during the creation of development maps). The resulting system for the designation of districts therefore includes 5 digits in the case of judicial districts and 6 digits in the case of political districts. The sixth digit represents the number of judicial districts subsumed within the political district in question¹². The territorial coding systems are included in the attribute tables of all shp/dbf files of individual GIS layers.

The methodological approach described above yielded a Geographic Information System of administrative borders of territorial units which includes 45 polygon layers of judicial districts (or districts since 1961), as well as the political districts (and regions) they combine into, on the territory of Czechia. Furthermore, it also provided the polygon layers of cadastres and census tracts existing during specific census years on the territory of Prague. Data is compiled in the ESRI Shapefile format (.shp) and, for more demanding users, also in the ESRI Geodatabase (.gdb) format. The layers contain basic attributes – names and numerical codes of relevant territorial units. The databases are gradually being filled with statistical data from the historical population censuses.

4. Case studies

During the observed period, certain territories have experienced significant changes of administrative borders. These changes caused by the effects of both, natural and social forces, need to be tackled more specifically on the basis of detailed documentation. Generally known and the most obvious examples would be undoubtedly changes of the national (state) borders. Despite the fact, that 1920s, the changes of state borders have mostly had the character of minor adjustments (or recalculations of the specific course of a given border), exactly these changes tend to receive public attention. However, the most of both, quantitatively and qualitatively taken changes of borderlines occur on lower than the national scale level.

The increased number of these changes in the form of insensitive interventions that ignore historical or natural boundary lines at different scale levels is quite typical for the period of socialism (1948–1989). The most obvious examples of this propensity would be creation of completely new administrative units, establishment of

¹¹ See e.g. (CZSO 2013b): Publication of the Czech Statistical Office: Elections into legislative functions in the Czechoslovak and the Czech Republic 1920–2006.

¹² In unclear cases where such aggregation proved problematic, number 9 was assigned instead.

extensive military proving grounds, or changes of administrative borders of large cities (initially associated with gerrymandering, later with large-scale constructions of housing estates). Burda et al. (2014) also draws attention to the massive constructions of dams as the reason for these changes. The aforementioned specific examples of border changes are often very difficult to reconstruct. Case studies of borderlines changes presented below will attempt to shed some light on the matter.

4.1 Boletice military proving ground

Former proving grounds certainly belong among the areas where the reconstruction of the course of historical borders is rather difficult. The delimitation often did not pay attention to historical cadastral borderlines, which otherwise tend to be rather stable and well respected. Moreover, due a certain degree of secrecy, the borders of military proving ground were often portrayed rather vaguely and inconsistently over time.

The northern part of the Boletice proving ground presents one such case. The proving ground was founded in 1950 in the Western section of the district of Český Krumlov, bordering on Prachatice district. The 1950 district border, which had respected the original cadastral partitions, was reconstructed from a Synoptic map of territorial organisation from 1949, produced at a scale of 1 : 200,000. The reform of territorial units in 1960 assigned the entire proving ground to the district of Český Krumlov. The administrative map from 1960 (Figure 1) depicts the district border in a very schematic fashion which does not reflect contemporary cadastral partition. In some places, it does not even reflect the administrative reality of the following years, which could have either been caused by further changes during the 1960s, or more likely by an initially inaccurate map depiction.

The fate of two villages – Dobročkov and Březovík – is particularly interesting. According to the administrative map and the municipal register from 1960, these settlements, located in an immediate vicinity of the military

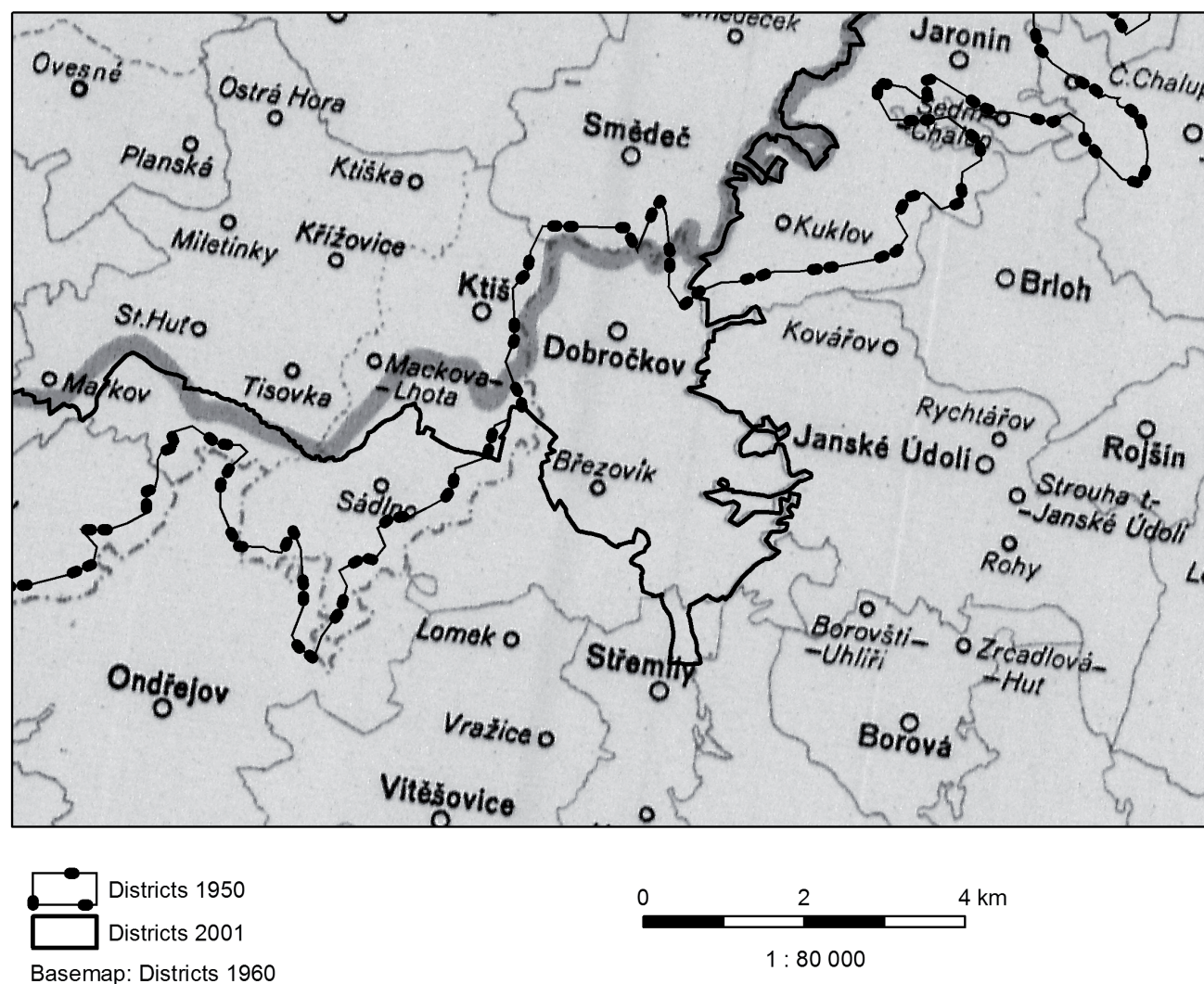


Fig. 1 Changes of district borders caused by the establishment of the Boletice proving ground.

Source: Synoptic map of territorial organisation by February 1, 1949; Polygon district layer from census 2001 (okresy_201102.shp); Map of administrative subdivision of the ČSR 1960; (for reference see Table 2).

proving ground, are both part of the district of Český Krumlov. In the following years, however, the villages are registered as part of the Ktiš municipality within the Prachatice district. Since these villages had been almost abandoned after the war, they joined the geographically closest municipality of Ktiš, which was, however, located in the district of Prachatice. This unification in effect brought about a change of district borders.

4.2 Milovice military proving ground

The Milovice proving ground represents perhaps the most complicated of these cases, because its borders did not respect cadastral units and also frequently changed with the expansion of local military infrastructure (barracks, airstrip). On the available maps, the ground's border tends to be inaccurate and very schematic (Figure 2). In 1950, all parts of the current city of Milovice

– Milovice, Mladá, Boží Dar, and Benátecká Vrutice had been parts of the district of Nymburk. Later, Mladá and Boží Dar were registered under the district of Mladá Boleslav. Before 1980, the extent of the Mladá Boleslav district increased even further to encompass the entire proving ground, including the airstrip at Boží Dar. Mladá was part of a different district than Milovice. After 1990, Mladá and Milovice were reunited, which moved the district borders back in the northern direction.

Inaccuracies in the depictions of the borders of military proving grounds on contemporary maps at average of smaller scales reflect a desire to map the course of territorial borders within these sensitive territories in light of the government's emphasis on secrecy. A significant shift in this attitude only came after the revolution, when the border lines of military proving grounds could be precisely delineated with use of the .shp layer provided by the CZSO in 1991.

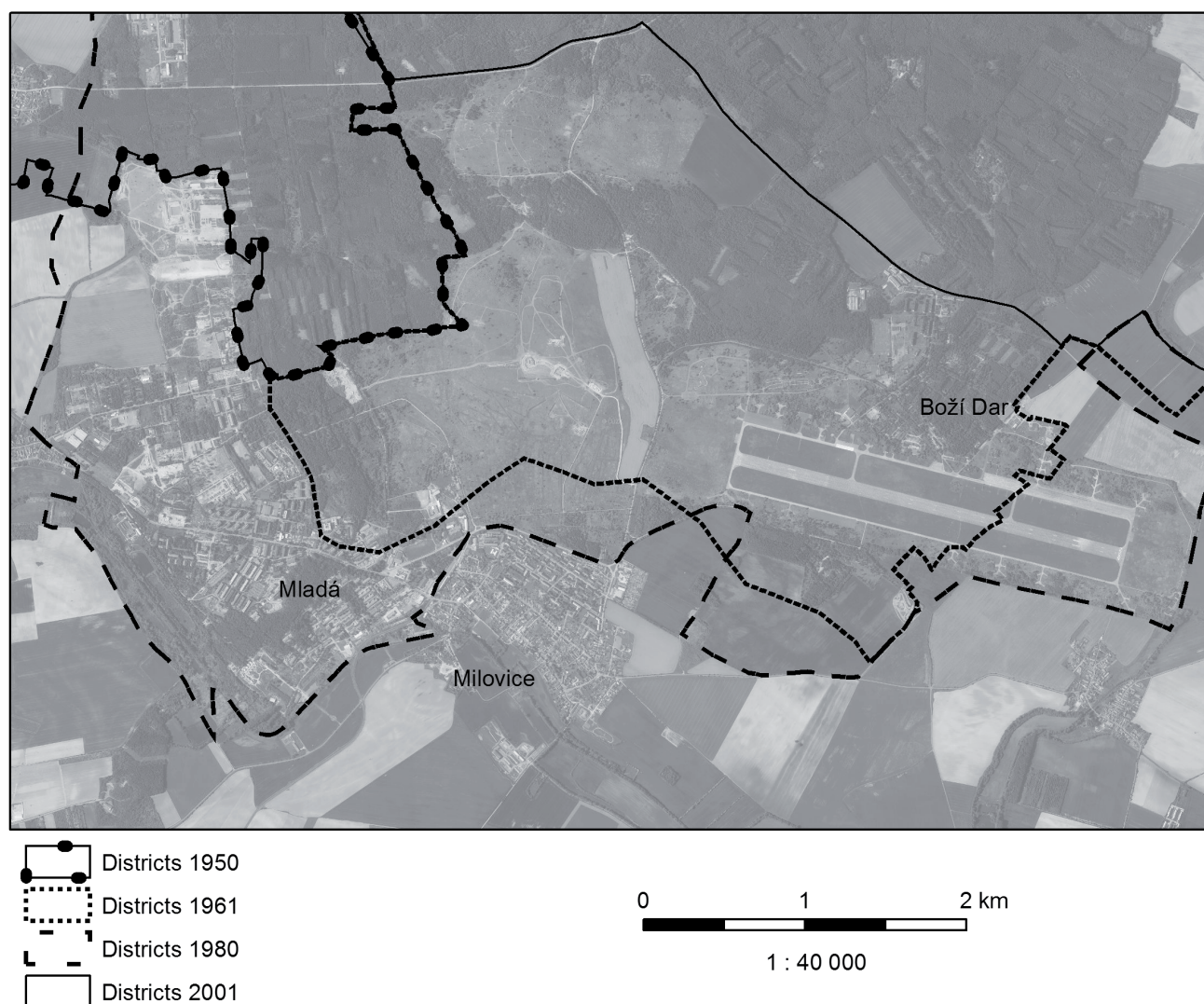


Fig. 2 Changes of the district borders of Mladá Boleslav caused by the establishment of the Milovice proving ground.

Source: Synoptic map of territorial organisation by February 1, 1949; Map of administrative subdivision of the ČSR 1960; Map of administrative subdivision of the ČSSR 1980; Polygon district layer from census 2001 (okresy_201102.shp); Orthophoto of Czechia (ČÚZK 2013); (for reference see Table 2).

4.3 Reconstruction of borders between Ostrava and Opava/Hlučín

Administrative borders led along watercourses experienced changes associated with both natural alterations of river basins and their artificial transformations made by man. Border changes were also commonly triggered by further expansion of large cities. Both factors are involved in the changes of borders between the districts of Ostrava and Opava/Hlučín (Figure 3).

The specialised map of the III. Military mapping (revised in 1927), which was used for the reconstruction of district borders existing in 1921, depicts the border between the two district as following the meandering Odra river. This, of course, does not resemble the extant regulated course of the Odra, nor does such border reflect the current cadastral partition which adapted to the regulation of the watercourse. In 1949, the Petřkovice

municipality became part of the district of Ostrava, although it lays on the opposite bank of the Odra. At that point in time, the district border ran between Petřkovice and Ludgeřovice. This state of affairs had lasted until 1960, when the district of Ostrava – city was established. This new district included only the immediate metropolitan area, and Petřkovice were subsumed by the district of Opava. The border therefore returned to the river Odra, although its meandering course (as captured by the administrative map of 1960) now differed from the version depicted by the III. Military mapping. In 1976, the municipality of Petřkovice was added to the city of Ostrava, wherefore the resulting border more or less copied the district border from 1950.

The regulation of the Odra river basin performed in the following years lasts till today. Since no currently available vector layers depict the meandering flow of the Odra prior to its artificial regulation, this natural border

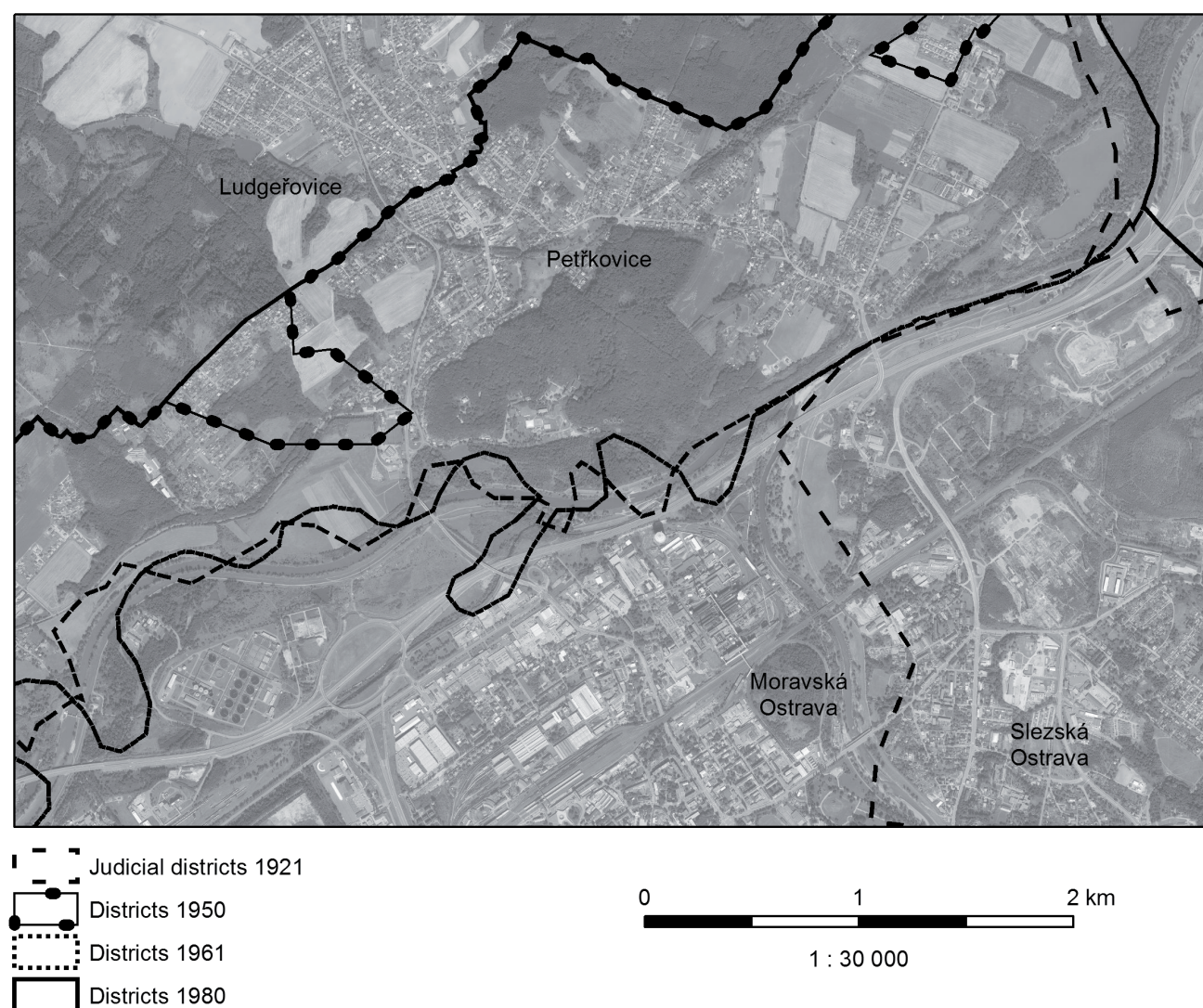


Fig. 3 Changes in the course of a border between the districts of Ostrava (Ostrava-město) and Hlučín/Opava.

Source: III. Military Mapping revised in 1927; Synoptic map of territorial organisation by February 1, 1949; Map of administrative subdivision of the ČSR 1960; Map of administrative subdivision of the ČSSR 1980; Polygon district layer from census 2001 (okresy_201102.shp); Orthophoto of Czechia (ČÚZK 2013); (for reference see Table 2).

had to be reconstructed with the assistance of contemporary source maps. However, each of the relevant maps portrays a somewhat different course for the meandering river. For an earlier period (until 1949), we used the river course captured by the map of the III. Military mapping, which is the most accurate of the available maps in terms of the reconstruction of historical borders. For the later time horizons (1961, 1970), we used the administrative maps pertaining to the specific years.

We are aware that it is impossible to cover all problems and challenges, let alone all cases for which the reconstruction of historical borders appeared to be problematic, over the course of one publication. Therefore, we tried to use these case studies to illustrate some of the typical difficulties which we encountered and which others are likely to encounter during a reconstruction of historical borders.

5. Discussion and conclusions

Although the creation of specific GIS layers always requires a certain degree of individualism (which would reflect the source data it builds upon, its purpose, its audience, etc.), it is necessary to maintain a unity of the system. This means using unified inputs for the vectorization and georeferencing, employing a unified coordinates system and proceeding according to a unified methodology. It is essential to preserve a unified topology across the entire dataset and to secure the production of relevant metadata. However, specific GIS elements which were subject to change over time demanded a specific way of processing – such as a coding system or the use of additional sources which could help with the reconstruction of border lines in areas with significant changes.

Cartographic visualization of historical statistical data have mostly only been possible within rather inaccurate borders and outside of the framework of GIS. Even partial outputs produced through the GIS have yet to fully make use of layers modified according to contemporary historical maps. This project is the first to introduce a reconstruction of the course of selected administrative borders in Czechia during the years of individual population censuses.

The aim was not only to propose a methodology for the processing of historical spatial and statistical data in the GIS, but primarily to provide the outputs of our applied research – authentic map layers and selected sorted statistical data, which form an interconnected spatial database. This database can be utilised by experts, students, or members of the public who wish to operate within the GIS environment and the outputs can be used in further basic or applied geographic research, as well as for teaching at both universities and high schools. One of their primary advantages is the nearly unlimited option to create custom “historical maps” within the GIS framework.

The discussed methodology for the application of historical spatial data within the GIS environment offers a detailed description of the approach from the selection of source map records, through the digitalisation of acquired data, georeferencing, all the way to the creation of shp layers and their joining with population censuses data. It places emphasis on the possibility of a replication of this approach in case of further, more detailed research carried out at the scale level of Czech municipalities, or of a reconstruction of a specific territory with changing administrative borders. Our broadly defined goal is to make historical spatial and statistical data produced during the past century accessible in the GIS framework. In light of this, we are open to collaboration with a range of organisations and institutions, as well as to constructive criticisms and suggestions for the improvement of the approaches presented in this article, in order to improve the access of both experts and members of the public to valuable sources of information on our national history.

The product of our research – the Geographic Information System of selected administrative units' borders in Czechia – includes 45 polygon layers of judicial districts (or districts since 1961), as well as the political districts (and regions) they combine into, on the territory of Czechia. It also provides the polygon layers of cadastral and census tracts existing during specific census years on the territory of Prague. All data is compiled in the ESRI Shapefile format (.shp) and the ESRI Geodatabase (.gdb) format, with names and numerical codes of relevant territorial units included in the attribute tables of these layers. We provide our outputs in two formats due to their distinct advantages. The advantage of the shapefile format consists in its unproblematic transferability between software types, its simplicity and accessibility (ability to easy access to the attributes), and its widespread use. The ESRI Geodatabase format then is designated to more advanced users, it compiles data into a single file and offers options to work with topologies, domains, subtypes, or spatially dependent attributes (Kartografie, e-learning portal 2013). Upon user registration, the elaborated files are freely available to the wider public for download, or comments, at www.historickygis.cz. The web portal also stores metadata files for the individual layers.

The project's principal output – the Geographic Information System of selected administrative units' borders in Czechia – will be further used for the creation of specialised large-scale maps and the Historical Population Atlas of the Czech Lands. These outputs will further contribute to a greater understanding of national and cultural identity and will open avenues for further research. However, we hope for a much more widespread utilisation of the produced outputs through research analysing the causal and developmental mechanisms of spatial polarisation, changes of sociocultural patterns, or socio-economic differentiations in Czechia. Proposals on further practical applications of the produced outputs are also

gradually being published in other publications (Ouředníček and Pospíšilová 2013; Semotanová 2013; Přidalová and Ouředníček 2014; Svoboda, Přidalová and Ouředníček 2014).

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RESUMÉ

Zpřístupnění historických prostorových a statistických dat okresů Česka v prostředí GIS

Článek je výstupem širokého výzkumného týmu sociálních geografů, kartografů, historiků, statistiků a archivářů, jejichž spolupráce byla nutná pro vytvoření doposud unikátních datových podkladů vztahujících se k historickým hranicím v prostředí geografických informačních systémů. Cílem článku je popis a vysvětlení jednotlivých kroků při přípravě prostorových vrstev (administrativních hranic) navázaných na rozhodné okamžiky sčítání lidu na území dnešního Česka v letech 1921–2011 a jejich zpřístupnění v prostředí GIS. Hlavním výsledkem práce je 45 datových sad ve formátech .shp a .gdb, které obsahují historické hranice soudních, politických a současných okresů pro celé území Česka a dále hranice městských obvodů, katastrálních území a urbanistických obvodů pro území hlavního města Prahy. Článek popisuje práci při získávání podkladových administrativních map, jejich zpracování, vektorizaci, georeferencování, přizpůsobení administrativním hranicím v rozhodné okamžiky sčítání a následné propojení s populačními daty obsaženými v jednotlivých sčítáních lidu mezi lety 1921–2011. Na případových studiích jsou detailně vykresleny hlavní problémy řešené při zpracování prostorových dat na příkladu vojenských újezdů nebo hranic vedoucích po měnicích se vodních tocích. Metodika tvorby datových podkladů i všechny výstupy jsou k dispozici odborné i širší veřejnosti na specializovaném internetovém portálu www.historickygis.cz.

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