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ATTEMPTS AT SPATIAL ANALYSES OF DATA FROM THE POLISH ARCHAEOLOGICAL RECORD

ABSTRACT

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Since the mid-1970s, the Polish Archaeological Record has been a national program in Poland with the primary objective of cataloguing archaeological sites, providing detailed descriptions and exact geographical locations. It is in operation to this day. So far, approximately 90% of the area of Poland has been prospected and almost 470,000 archaeological sites catalogued. Currently, work is underway to digitise the entire database. This paper presents our attempts to use the digitised data from this database to study the intensity of settlement processes in the past as well as how to visualise these data on a map. For the purpose of this research, archaeological data from an area in the northeast of Poland were digitised in a GIS environment. Examples of similar spatial analyses were taken from Scottish and Czech research and adapted to this case. The results, a series of maps showing the intensity of traces of human habitation in different time periods, demonstrate the strengths and weaknesses of such visualisations.

Keywords: GIS, Polish Archaeological Record, archaeological prospection, spatial data, spatial analysis
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INTRODUCTION

As David Unwin noted back in 1996, the importance and availability of spatial analyses will grow, especially those based on data that can be easily imported into a GIS (Geographic Information System) environment – GISable (Unwin 1996, 548-549; Openshaw and Clarke 1996, 21-30). Now, over 20 years after this statement, spatial analyses performed in a GIS environment are ubiquitous in almost every area of life and the economy. The ease of preparing this type of analysis results from the relative ease of collecting spatial data on the basis of currently available instruments and methods. A problem arises, though, when we want to use for spatial analysis data that were not collected with the intention of being used in a GIS environment. The Polish Archaeological Record is a large archive of such spatial data.

The first attempt at making a systematic catalogue of archaeological sites in today's Poland can be dated back to the mid-19th century. The field prospection carried out at that time, however, did not have a standardised methodology and was rather local in scope. The methodology of this type of research was significantly developed in 1965-1974, when Stefan Woyda (then conservator of the Warsaw Voivodeship) conducted a large-scale survey of the area around Warsaw, inventorying dozens of previously unknown archaeological sites (Woyda 1981, 11-20; Kozioł *et al.* 2012, 133-135). Based on these experiences, efforts were made to extend the research to the entire territory of Poland. The year 1978 can be regarded as the official start date of the national program "Polish Archaeological Record" (pol. Archeologiczne Zdjęcie Polski – AZP). It was then that the methodology for conducting surface archaeological prospection was formulated for this project, a manual for the preparation of documentation was created, and the "Form of Archaeological Site" (pol. Karta Ewidencji Stanowiska Archeologicznego – KESA) was developed (Grabowski 2012, 73, 74). In following years, the name of the form was changed to Archaeological Monument Record Sheet (pol. Karta Ewidencji Zabytku Archeologicznego – KEZA), and its current name is Land Archaeological Monument Record Sheet (pol. Karta Ewidencyjna Zabytku Archeologicznego Lądowego – KEZAL).

For the Polish Archaeological Record project the entire area of Poland was divided into rectangular polygons. In the assumptions made in the 1970s, such a polygon should have a size that fits an A4 sheet of paper when scaled to 1:25,000 on a map. According to this, in reality, the size of a polygon is approximately 5 km North-South and 7.5 km East-West, with an area of 37.5 km^2 (Kozioł *et al.* 2012, 134; National 2012). Every such polygon has a unique number. A grid of these polygons is available to download as a WMS (Web Map Service) and free to use in a GIS environment.

The Polish Archaeological Record project continues to the present day and over the years has been periodically modernised, including the use of GPS (Global Positioning System) devices and GIS applications (Bryk and Chyla 2013, 19-27), DEMs (Digital Elevation Model) obtained with the use of LiDAR (Light Detection and Ranging) technology (Zapłata *et al.* 2018, 95-103), and the inclusion of archaeological sites located within cities (Florek 2018, 59-67) and underwater (Kaźmierczak 2018, 83-89). Recently it has been focusing on acquiring information about archaeological sites with the use of non-intrusive prospection (Oniszczuk and Makowska 2021). So far, approximately 90% of the area of Poland (the area of Poland is 312.696 km^2) has been surveyed, and almost 470,000 archaeological sites have been catalogued (Siemaszko 2018, 7, 8; Niedziółka 2016, 122). Over the past few years, work has been underway to digitise the entire database. Part of it is already included on the website of the Polish National Institute of Cultural Heritage, which is currently managing this database (Oniszczuk and Makowska 2017).

According to David Ebert's hierarchy, which consists of three levels of GIS application in archaeology (Ebert 2004, 320, 321), the Polish Archaeological Record database pertains to the first two levels: "visualisation" – it shows the location and size of archaeological sites, and "management" – it organises and generally classifies information about archaeological sites. Combined data from these two levels enable us to perform the procedure from Ebert's third level: "analysis".

This paper presents our attempts to use the digitised data from the Polish Archaeological Record to study the intensity of settlement processes in the past and how to visualise the results of spatial analysis on a map. Similar efforts were performed recently on the basis of the same data, but these have tended to focus on changing the parameters of visualisation (Kołodziej 2011, 85-91) or on statistical analysis (Niedziółka 2018, 115-134), rather than typical spatial analysis. Here, spatial analysis will be carried out using GIS. The results, a series of maps presenting the intensity of traces of human habitation in different time periods, will show the strengths and weaknesses of such visualisation.

METHODS AND RESULTS

In the Polish Archaeological Record project, every archaeological site has its own record sheet. A set of information about each archaeological site is described therein, including precise administrative information (town, municipality, county) and details specifying the type of archaeological site, its chronology, type of acquired archaeological sources and also specifying who conducted the research and when. The area and location of an archaeological site is shown on the attached map at a scale of 1:10,000. A geoportal with the location of already digitised archaeological sites is available at https://zabytek.pl. This enables archaeologists to display and categorise the locations of archaeological sites (defensive architecture <fortifications, shafts, castles>, sacral architecture <places of worship, temples>, manor houses and palaces, mounds, battlefields, sites with an economic function, settlement sites <hillforts, caves, settlements>, sepulchral sites and others) and chronology (the main periods being Palaeolithic, Mesolithic, Neolithic, Bronze Age, Iron Age, 600 AD, 1000 AD, 1500 AD, 1700 AD, 1900 AD).

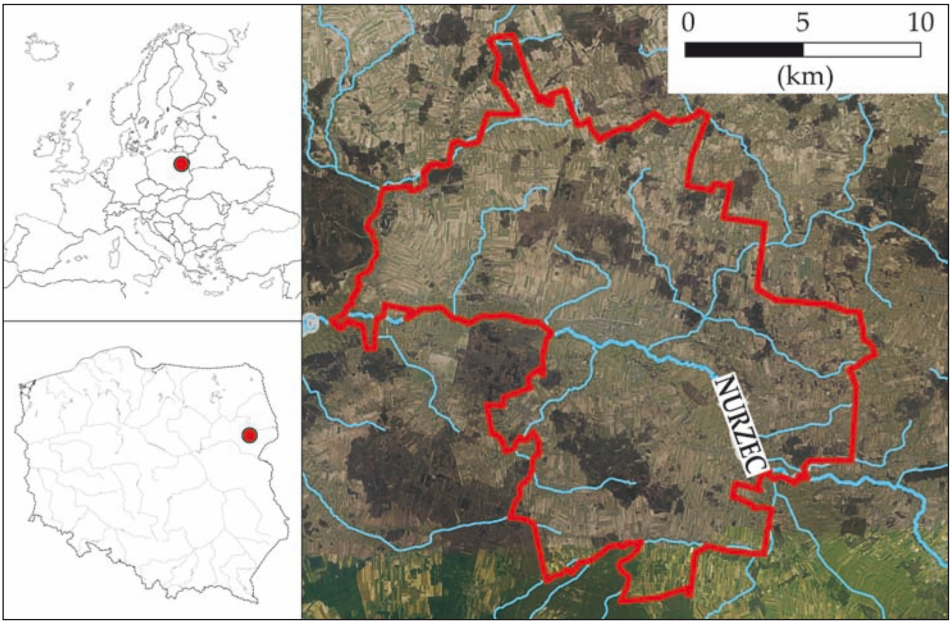

Fig. 1. Location of Brańsk Commune, an administrative area the Archaeological Record of which is the subject of spatial analysis (source: www.geoportal.gov.pl; processing by R. Solecki)

For the purpose of this research, archaeological data from one administrative region in Poland was scanned from the original paper documents, then digitised, vectorised and optimised for GIS. Brańsk Commune in northeast Poland was chosen as the geographical area of interest (Fig. 1). It has an area of 259 km². It is located on a plain, which is crossed by the Nurzec River, flowing from east to west. Two significant tributary rivers, the Siennica and the Czarna, also run through the area. This area is of interest because of the presence of 1208 catalogued archaeological sites with traces of human habitation (Table 1). The oldest confirmed archaeological finds can be dated back to the Palaeolithic era, with many sites from the Mesolithic, Neolithic and Bronze ages also present (Romaniuk 1994, 4-13), but there are also traces of human habitation from the Early Iron Age linked with the pre-Roman period and then from Early Mediaeval to Early Modern times. For the purpose of preparing the GIS database, when traces of two or more phases of habitation were found in one location, each phase was counted as a separate archaeological site

Brańsk Commune is covered by 15 AZP polygons. All archaeological records within these polygons were digitised in the GIS and described with five characteristics:

• AZP ID – the unique number attributed to every catalogued archaeological site.

• Type – the type of archaeological site. They were classified as traces of habitation (513 sites), small temporary camps (228 sites), settlements (444 sites), cemeteries (19 sites), hillforts (3 sites) and a manor (1 site).

Table 1. Information about the chronology and types of archaeological sites within the borders of Brańsk Community (processing, R. Solecki)

	Palaeolithic	Mesolithic	Neolithic	Bronze Age	Early Iron Age	Early Medieval	Medieval	Late Medieval	Early Modern	Sum
Traces of habitation	78 15.2% 84.8%	62 12.1% 81.6%	18 3.5% 69.2%	93 18.1% 58.5%	47 9.2% 51.6%	49 9.6% 24.6%	37 7.2% 40.2%	47 9.2% 30.7%	82 15.9% 25.6%	513 100% 42.5%
Small temporary camps	14 6.1% 15.2%	13 5.7% 17.1%	6 2.6% 23.1%	24 10.6% 15.1%	3 1.3% 3.3%	44 19.3% 22.1%	19 8.3% 20.7%	25 11.0% 16.3%	80 35.1% 25.0%	228 100% 18.9%
Settlements		1 0.2% 1.3%	2 0.4% 7.7%	39 8.8% 24.5%	37 8.3% 40.7%	94 21.2% 47.2%	35 7.9% 38.0%	81 18.3% 53.0%	155 34.9% 48.5%	444 100% 36.7%
Cemeteries				3 15.8% 1.9%	4 21.1% 4.4%	10 52.6% 5.1%			2 10.5% 0.6%	19 100% 1.6%
Hillforts						2 66.7% 1.0%	1 33.3% 1.1%			3 100% 0.2%
Manors									1 100% 0.3%	1 100% 0.1%
Sum	92 7.6% 100%	76 6.3% 100%	26 2.2% 100%	159 13.2% 100%	91 7.5% 100%	199 16.5% 100%	92 7.6% 100%	153 12.7% 100%	320 26.4% 100%	1208 100% 100%
Entry: quantity % in row % in column										

• Chronology – assigned to predetermined periods – Palaeolithic (92 sites), Mesolithic (76 sites), Neolithic (26 sites), Bronze Age (159 sites), Early Iron Age (91 sites), Early Mediaeval (199 sites), Medieval (92 sites), Late Medieval (153 sites), Early Modern times (320 sites). This division was necessary to identify the distinct categories that would apply to every type of archaeological site chronology recorded on the record sheets. The original descriptions varied – sometimes they referred to an archaeological culture (*e.g.*, Corded Ware culture), sometimes to an archaeological epoch (*e.g.*, Stone Age) and sometimes to a specific century or even decade. Without systematisation it would not be possible to use this data in further analyses.

• Artefacts – amount of artefacts – mostly ceramic sherds of different vessels – collected during field prospection.

• Size – determined upon gaining information on the archaeological site during field prospection. Here, there were six categories:

$\mathbf{1} \le 100\ m^2 < \mathbf{2} \le 5000\ m^2 < \mathbf{3} \le 10000\ m^2 < \mathbf{4} \le 50000\ m^2 < \mathbf{5} \le 150000\ m^2 < \mathbf{6}$

The size categories presented above, which correspond to the amount of ceramic sherds found during field prospection, served as the basis for assigning a value to each archaeological site.

The intensity of occurrence of archaeological sites in given area, which may be linked with density of habitation, can be visualised as a choropleth map, in a grid of squares. Similar attempts to visualise the intensity of occurrence of archaeological sites in a specific area were undertaken in Scotland. From the mid-1980s, field prospections were carried out by the former Royal Commission on the Ancient and Historical Monuments of

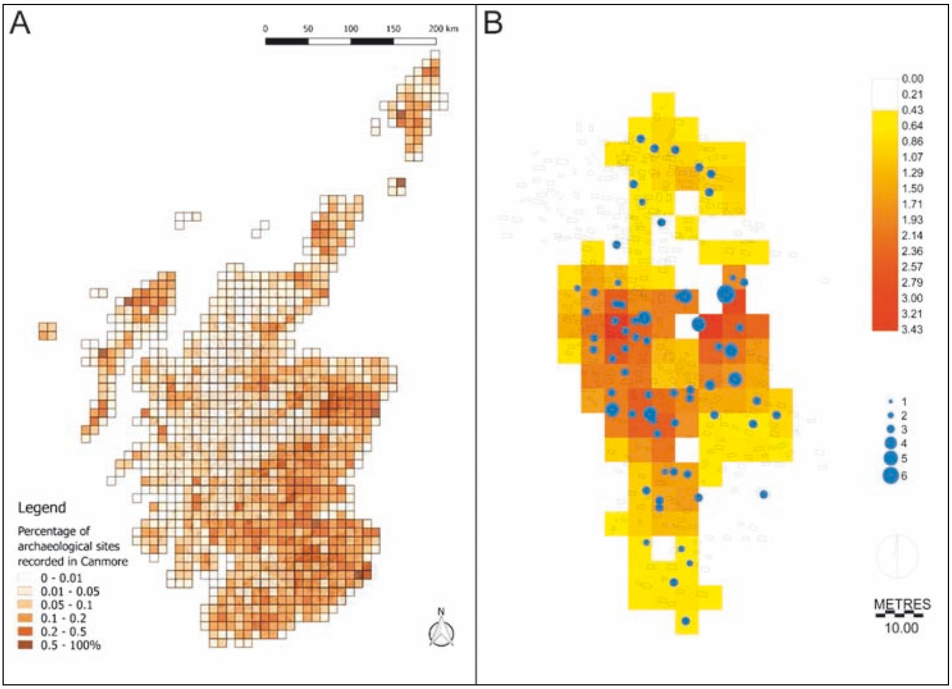

Fig. 2. A – density of archaeological records in Scotland (Banaszek *et al.* 2018, fig. 2), B – distribution of artefacts among the cemetery visualised in the square grid (Šmejda 2004, fig. 10)

Scotland (abbrev. – RCAHMS) and recently by Historic Environment Scotland (abbrev. – HES). The results were catalogued in the National Record of the Historic Environment (abbrev. – NRHE). Because of the uneven coverage of prospection across the country, the data cannot be used for spatial analyses on a national or regional scale. For the purposes of presenting the current state of the archaeological database, an interesting map was prepared (Fig. 2: A) which shows the density of archaeological records in Scotland organised in 10 km grid of squares (Banaszek *et al.* 2018). Such maps with a grid of squares are constructed in such a way that the intensity of colour in each cell represents the density of archaeological sites. A regular pattern enables spatial analysis in a GIS environment, which is characteristic of raster data (Herbei *et al.* 2018, 151-156).

Another similar example of presenting spatial data, but of micro-scale, was that from a prehistoric cemetery at Holešov in the Czech Republic. The method of presenting spatial analyses results in regular 5 m grid squares was used there to show the distribution of artefacts within the cemetery. It is important to note that the value shown in each cell was not the result of counting of artefacts within its borders but was instead recalculated using a mean filter with a kernel made up of a 3 × 3 grid of cells (Fig. 2: B). This procedure was used to reduce the errors that can be visible while visualising the "raw" values; these errors

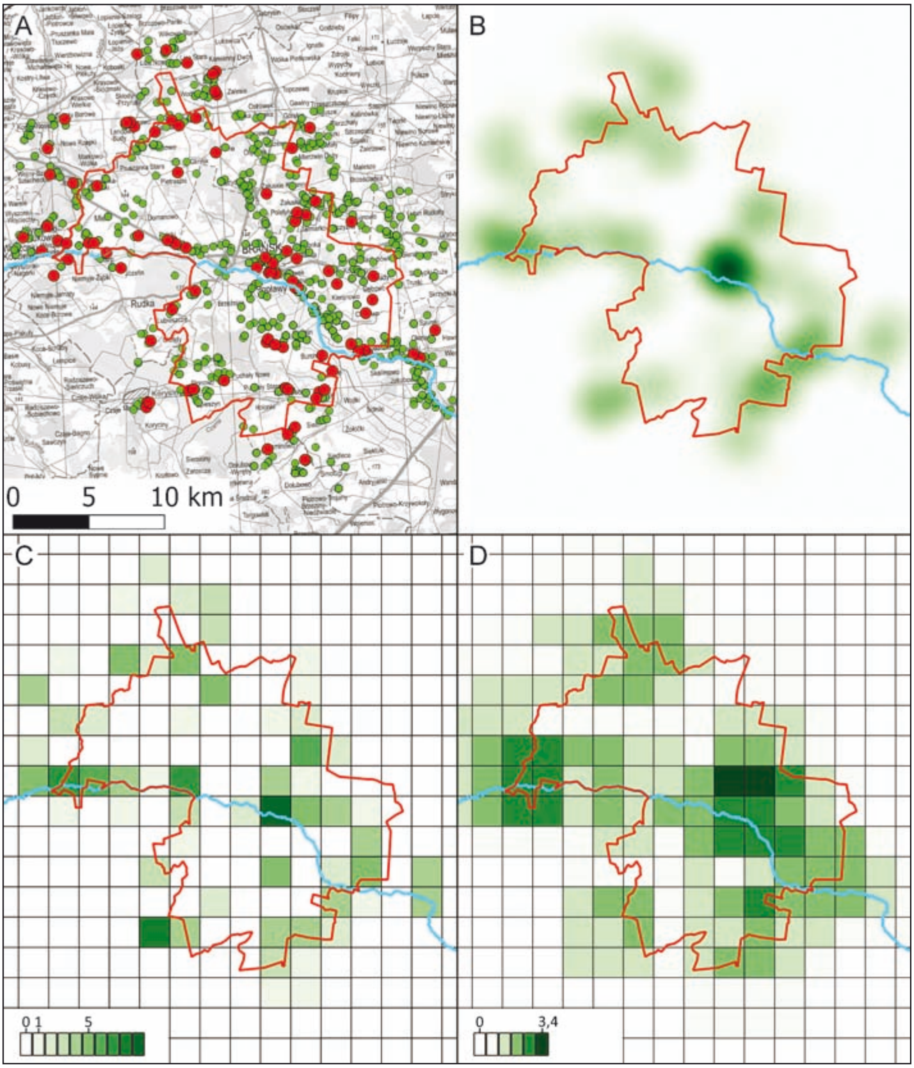

Fig. 3. Examples of visualisation of the density of Palaeolithic sites within the borders of Brańsk Community: A – on the background of a topographic map (green points – all archaeological sites; red points – Palaeolithic sites), B – the cluster map, C – grid of squares colourised on the basis of the quantity and size of the sites, D – grid of squares colourised on the basis of the quantity and size of the sites and then recalculated with a mean filter with a specified kernel size (processing R. Solecki, P. Smereczyńska)

can appear when the input point of the grid is changed and the grid is moved (Šmejda 2004, 59-63).

The simplified method – without using a mean filter with a specified kernel size – had already been used in Poland to analyse the distribution of flint material at the Neolithic

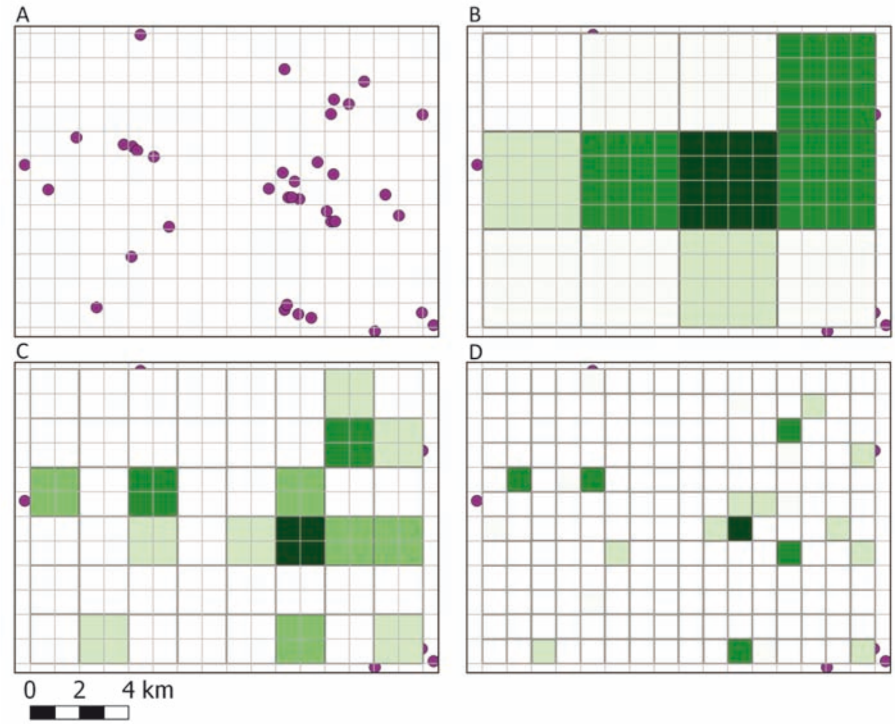

Fig. 4. Different variants of visualisation of archaeological sites located in the same area: A – location of sites in relation to a grid of squares, each with side length of 1 km, B – visualisation of the density of sites in relation to a grid of squares, each with a side length of 4 km, C – visualisation of the density of sites in relation to a grid of squares, each with a side length of 2 km, D – visualisation of the density of sites in relation to a grid of squares, each with side length of 1 km (processing, P. Smereczyńska)

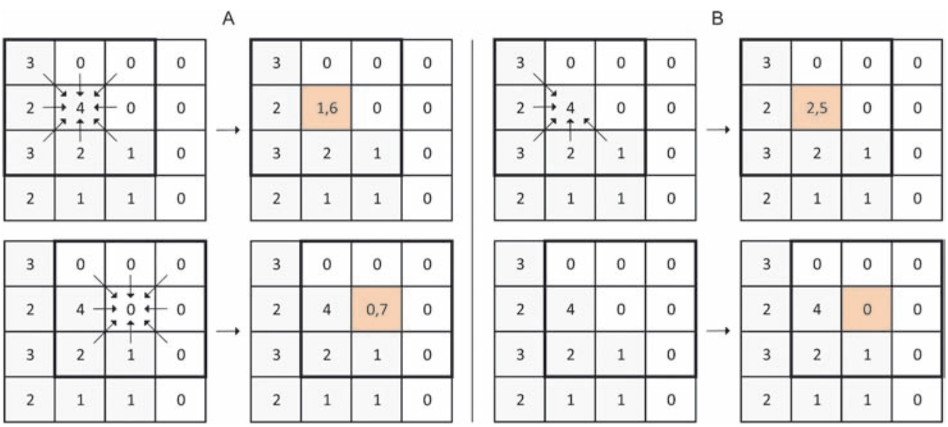

Fig. 5. Methods of recalculation of values: A) mean filter with a kernel in a 3 × 3 grid, B) a mean filter with a kernel in a 3 × 3 grid, ignoring cells where the value is "0" (processing R. Solecki)

flint mine “Oszybka” in Pakosław. Apart from this analysis, there was a cluster map that showed the concentration of artefacts. This kind of visualisation of spatial data was easy to perform and refine (Szubski *et al*. 2017, 116-119).

Here it is worth to mention the presentation of spatial data in the form of choropleth map needs a proper source data (absolute or relative, unprocessed or processed), carefully chosen aggregation area and a proper graphic scale (Pieniążek and Zych 2017, 122-130; Pieniążek *et al*. 2015, 50-59; Nowacki 2019). It is also important to choose a proper classification method to show analysed spatial data with the most higher accuracy (Całka 2018). Without a proper alignment of these variables the choropleth map will show an invalid presentation.

In order to visualise the data from the Polish Archaeological Record, tools and plugins provided by QGIS were used (version 3.22 Białowieża). The results of spatial analyses performed are in the form of maps showing the intensity of occurrence of archaeological sites. As an example, Figure 3 shows visualisations of Palaeolithic sites, with the intensity of occurrence displayed as a green gradient.

The easiest way to visualise the data was by using a “Heatmap renderer”. This allows one to set the radius of the occurrence and to define the weight of the points based on a specific characteristic – here it was based on the size of the archaeological site (Fig. 3: B). This kind of visualisation does not require any additional actions and can be prepared straight after the database is properly completed.

The second example of visualisation requires a regular grid of squares, each with a side length of 2 km, to be laid over the region of interest. The grid was set parallel to the axis of the flat rectangular coordinate systems PL-1992 (EPSG 2180). The input location of the grid was chosen randomly in order to potentially cover the digitised locations of archaeological sites evenly. The 2 km grid seemed to show the optimal precision of analysed data – the 4 km grid was too generalised, and the 1 km grid was too itemised (Fig. 4).

To visualise the data in a prepared grid of squares, it is necessary to count the cumulative value of the archaeological sites in every cell and classify it in equal intervals (Całka 2018, 23). The maximum of that range is the highest summation value (Fig. 3: C). This kind of visualisation is closest to the original data recorded in the Polish Archaeological Record archive, but it is not robust when the input point of the analytical grid is changed – shifted along the X or Y axis. To make the visualisation more robust, a mean filter with a 3x3 kernel was applied to the recalculation in a square grid (Fig. 3: D). Such recalculation gives a more stable visualisation, but the precision is significantly lower. This is because during recalculation with this method, cells where there were no archaeological sites and which had a value of “0” gained a new mean value (Fig. 5: A).

To reduce the blur effect, cells with a value of “0” were ignored during the recalculations. A mean filter with a 3 × 3 kernel was applied to cells with a value greater than “0” (Fig. 5: B). This procedure has made the visualisation of data more resistant to changes of location of the grid, and only cells containing archaeological sites were colourised. It also

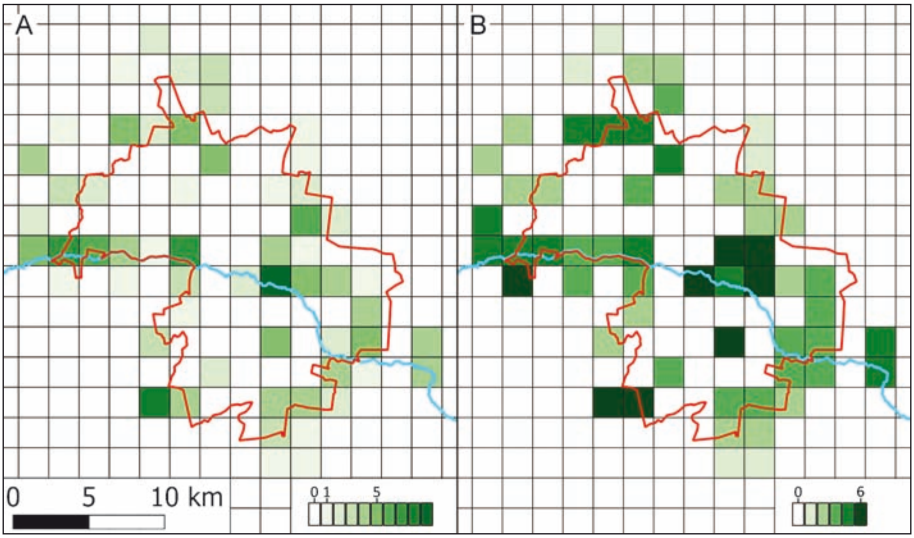

Fig. 6. Examples of visualisation of the density of Palaeolithic sites within the borders of Brańsk Community: A – a grid of squares colourised on the basis of the quantity and size of the sites, B – a grid of squares colourised on the basis of the quantity and size of the sites, recalculated with a mean filter with a kernel in a 3 × 3 grid, ignoring cells where the value is "0" (processing, R. Solecki, P. Smereczyńska)

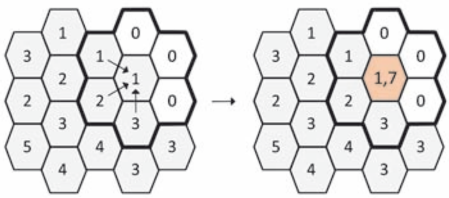

Fig. 7. Method of recalculation of values by mean filter with a kernel in a super-hexagon built with seven hexagons and ignoring cells where the value is "0" (processing, R. Solecki)

presents the density of archaeological sites at a similar level to the one where there was only counting and visualising of sites in the grid (Fig. 6).

The third example of visualisation is similar to the second one but with a difference in the shape of the cells in the grid – they are no longer squares but hexagons inscribed in circles with a radius of 2 km. Hexagonal grid cells are better suited for the purpose of spatial analyses as the distances between the centres of neighbouring cells are the same, while in a square grid there are two different values (Sousa *et al.* 2006, 191-194). Moreover, despite the hexagonal shape, they can still be processed and analysed like raster graphics (Sousa and Leitão 2018). This means that the modified mean filter with a kernel – in a grid of super-hexagons composed of seven hexagons – can be calculated to reduce the blur effect

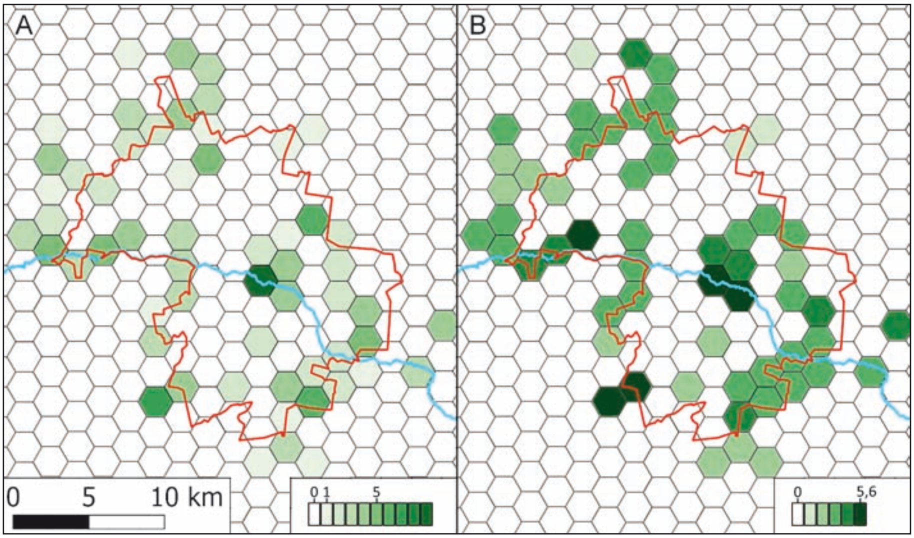

Fig. 8. Examples of visualisation of the density of Palaeolithic sites within the borders of Brańsk: A – a grid of hexagons colourised on the basis of the quantity and size of the sites, B – a grid of hexagons colourised on the basis of the quantity and size of the sites and then recalculated with a mean filter with a specified kernel size (processing, R. Solecki)

in cells where there is no archaeological site (Fig. 7). The simple counting and visualising of sites in the grid of hexagons (Fig. 8: A) looks clear and is readable, but with the addition of a mean filter with a specified kernel size (Fig. 8: B) it has both previous advantages and additionally it is more resistant to changes in the input point of the analytical grid.

DISCUSSION

When it comes to the Polish Archaeological Record project, the raw information gathered during field prospection and archived on the archaeological sites record sheets, are difficult to use automatically within a GIS environment. The problem is not only in digitising this information. The main issue is that the records are unsystematised. The way the record sheets were filled in was arbitrary because for many years, basically, every researcher did this in his or her own way. In many cases some parts of the record sheets were left blank. Now, after the Polish National Institute of Cultural Heritage has published more and more complete instructions for filling in the record sheet, recently filled in forms are usually correct. However, the older documents are still waiting to be standardised.

The problem with visualisation of data from the Polish Archaeological Record project is also that it covers the area of Poland in uneven way. This is because the archaeological data gathered in the 20th and the beginning of 21st centuries were mostly acquired from open, agricultural fields. The forested areas were left without prospection. This changed when LiDAR technology allowed the localisation of archaeological sites also beneath the tree canopies, which had a big impact on Polish archaeology (Stereńczak *et al*. 2020). The result of omitting of forested areas during field prospection is the Polish Archaeological Record is incomplete. That means the results of spatial analyses will always be subject to error.

To visualise the spatial data other methods can be used as well, for example contour line method. Such attempts have been already made in archaeology (Ahlrichs *et al*. 2016). The visualisation methods presented here, as stated in title of the article, are just our attempts to use the data from the Polish Archaeological Record archive as a basis for spatial analyses of the intensity of the occurrence of archaeological sites. When developed, this may be used to analyse past habitation processes. However, even at this stage, it shows how relatively quickly and effectively we can assess the development of settlement in a given area.

The squares used to build the grid had sides with a length of 2 km and the hexagons were inscribed in circles with a radius of 2 km because this size was the most useful to analyse the discussed area. The size of the cells can be easily modified if it is necessary to analyse a larger or smaller area and to obtain the best research results.

The area in which this study took place was somewhat out of context because it was not the territory of any particular archaeological culture but rather an artificially created administrative unit. Selecting, for example, an area occupied by a specific archaeological culture for analysis could bring much more interesting results.

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