ANALECTA ARCHAEOLOGICA RESSOVIENSIA
VOLUME 12 RZESZÓW 2017

DOI: 10.15584/anarres.2017.12.17

Piotr Szmyd*

Using Geografic Information System (GIS) Tools to Determine the Settlement Preferences in the Upper Wisłoka Valley and to Demarcate Potential Archeological Sites on the Example of Early Medieval Sites

ABSTRACT

Szmyd P. 2017. Using Geografic Information System (GIS) Tools to Determine the Settlement Preferences in the Upper Wisłoka Valley and to Demarcate Potential Archeological Sites on the Example of Early Medieval Sites. *Analecta Archaeologica Ressoviensia* 12, 299–328

The article's objective is to conduct a diagnosis of early medieval settlement and to determine settlement clusters and preferences. The analysis results enable the preparation of maps depicting potential sites. The basic source for the data used in the analyses consists of information collected since the 1970s within the framework of the nationwide Polish Archaeological Record (PAR) project. The data have been subjected to analyses using Geographic Information System tools, such as QGIS, GRASS GIS or Saga GIS.

Key words: GIS, archaeological national heritage, predictive modelling, archaeology, Upper Wisłoka Valley, QGIS, SAGA, GRASS GIS, settlement archaeology, Geographic Information System, Archaeological Predictive Modelling

Received: 15.10.2017; **Revised:** 01.11.2017; **Accepted:** 01.12.2017

Using Geographic Information Systems (acronym GIS) in archaeology enables a multidimensional analysis of the gathered spatial data, including PAR data. It also allows for acquiring new information through merging data originating from different sources, enabling the formulation of hypotheses and their initial testing. An additional advantage is the possibility of introducing new methods of analysis and visualising archaeological data in a three-dimensional form that had been thus far unachievable. This form of presentation is attractive for the general public, i.e. people who do not have contact with archaeology on a daily basis. The term Geographic Information Systems encompasses various spatial and descriptive data (e.g. PAR data, satellite images, documentation from archaeological research), computer software, such as QGIS or GRASS, the user, e.g. the author of this article. GIS enables bringing together data originating from different sources. It makes use of all digital and

* The Carpathian Troy Open-Air Museum at Trzcinica, Trzcinica 646, 38-207 Przysieki, Poland; pszmyd@poczta.fm

analogue materials, e.g. records from archaeological research or non-invasive surveys, satellite imagery, aerial photographs, data from laser scanning. At the heart of every information system there is a database in which all descriptive data is gathered (Borowski, Zapłata 2013, 104). GIS is not a single computer programme but rather a "spatial toolbox" that contains combinations of a few different programmes and technologies.

The use of GIS in archaeology dates back to the end of the 1970s and the beginning of the 1980s. However, due to technological progress and the popularisation of computers, GIS only became widely used in the 1990s. It is worth adding that a number of programmes for analysing spatial information exist, accessible online on Open Source licences (Borowski, Zapłata 2013, 104).

All of the below presented analyses and activities aim to enable acquiring knowledge and a better understanding of the factors that shaped settlement in the Upper Wisłoka Valley. They provide aid in determining clusters and reading settlement preferences, which ultimately will enable determining the factors that had an influence on the choice of locations for settlement.

The analysed territory consists of 11 PAR areas covering about 427 km^2. These areas are located in strips 108–111 and in columns 70–72. The PAR data used in the analyses conducted below were provided by the Subcarpathian Museum in Krosno (Figs. 1, 2).

In administrative terms, the vast majority of the discussed area is located in the Podkarpackie (Subcarpathian) Voivodship in Jasło County. This terrain is diverse in terms of its geological structure, landform and type of soil. From the south, the area opens with the rolling landscape of the Foothills of Jasło, which to the north border the Jasło and Sanok Valleys and the Gorlice Depression. To the north, the area ends with the Hills over the Warzyce, which constitute part of the Foothills of Strzyżów and with the dominant massif of Liwocz Mountain, part of the Ciężkowickie Foothills (Fig. 3).

Thanks to the Polish Archaeological Record (PAR) project conducted since 1978, the reference databases for studies into prehistoric and medieval settlement have been greatly expanded. The data acquired in the course of surface surveys constitute the main framework for the below-presented analyses. This article also makes use of data from the so-called ASTER Digital Elevation Model (DEM), which maps the surface of the terrain, constituting a basis for the preparation of exposure

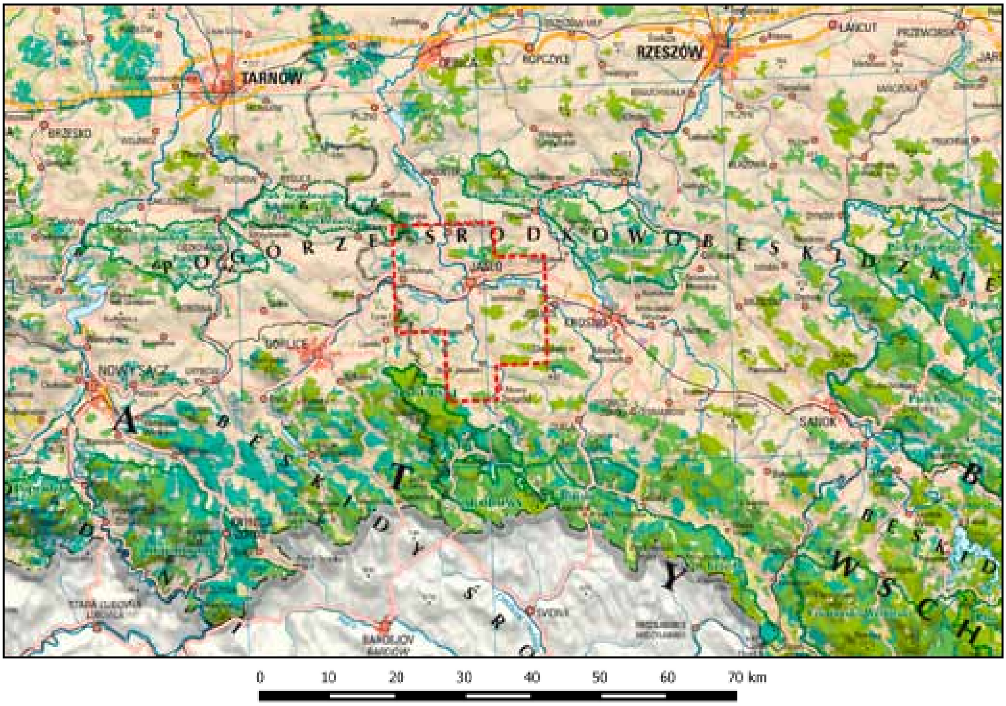

Fig. 1. Research area marked with a red dashed line

maps, slope gradients, as well as height and humidity charts and 3D visualisations. It also enables preparing an analysis of the visibility or of the profile cutting for the selected area.

All of the analyses presented below were made using open-source programmes available online. The core of the analyses was done using the 2.8.2 and 2.12.3 versions of QGIS software and the GRASS programme. My research also involved the application of SAGA GIS software. The ASTER Global Digital Elevation Model (GDEM) was downloaded from the following site: https://asterweb.jpl.nasa.gov/gdem.asp.

In the first stage of my work, I digitalised the PAR map sheets, which were then georeferenced, i.e. they were written into the spatial arrangement. The PAR map sheets were transformed to fit the 1992 National Geodetic Coordinate System (Państwowy Układ Współrzędnych Geodezyjnych). Next, each of the sites registered during the PAR studies was vectorised as polygon layers. Each of them was assigned its own unique features taken from the archaeological site index card. Information

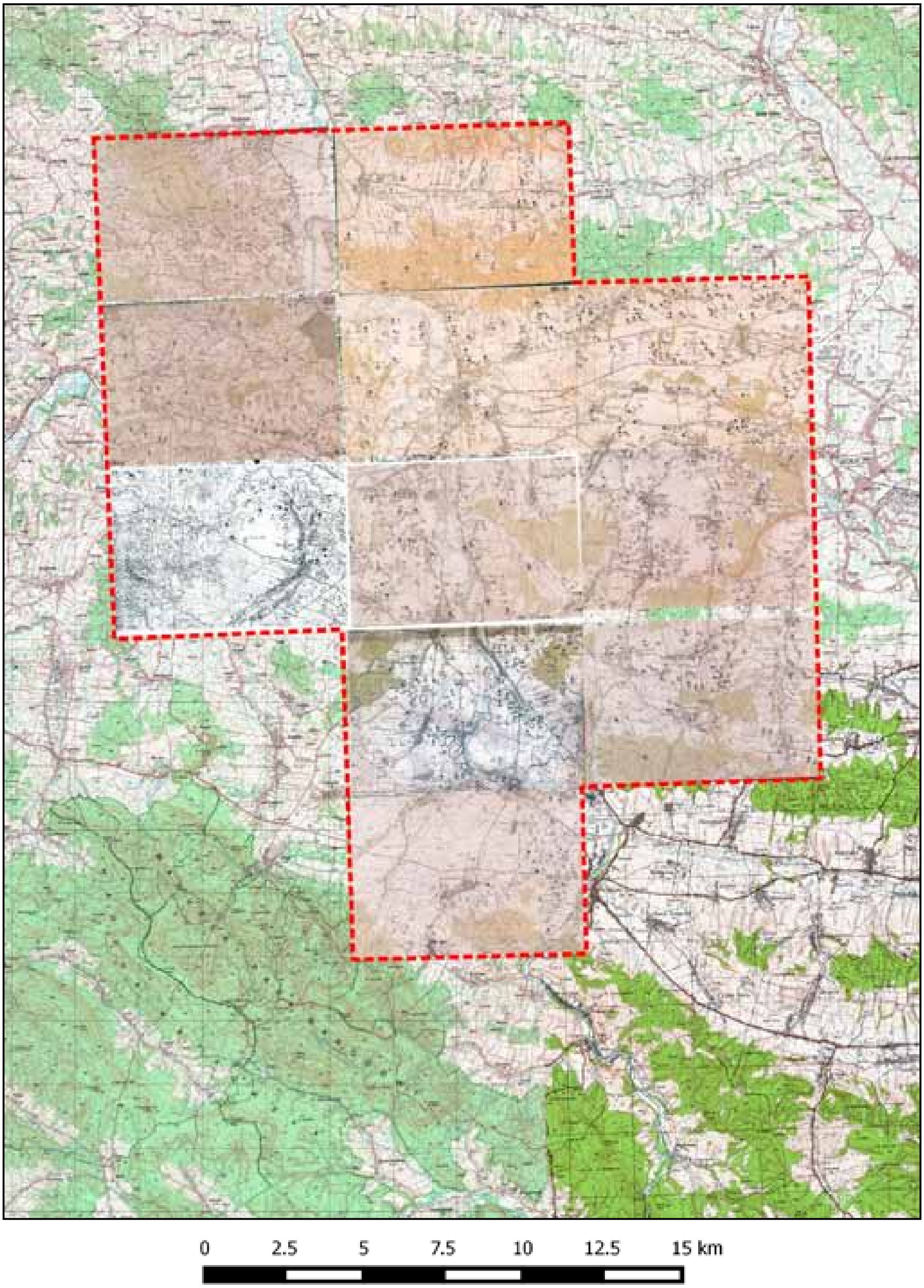

Fig. 2. Research area – close-up. The analysed area includes 11 PAR map sheets

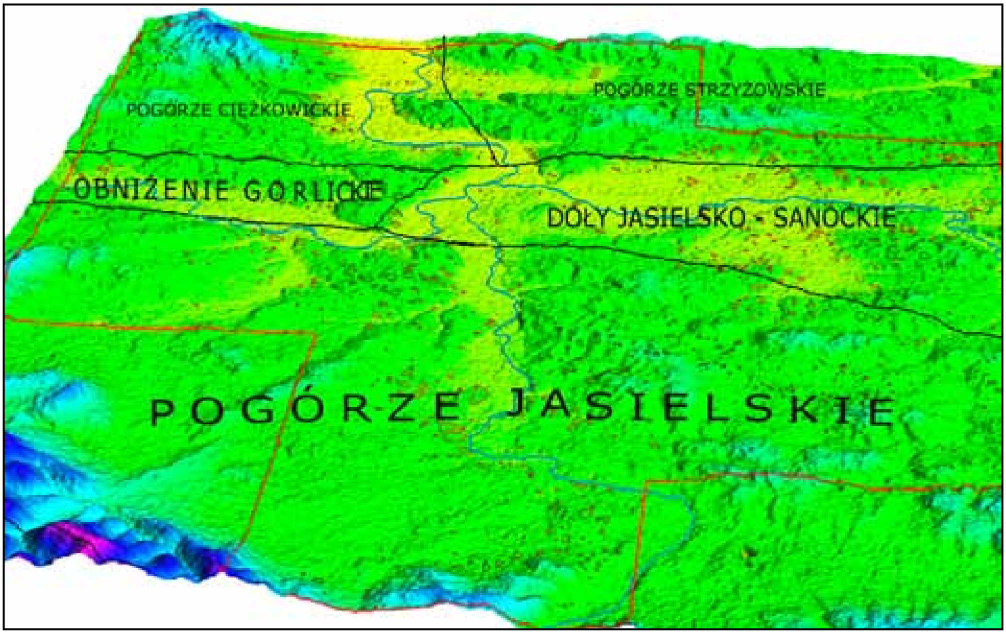

Fig. 3. Plastic representation of the studied area with a division into microregions accordnig J. Kondracki 1980

about the chronology, structure functions, type and quantity of discovered artefacts were found in the QGIS database. The data was subjected to analysis, the result of which will be presented in the form of maps. One advantage of creating such databases is the possibility of reusing them depending on the objective and area of analysis and the scale of the studied surface.

In an area covered by 11 PAR map sheets, on a surface amounting to ca. 427 km^2, 1010 archaeological sites were recorded, out of which 183 were dated to the Early Middle Ages (7th/8th–12th centuries). These latter sites constitute the basis for further multifactorial analyses aiming to determine settlement clusters, identify the nature of early medieval settlement and establish settlement preferences, which would allow for a demarcation of places with conveniently located archaeological sites (Fig. 4). From among the 183 sites dated to the Early Middle Ages, settlement points were identified in 79 of them. 63 sites were shown to have traces of settlement. 37 sites were categorised as settlements. The function of a settlement was established based on the amount of

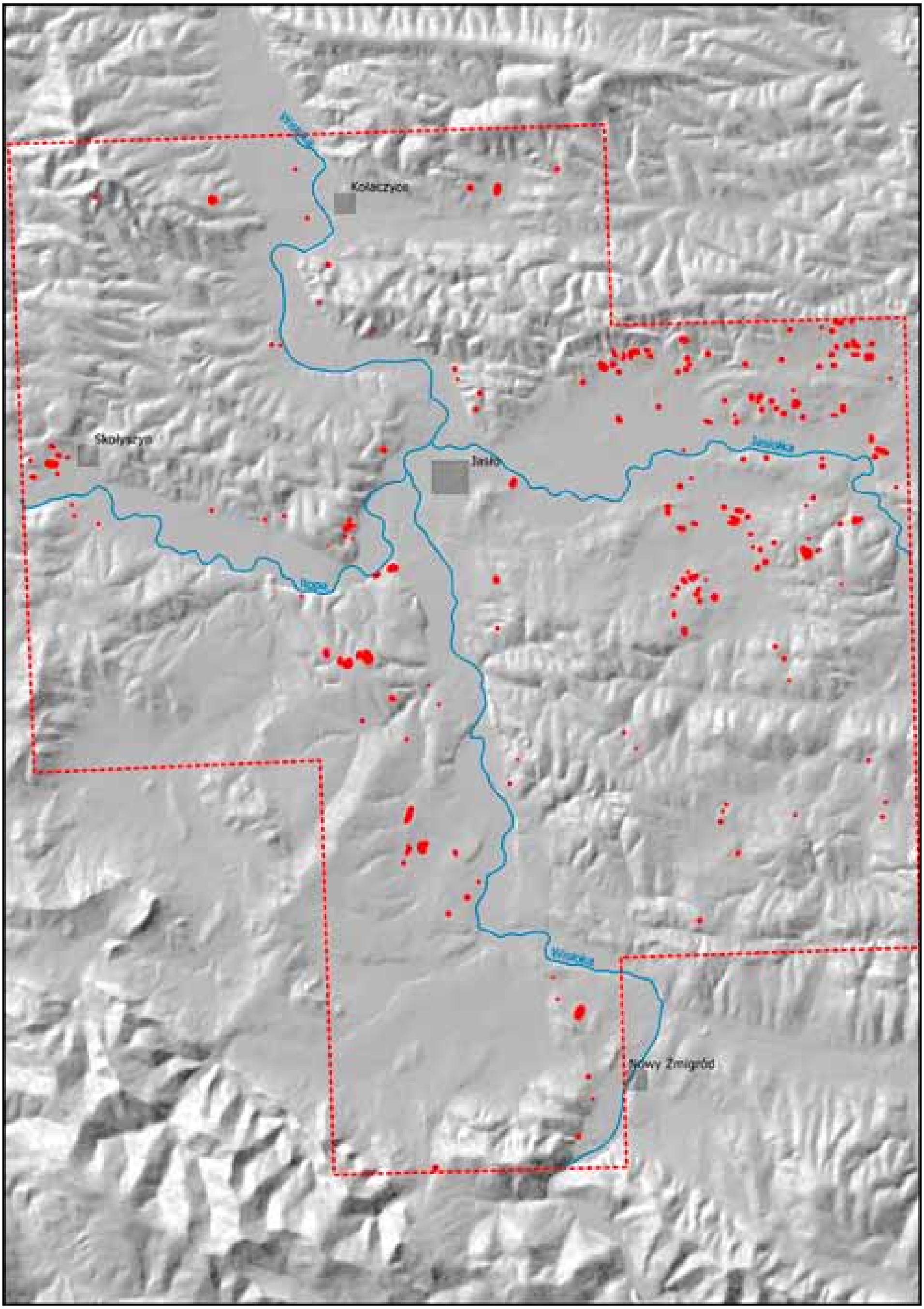

Fig. 4. The locations of archaeological sites dated to the Early Middle Ages. Sites marked with red circles. Based on PAR data

historical material found there. Aside from the above-listed sites, the following elements were located: 3 cemeteries, 1 hillfort in Trzcinica in Jasło County and 4 presumed settlements performing a defensive function.

Marking settlement clusters

Similarly to J. Michalski, the term "settlement cluster" is understood as a concentration of archaeological sites „characterised by internal territorial cohesion and separated from other units of this type by sparsely-settled areas or empty spaces" (Michalski 1989, 294, *translated from polish*).

QGIS software offers a number of tools for the demarcation of settlement clusters. The first of these is a method termed the "Voronoi Diagram" or „Voronoi Polygons" (Fig. 5). This is one of the oldest methods used to demarcate domains of influence. Polygons are defined by boundary points that intersect at equal distances from the applied set of point data. The larger the density of sites, the smaller polygons will be formed.

Another applied method is establishing the amount of sites per km^2 (Fig. 6). The entire studied area was divided into a grid consisting of 1×1 km squares. On this basis, using a palette of colours it is possible to determine the locations with the highest settlement intensity.

An interesting example of the graphic representation of settlement clusters is the so-called thermal map (Fig. 7). This tool uses a buffer to form a halo around a point (site). With the aid of so-called "foci", the map depicts the intensity of a particular phenomenon. The final effect comes in the form of a graphic visualisation of archaeological site concentrations. The intensity of the phenomenon (settlement) increases along with the rise in the colour intensity.

The identification of settlement clusters based on the amount of artefacts found is yet another very important example of an analysis method used to isolate settlement clusters (Fig. 9). The objective of such an analysis is establishing locations at which the highest concentration of moveable archaeological artefacts were discovered, and thus – to indicate the places with the highest intensity of past human activities. Voronoi polygons, determining the amount of sites per km^2, and thermal maps do not take into account the amount of historical material found, only accentuating site concentration, which might lead to the deceptive impression of human activity having been present in places where it was purely incidental. There is some risk that a settlement cluster will

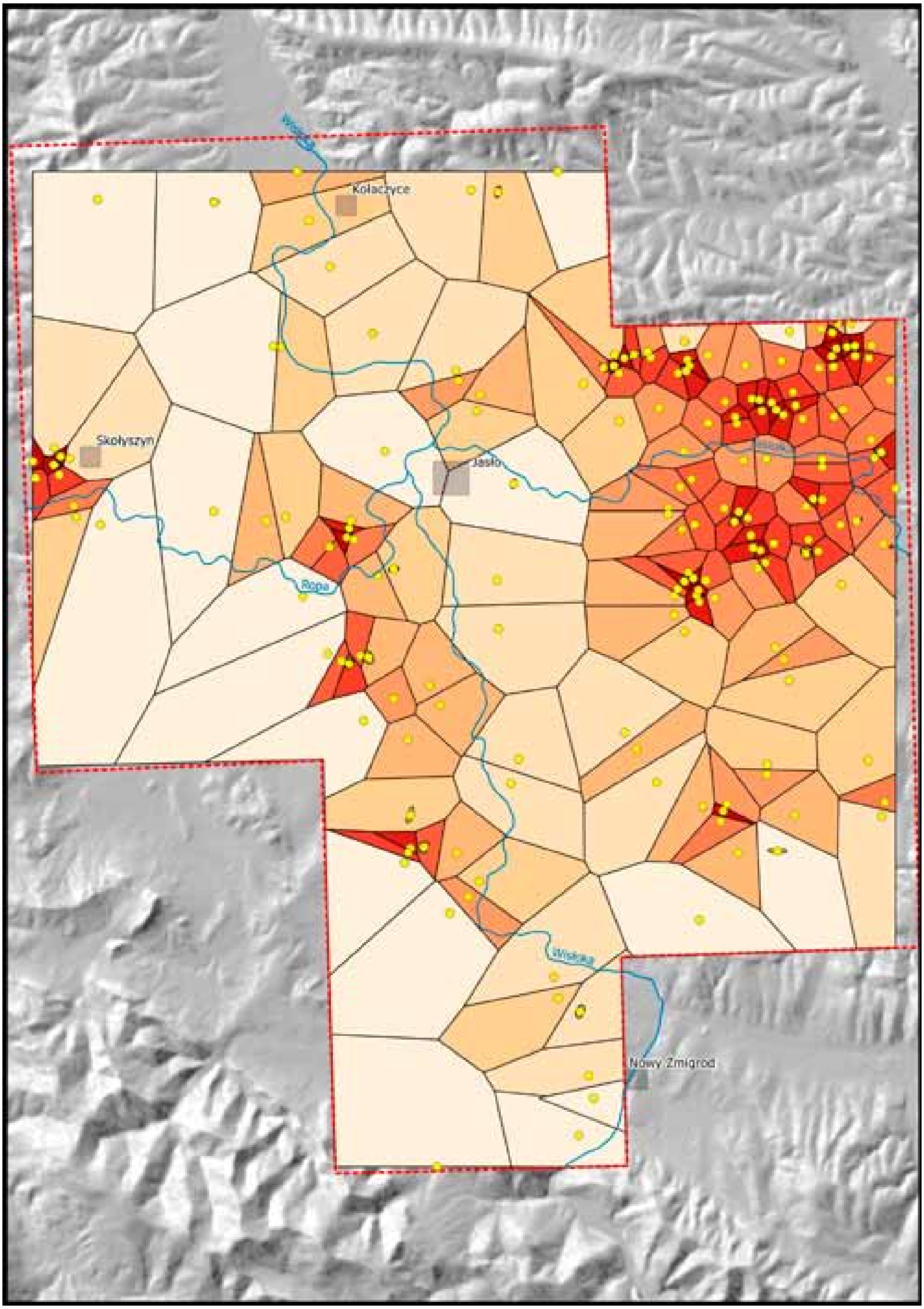

Fig. 5. Representation of Voronoi's Polygons for sites dated to the Early Middle Ages. The higher colour intensity indicates larger site density. Based on PAR data

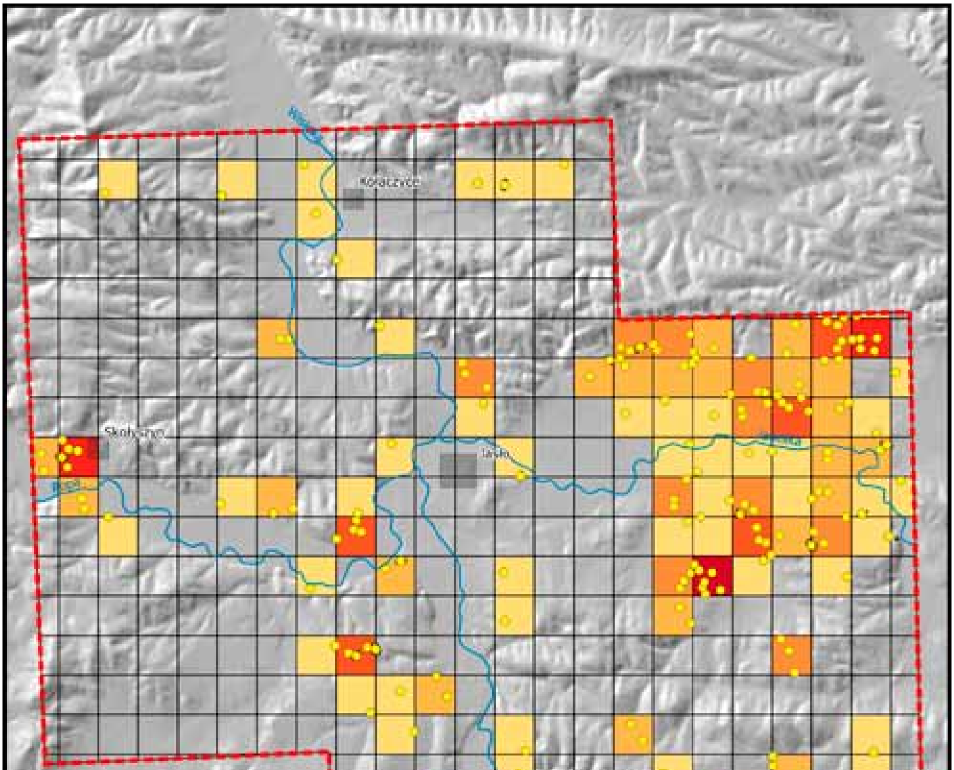

Fig. 6. Establishing the amount of sites per km². The higher colour intensity indicates larger site density. Based on PAR data

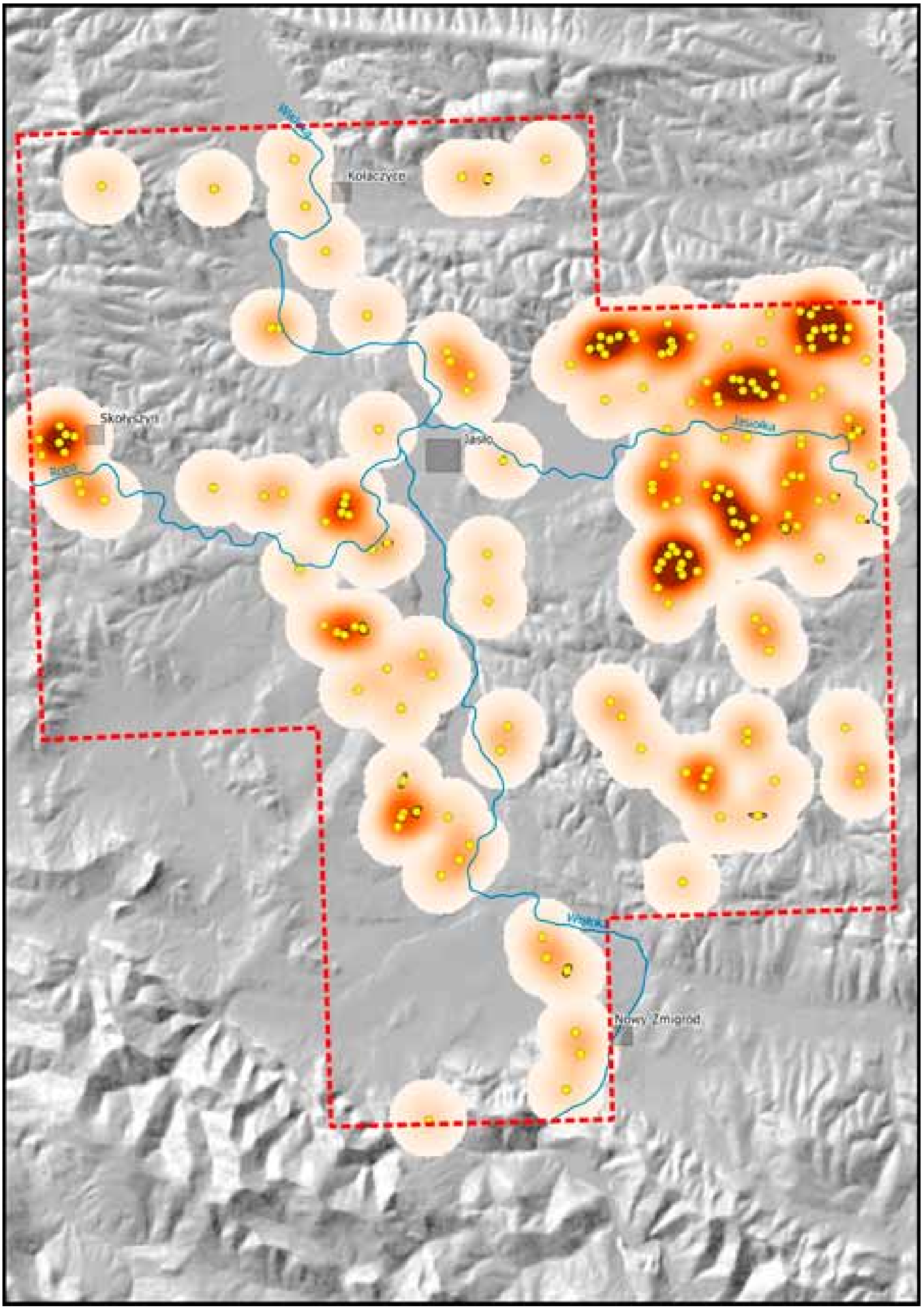

Fig. 7. Thermal map presenting settlement clusters for early medieval sites in the Upper Wisłoka Valley. The higher colour intensity indicates larger site density. Based on PAR data

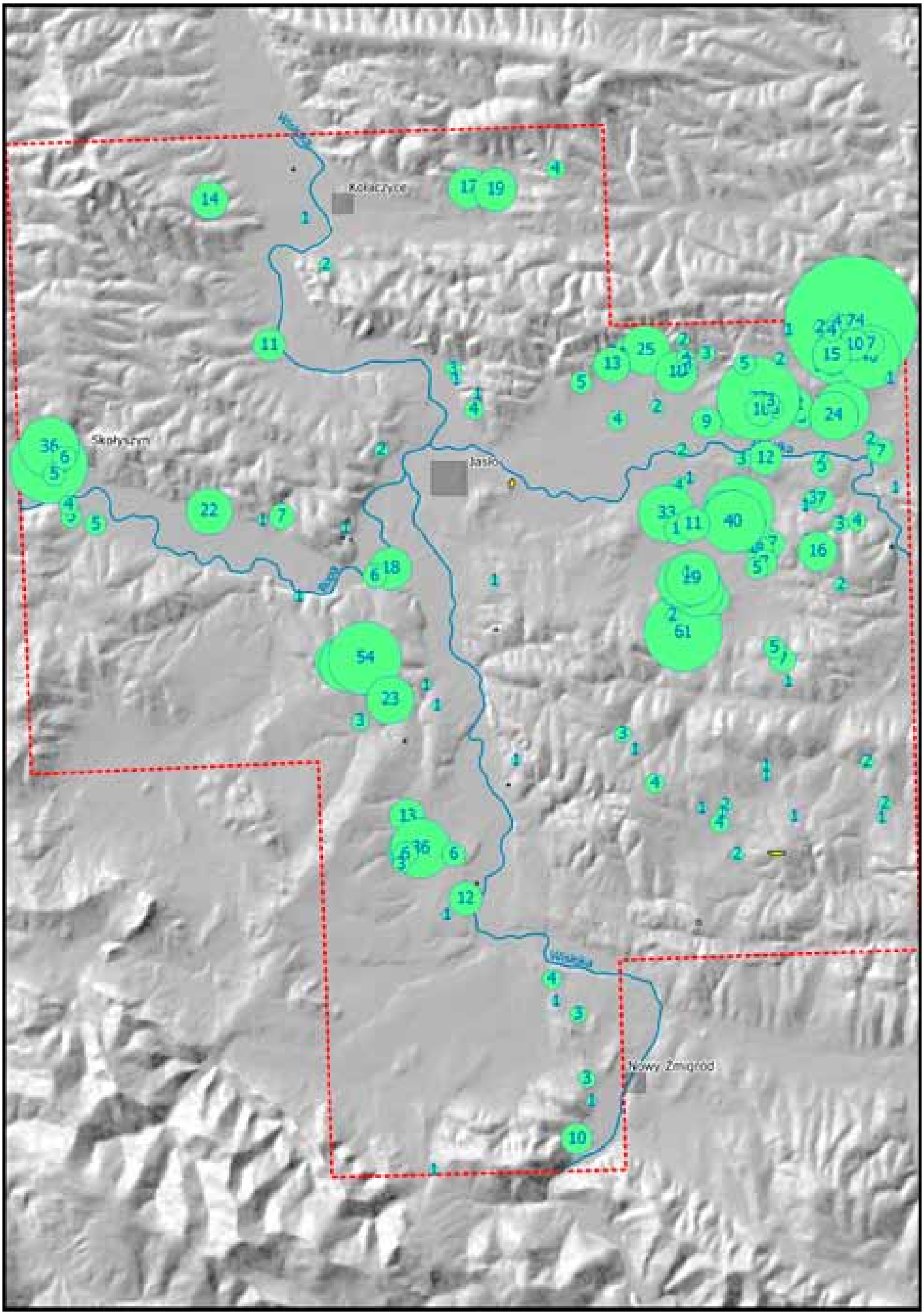

Fig. 8. The analysed area in the Upper Wisłoka Valley. The map depicts the amount of archaeological found in the area (numbers marked in blue). The size of the circle is directly proportional to the amount of discovered material. Based on PAR data

be incorrectly assigned to a spot despite finding minimal amounts of archaeological material. The Łajsce and Łubienka region might serve as such an example. An analysis of the thermal map (Fig. 8) indicates more intense human activity as compared to the map presenting the amount of archaeological material found in the area.

Ultimately, it has been possible to distinguish a number of settlement clusters, temporarily named after neighbouring villages:
1) the „Skołyszyn" cluster – 8 sites, 112 potsherds; 2) the „Trzcinica" cluster; 3) the „Osobnica" cluster – 5 sites, 128 potsherds; 4) the „Wola Dębowiecka" cluster – 4 sites, 50 potsherds; 5) the „Warzyce" cluster – 14 sites, 97 potsherds; 6) the „Szebnie" cluster – 11 sites, 120 potsherds; 7) the „Niepla" cluster – 13 sites, 289 potsherds; 8) the „Tarnowiec" cluster – 10 sites, 130 potsherds; 9) the „Umieszcz" cluster – 11 sites, 122 potsherds.

An analysis of the discussed clusters shows a tendency towards the arrangement of settlements along the Wisłoka River Valley and its tributaries – Ropa and Jasiołka. An exceptionally high concentration of settlements can be observed on the southern slopes of the Hills over Warzyce that dip down towards the Jasiołka and Sanok Depressions. Rich traces of settlement can also be found in the valley of the Czarny Potok – the left-bank tributary of the Jasiołka stream, where numerous early medieval sites have been located near the villages of Tarnowiec and Umieszcz. It is worth nothing the fact that the cone-shaped gord in Brzezówka is situated at a short distance from the discussed area.

In order to designate places with features conducive to settlement, we must identify their character and determine the settlement preferences in the Early Middle Ages.

A wide range of factors influences the choice of a location for establishing a settlement or some other form of human activity. The most important such factors include the landform, water relations, climate, type of soil, altitude above sea level, insolation. Decisive factors influencing the site selected for an open settlement are different to those that had an impact on the location of a place of cult or defensive settlement. People choosing a place to live during a more dangerous period in history follow different criteria than during times of peace. In the former case, the defensiveness of a place comes to the foreground, including the steepness of the slopes and possibility of constructing fortifications with the least amount of effort. The actions undertaken are limited by the encountered environmental conditions, which are not identical in various surrounding landscape. Many different limitations can be listed. In general, human beings and livestock must have access to a steady source of water. Agricultural societies cannot function on very steep slopes or without fertile lands. They must also have enough space for residential buildings and outhouses.

Hunter-gatherer communities will be guided by different environmental factors than those relevant to societies that have developed agricultural activities and livestock breeding. An agricultural economy is the most demanding and the most dependent on natural environmental conditions (Tunia 2004, 330). The method of farming given terrain depends on many constitutive environmental factors, which limit the usefulness of the land. Slopes appropriate for agricultural purposes must be at an angle of between 0 to 12 degrees (Pullen *et al.* 2003, 31), but at an angle of over 6^{O} erosion processes increase (Reniger 1954, 63; 1954a, 42; Starkel 1954, 202; Tunia 2004, 333). Horse ploughing can be applied at an angle of up to 30^{O} (Starkel 1954, 202; Tunia 2004, 333). Cultivation fields should have the best soil possible and a quite small slope angle. They should also have the appropriate level of insolation and not be covered too long by snow. They should also have the right humidity. If it is too low, the plants will dry up; on the other hand, if it is too high they will rot.

Knowing the cultural, economic and political conditions is important in any attempt at identifying settlement networks and can significantly aid in designating places with archaeological sites.

The example of the Ammassalik people, who live on the eastern coast of Greenland, is an ideal illustration of the lifestyle and economy of hunter-gatherer groups. This community living in the subarctic climate returns to its large patriarchal homes in September in order to spend the winter. During this period, the hunters go out to hunting in dog sleds. Once the summer comes, i.e. at the beginning of June, the families abandon their shared homes and scatter across the area for three months to search for food. The families travel following game animals and building temporary camps. This is a period of intensive gathering of wild plants (Gessain 1978, 16).

Changes in the settlement patterns may occur within a single generation or cultural unit. Such a transformation might result from the appearance of a military threat or the introduction of technological innovations. The Gava culture, inhabiting the eastern part of the

Kłodzko Valley in the Bronze Age, can serve as such an example. Their economy was based on livestock breeding and the cultivation of plants. The appearance of nomads and their aggressive politics forced the Gava to leave the territory they had previously occupied and to build fortified refugee settlements in highlands and mountainous areas (Chochorowski 1989, 536–542; 2014, 9–12). Technological innovations might be another factor influencing changes in settlement preferences. According to L. Starkel, the introduction of iron tools enabled cultivating heavier soil types, which up until that point had been inaccessible for communities during Roman influences in the area (Starkel 2001, 54).

Three factors have been selected for the identification of settlement preferences: the direction of the exposure, the slope gradient and the distance from the main rivers – Wisłoka, Jasiołka and Ropa. These allow for establishing the character of the settlement and finding correlations between the site's location and the environmental features.

Assuming that the selection of the place for founding the settlement was not random and that natural environmental conditions have some influence on the choice of the site for building a settlement, it can be speculated that human behaviour in terrain of a similar character should exact similar activities (Tunia 2004, 330). Czopek and Poradyło have rightly noted that „as is apparent from geomorphologists' synthetic determinations, areas that offer prehistoric societies diverse environmental conditions were especially attractive (Łanczont, Wojtanowicz 2005, 44–45), which was generally linked to the possibility of running a multidirectional economy and relative ease in acquiring diverse nourishment" (Czopek, Poradyło 2008, 7).

Within the framework of the Polish Archaeological Record and the conducted surface surveys, a significant amount of historic material was acquired dated to the Early Middle Ages. Nonetheless, the level to which the archaeological sites have been excavated remains unsatisfactory. Only a few of them were studied archaeologically (usually through sondages). In these terms, the gord in Trzcinica and its surroundings have been subjected to the most detailed studies (Gancarski 2006). A few structures with an early medieval chronology have been identified in this vicinity, while a few others have been noted on the surface. Unfortunately, they are being destroyed by agricultural activities. These are sites that have a certain location in space. A few of the sites, like site no. 14 in Nienaszów in Nowy Żmigród commune, site no. 7 Niepli in

Jasło commune, research conducted by Anna Tyniec. In the course of road construction in Warzyce in Warzyce, district of Jaslo site no. 20 structures were uncovered from the early medieval period, identified during surveys. The remaining sites have been dated based on material found on the surface. Due to issues with precise dating, it is impossible to distinguish settlement clusters in particular settlement phases. Ultimately, we have a "flattened" image of settlement in the area. Sites that might come from different phases appear together in the images.

Transferring the archaeological sites from the PAR maps allows for their exact localisation in geographic space within a broader space. The mapping procedure enables recreating the range of the permanently inhabited areas, as well as allowing for the precise designation of empty spaces in terms of settlement and tribal areas. It also enables plotting areas with increased activities into tribal groupings.

The Slavic population in the Early Middle Ages located its settlements according to specific preferences. It chose terrain with low denivelations, not exceeding a height of 350 m. a.s.l., and with fertile soil. These were the conditions met by the Jasło-Sanok Valleys and the Rzeszów-Przemyśl Loesses (Parczewski 1991, 21). Terraces were selected in flood plains along watercourses. In his analysis of settlement in the Kisielina, Uszwica and Raba river basin, Jacek Poleski observed a certain regularity in the oecumene occupied by the Slavs. The sites are located in flood plain terraces along watercourses. Aside from a few exceptions, the isohypse of 350 m. a.s.l. was not exceeded (Parczewski 1991, 21, Fig. 2; Poleski 2006, 46). It seems that the Slavs did not know of the phenomenon of thermal inversion (Kostrakiewicz 1967; Poleski 2006, 47).

Establishing settlement preferences

The objective of the first determinant is establishing the location of the site in relation to the direction of exposure.

The map portraying the exposure and slope gradient was generated using the GRASS GIS programme. The maps were created based on a numeric terrain model showing the earth's surface – ASTER GDEM. Using the r.slope and r.aspect functions, I created a map of the exposure and slope gradient. Next, the maps were reclassified, forming a layer consisting of 4 classes for exposure maps (classes accordant with the points of the compass: north N, south S, east E and west W) and 5 classes for the slope gradient map (class 1 for slope gradient 0–1 degrees, class 2 for slope gradient 1–3 degrees, class 3 for slope gradient 3–7 degrees, class 4 for gradient 7–15 degrees and class 5 for slope gradient 15–30 degrees).

In terms of the direction of exposure, southern slopes were preferred, showing the highest amount of sites – 52 (with 205 ha/site). The amount of sites on W and E slopes is similar, with a slightly more W slopes, 45 (214ha/site) and 50 (220 ha/site) respectively (Fig. 9).

Slopes with a northern tilt were avoided as they were unattractive for medieval settlement due to the lower insolation and longer retention of the snow cover (Tunia 2004, 338; Hess 1965, 155–160).

Northern slopes receive much less insolation than southern ones; however, in the morning and evening, as well as during long summer days they receive a large amount of energy. They are subjected to longer winter periods, and a higher amount of days during which snow and frost is retained. The last ground frost occurs here 10 days later than on the southern slopes (after Tunia 2004, 338; Hess 1965, 155–160). The average difference in temperature between northern and southern slopes amounts to 6–7°. This difference in temperatures leads to a delay in the plant-ripening period by 1–2 weeks (Tunia 2004, 338; Mosołow 1950, 14). Northern slopes are very similar in character to eastern ones. On northern slopes, „along with the increase in the gradient, the angle at which the sun's rays fall decreases, which leads to a lowering in radiation intensity „ (Tunia 2004, 338; Bury-Zaleska 1963, 45).

Southern slopes are the most attractive terrains for plant cultivation. They are the warmest, while the sun's rays are almost perpendicular. Western slopes are similar in character to southern slopes.

Meadows located on southern slopes provide better quality fodder for animals (Hołub-Pacewiczowa 1931, 181; Kubijowicz 1927, 10–12; Kowalska-Lewicka 1980, 107). The snow cover lingers for shorter periods on southern slopes. This fact is relevant in the case of free-grazing animals, which may have to dig through the snow in search for food. In the case of domestic cattle, the maximum limit is 30 cm, while it is 15 cm for sheep (after Tunia 2004, 342; Naumow 1961, 352–358).

The next factor aims to determine the location of the site in relation to the slope gradient. The conducted analyses indicate a preference for slopes with a gradient of 1–3°. 42 such sites were registered in an area covering a surface of 7,685.8 ha (18% of the analysed surface).

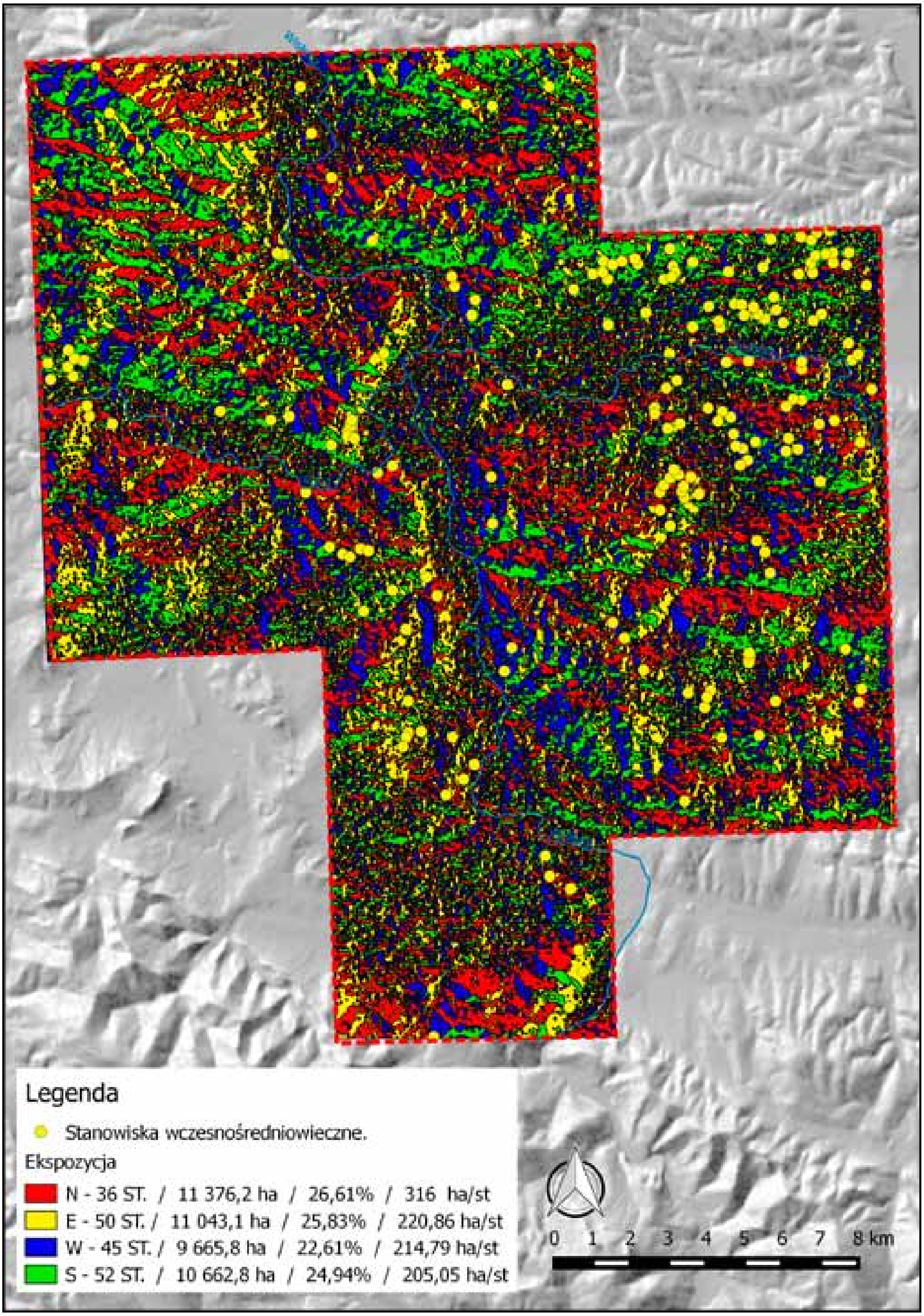

Fig. 9. Exposure map based on ASTER GDEM data

One site amounts to 192.14 ha. Slopes with a gradient of between 3 and 7^{O} are second in line. 87 sites were registered in a surface covering 18,114.8 ha (42.4% of the studied area). Terrain with a gradient of between 7 and 15^{O} is in third position, with 50 sites. Such areas cover a surface of 13,461.2 ha (31.5% of the studied surface), which amounts to 375 ha/site. Settlement density becomes lower as the slope gradient rises (Fig. 10).

Another important factor that should be considered is the distance of the archaeological site from permanent water reservoirs or watercourses. Water is a key resource with a huge influence on where settlements are situated. It is also accessible in the form of rain or snow, i.e. temporary sources, or as water reservoirs such as lakes and rivers. The last of the selected determinants aims to determine the location of the sites in relation to their distance from rivers. Many sites are concentrated along the valleys of the main rivers – Wisłoka, Jasiołka and Ropa, with the highest amount – 60 sites – at a distance of up to 1 km from the present-day course of the river. Slightly less, i.e. 46 sites, were located at a distance of between 1 and 2 km, while 45 sites – between 2 and 3 km. The amount of sites decreases at a distance of more than 3 km from the riverbanks (Fig. 11).

Upon demarcating the areas with the densest settlement patterns, we receive terrains located at a distance of 1 km from the rivers, with a southern exposure and 1–3^{O} slope gradient. After separating out the areas with the densest settlement patterns and distinguishing the parts that overlap, we receive the zone with the most convenient features for settlement – probability I areas, i.e. those on which archaeological sites are probably located (Figs. 12, 13). These can be broadened to encompass areas with a western exposure and a 3–7^{O} gradient and lying at a distance of 3 km from the riverbanks (Figs. 14, 15).

Based on the identified settlement preferences among early medieval people, it is possible to designate places with the most convenient qualities for founding a settlement. Such a technique attempting to foresee the location of archaeological sites is termed Predictive Modelling, with the acronym PM (Chapman 2006; Kohler, Parker 1986; Kvamme 1990; Lock 2003). In archaeology, predictive modelling uses knowledge about the location of identified archaeological sites and their relation to the surrounding environment, and then "transfers" this information onto terrain with similar environmental parameters,

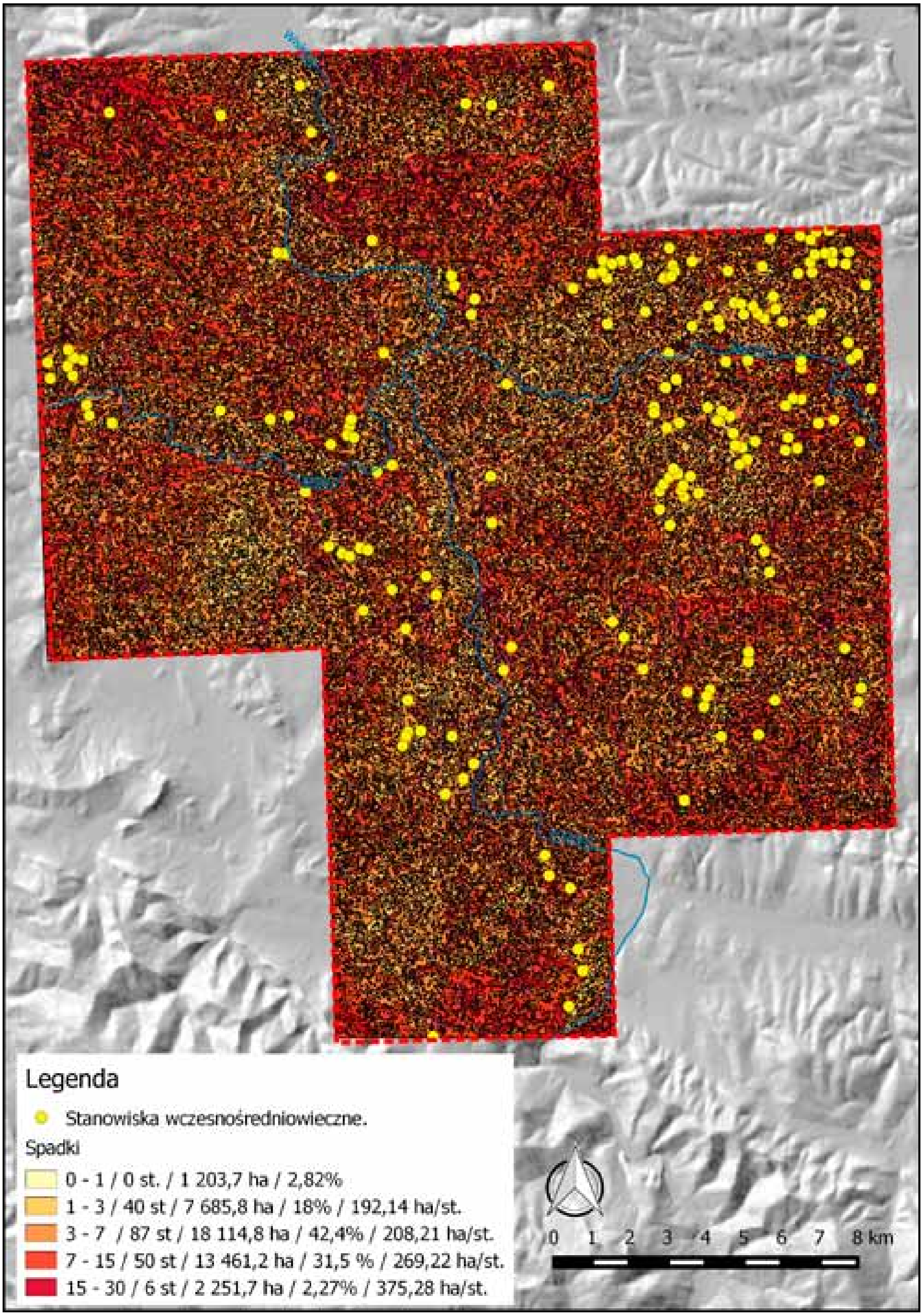

Fig. 10. Map depicting the down gradient of the terrain based on ASTER GDEM data

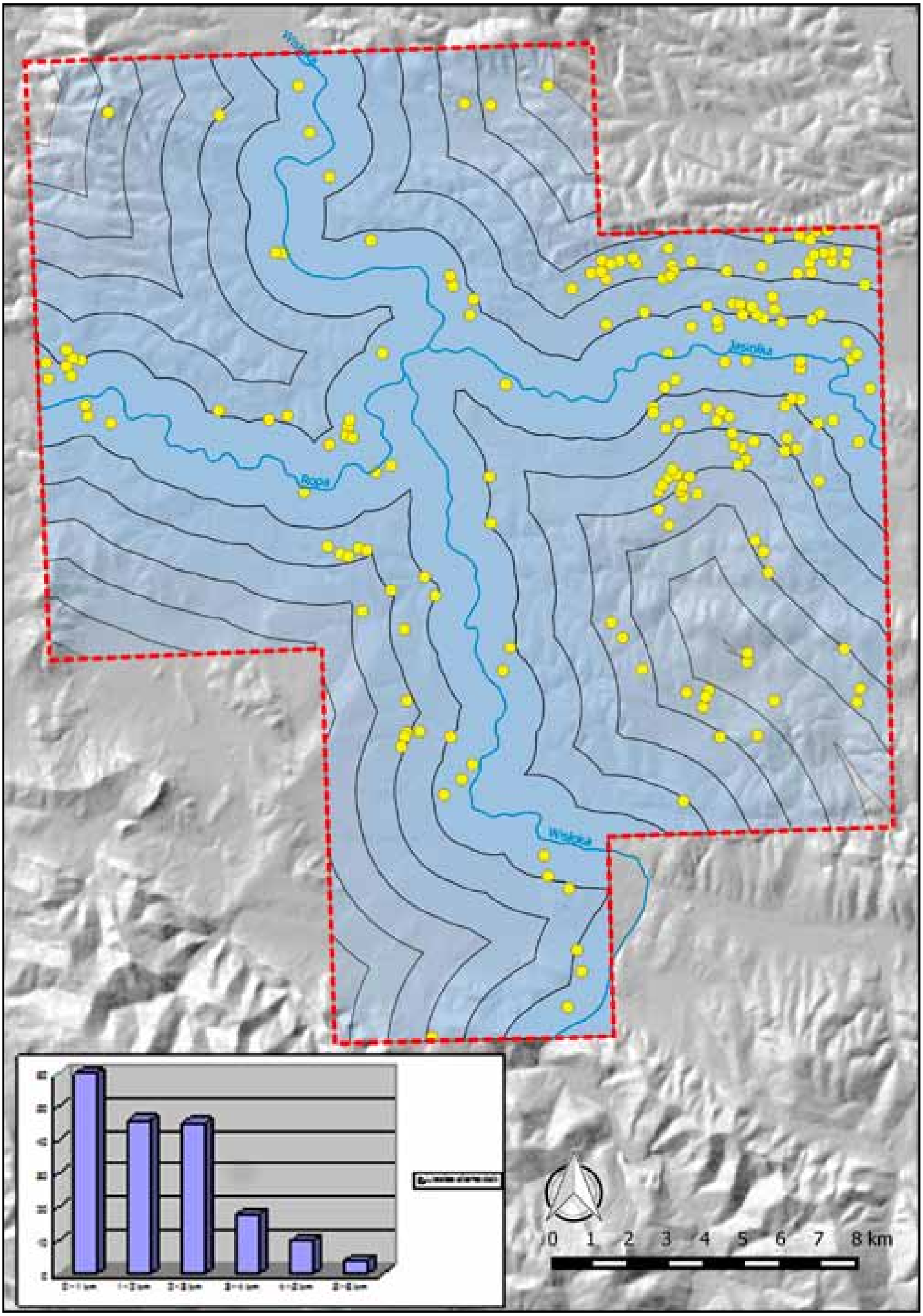

Fig. 11. Map presenting buffers at a distance of 1 km

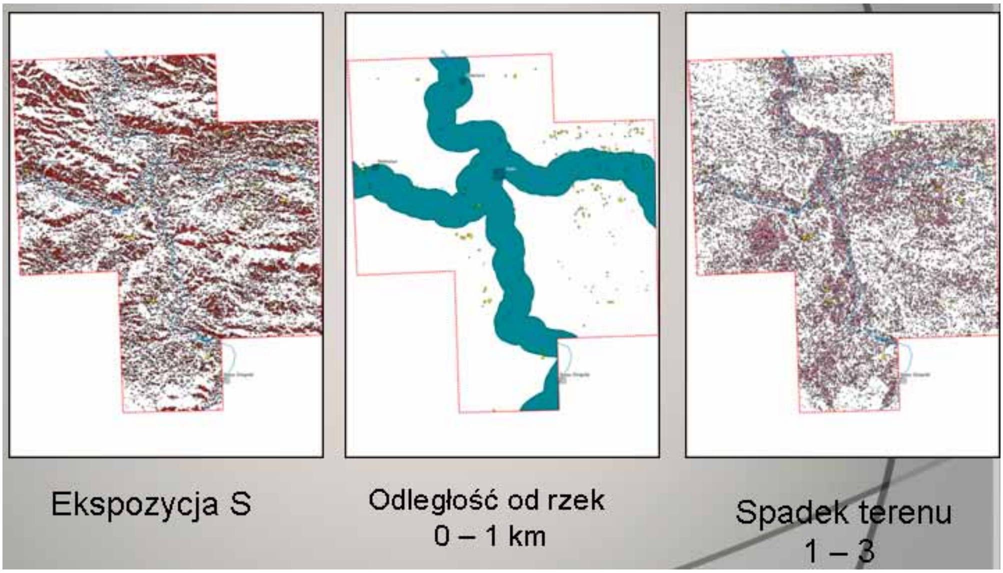

Fig. 12. The distinguished areas have the highest amount of archaeological sites

in which the areas have not yet been studied archaeologically due to the vegetation cover or urban development. Predictive modelling is based on finding a relation between the location of the archaeological site and environmental factors. Constructing predictive models is useful as an activity supplementary to surface surveys and preceding investment. It constitutes the first step in the non-invasive search for archaeological sites (Zapłata, Borowski 2013), enabling the better identification of the researched area and the formulation of initial hypotheses that can later be verified.

Rafał Zapłata and Marcin Borowski describe predictive modelling as a process "based on the use of knowledge and information about identified archaeological sites and their surroundings and determining the mutual relations between data and phenomena, linking this information with environmental conditions, as well as 'preferences' known, for example, based on the analyses of the landform, types of soil or distance from water reservoirs" (Chapman 2006, s. 157; Kamermans 1999; Borowski, Zapłata 2013, 105).

Factors linked to the environment, topography and infrastructure narrow the occurrence of phenomena. Predictive modelling attempts to describe these limitations through the spatial correlation of historical

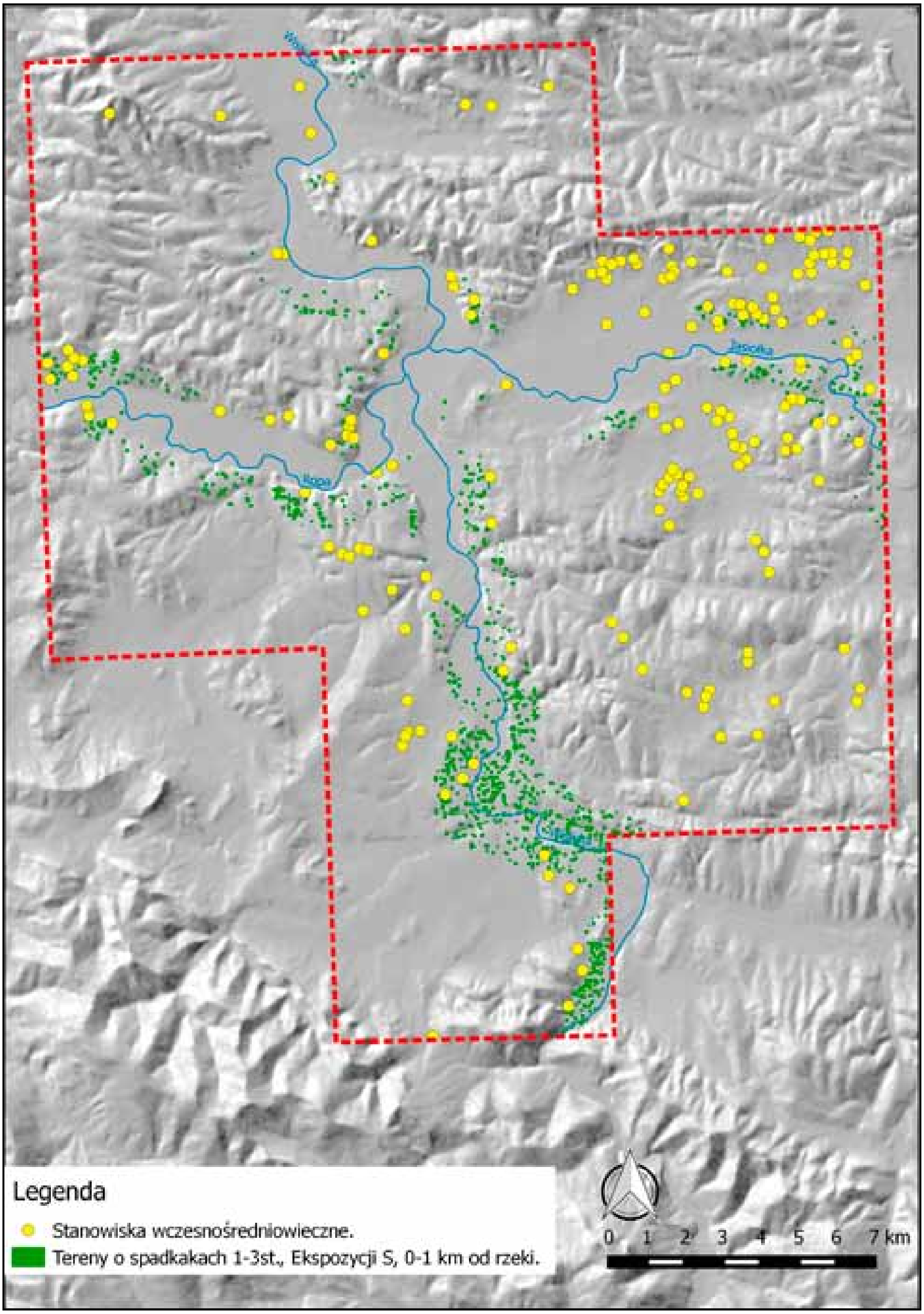

Fig. 13. Distinguished areas with an S exposure, a slope gradient between 1 and 3 degrees and located at a distance of 1 km from the river's course

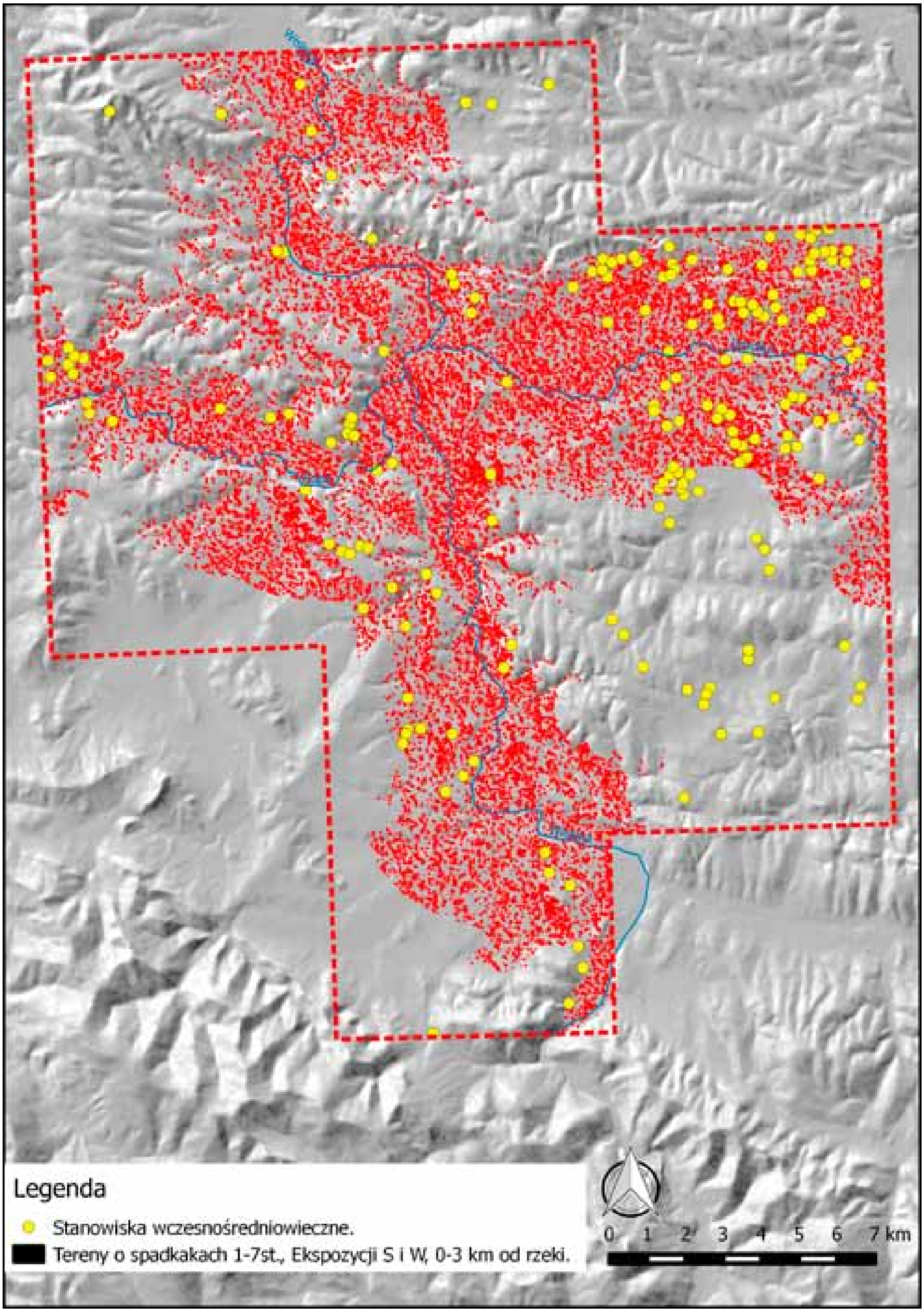

Fig. 14. Distinguished areas with an S, W and E exposure, a slope gradient of between 1 and 7 degrees and located at a distance of 0–3 km from the river's course

Fig. 15. The correlation between the distinguished areas from satellite images depicting the buildings in the village of Dębowiec. Green is used to mark areas with an S exposure, a 1–3° slope gradient, located at a distance of 1km from the river. Red is used to mark areas with S, E, W exposure, a 1–7 slope gradient, located at a distance of 3 km from the river

events with environmental factors.

Criticism of predictive modelling

Using PM in the management of national heritage resources has met with both supportand criticism. In countries such as the USA, Canada, the Czech Republic, Australia and – to a lesser extent Germany, predictive modelling is regularly used to establish the density of archaeological sites. In some countries, it is used in order to map out the terrain before research is done there or as a tool providing support in making decisions about area management. In some countries, like England and France, the use of PM is rejected completely in national heritage management. The argument used to justify this is the impossibility of predicting the location of all archaeological sites. This is especially relevant in the case of terrains classified as areas with a low probability of containing archaeological sites. They might be completely omitted in the reconnaissance, and thus all sites located there would be irrevocably lost (Verghen, Whitley 2012).

One significant problem with this method that should be mentioned is the way in which data is "prepared" for analyses aimed at determining the locations of potential sites. Vectorised archaeological sites are recorded in the form of polygon layers. It is necessary to substitute the polygon layer by a point layer to meet the requirements of the analysis, wherein the programme automatically determines the centre of the polygon layers. This substitution leads to errors, e.g. when the site includes western, eastern and southern slopes, then the central point can only be assigned as being located on the western slope. The amount and quality of the analysed data influences the results of the analyses. In the above analyses, data gathered in the course of the largest Polish research project – the Polish Archaeological Record – were used. The research itself provided a lot of very valuable information useful for describing prehistoric settlement in Poland. However, it has also been criticised. PAR's most frequently listed faults include: the artificial condensation of the settlement network, huge difficulties in dating archaeological material, as a result of which the majority is dated very generally, e.g. to the Neolith or Bronze Age or the Early Middle Ages, i.e. four centuries [7^{th}/8^{th} – 11^{th}–12^{th}], the proliferation of sites through archaeological material being moved (Poleski 2006, 45–46, after Moździoch 2002, 14–15), the archaeological material found on the surface does not always coincide with the presence of structures, the size and location of the sites is determined based on a few artefacts recovered from the surface.

There is no possibility of recreating the dynamics of change in the settlement's oecumene, which results in a static "flattened" image of settlement. This is because PAR research constitutes the sum of diverse past human activities. It does not enable tracking the changes in the settlement's dynamics. Sites from various phases can be included in the presented map of early medieval settlement. The term "Early Middle Ages" can refer to ca. four centuries of history.

Summary

The results of the analyses depend on the type and quality of the introduced data. One should be aware that the presented model is not a magic wand that can determine the location of an archaeological site, but rather a set of tools allowing one to select spots with the best conditions for settlement, and – thus – potentially having archaeological sites.

For such considerations and analyses, sites and structures that have been precisely located in the terrain are especially important. Unfortunately, the vast majority of archaeological sites have been identified based on a few artefacts discovered on the surface, while the defined range of settlement does not coincide with the actual area the site covers.

Merging the results of PAR research and GIS tools allows for an initial reconstruction of prehistoric and early medieval settlement in a selected area and provides images of this settlement in the form of maps. Nonetheless, one should keep in mind the incompleteness of the PAR data. Sites that had until recently been unknown are constantly being discovered and one must be aware of the existence of archaeological sites hidden beneath modern-day buildings in towns and villages.

One advantage of using GIS software is acquiring new information through associating data originating from various sources, e.g. analogue data, such as field documentation, which can be referenced with digital data, e.g. from satellite images, ALS data or the results of non-invasive surveys. The end product of predictive modelling might be a map illustrating a few variations of high, medium and low probability of encountering an archaeological site in the studied area. Such maps can be useful in land planning and management.

Using GIS in archaeology is another example of associating the efforts of many different researchers participating since 1970 in the largest non-invasive survey project (PAR) with new technologies. Testing new research techniques might contribute to providing new information about the prehistoric settlement landscape. Such research is very significant in the precise establishment of the location of tribes and intertribal empty regions. Undoubtedly, GIS software works well as a tool used by an archaeologist for collecting, searching and analysing archaeological data. An additional asset in the case of ready databases is the possibility of reusing them in any scale, within any scope and any chronological framework, while the research results can be illustrated in the easily comprehensible form of maps.

References

Borowski M. and Zapłata R. 2013. GIS w archeologii – przykład prospekcji i inwentaryzacji dziedzictwa archeologiczno-przemysłowego. *Rocznik Geomatyki* 11 (4), 103–114.

Bury-Zalewska J. 1963. Schodzenie pokrywy śnieżne w terenie urzeźbionym w zależności od warstw i nachyleń. *Pamiętnik Puławski* 12, s. 11–36.

Chapman H. 2006. *Landscape Archaeology and GIS*. Stroud, Gloucestershire: Tempus.

Chochorowski J. 1989. Przemiany kulturowe we wczesnej epoce żelaza na terenach pół.-wsch. części Kotliny Karpackiej. In A. Barłowska and E. Szałapata (eds.), *Grupa tarnobrzeska kultury łużyckiej. Materiały z konferencji 12–14 listopad 1986 r. w Rzeszowie.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 527–583.

Chochorowski J. 2014. Scytowie a Europa Środkowa – historyczna interpretacja archeologicznej rzeczywistości. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego* 35, 9–58.

Czopek S. and Poradyło W. 2008. *Warzyce, pow. Jasło, stan. 17 – osada z epoki brązu i wczesnej epoki żelaza (= Collectio Archaeologica Ressoviensis* 10). Rzeszów: Fundacja Rzeszowskiego Ośrodka Archeologicznego.

Gancarski J. 2006. *Trzcinica – Karpacka Troja*. Krosno: Muzeum Podkarpackie w Krośnie.

Gessain R. 1978. *Ammassalik.* Warszawa: Iskry.

Hess M. 1965. Piętra klimatyczne w polskich Karpatach Zachodnich, *Zeszyty Naukowe Uniwersytetu Jagiellońskiego 115, Prace Geograficzne 11*. Kraków: Uniwersytet Jagielloński.

Hołub-Pacewiczowa Z. 1931. Osadnictwo pasterskie i wędrówki w Tatrach i na Podtatrzu. *Prace Komisji Geograficznej PAU* 1, Kraków: Polska Akademia Umiejętności.
Kohler T.A. and Parker, S.C. 1986. Predictive models for archaeological resource location. In M.N. Schiffer (ed.), *Advances in Archaeological Method and Theory 9*, New York: Academic Press, 397–452.
Kamermans H. 1999. Predictice modelling in Dutch archaeology, joining forces. In J.A. Barceló, I. Briz and A. Vila A. (eds), *New Techniques for old times. CAA98 Computer applications and qantitive methods in archaeology*. Oxford: Archaeopress, 225–229.
Kondracki J. 1980. *Geografia fizyczna Polski*, Warszawa: Państwowe Wydawnictwo Naukowe.
Kowalska-Lewicka A. 1980. *Hodowla i pasterstwo w Beskidzie Sądeckim*. Wrocław: Zakład Narodowy im. Ossolińskich.
Kostrakiewicz L. 1967. Nomogram do obliczania średnich rocznych sum opadów w Karpatach polskich poniżej poziomu inwersji. *Problemy Zagospodarowania Ziem Górskich* 2(15), 129–146.
Kubijowicz M. 1927. Życie pasterskie w Beskidzie Magórskich (= *Prace Komisji Etnograficznej PAU* 2). Kraków: Polska Akademia Umiejętności.
Łanczont M. and Wojtanowicz J. 2005. Uwarunkowania przyrodnicze rozwoju osadnictwa pradziejowego w Kotlinie Sandomierskiej. In M. Kuraś (ed.), *Archeologia Kotliny Sandomierskiej* (= *Rocznik Muzeum Regionalnego w Stalowej Woli* 4). Stalowa Wola: Muzeum Regionalne, 39–55.
Kvamme K.L. 1990. The fundamental principles and practice of predictive modelling. In A. Voorrpis (ed.), *Mathematics and Information Science in Archaeology: A Flexible Framework* (= *Studies in Modern Archaeology* 3), Bonn: Verlag-Holos, 257–295.
Lock G. 2003. *Using computers in archaeology. Towards virtual past.* London: Routledge.
Mosołow W.P. 1950. *Rzeźba terenu a rolnictwo*. Warszawa: Państwowe Wydawnictwo Rolnicze i Leśne.
Naumow N.P. 1961. *Ekologia zwierząt*. Warszawa: Państwowe Wydawnictwo Rolnicze i Leśne.
Michalski J. 1989. Skupienia osadnicze na obszarze grupy tarnobrzeskiej kultury łużyckiej. In A. Barłowska and E. Szałapata (eds.), *Grupa tarnobrzeska kultury łużyckiej. Materiały z konferencji 12–14 listopad 1986 r. w Rzeszowie.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 293–304.
Moździoch S. 2002. *Castrum munitissimum Bytom. Lokalny ośrodek władzy w państwie wczesnopiastowskim*, Warszawa: Wydawnictwo DiG.
Parczewski M. 1991. *Początki kształtowania się polsko-ruskiej rubieży etnicznej w Karpatach. U źródeł rozpadu Słowiańszczyzny na odłam wschodni i zachodni*. Kraków: Instytut Archeologii Uniwersytetu Jagiellońskiego.
Poleski J. 2006. Przyczynek do poznania wczesnośredniowiecznego osadnictwa w polskiej części Karpat Zachodnich – dolina Dunajca i Raby, In J. Gancarski (ed.), *Wczesne średniowiecze w Karpatach Polskich.* Krosno: Muzeum Podkarpackie w Krośnie, 33–75.

Pullen J.D., Rothaus M.R. and Tartaron F.T. 2003. Searching for Prehistoric Aegean Harbors with GIS, Geomorphology, and Archaeology. *Athena Review* 3 (4), 27–36.
Reniger R. 1954a. Charakterystyka rzeźby terenu jako jedna z podstaw właściwego jego użytkowania i zagospodarowania. *Postępy Nauki Rolniczej* 1(6), nr 1, 60–71.
Reniger R. 1954b. Znaczenie rzeźby terenu dla rolnictwa. *Przegląd Geograficzny* 26/4, 37–47.
Starkel L. 1954. Znaczenie mapy geomorfologicznej dla rolnictwa. *Przegląd Geograficzny* 26/4, 198–212.
Starkel L. 2001. Przemiany krajobrazu – rola erozji gleb w przekształcaniu środowiska naturalnego. In M. Kotarba (ed.), *Przemiany środowiska naturalnego a ekorozwój.* Kraków: Wydawnictwo TBPŚ „Geosfera", 49–63.
Tunia K. 2004. Środowiskowe uwarunkowania gospodarki rolniczo-hodowlanej na terenach górskich w czasach prahistorycznych. Casus zachodniokarpackiego osadnictwa późnorzymskiego. In J. Gancarski (ed.), *Okres lateński i rzymski w Karpatach polskich*, Krosno: Muzeum Podkarpackie w Krośnie, 329–356.
Verhagen P. and Whitley T.G. 2012. Integrating Archaeological Theory and Predictive Modeling: a Live Report from the Scene. *Journal of Archaeological Method and Theory* 19(1), 49–100.

Website
https://asterweb.jpl.nasa.gov/gdem.asp