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Cartographic modelling of administrative divisions in the "Historical Atlas of Poland"

Abstract. The author's aim is to reflect on the cartographic modelling of historical borders based on the example of the series "Historical Atlas of Poland. Detailed maps of the 16th century" (HAP). HAP presents secular (state, palatinate, district) and religious borders (dioceses, archdeaconry, deanery, parish). The belonging of historic settlements to administrative units is determined on the basis of written sources. During work on the current volumes of HAP, the borders were reconstructed through their manual interpolation (the so-called linear model). Digital tools enable the automatic generation of administrative units based on settlements in point geometry (Thiessen polygons) or the use of modern divisions (precincts [obręby ewidencyjne]) as a reference to them (semi-automatic method). The article compares and assesses the three mentioned methods of determining historical borders and the possibilities of harmonizing them in relation to contemporary administrative divisions. The source material consisted of 18,357 settlements from the volumes of HAP published so far and 235 parishes for detailed analyses. Precincts were adopted as reference areas due to the possibilities of data harmonization.

Keywords: historical cartography, historical atlas, historical geography, administrative divisions

1. Introduction

Reconstructing former administrative divisions and borders is in historical geography one of the most important parts of research on the so-called historical and political landscape. The role of cartography cannot be overestimated here: old maps are a source of data, and modern historical maps are a visualization of the reconstruction. An old map can provide direct information about the course of borders, which can be redrawn or – in the case of earlier periods – can serve as auxiliary material for the retrogressive method (B. Szady 2018). In the latter case, mainly written sources are used, which allow to assign settlements to given administrative units, and the borders between them are drawn by interpolation and topography analysis. The role of the historical map is to present the reconstruction of borders, usually in the form of lines. However, it informs rather about the settlements's belonging to specific administrative units. It is not a precise delimitation. For this reason, there were discussions regarding the reliability of the reconstruction of borders in cartographic form due to the high degree of hypotheticality of their course depending on the methods or sources used (F. Bujak 1906; T. Manteuffel 1929). Today there are also maps whose authors avoid linear presentation. This is how the parish territorial affiliation was presented in the Duchy of Nysa in the 14th century, as well as (W. Schich, J. Stephan 2015, p. 211) properties in the Brancion-Uxelles castellany in the 12th century (P. Boucheron 1998). The model of linear borders was recently criticised by Luca Scholtz (2019) who recognised – based on the example of the Palatinate in the 17th century – the point model for representing territorial affiliation as more adequate and devoid of uncertainty. It is not a coincidence that the above examples relate to the pre-industrial era. We are dealing with the

reconstruction of borders, and not redrawing them directly from old maps.

The first works of the administrative units cartographic reconstruction of Polish lands have been related to the pre-industrial era and today are continued in the series "Historical Atlas of Poland. Detailed maps of the 16th century" (hereinafter: HAP) being published in its present form since 1966 (H. Rutkowski 2018). The need to reconstruct borders appeared at the end of the 19th century together with a paper by Stanisław Smolka at the First Congress of Polish historians in Cracow in 1880. In line with the German current of research, the so-called *Grundkartenforschung,* he advocated the development of maps with border divisions and major settlements for the most important periods (B. Konopska 1994). Such maps were to serve other researchers and enable the development of a detailed historical map of Polish lands (S. Smolka 1881). Smolka's idea was implemented quite quickly. Aleksander Jabłonowski in the *Atlas of Ruthenia* determined borders depending on the quantity and quality of source materials, also taking into account rare border acts. In densely populated areas, he used the interpolation method, and in others he took into account the topography, including river basin ranges. He took into consideration the boundaries of estates, and sometimes determined borders mathematically (A. Jabłonowski 1899-1904; K. Chłapowski 2019). In the *Map of the Cracow Palatinate during the Great Sejm (1788-1792)* published before World War II, its authors Władysław Semkowicz and Karol Buczek (1930) quite accurately recreated the borders of the palatinates, districts, municipalities and church administration units (dioceses, archdeaconries, deaneries and parishes), using tax sources, lustrations of King's properties, censuses, and old maps. After World War II, the concept of modern HAP was developed. Six volumes have been published so far and the end of the series is planned for 2020. The most important part of the atlas is the main map in the scale of 1:250,000, which shows settlements (with name, type, size and ownership) and administrative boundaries: secular and religious from 16th century and topography (lakes, rivers, forests) based on maps from the turn of the 18th and 19th centuries (H. Rutkowski 2018).

The methodology of modelling (reconstructing and visualizing) borders in HAP has a long tradition, but in the era of digital tools it is subject to changes resulting from both the possibility of their determination (spatial analysis in GIS) and storing (databases) (I.N. Gregory 2002). The aim of the author of the article is to reflect on the cartographic development of historical borders in this series by analysing borders reconstructed using the traditional method and using digital tools. During the work on the previously published volumes of HAP, the borders were reconstructed in an analogue way, manually interpolating the lines between settlements belonging to different units (the so-called linear model). Digital tools enable the automatic generation of administrative units based on settlements in point geometry (Thiessen polygons) or the use of modern divisions (precincts [obręby ewidencyjne]) as reference data (semi-automatic method). The article compares and evaluates the three previously mentioned methods of determining historical borders and the possibilities of harmonizing them in relation to contemporary borders. The source material consisted of 18,357 settlements from the volumes of HAP published so far and 235 parishes for detailed analyses (the smallest administrative units). The analysis took into account the number of polygons (in the context of exlaves/enclaves), area, length and qualitative factors – a visual assessment of borders, the amount of time needed for preparation, and the possibilities of harmonization.

2. Borders in the "Historical Atlas of Poland"

Borders in the Early-Modern period, i.e. until 1795, were divided into two groups: public, which included secular and religious borders, and private ones, i.e. the borders of estates and property (K. Chłapowski 2019). Secular borders are primarily the state border, i.e. the Kingdom of Poland, the borders of palatinates, lands and districts. The latter were the smallest units of administrative division. The religious borders (related to the Catholic church) were designated by the dioceses, archdeaconries, deaneries and parishes. The parish was not only the smallest religious unit, but also played a role in organising secular space. Tax registers in the 16th century were organised by parishes (M. Gochna 2014).

The main map of HAP on a scale of 1:250,000 includes all of the above-mentioned types of borders, with the exception of the deanery borders, which are only shown on the church border map on a scale of 1:500,000. Borders are distinguished by color (secular – black, church – purple) and the complexity of the line suggesting their weight. Ownership borders are not included in any of the maps (except for the schematic distribution of ownership on the 1:500,000 map), but when determining public borders, they are taken into account.

Public borders have rarely been designated in the field, and rare delimitation documents have been preserved mostly for state borders, hence their reconstruction is approximate (K. Chłapowski 2019). Administrative affiliation concerned rather specific locations, hence in less populated areas, the drawn borders have a schematic course. Although there are sources which allow for their local, quite accurate reconstruction, these are rare situations and apply to small areas and require a lot of work (T. Związek, T. Panecki 2017; H. Rutkowski 2017). The reconstruction of borders in HAP is presented not only cartographically. An inherent element of each volume is a separate chapter entitled "Borders" (e.g. M. Gochna 2017; B. Szady 2017), in which the method of determining borders is described, as well as the difficulties and various problem-solving methods.

3. Methods for determining borders in HAP

3.1. Linear model

The linear model as a method of reconstructing borders was adopted by HAP in the 1950s and is based on the interpolation of the line between settlements belonging to various administrative units according to 16th-century sources. When drawing border lines, topography, historical and contemporary boundaries are taken into account on the principle of retrogression (H. Rutkowski 2019). Stanisław Herbst, when discussing the assumptions of the HAP draft (still in the scale of 1:200,000), recognised the reconstruction of borders as a very important element of the map content due to the retrospective study of earlier divisions, but also because of the possibility of carrying out statistical calculations on them (S. Herbst 1978). The basis for establishing the borders were parishes, because – firstly – the settlements in the tax registers (the main source of data for HAP) were ordered according to this key, and – secondly – they constituted the smallest spatial unit on the map. Their borders were delineated on the map using fragments of modern and historical borders – those that were reflected in old maps. The retrogression and interpolation methods were used. On the network of parish boundaries prepared in such a way, the borders of higher-order units, both religious and secular, were recreated. However, the borders of the parishes did not always coincide with the borders of districts (S. Herbst 1978).

The boundaries determined by this method are part of the content of HAP volumes published in 1966-2017, i.e. the Lublin, Mazovia, Łęczyca, Sieradz, Sandomierz, Cracow, Poznań and Kalisz palatinates[1]. In a sense, they can be a reference for (semi) automatic methods, discussed below, because they were developed by expert methods. However, their disadvantage is they require a lot of time. The atlas was developed manually (1966-1998), in graphic design software (2008) and in the GIS program (2017). The use of GIS in the work on HAP enabled to digitally harmonize data with other resources, e.g. contemporary borders and other geohistorical projects. As a result of work on the HAP English volume, which was an edition of the volumes from 1966-2008, the data was stored in a spatial database (M. Słoń 2014). The result is not only vectorized boundaries in linear geometry, but also a continuous surface model developed on the basis of the Least Common Geometry (T. Ott, F. Swiaczny 2001). Each polygon has a uniform set of attributes regarding administrative affiliation: secular (district, palatinate) and religious (parish, deanery, archdeaconry, diocese). This data, together with the settlements in point geometry, are available for download on the website of the project (Korona 2019). The result of developing the surface model based on linear borders is a grid of polygons that would serve as reference surfaces in further work on HAP, both in terms of territorial and chronological expansion. At that time, it was planned to introduce time attributes for individual polygons. The disadvantage of the reference layer adopted in this way were diffi-

[1] The last two were already developed in GIS and automated methods were partly used here.

culties in harmonizing historical data with modern administrative units, e.g. with the National Register of Borders - NRB [Państwowy Rejestr Granic - PRG]. Currently, 2785 polygons are in the database.

3.2. Thiessen polygons

An attempt to partially automate the determination of borders in HAP was made during the preparation of the volume covering Greater Poland (Poznań and Kalisz palatinates), where Thiessen polygons (also known as Voronoi diagrams) were used as an auxiliary means. It is one of the methods of automatic area tessellation and change of the discrete-point model into a continuous-surface model (K.E. Brassel, D. Reif 1979; W. Pokojski, P. Pokojska 2018). Polygons are created in such a way that the boundaries between points (e.g. settlements) are drawn exactly in the middle of the distance between them, which reflects the strength of the spatial impact of these points. The main feature of Thiessen polygons is the change of the phenomenon representation from point to surface using geostatistics and mathematical operations. As a result, the obtained model is a spatial model, continuous, but of a non-geographical nature, because when generating polygons, topographic barriers are not taken into account, only the distances between points. However, as research has shown on the example of the 18th-century Łuków distict, differences between the so-called the linear (analogue) model and the network (Thiessen polygons) model is 1.4% of the area (B. Szady 2010).

In this model, each point (one settlement) corresponds to one polygon (approximated area of the settlement). Assuming that settlements have a specific affiliation to administrative units, the *spatial join* tool can be used to transfer this information to polygons, and then *dissolve polygons* with uniform attributes (e.g. by district) and thus obtain a continuous and spatial reconstruction of borders automatically. The analysed data set covered 18,357 settlements, so the same number of polygons was created.

3.3. Precincts

Precincts [obręby ewidencyjne] are surface units of the division of the country, determined for the purposes of land and building records (the real estate cadastre in Poland)[2]. In rural areas, the precinct should include the area of the village and the physiographic objects adjacent to this settlement unit. In urban areas, the precinct may cover the entire city or a selected part of it. Precincts, and above all their borders, are directly related to the administrative division of the state. Precincts make up units [jednostki ewidencyjne], i.e. areas of land located within the administrative boundaries of the municipality, and if the municipality includes a location with the status of a city – also within the administrative boundaries of the city. One precinct is part of one unit, and one unit is part of one municipality. In this way, the precinct borders can also constitute the borders of a municipality, poviat, voivodship, and country. Precincts are made available as an element of NRB. Despite their official (state) nature, data from NRB has some inconsistencies in relation to other registers: the National Register of Geographic Names – NRGM [Państwowy Rejestr Nazw Geograficznych – PRNG] and the National Register of Administrative Units – NRAU (Krajowy Rejestr Urzędowy Podziału Terytorialnego Kraju – TERYT). The inconsistencies concern both the number and types of settlements, e.g. 604 villages which are part of the NRAU database are missing in NRB (J. Zieliński 2019). The choice of NRB as the reference base for harmonizing the HAP borders results from the surface nature of this register (NRGM and NRAU store point data).

The methodology of using precincts to set boundaries in HAP assumes giving them administrative attributes of historical places. In the case of analogue interpolation of border lines, the border is drawn between settlements (points) and can be processed into a continuous (polygonal) form. For Thiessen polygons, borders are automatically generated around the settlement. The effect of both approaches is an area with attributes of administrative affiliation. When using precincts, the stage of drawing or generating borders is skipped for the benefit of assigning attributes to particular precincts in the area of which there are settlements with specific administrative affiliation.

[2] http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU20190000393/O/D20190393.pdf

In the analysed set collected in 2018, there were 54,001 precincts. This resource was limited to 31,144 precincts as they only included precincts which in whole or in part lay within the area of analysis designated by the HAP volumes developed until 2017. The next step was to assign each precinct information about the 16th-century administrative affiliation, using spatial relations with settlements in point geometry for this. Therefore, in the case of this method, we have a relationship between historical points and contemporary polygons, not historical and contemporary polygons. Four scenarios were possible by assigning data from the settlements to the precincts (fig. 1).

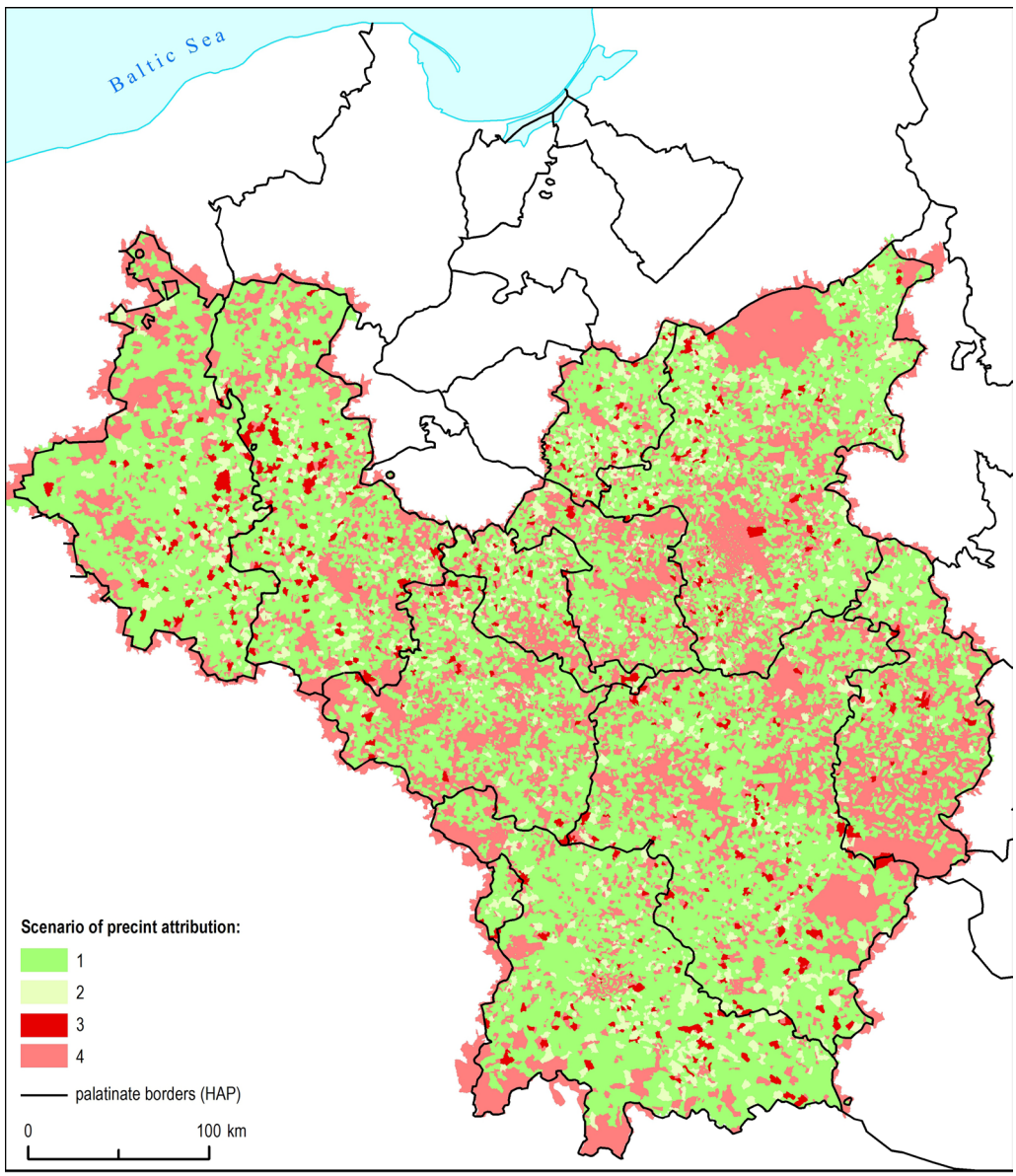

Fig. 1. Assigning attributes of historical administrative belonging to precincts

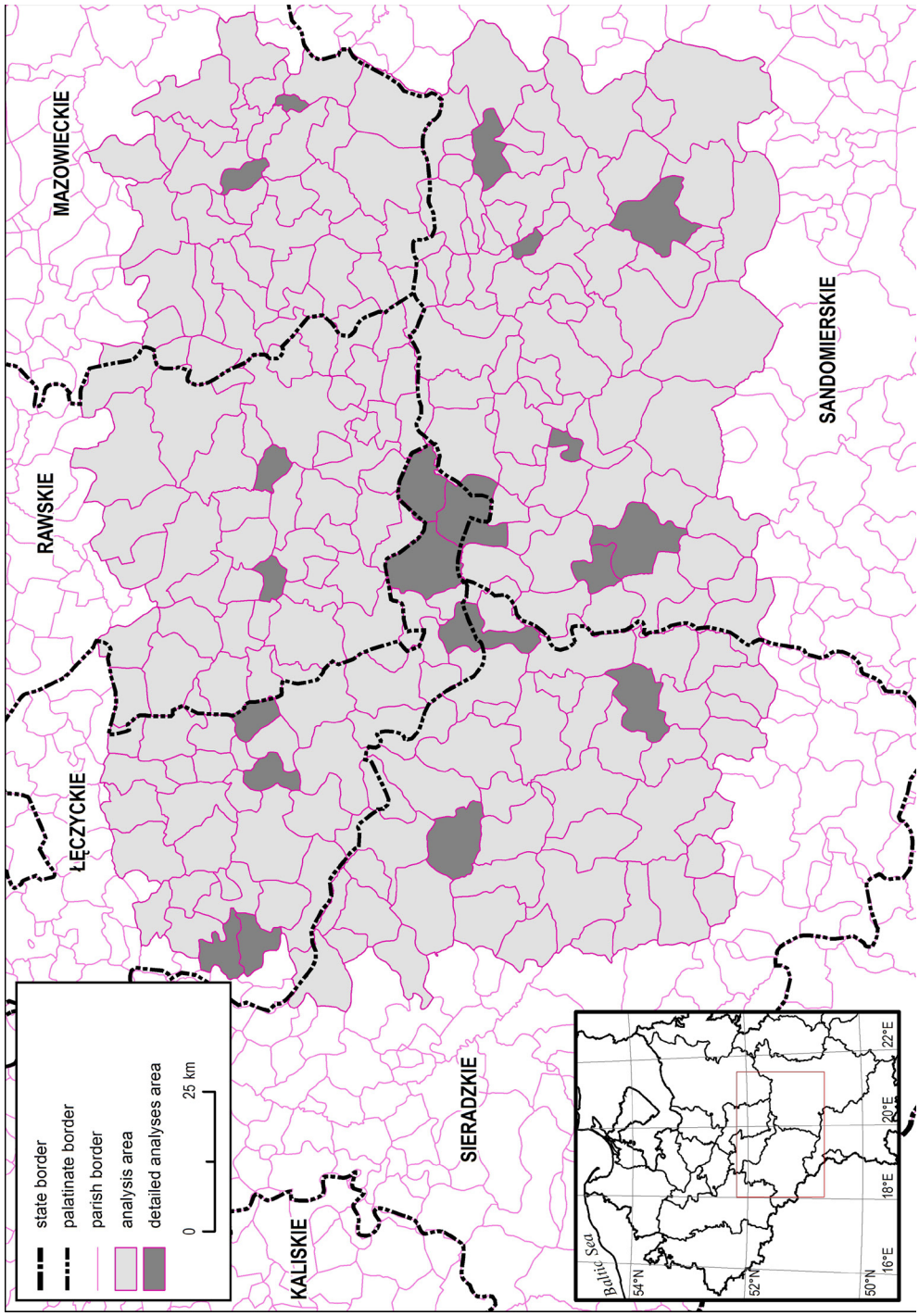

Fig. 2. Area of detailed analysis. 235 parishes from the area of the 16th-century Kingdom of Poland

The first, positive scenario, is when there is one historic settlements in the area of the precinct. The precinct in which this settlement is receives its attributes (43% of precincts).

The second scenario, also positive, is when there is more than one historical settlement in the area of the precinct, but they have the same administrative (secular and religious) affiliation. There were 1658 (5.3%) such precincts, of which 85% were precincts with two settlements.

The third, negative scenario is a situation where there is more than one settlement in the precinct area and their administrative affiliation is contradictory. This means that such precinct should be divided until the given polygon will contain settlements with consistent attributes. This division is done manually using the retrogression method, as in the case of the interpolation of linear boundaries in previous volumes of HAP. There are 488 (1.6%) of such precincts, of which 439 relate to inconsistencies in parish affiliation, 105 district affiliation, and 51 – in both.

The fourth, also negative scenario is when there is no settlement in the precinct. In this situation, each precinct (49%) should be assigned the attributes of the settlement nearest to it in accordance with Tobler's first law of geography (1970).

4. Detailed analysis results

Detailed analysis, which took into account the number of units with exclaves, their areas, and the length of borders, was carried out for parishes. These are the smallest administrative units, of which (with few exceptions) consist of higher-order units, both religious and secular. In the entire analysed area, i.e. the crown palatinates developed in HAP until 2017, there are 2,390 parish polygons, including their exclaves. 10% of them were selected for detailed analyses, located possibly in the central part of the entire area so that the problem of extrapolation of borders (Thiessen polygons, harmonization to precincts) was not significant (fig. 2). There were 2,592 settlements in the area, of which 4 had uncertain parish affiliation ("X or Y" parish), but nevertheless were included in one of these parishes in HAP, and 13 were located in two parishes (parish "X" and "Y"), which means that the point with the settlement was on the border of the polygons.

In the linear model, which was created as a result of the direct vectorization of HAP, 239 polygons corresponding to 235 parishes were in the analysed area (4 of them had exclaves). There are 11 more parishes in the model based on Thiessen polygons and precincts, which results from the aggregation of data according to parish affiliation ("X and Y"). A separate polygon is e.g. the "Drzewica and Bieliny" parish, while Zychorzyn located in this area in the linear model lies on the border of both parishes (fig. 2). Data on the number of polygons is presented in table 1.

In the light of this analysis, it can be concluded that (semi) automatic models generate a greater number of exclaves of administrative units than the linear model. A large number of exclaves in the model based on precincts results from their high level of detail. In this case, we are also dealing with a parish, which is divided into 6 polygons (as opposed to two in the other models).

The next criterion for assessing these methods is the surface area of the units and the length of the borders developed or generated using them. 20 parishes were randomly selected for this analysis from among the analysed parishes (fig. 2). The choice was made only on the basis of settlements with a certain parish affiliation. Excluded from the analysis were those in the area of locations belonging to two parishes (Thiessen polygons and precincts), and whose border passed through a point with a settlement (linear model). The results of the analysis are presented in tables 2 and 3.

Table 1. Number of polygons according to analysed methods

	Linear model	Thiessen polygons	Precincts
Number of polygons	239	260	282
Number of polygons with exclaves	4	14	26
2 exclaves	4	13	19
More than 2 exclaves	0	1	4

Table 2. Length of borders according to analysed methods (20 random parishes)

Parish name	Linear model [km]	Thiessen polygons [km]	Length of border in comparison with the linear model [%]	Precincts [km]	Length of border in comparison with the linear model [%]
Babsko	26,3	22,9	87,1	31,9	121,3
Chorzęcin	53,2	49,8	93,6	77,4	145,5
Chynowo	26,5	23,5	88,7	30,8	116,2
Dalikowo	35,9	31,5	87,7	42,5	118,4
Dłotów	43,1	50,7	117,6	57,9	134,3
Dobra	31,3	33,9	108,3	43,7	139,6
Domaniewo	44,2	43,0	97,3	58,4	132,1
Goworczów	24,0	23,4	97,5	29,3	122,1
Inowłodz	50,5	55,1	109,1	82,7	163,8
Janisławice	25,0	24,7	98,8	26,8	107,2
Jarosławice Nadolne	17,9	18,5	103,4	25,6	143,0
Jastrząb	53,7	49,7	92,6	69,0	128,5
Lubocheń Wielki	49,9	40,7	81,6	64,6	129,5
Mierzyn	47,3	54,4	115,0	62,0	131,1
Niesułków	26,7	25,8	96,6	34,4	128,8
Rozniszewo	17,3	13,3	76,9	21,7	125,4
Rzeczyca	40,5	39,6	97,8	63,8	157,5
Wojcin	33,2	34,9	105,1	37,6	113,3
Wsola	40,6	49,9	122,9	51,0	125,6
Żarnów	57,8	64,5	111,6	74,0	128,0
SUM	744,9	749,8	N/A	985,1	N/A
MEAN	37,2	37,5	99,5	49,2	130,6

The analysis shows that in the model based on Thiessen polygons, the border lengths are very similar to those developed in an analogue way (99.46%). This may indicate a similar degree of line generalization that can be obtained by manual interpolation and the automatic method. 12 parishes had shorter borders, and 8 had longer borders (changes from –23.1% to +22.9%). The unit areas are on average smaller by 6% compared to the reference ones. In the case of 13 parishes, the area obtained with Thiessen polygons was smaller than in the linear model, and in the case of 7 parishes it was larger (from –29.5% to +12.5%). These differences may be due to the non-geographical nature of the area's tessellation and the demarcation of the border between points halfway between them, without taking into account topographical obstacles or modern borders. The reverse situation is in the model based on precincts. The unit surfaces are similar (only 1.33% larger). For 9 units they are smaller and

Table 3. Area of units according to analysed methods (20 random parishes)

Parish name	Linear model [km^2]	Thiessen polygons [km^2]	Area of unit in comparison with the linear model [%]	Precincts [km^2]	Area of unit in comparison with the linear model [%]
Babsko	35,3	24,9	70,5	31,7	89,8
Chorzęcin	84,7	74,0	87,4	86,1	101,7
Chynowo	31,8	31,9	100,3	31,3	98,4
Dalikowo	52,5	46,8	89,1	53,8	102,5
Dłotów	100,2	101,9	101,7	104,6	104,4
Dobra	44,7	42,2	94,4	45,6	102,0
Domaniewo	55,3	44,4	80,3	46,4	83,9
Goworczów	21,2	17,5	82,5	20,3	95,8
Inowłodz	116,8	131,4	112,5	115,9	99,2
Janisławice	30,4	29,5	97,0	30,3	99,7
Jarosławice Nadolne	16,9	18,1	107,1	16,9	100
Jastrząb	117,6	122,1	103,8	126,1	107,2
Lubocheń Wielki	121,7	102,5	84,2	128,4	105,5
Mierzyn	92,7	90,1	97,2	89,0	96,0
Niesułków	40,2	35,4	88,1	44,1	109,7
Rozniszewo	13,0	10,6	81,5	17,6	135,4
Rzeczyca	79,7	74,4	93,4	82,4	103,4
Wojcin	45,2	39,4	87,2	45,9	101,5
Wsola	63,4	68,4	107,9	60,0	94,6
Żarnów	124,9	137,3	109,9	119,8	95,9
SUM	1288,2	1242,8	N/A	1296,2	N/A
MEAN	64,4	62,1	93,8	64,8	101,3

for 11 they larger (from –16.1% to +35.4%). For one parish, the area obtained by both methods was the same. However, the length of borders using this method increased by 30%. All parishes have longer borders (from +7.2% to +63.8%). This is mainly due to the high detail of the image of the precincts, which are a derivative of land borders. The consequence of this would be the need for generalization so that their level of detail corresponds to a 1:250,000 map.

In assessing individual methods in the context of their usefulness for determining borders in HAP, more qualitative aspects should also be taken into account, such as: a visual analysis of borders, the time required for implementation, and the possibility of harmonizing units with other resources, e.g. contemporary ones. Figure 3 presents a fragment of the HAP main map with borders developed using three methods. In general, the course of the borders is similar. Each unit contains locations that have

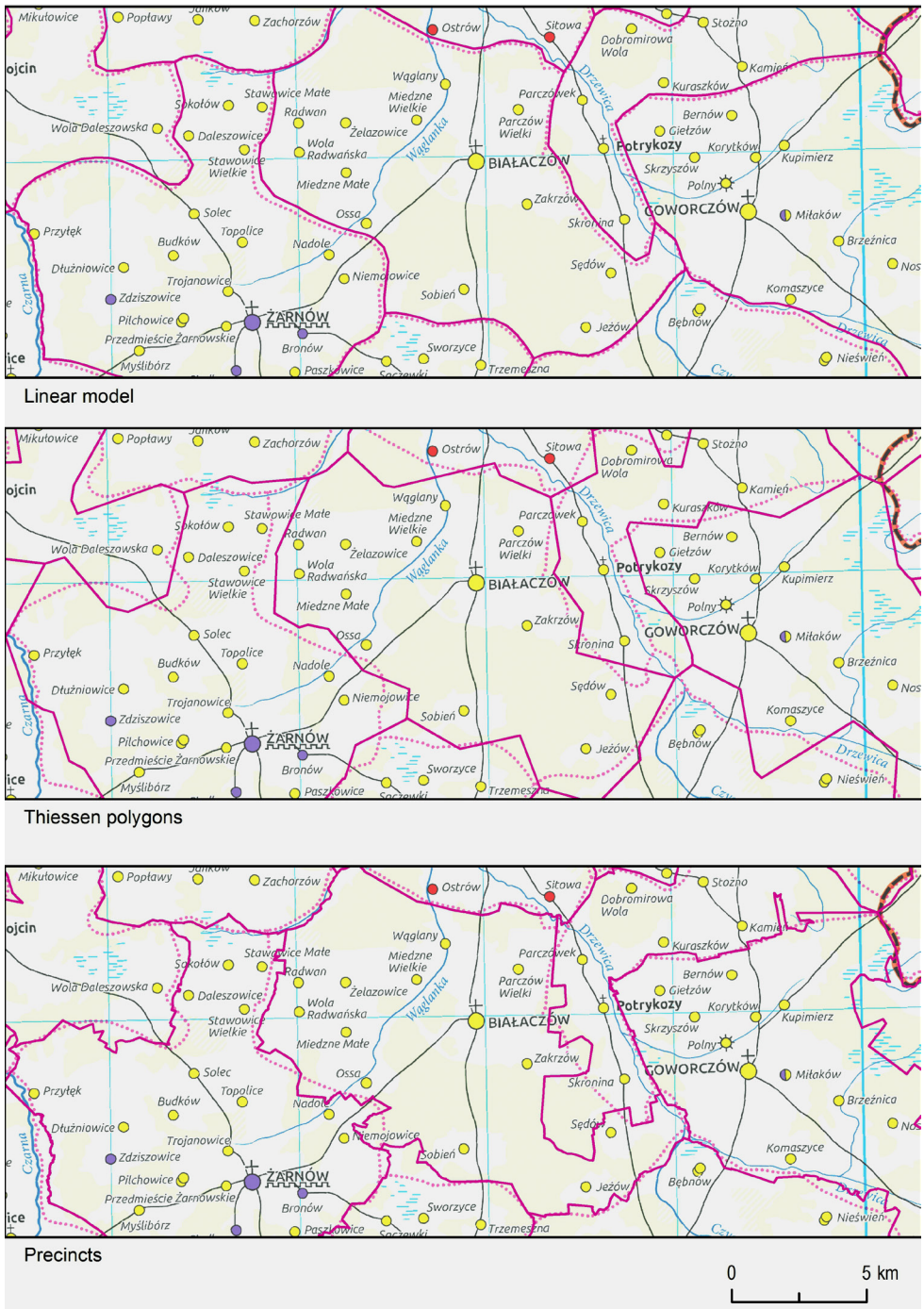

Fig. 3. A part of the HAP main map with parish boundaries developed using three methods: the linear model, Thiessen polygons, and attribution of precincts; the base map is an English edition of HAP, and the dotted line represents the linear model

the same attributes of historical administrative affiliation. The higher the settlement density, the more accurate the picture is, regardless of the method used. Thiessen polygons provide a picture that is by far the most schematic, differing from the linear model, but also from the precincts due to the omission of topography at the stage of generating borders. Borders developed on the basis of precincts have a very detailed course, which requires generalization and simplification, not only graphic but also substantive. Contemporary borders were shaped largely on the basis of 19th-century ownership divisions (e.g. as a result of land subdivision), which are ahistorical in relation to the 16th-century divisions. In terms of time consumption, the Thiessen polygon method is by far the quickest in determining borders. Only points with settlements and attributes are needed to generate them. Attributing precincts through spatial relationships requires – in some cases – their division, and is also burdened with uncertainty for those precincts in which there is no data (locations). The linear model is the most time consuming and requires the manual vectorization of boundaries. Harmonizing administrative units with other resources, including modern ones, is possible in principle only for precincts. Historical borders from different years can be referenced to them, which ensures data integrity.

5. Summary

For the cartographic visualization of borders, both (semi) automatic methods should be used only for the initial stage of its preparation. The second stage consists of editing, including adapting the drawing to the map scale and considering the base content. In the context of work on HAP, the advantage of Thiessen polygons is the speed of generation, while the advantage of precincts is the possibility of harmonization with other data. The disadvantage of Thiessen polygons is too much schematicity and the need for more detail, and the disadvantage of precincts is too much detail and the need for generalization. A feature of both automatic methods is the difficulty in modelling certain situations, e.g. settlements located on borders, which have "X and Y" in their attributes. Such cases require manual adjustment and result from the nature of the modelled phenomenon.

Given the above, in the work on the last volumes of HAP (Royal Prussia, Kujawy and Podlasie, planned to be completed in 2020), it was decided to use the precincts as the basis for reconstructing borders. This was primarily due to the desire to harmonize historical administrative divisions with contemporary ones, which only this reference set enables. However, the precincts are not directly mapped, but are subject to cartographic editing in accordance with HAP requirements. They require editing, which can be partly automated using the generalization algorithms available in GIS programs. In their source form, together with the attributes of 16th-century administrative units, they constitute one of the main layers in HAP spatial data resources.

To sum up, in historical cartography we will therefore strive to develop two related data models: the source model (precincts or other reference data) and the cartographic model (generalized borders developed on their basis), which requires the development of a conceptual model and its two physical implementations. The analogy to the topographic (landscape) and cartographic (symbol) model present in topographic cartography is clear here (A. Głażewski 2006).

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