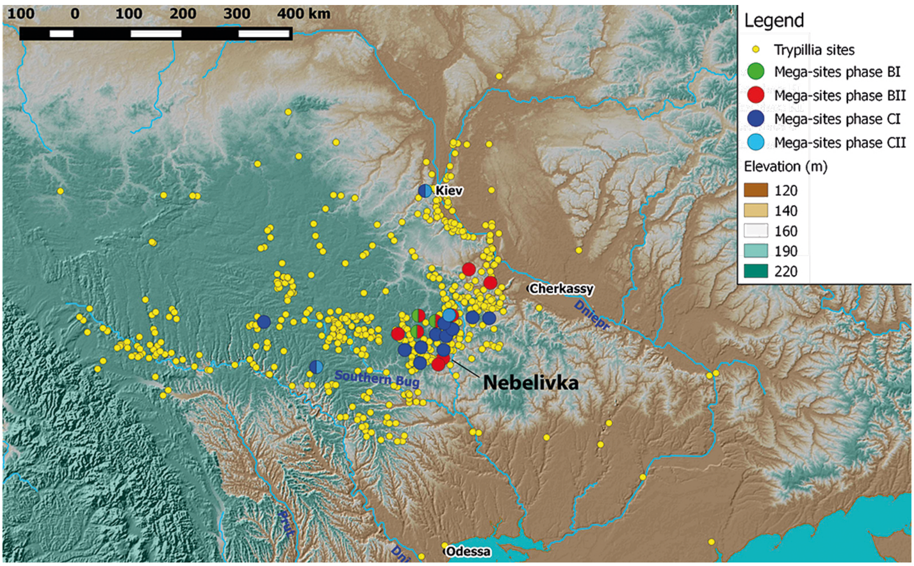
Marco Nebbia & Joe Roe

3 Landscape Studies

In this chapter, Marco Nebbia presents the multi-scalar results of landscape investigations ranging from the critical analysis of Ukrainian heritage data for Trypillia settlement, through the interrogation of satellite images for a 25km zone around Nebelivka, targetted fieldwalking in the 25km radius and systematic, intensive fieldwalking in the 10-km territory to site-based gridded collection at four Trypillia sites. Neither of the principal two features visible on the satellite images could be closely dated – a palaeo-hydrological network of small, anastomosing streams and a spread of burial monuments (barrows, dating from the EBA to LIA) which proved to be the *only* site form dispersed across interfluvial areas. The fieldwalking programmes yielded a spatially precise sequence of settlement distributions from the Trypillia period to the Modern era which showed remarkably consistent choices of site location close to the confluence of river courses. Dr. Nebbia's critical 'cleaning' of the 'Trypillia Encyclopaedia' settlement data produced a secure data set for innovative spatial-statistical analyses of Trypillia settlements, focussing on the Southern Bug-Dnieper interfluve with its concentration of megasites. The paucity of small Trypillia sites within a 25km radius of Nebelivka showed the value of settlement analysis at the 100-km scale.



Marco Nebbia

3.1 Introduction

This Chapter will look into the way the project investigated the wider landscape that surrounds the megasite of Nebelivka. For the first time in Trypillia studies, a systematic analysis of the contextual environment that constitutes the settings of megasites has been planned and carried out. The scope was of course to use a number of tools and field methods that sheds new light on the environs of megasites and how these influenced the emergence, development and demise of these large settlements. The investigation followed a trans-scalar approach where micro- and macro-regions have been defined and then studied, 'from the air' by means of remote sensing analysis, and from the ground through intensive and extensive field survey. The data collected and processed have been integrated with the bulk of existing grey literature of known Trypillia sites. Primary field and remote sensing data were combined and used for the first thorough accuracy assessment of the legacy archaeological data, while a new spatial database of known Trypillia evidence has been produced for the Ukraine. This dataset was then studied by means of advanced statistical analytical tools with the aim to identify large-scale settlement pattern changes throughout the five phases of Trypillia occupation. The results of these analysis shed new light on the nature of Trypillia megasites and their possible relationship with the coeval settlement pattern. New insights on the scale of social movements that Nebelivka and other large settlements involved in their development and occupation were drawn upon for the first time in Trypillia studies. Clearly, the benefit of the landscape approach integrated with a small-scale site investigation brought a more nuanced understanding of the function and organisation of megasites. Moreover, new research questions arose from the wider context of small sites, the sites which we shall term "mega"- *off sites*" and their relevance in the emergence of megasites. Overall, the project benefitted from the multi-disciplinarity of the underpinning methodology.

Marco Nebbia

3.2 Remote Sensing

3.2.1 Introduction

In this section, the main contributions of remote sensing to Trypillia studies will be elucidated. A number of available satellite imagery, ranging from 1960s CORONA images to the more recent WorldView-2 datasets, will be evaluated for their potential value in researching megasites, as well as smaller Trypillia (and other periods) features. Results of the photo-interpretation will also be discussed.

Since the 1960s, Trypillia settlements have been mapped from aerial photographs, starting with the military topographer Shishkin's flights in 1964. Shishkin later surveyed several sites, including the major megasites of Majdanetske, Taljanki and Dobrovodi (Shishkin 1973, 1985). The visibility of archaeological sites and features from satellite images varies according to the shape and size of the site/feature, the nature of the site/feature, the location of the site/feature, the contrast between the land cover of the surroundings and of the site/feature itself, the state of preservation of the site/feature, the spatial and spectral resolution of the image, the time of acquisition of the image and the different satellite sensors (Sabins 2007). All these variables have even more impact on the recognition of archaeological remains that are completely buried under the ground surface, as is the case for Trypillia sites. Hence, two further factors have to be taken into consideration in order to understand what we can see from the imagery, namely the depth of the archaeological horizon and the land cover of the area at the time of the data acquisition.

3.2.2 High-Resolution Imagery

In order to detect and map buried archaeological remains such as Trypillia sites, a set of high-resolution imagery was needed, for which an assessment of the potential of various data sets was undertaken. Only high spatial resolution allows for the detection of archaeological features and the so-called "anomalies" indicating the presence of something underground can be of various types; the ways archaeological features (or other phenomena) manifest themselves on aerial images can be *crop*marks (when there is a differential growth in the crops), *soil*marks (when there is a differential moisture content in the soil), *shadow*marks (when the object topographical expression produces a shade) and several others (Wiseman and El-Baz 2007; Lillesand et al. 2014). In the Ukrainian study, two sets of images have been tested and only one of them turned out to be useful for the identification of archaeological features in the study area around Nebelivka.

3.2.3 CORONA Imagery

The CORONA was the first American satellite programme, operational from 1959 until 1972, devoted to a photographic surveillance of the Soviet Union, People's Republic of China and other key areas. The great potential of such imagery in arid and semi-arid areas has been established over 15 years of research; CORONA images have been used with particular success in exploring the archaeology of the Near East, where the remains of tells, flat sites and route ways are clearly visible on the images (Wilkinson 2003; Ur 2003: 2005; Hritz 2014). The three main advantages of CORONA are, 1) the relatively low cost for a vast coverage of each frame (200km ×

15km); 2) the fact that they give a time-depth of the archaeology before recent urban or agricultural encroachment; and 3) the availability of time-series of images which provides the possibility of seeing features that might be masked in different years. This gives CORONA the potential to be the favourite satellite dataset for archaeologists. Nevertheless, they are not always the ideal dataset for archaeological reconnaissance and its potential has to be evaluated for each specific research area.

A set of panchromatic CORONA full-frame images acquired in 1967 with a spatial resolution of 2m was purchased for the entire study area in order to acquire suitable quality for archaeological applications (Fig. 3.1).

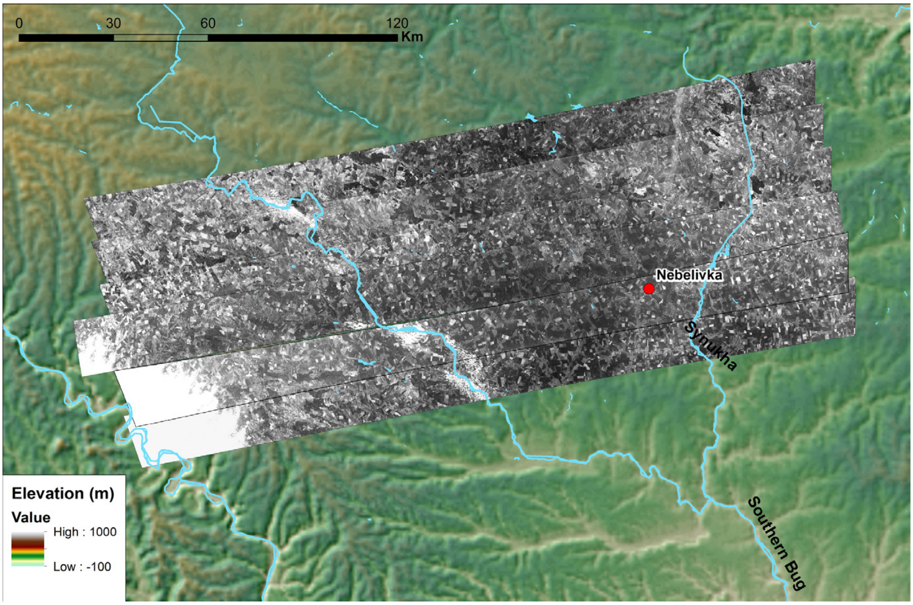


Figure 3.1: Coverage of CORONA imagery for the study area (by M. Nebbia; copyright: The Project).

The assessment of the imagery potential for archaeological reconnaissance consisted of two tests of the mapping of archaeological features in the Ukrainian steppe; 1) a predictive photo interpretation in *terra incognita* of the area of interest; and 2) a post-dictive comparison of known sites clearly discernible on other high-resolution datasets, such as WorldView-2 (for the micro-region) and Google Earth sets of images (for the regional domain).

The knowledge of the archaeology in the territory assisted in the second post-dictive assessment; after checking the visibility of known Trypillia megasites on the CORONA images, it turned out that only one settlement (Nebelivka) out of eight manifested itself on the image as a slight anomaly that can be interpreted as a potential archaeological site.

In conclusion, the contribution to the study made by CORONA imagery is, unfortunately, very limited, and therefore the project necessarily purchased higher resolution, more expensive datasets, such as WorldView-2, for targeted areas.

3.2.4 WorldView-2 Imagery

The ratio of cost to coverage always dictates the research strategy. Therefore, a first sample set of images was acquired for the 5km hinterland around Nebelivka. WorldView-2 was judged the best dataset on the market for archaeological application, both in terms of its spatial and spectral resolution, and its ability to overcome the above-mentioned visibility limitations (Fig. 3.2).

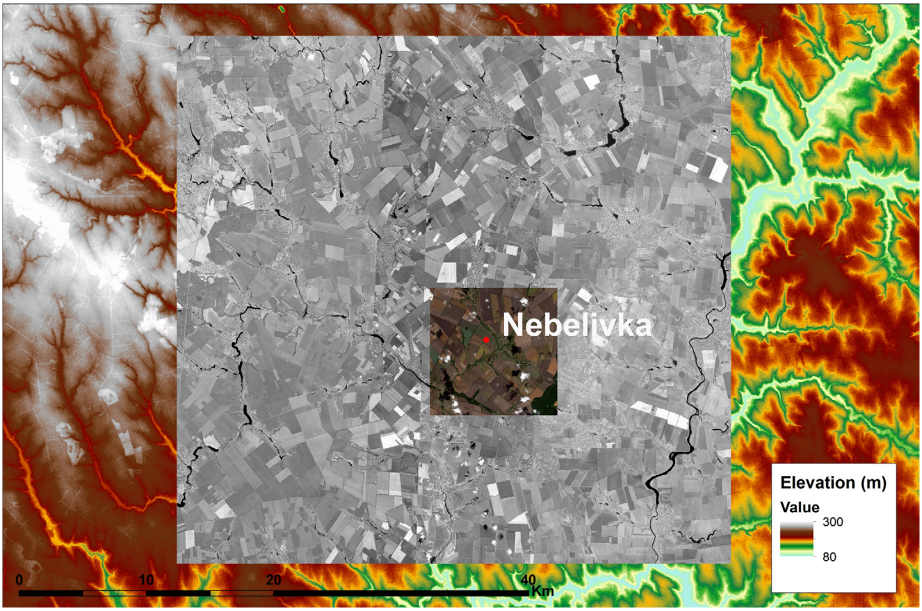


Figure 3.2: Coverage of the acquired WorldView-2 satellite images (8-band multispectral 1.85 m and panchromatic 0.46 m) for the Nebelivka micro-region (5 km radius) and panchromatic (0.46 m) satellite image for the Nebelivka macro-region (25 km radius) (by M. Nebbia; copyright: The Project).

WorldView-2 is a commercial Earth observation satellite owned by the company DigitalGlobe[26] which provides panchromatic imagery of 0.46m resolution and 8-band multispectral imagery of 1.85m resolution. It was launched in October 2009

26 https://www.digitalglobe.com/about-us/content-collection (accessed 4th June 2018).

and it takes a photograph of any spot on the Earth almost every day. Having a multi-spectral dataset allows the performance of a number of image processing and feature enhancements, thus stressing the vegetation growth and soil moisture content as key factors in detecting buried archaeological remains. At first, the focus was on the near-hinterland (5km radius) of Nebelivka for which the project purchased a mosaic of multi-spectral and panchromatic images which included a small element (0.034%) of cloud cover. After a pansharpening[27] process, a higher resolution of 0.46m has been achieved for the multi-spectral imagery as well, thus producing the best satellite imagery available commercially, in terms of both spatial and spectral resolution.

The choice of selecting an area of 25km radius around Nebelivka as the study area has been dictated mainly by cost, as it would have been too expensive to purchase WorldView-2 images for a wider territory. Therefore, a full coverage of panchromatic (0.46m resolution – 0.001% cloud cover) imagery was purchased for the Nebelivka macro-region (Fig. 3.2)[28].

The dataset covers a territory where a Trypillia presence is known in the Western part, whereas the South-Eastern area was archaeologically poorly explored. This presented the opportunity to test the potential of the remote sensing data both on an archaeologically known area and in *terra incognita*.

3.2.5 Mapping Archaeology in Ukraine

The feature mapping process has been developing since the beginning of photo-interpretation analysis, and new ways of storing mapped data have been theorized and applied. The best toolkit to manage spatial data are GIS platforms and their embedded geodatabases, which develop from a bespoke data model for the topological nature of the information.

A geodatabase customized for remote sensing analysis has been structured so that every useful piece of information regarding the buried features could be stored and represented geometrically as a point, a polyline or a polygon. Each object is represented as a **polyline**, because what is being mapped is conceived as the interface (therefore a line) between the anomaly produced by the object and the image background.

27 Pansharpening is the process of combining a high-resolution panchromatic image with a low-resolution multi-spectral image in order to obtain a high-resolution multi-spectral image. In most remote sensing software packages such as ERDAS Imagine (used in this study), this procedure is easy, automated, time-effective and accurate.

28 The data purchased were collected at different dates: 30th March 2014, 27th April 2012, 14th April 2008, and 6th September 2011.

The data recorded describe each mapped object with various attributes. All the values of each attribute are predetermined – on the basis of a general knowledge of what kind of information can be extracted from an image – and organized in different lists of close vocabularies, termed *Domains*, thus preventing redundancies in the database.

The intensive analysis of the multi-spectral WorldView-2 image produced over 300 features, mapped using a natural colour display (WorldView-2 multispectral acquired on 17 September 2011) (Fig. 3.3).

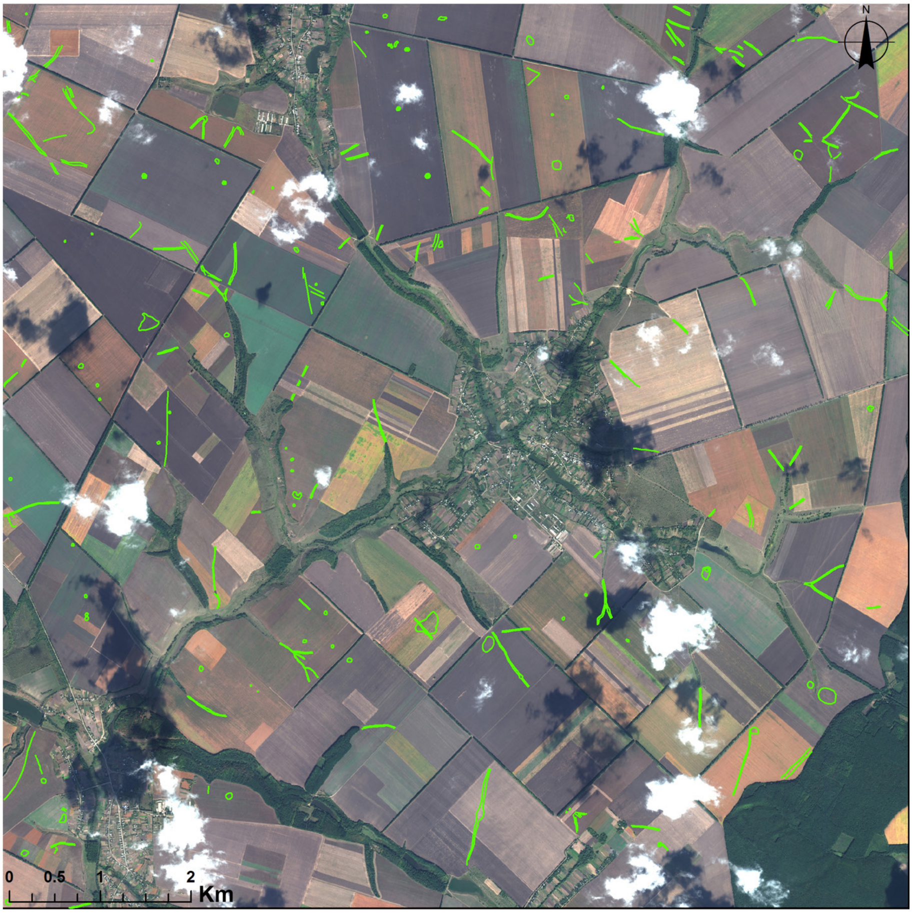


Figure 3.3: Distribution of anomalies mapped on the WorldView-2 satellite image, Nebelivka micro-region (by M. Nebbia; copyright: The Project).

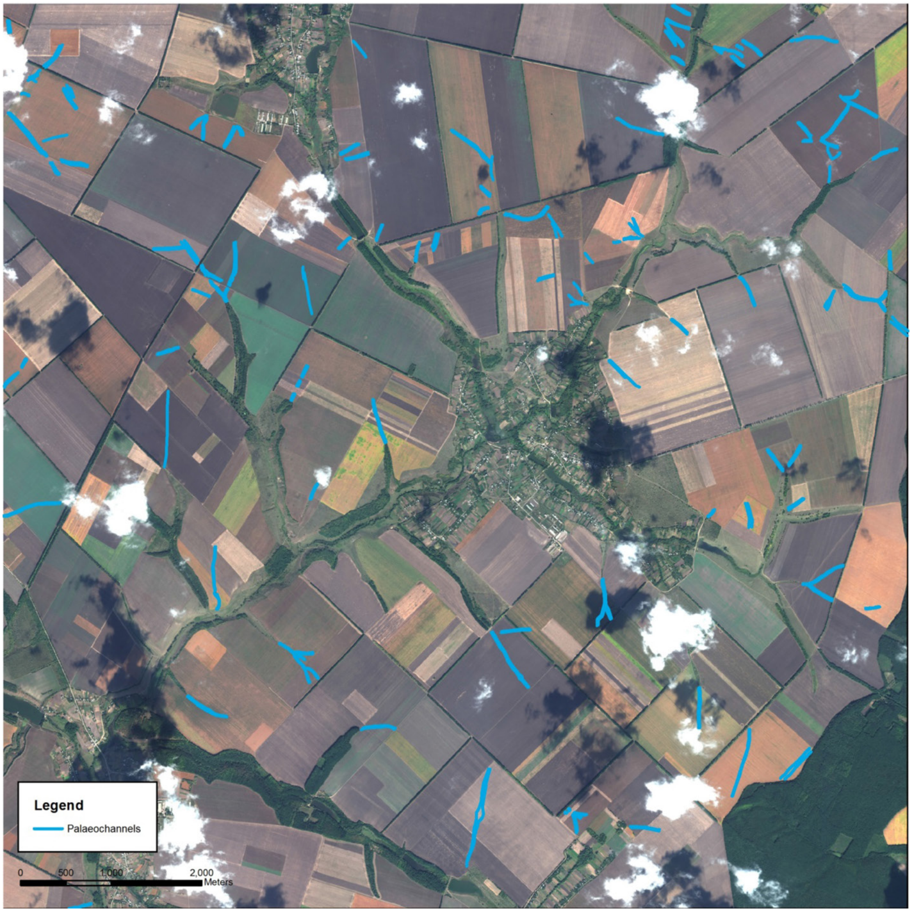


Figure 3.4: Distribution of anomalies interpreted as traces of a palaeo-channel network, the Nebelivka micro-region (by M. Nebbia; copyright: The Project).

The results showed that 51% of the features were manifested as cropmarks – viz., the presence of buried features restrained the crop growth – and 43% as soilmarks, i.e., the presence of features affected soil moisture. Only 21% of the features have been attributed to an anthropogenic origin, whereas the majority of the rest show an intricate but undated palaeo-hydrological network (Fig. 3.4). Considering only those features relating to potential archaeological sites (which include the Nebelivka megasite, burial mounds and other potential smaller sites), 76% showed up as soilmarks (Fig. 3.5). The rotating agriculture regime allows us to appreciate the different visibility of

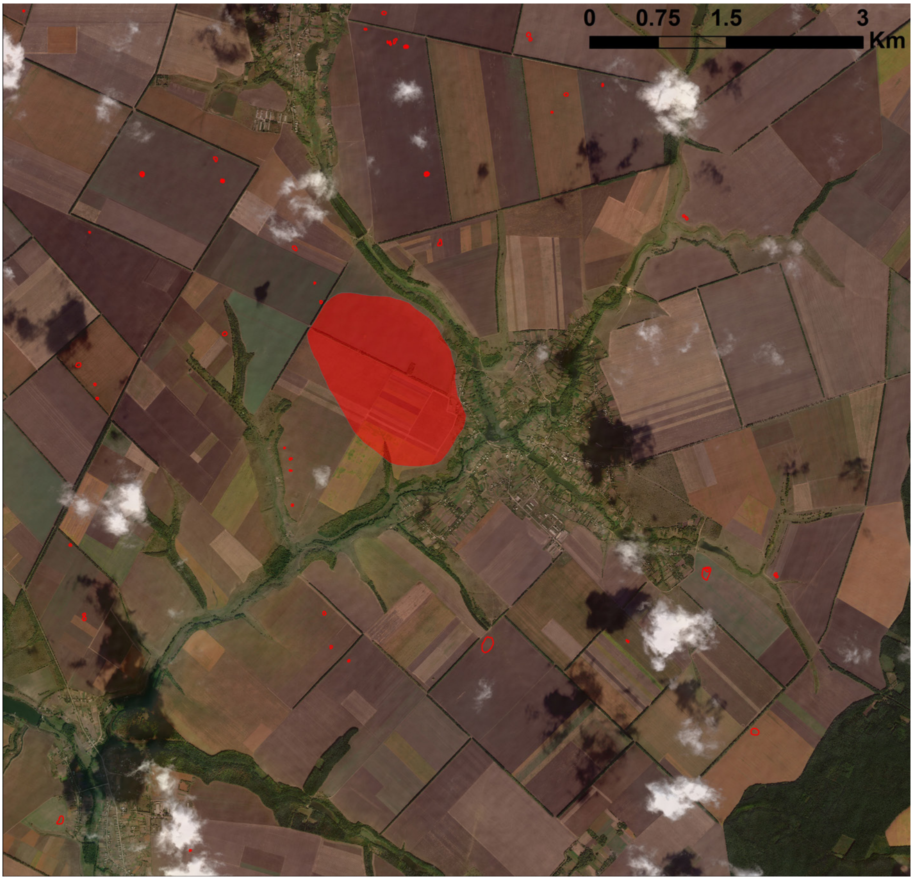


Figure 3.5: Anomalies mapped on the WorldView-2 pansharpened multispectral 8-band (0.46 m) satellite image, which have been interpreted as having anthropic origins (by M. Nebbia; copyright: The Project).

the same feature under two different land uses;[29] therefore, it was possible to state that, in cultivated fields, the archaeological anomalies are virtually invisible.

As for the case of Nebelivka, where the site extends across more than one field, it was possible to verify the decrease in the visibility of the anomalies indicating the Trypillia settlement on the cultivated areas. Moreover, the analysis of the archaeological deposit depths across the site shows how the features in the North-Eastern part are more visible because the anthropic horizon is closer to the current ground surface (see below, p. 217 & Fig. 4.47). A combination of tillage erosion and water run-off arguably explains the high visibility of features on the satellite image in

29 This is possible whenever we have two images, taken at different times and covering the same area.

the North-Eastern part of the site, in correspondence with the ground surface sloping downhill towards the river valley bottom (Fig. 3.6). Another WorldView-2 image, taken on 14 April 2008, shows the good visibility of the South-Western part of the site in crop-free conditions, since the features appear as soilmarks. Nevertheless, the higher visibility of the North-Eastern part of the settlement is confirmed, as the run-off effect is the major contributor to the shallowness of the topsoil. For another Trypillia megasite (Perehonivka, Cherkassy region – 7km South of Nebelivka), we have a double coverage of panchromatic WorldView-2 images, one taken in April 2008 and the other in September 2011. Since the whole of the 25ha site lies within a single field, the land use evenly affects the visibility of all the features constituting the settlement (Fig. 3.7). The comparison of the two images clearly demonstrates that, while the April 2008 crop-free image shows the site in its entirety, the September 2011 image does not even suggest the presence of buried features as the field is totally covered in crops.

The results of the assessment show the ways in which archaeological remains of Trypillia settlements can be detected and mapped on satellite imagery under very specific geomorphological and vegetation conditions. Moreover, ploughing and natural drainage erosion contributed significantly to archaeological visibility in remote sensing data. This may well explain why historical images like CORONA, which were taken 50 years ago, are not well suited for the identification of Trypillia sites in this area. Paradoxically, erosion through intensive and deep ploughing over the last century did not just destroy the sub-surface archaeological remains, but helped to make them more visible on the satellite imagery.

Since the visibility of archaeological features as cropmarks is very poor in this area, the most effective image-processing techniques involved the enhancement of visual capacity for distinguishing features of interest from the background. A number of procedures have been tested and the results showed how a PCA applied to the full spectrum of eight bands slightly enhanced the visibility of most of the features, but did not show more traces than a standard natural colour display. A decorrelation stretch applied to the RGB bands significantly enhanced the visibility of the anomalies, but no extra features could be detected compared to natural colour visualization. Finally, a decorrelation stretch using the near IR – 1 (band 7), red (band 5) and yellow (band 4) wavelengths gave the best results in terms of the visibility of features showing as anomalies. The number of features detected and mapped, however, has not increased, meaning that all the anomalies are potentially visible on the natural colour stretch. This outcome has to do with the particular sensitivity of the near-infrared wavelength to soil moisture level, which is affected by the presence of buried archaeology.

The systematic photo-interpretation of the WorldView-2 imagery resulted in different archaeological features being mapped both within the Nebelivka hinterland (5km radius) and within the macro-region (25km). There are relatively similar patterns in terms of object types detected in the two areas, with a significant difference regarding the presence of Trypillia evidence. The majority of the features can be interpreted as traces of an old hydrological system constituted by dry gullies

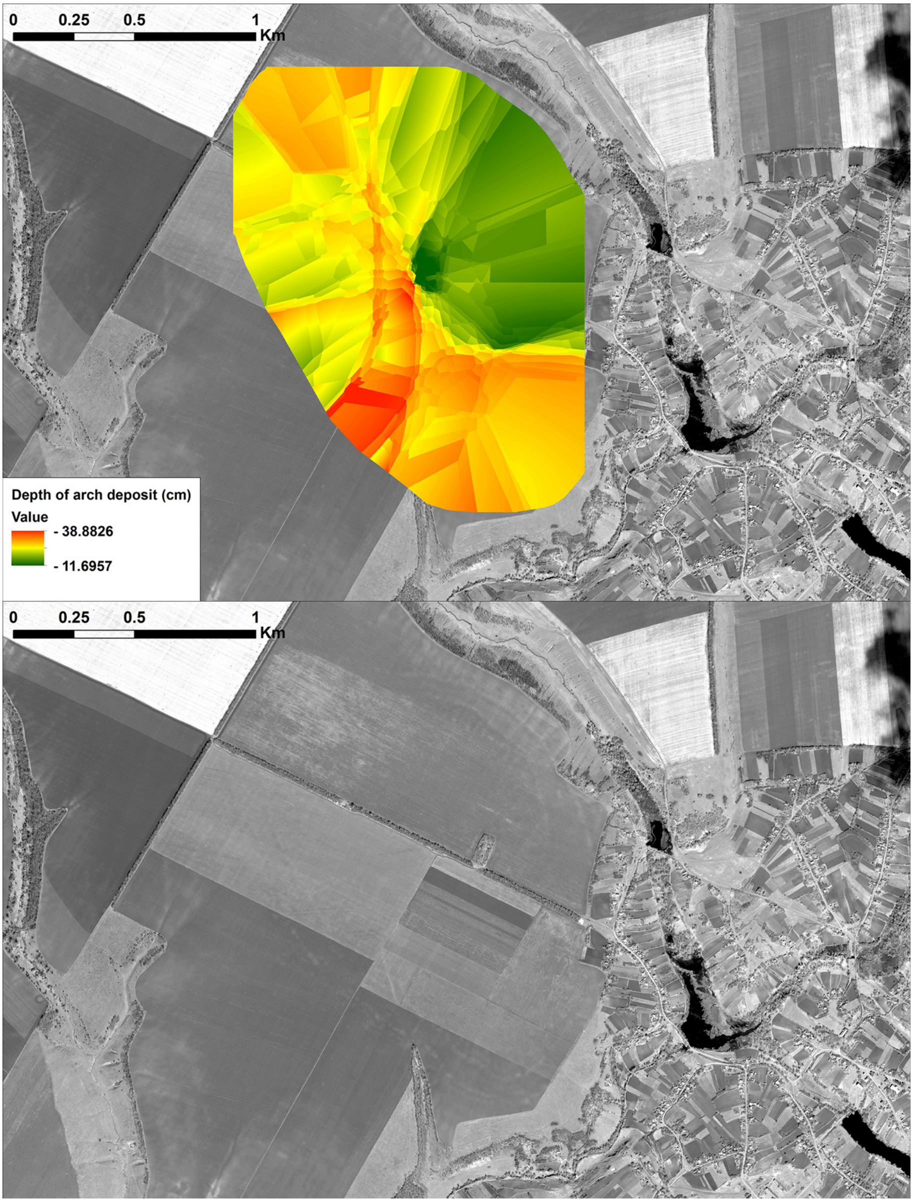


Figure 3.6: Shallow depth of the top of the anthropogenic deposit on the North-Eastern part of Nebelivka, allowing a better visibility of the anomalies compared to the rest of the site (by M. Nebbia).

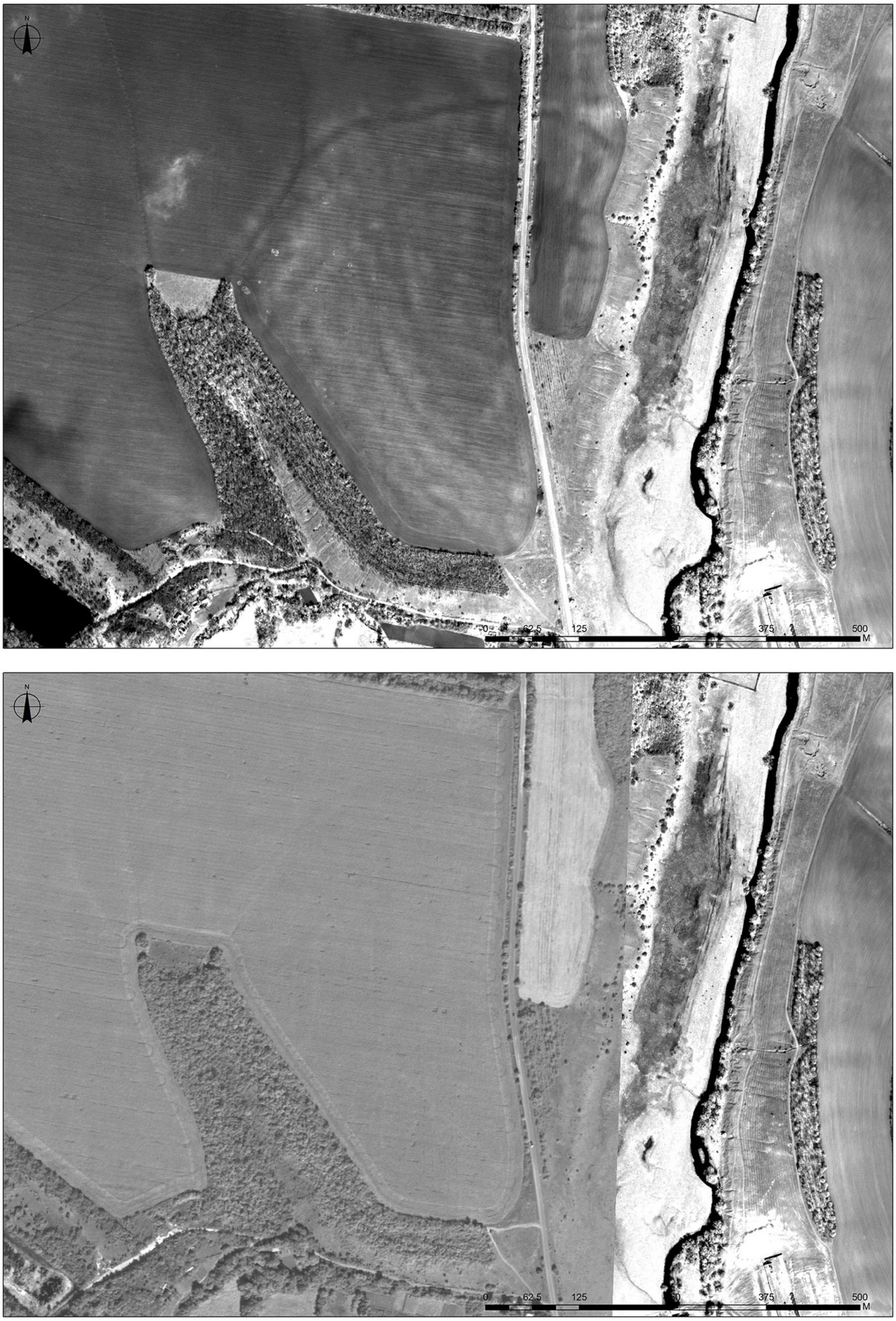


Figure 3.7: Two views of the Trypillia site of Perehonivka (BII): clearly visible in crop-free field conditions (upper) and totally invisible when the field is cultivated (lower): WorldView-2 panchromatic images (0.46m resolution), acquired on April 2008 (upper) and September 2011 (lower).

and relict palaeo-channels connected with still active, major rivers (Fig. 3.4). The scenario represented by these natural features suggests a denser network of rivers and streams, which was active in the past. Unfortunately, there is no chronological evidence to date the older features [30], although we can argue that the fact that one of the palaeo-channels runs across the two outer circuits of the site in Nebelivka and that the layout of the dwellings respects its limits, could suggest that it was active during the occupation of the Trypillia megasite (Fig. 4.14 lower).

Most of the other archaeological features mapped within the Nebelivka hinterland refer to burial mounds, which can date from the Early Bronze to the Late Iron Age. Burial mounds were preserved differently as they are situated in currently cultivated fields and therefore ploughing activity has levelled some of them out. Their height varies from 0.30m to 4–5m but even the subtler ones can be detected and mapped on satellite imagery (Fig. 3.8). The eroded mound tops reveal the subsurface soil composition which has a spectral signature distinguishable from the background field.

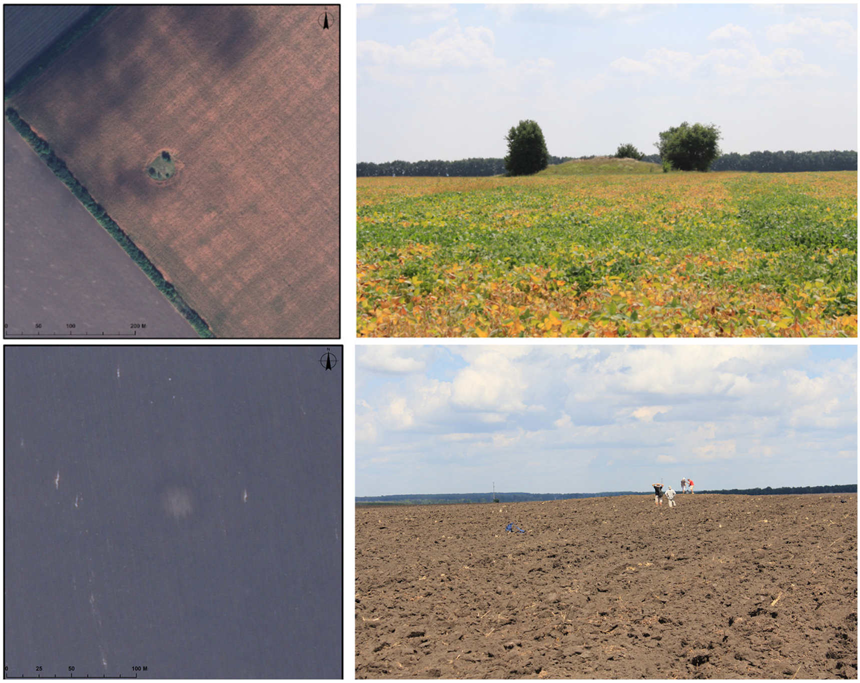


Figure 3.8: Comparison between two extreme examples of barrows as they appear on the WorldView-2 satellite image and on the ground (by M. Nebbia; copyright: The Project).

30 No OSL dating has been scheduled within the project for these features.

Barrows are one of the major categories of archaeological evidence that marks the territory under study at all scales. They are primarily situated on natural ridges or high topographical zones and mostly occupy inter-fluvial areas (Fig. 3.9). The mapping of the macro-region of Nebelivka yielded around 800 anomalies, which can with 95% certainty be referred to as burial mounds of different time periods. Although their shape is quite discernible from the background across different land uses, there is a number of false positives – i.e. anomalies which originate from modern human activities such as spoil heaps of agricultural waste, that resemble the shape and the topography of burial mounds.

Trypillia megasites are quite visible on the panchromatic WorldView-2 image, although, as already mentioned, only in crop-free conditions. More Trypillia sites have been mapped in the macro-region and the patterns of their visibility on the imagery are similar to that of Nebelivka, where the parts of the sites lying on the slope towards the river valleys are considerably clearer. Sites like Sushkivka, Yatranivka and Volodymyrivka present a similar layout as Nebelivka, with two outer concentric circuits of dwellings and radial rows leading to the inner open area at the centre; they are all situated in comparable geomorphological locations at the junctions of two river valleys or along a sharp river bend. The run-off areas show the archaeological remains more clearly than the top of the field where the sites are nested.

Sites like Majdanetske and Taljanki (the biggest Trypillia megasite) are not so easy to detect on the imagery, probably due to two main factors. The first is that, arguably, the archaeological deposit is deeper compared to the other sites and therefore the presence of buried remains does not affect soil moisture content enough to produce a clear anomaly. Secondly, the simple fact is that one single image cannot guarantee the best condition for the identification and mapping of a feature. The results of the remote sensing analysis show how only 8 out of 24 sites are visible – whether completely or partially – on the images within the macro-region; and only 15 out of 500 sites recorded in the whole Ukraine.[31] However, smaller sites like Apolianka can also be mapped if the land use conditions are favourable. This site is an example of a scatter of potsherds and building materials indicating very low-density settlement occupation, where the mean average distance between dwellings is nearly 40 m. From the photo-interpretation, the structures can be detected and mapped individually; therefore, we can argue that the anomalies on the image represent *in situ* archaeological features. This can be argued also for the megasites where the more regular planning shows clusters of dwelling nested one next to the other, thus revealed on the image as a continuous linear feature. In the case of megasites, the high proximity of archaeological remains produce an uninterrupted anomaly but single structures can still be detected from the surface scatter of potsherds and building materials confined to each structure (Roe, n.d.; see below, Chapter. 3.2.2) (Fig. 3.11).

31 The assessment was performed with Google Earth which provides a wide range of images, taken in different times of the year for different years.

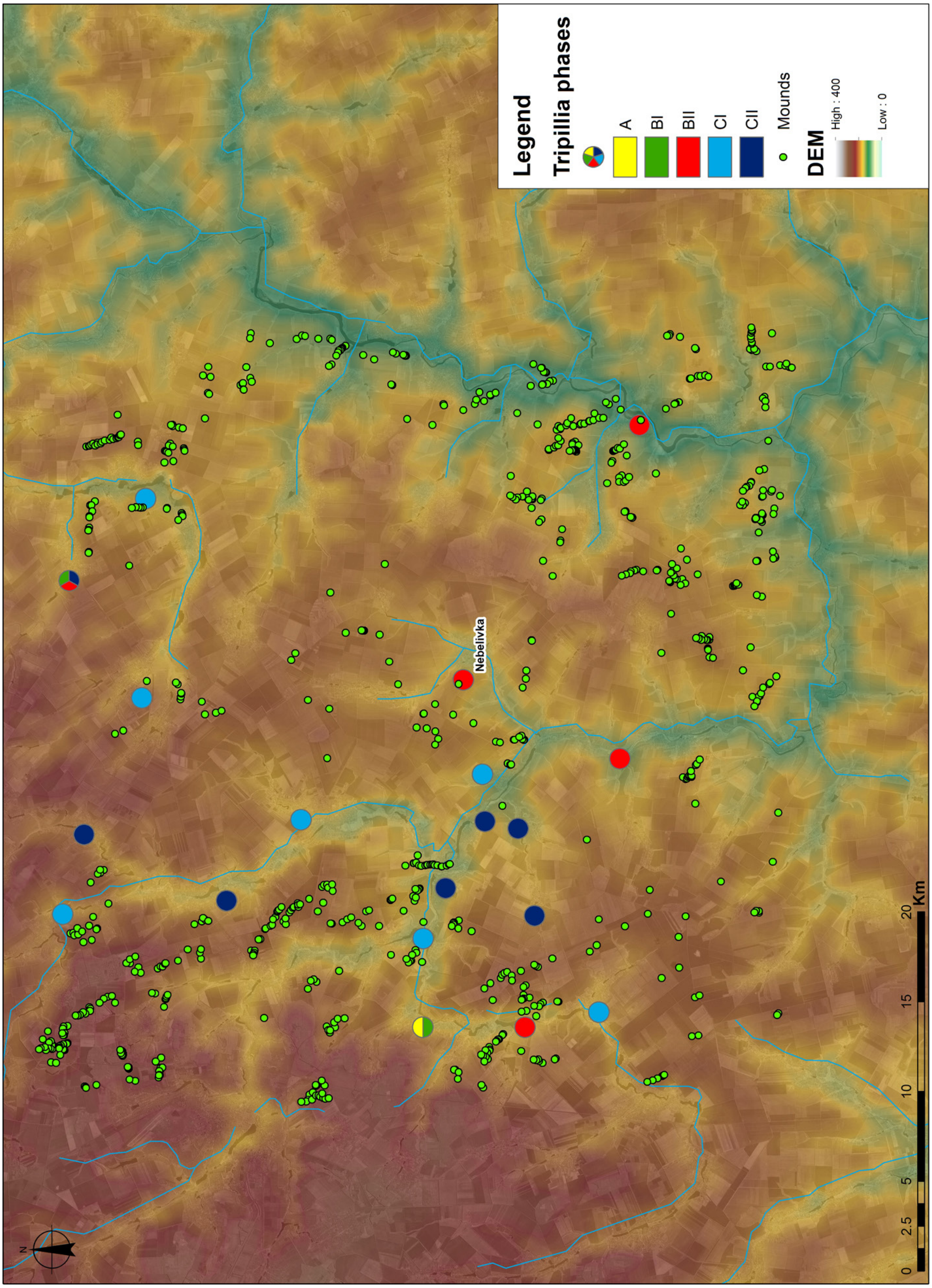


Figure 3.9: Distribution of all the anomalies that can be interpreted as burial mounds mapped within the Nebelivka macro-region, with Trypillia sites by Phase (copyright: The Project).

Overall, the remote sensing analysis has been shown not to be the best method for discovering sites in the Nebelivka micro-region. This is due to several factors, but mainly to the limited availability of satellite datasets. In fact, a wider range of land uses, different times of data acquisition and different sensors could help in overcoming some of these limitations. The tendency is now to use multiple data sources combined in order to produce images containing a high level of information for archaeological applications. Only the availability of more data and a more accurate assessment of the best temporal window for data acquisition can improve the applicability of remote sensing analysis in this area (Aqdus et al. 2012; Agapiou et al. 2013).

The great contribution of Very High Resolution (VHR) remote sensing datasets resides in the direct correspondence between the anomalies and the archaeological features, which allows for a better estimation of the site size and occupation density. Individual structures are visible as *in situ* features, rather than homogeneous halos representing surface and sub-surface scatters of material. Therefore, site layouts, the number of dwellings and their orientation, and site limits can be recorded and estimated more accurately.

Marco Nebbia

3.3 Fieldwalking

3.3.1 A New Methodological Agenda for the Ukrainian Forest-Steppe

Since the outset, the research agenda of Trypillia studies has not included systematic field survey investigations. The Ukrainian literature yielded very few reports on unsystematic surveys, carried out mostly as “supplements” of major excavations on Trypillia sites and megasites. Archaeologists mostly relied on local farmers’ knowledge of Trypillia potsherd scatter locations in the fields, and most of the sites were found thanks to sporadic and unsystematic field surveys (in Russian, *razvedki*).

Data recording systems have been developing, and the introduction of GPS has considerably improved the site location process in the last few years. Nevertheless, data collection methods do not follow procedures that are now standard in Western European archaeology and they are still inadequate for the level required by the scientific community. Ukrainian methods of investigations in the field have always been quite traditional and not inclined towards technological and methodological innovations. As mentioned above, Ukrainian archaeologists have been using remote sensing since the 1960s without developing a tailored strategy for the specific case of Trypillia sites. The same conservative approach has been pursued with field survey, so that a new methodological agenda for field investigation was needed.

The Danish-Dutch-Ukrainian Dzarylgaz Survey Project (2007–2008) first introduced modern field survey methods into Ukrainian archaeology, including extensive, intensive and systematic investigations in the region around Lake Dzarylgaza and the hinterland of the Greek site of Panskoe I on the Tarchankut Peninsula, North-Western Crimea (Guldager Bilde et al. 2012). Although the project's main focus was population dynamics and interactions during the Greek period between colonisers and indigenous people, the research adopted a long-term diachronic approach to the study of landscape (Guldager Bilde et al. 2012, p. 13).

As for Trypillia studies, no systematic investigation of the landscape has been carried out so far. Therefore, one of the most fundamental impacts of the current Trypillia Megasites Project was the introduction of field survey methodologies into the Ukrainian research agenda, thus refining the understanding of settlement patterns dynamics in the forest-steppe belt in continental Ukraine before, during and after the Trypillia period.

Field survey has been conducted for four main reasons: (1) to assess the potential of field survey recovery for detection of Trypillia settlements and establish the intra-site structure of Nebelivka; (2) to establish patterns of archaeological evidence in the off-site domain of a Trypillia megasite, both during the occupation of the settlement and in other time periods; this information will help in understanding the complex processes of site emergence, development and abandonment; (3) at a smaller scale, field survey data have been used to assess archival information regarding site locations and sizes; since the majority of site sizes reported by the literature are based on surface collection, it was vital to cross-check the potential of the surface scatters as proxies for site extent estimation; and (4) to ground-truth the results of remote sensing mapping; it is essential to check a sample of features mapped from satellite imagery in order to establish the reliability of photo-interpretation and to assess the potential of the different types of datasets in the specific territory.

In the following sections, these four strategies will be discussed as they have been used in the field, and their contribution to the research elucidated.

Joe Roe

3.3.2 Intra-Megasite Collection

In addition to the program of fieldwalking in the landscape surrounding the site, an intensive survey of surface material on the megasite was conducted as part of the project's initial field season in 2009. The aim of this survey was to collect independent data on intra-site spatial patterning to compare to the pilot geomagnetic survey. Full details of the methodology and results of the results of this surface collection may be found in the Project Archive (https://doi.org/10.5284/1047599 Section 4.7.1) and were also the basis of an undergraduate dissertation (Roe n.d.).

The collection was undertaken on the same area covered by the 2009 geomagnetic survey, consisting of approximately 15 hectares on the Eastern edge of the megasite (Figs. 3.10 upper & 3.11). The area was divided into 30 × 30m grid squares but, due to time constraints, only about 85% of the area could be surveyed; squares that contained geomagnetic anomalies were prioritised. In those squares that were surveyed, a random, timed collection was carried out allowing thirty person-minutes per square. All visible material on the surface was collected, labelled by square, and taken back to the field lab to be classified, counted and weighed. Diagnostic potsherds that were not of a Trypillia type were identified and recorded as a separate class of find. Bone was recorded, but can be dismissed as being unlikely to be of any antiquity. Otherwise, it was assumed that all the material was associated with the Trypillia site. Particular attention was given to accounting for post-depositional factors that may have distorted the surface distribution, namely the depth of soil and consequent biases in dispersion due to ploughing, geomorphological slumping, and surface visibility during the survey itself. We were therefore able to rule out any of these factors having had a significant bearing on the surface collection data.

Vast quantities of pottery and daub were recovered from the surface of the megasite. Despite the significant ‘noise’ expected due to ploughing and other taphonomic effects, the distribution of these finds closely matches the sub-surface remains as seen on the geophysical plot (Fig. 3.10 upper). The two concentric rows of houses are clearly visible, as are the loosely-spaced interior houses and, to a lesser extent, the street dividing the rows into ‘Neighbourhoods’. The space between the rows was all but barren, indicating that whatever activities took place there during the use of the site, it left little material trace. The resolution of our surface collection was not sufficient to distinguish individual houses, although it is possible that one conducted using a smaller sampling grid would do so. We were not able to use the surface collection to distinguish burnt and unburnt houses, either by the density of surface material or the proportion of it that was vitrified. Pits were also only evident on the geophysical plot. Still, the macro-spatial layout of the megasite is readily apparent.

Interestingly, the two Assembly Houses in this area of the megasite are not at all visible in the surface collection data. Two conclusions may be tentatively drawn from this fact. One is that, despite their size, the Assembly Houses used relatively little daub compared to the average Trypillia house, adding weight to the interpretation that these were relatively light, open buildings. Similarly, the lack of pottery in comparison to houses suggests that they were used in a different way, i.e., not as domestic structures. Although these conclusions, drawn from unstratified and poorly preserved surface material, carry little interpretive weight in comparison with data from the subsequent excavations, they do immediately caution against the assumption that a structure with a “mega” footprint is necessarily substantial in an architectural sense.

Other than daub and Trypillia pottery, there were few other finds of interest. Only four ceramic sherds were identified as being non-Trypillia in origin, suggesting that, for the most part, this part of the site had only one phase of occupation, though plough action may also have affected our ability to diagnose sherds on the surface (Taylor, J. 2000). Bone and groundstone was sparse, probably due to poor surface preservation and resistance to ploughing respectively. The relative absence of chipped stone may

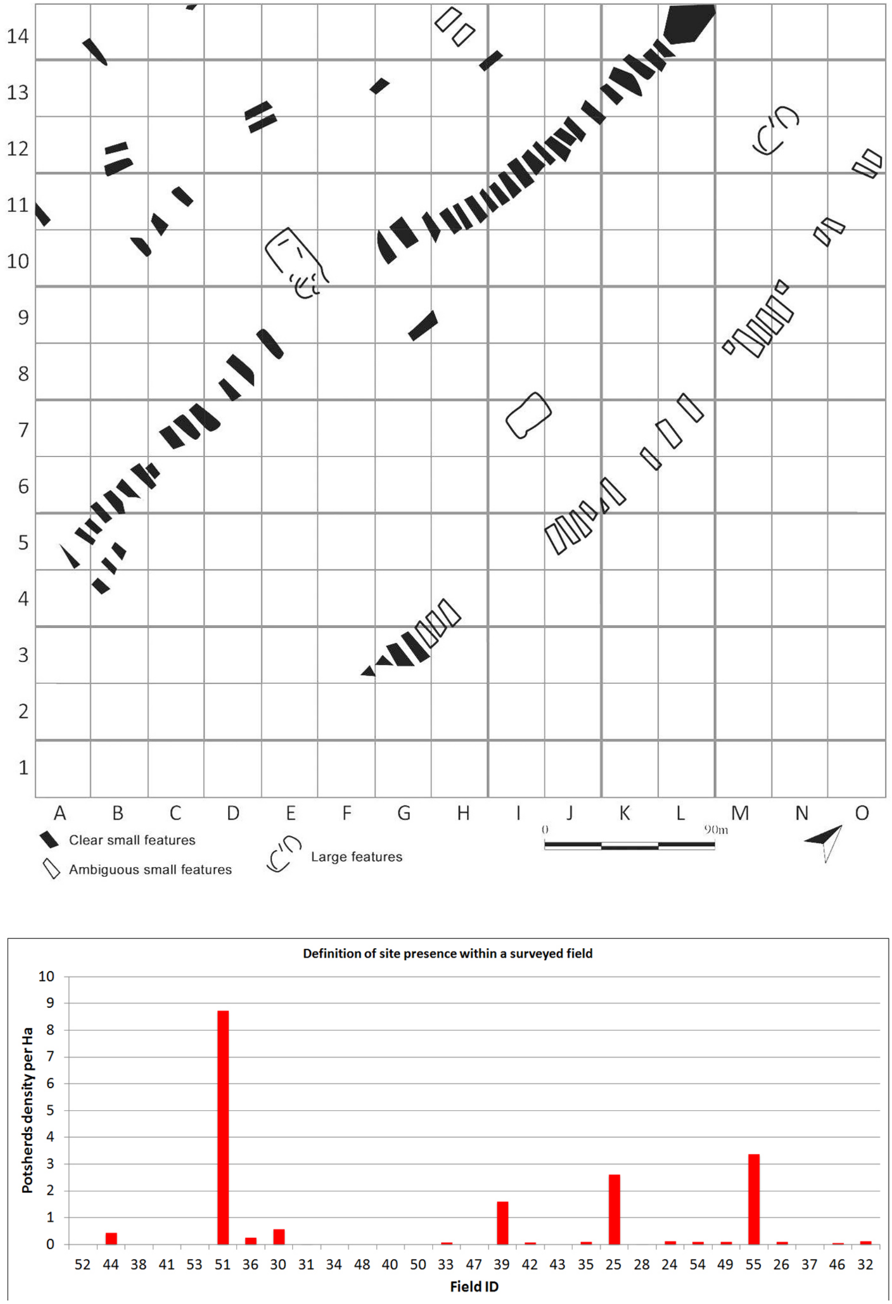


Figure 3.10: Upper: Interpretation of the geomagnetic survey, South-East corner of Nebelivka. Visible are parts of the two concentric circuits of houses (by J. Roe); Lower: sherd densities across the surveyed land units (by M. Nebbia).

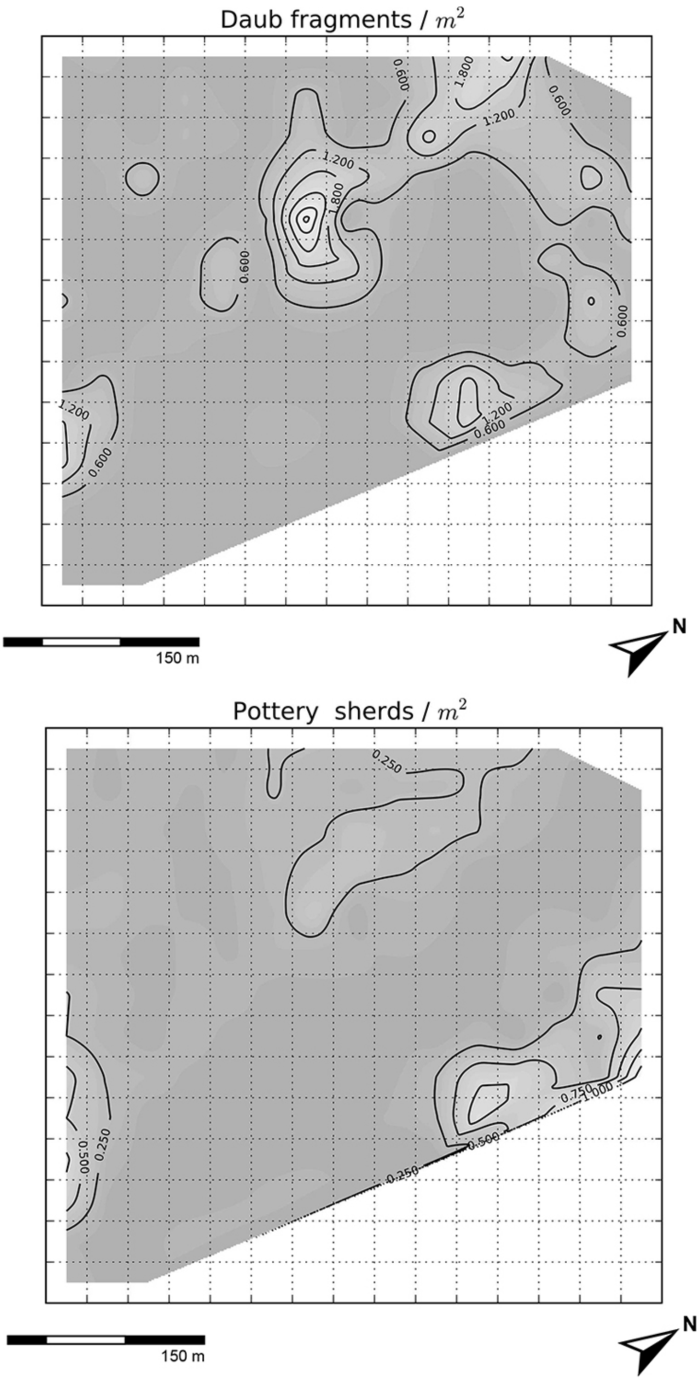


Figure 3.11: Interpolated contour plot of daub (upper) and pottery (lower) densities by number of fragments (by J. Roe).

be more meaningful. Certainly if there was knapping in this part of the megasite, we would expect to see more concentrated scatters on the surface. Some Trypillia sites can produce large lithic assemblages, but more frequently in the Western part of their range and in earlier periods (Zbenovich 1996, p. 224). The provision of lithics to Cucuteni-Trypillia sites in general is not well understood (Chapman 2002; see below, Section 5.2.5); quite possibly at Nebelivka and other Eastern sites, flint and chert were relatively scarce imports that were not readily discarded, similar to copper. Other miscellaneous finds included a possible figurine and a conical fired clay counter.

One interesting isolated find was a fragment of a Greek amphora handle, some 220m from the barrow (see below, Chapter 4.5.2). Scythian and Sarmatian groups on the Black Sea coast and Ukrainian forest-steppe had contact with the Aegean from the first millennium BC and Greek artifacts were frequently deposited in their barrows (Videiko 2008, pp. 207–11). The coincidence of these two observations (the amphora fragment and the possible ploughed-out mound) might therefore allow the tentative dating of an Iron Age barrow in that part of the site. A piece of slag was also recovered from the centre of the area, perhaps suggesting metal production activity of unknown date in the locality.

The overall conclusion is that the intra-site gridded collection demonstrated that it is informative of the broader pattern of spatial organisation of a megasite, especially considering the low investment of time and resources required to carry it out. Moreover, the 'mismatches' between the surface collection and geophysics, as for example the absence of finds over the Assembly Houses, highlights the complementary nature of the two datasets, and opens avenues for further investigation in the field.

Marco Nebbia

3.3.3 Trypillia Off-Megasite Survey: A Combined Adaptive Sampling Strategy

Since neither a systematic nor a designed field survey has ever been conducted in continental Ukraine (especially within Trypillia studies), the project deemed it necessary to plan a sampling strategy targeted at assessing the potential for recovering archaeological sites in general and to investigate the hinterland of a Trypillia megasite (Nebelivka). The sampling strategy is a fundamental step in the research design and key to understanding the data collected, particularly how representative and reliable they are "*within the bound of their (researchers') restricted time and monetary resources*" (Binford 1964, p. 427; Redman 1987).

The strategy was a combination of informal and formal sampling (Orton, C. 2000, p. 2). The first, *informal* choice was to investigate a radius of 5 km around the megasite to verify the presence of Trypillia sites and to assess the general site locations for all time periods. The choice was to conduct a block survey covering the entire extent of each field, thus recovering a representative sample of the landscape. Considering the limited amount of time available, a random coverage of fields with higher ground visibility has been sampled in order to have the most reliable results from a single survey. The rotating agricultural regime guarantees that, every year, every field changes crops; hence, the influence of modern land use on post-depositional processes and preservation of surface scatters is randomized. Therefore, we can consider the choice of surveying one field against another one independent from their influence to the potential of recovering surface finds aside from the current ground visibility at the time of the survey. We can then say that the choice of surveying only the fields with high visibility represents a *formal* random sampling with the highest potential to recover archaeological presence in a single survey season. Furthermore, this strategy allowed for the assessment of sites recovery on both inter-fluvial and peri-fluvial areas of different slope and aspect.

Embracing an adaptive 'non-site' sampling strategy (Thomas, D. 1975), where the smallest unit of investigation is the artefact and not the site as whole, the 2009 survey season focussed on collecting all the materials scattered on the surface of the walked field and plotting them using a hand-held GPS device[32] (Fig. 3.12). This gave an idea of how the finds were distributed on the surface and, therefore, helped the definition of site from off-site scatters. Students participating in the field season carried out the survey by walking transects across each field. After a first test of different spacing between transects, it turned out that 20 metres is the most cost-effective distance, which allows recognition of the different range of site scatters found in the surveyed area. The definition of site scatter has been broadly discussed since the beginning of modern archaeological surveying (Gallant 1986; Schofield 1991; Bintliff 2000; Waagen 2014), and numerous methods have been established in order to achieve the best results. In the case of Ukrainian ploughed fields, the differentiation of site scatter from off-site distributions of material resulted quite straightforwardly from the outcome of the first season of fieldwalking around Nebelivka.

From 2012 onwards, the adopted regular grid allowed for clear recognition of the concentration of potsherds defining a site against the average sherd density per ha. Field 25, for instance, has an expected sherd density of 2.6 per ha, whereas, in the South-Western corner, we identified a cluster of surface material with a density of 60 sherds (88% of the total number of sherds found within the field limits) per ha. Another example is Field 39, where the expected sherd density is 1.6 per ha, and the site identified on the Northern corner presents a density of 32 sherds per ha. If we compare surface finds densities across the 30 different surveyed fields we can clearly see how the four fields containing archaeological sites stand out, thus providing a threshold of 1 sherd per ha for land units containing scatters definable as sites (Fig. 3.10 lower).

32 See https://doi.org/10.5284/1047599 Section 2.2.

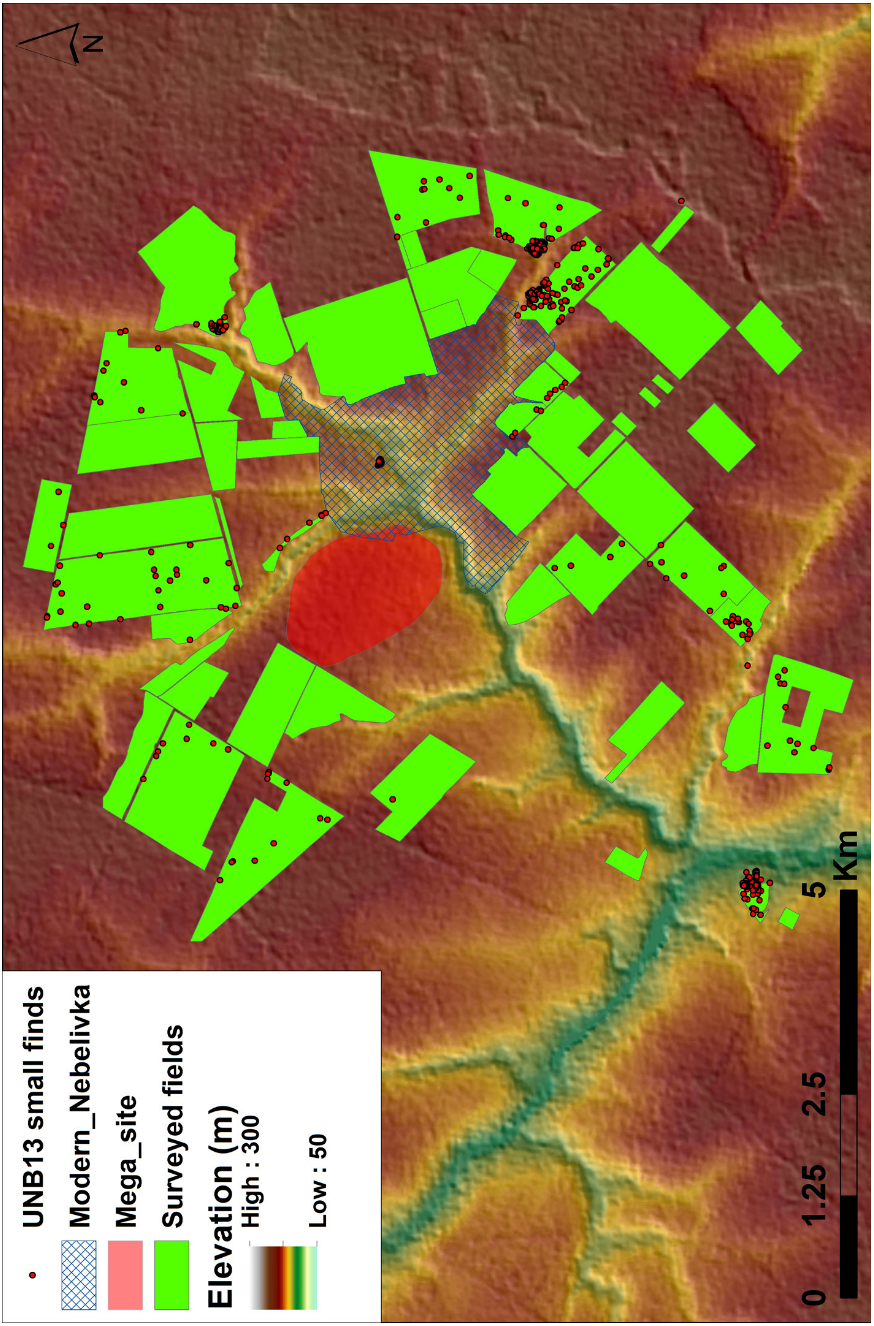


Figure 3.12: Fields surveyed with a non-site sampling strategy in 2009, 2012 and 2013, Nebelivka hinterland, to assess the definition of 'sites' from surface scatters (by M. Nebbia).

The data collection followed an adaptive cluster sampling (Orton, C. 2000, pp. 34–38). The starting sample unit is the regular transect until a high level of material concentration is found. Thereafter, the walking strategy adapts to the local variability of potsherd density by investigating the adjacent Neighbourhood until an expected density is found again. The localized anomaly in material density corresponds to what we defined as a site. The limited amount of time available did not allow any evaluation of the nature of these sites, although most of them returned mainly pottery and rarely any building material.

Sampling strategies in successive years built on this first assessment and aimed at confirming site locations, thus achieving a more accurate estimation of intra-site organization and establishing a methodology to document site size.

3.3.4 Peri-Fluvial Survey Investigations

The results of the first season of field survey suggest that a high proportion of archaeological sites sit on riverbanks at the junction of two or more river branches, very close to watercourses, with the inter-fluvial areas mostly free of settlements. The outcome of the first assessment suggested the planning strategy for further investigations of the Nebelivka hinterland. No Trypillia settlements were found within 5 km of Nebelivka, and no Trypillia potsherds were classified as off-site scatters. This result has multiple archaeological implications that will be discussed below (see pp. 106–108). After surveying 2,744ha of ploughed fields within a 40km^2 total area in 2012 and 2013, the four scatters defined as archaeological sites all reflect the same geomorphological settings, as mentioned above. Therefore, further investigations were planned along major and minor watercourses, some still active, others dried out and currently used as pathways. Table 3.1 summarizes the main periods and cultural labels that relate to the material collected during the field survey.

Table 3.1: Main periods and archaeological cultures found during the field survey (by M. Nebbia).

Period or cultural label	Dates
Bronze Age	3000/2900–1050/1000 BC
Iron Age	1050/1000 BC–2nd century AD
Cherniahov	2nd–5th century AD
Slavonic	5th–10th century AD

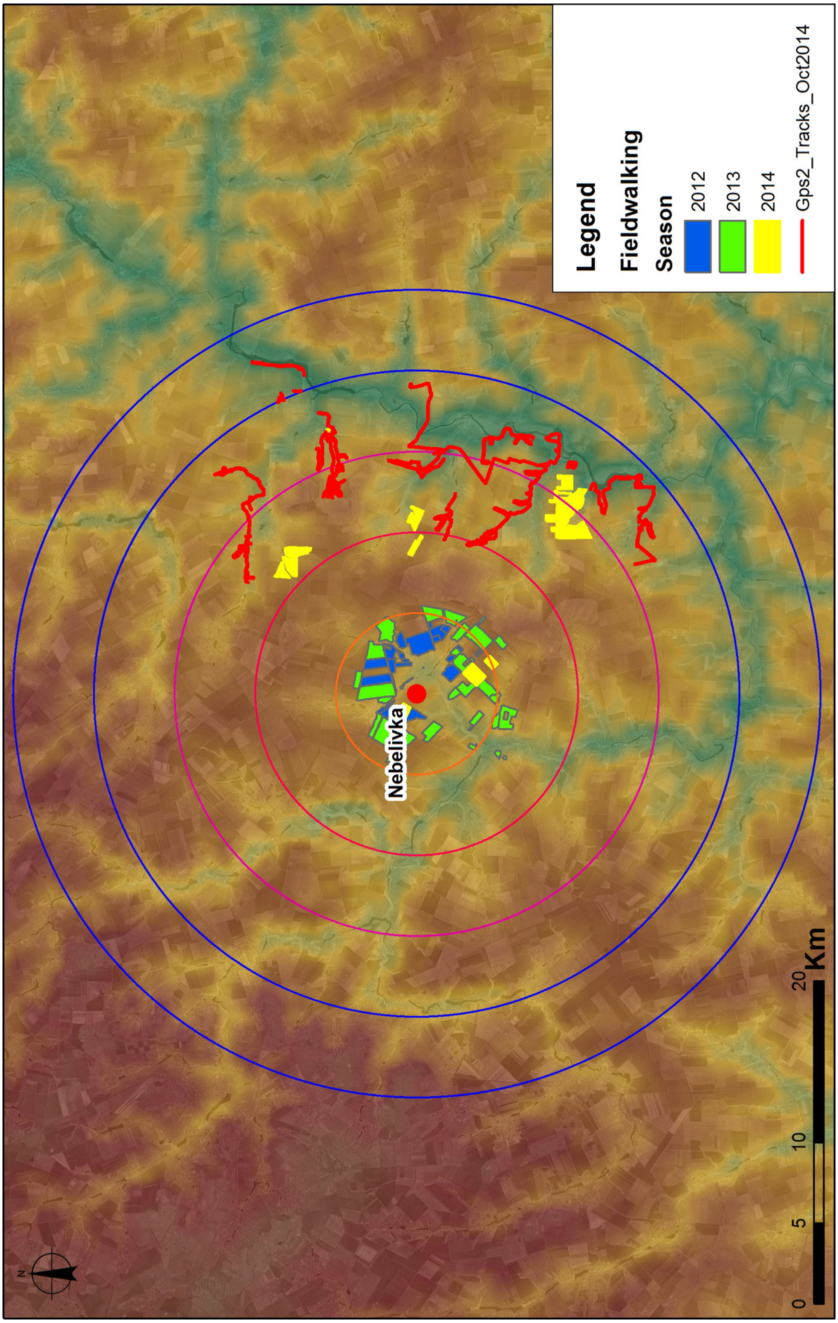


Figure 3.13: Areas covered by the field survey in the 2012–2014 seasons (by M. Nebbia).

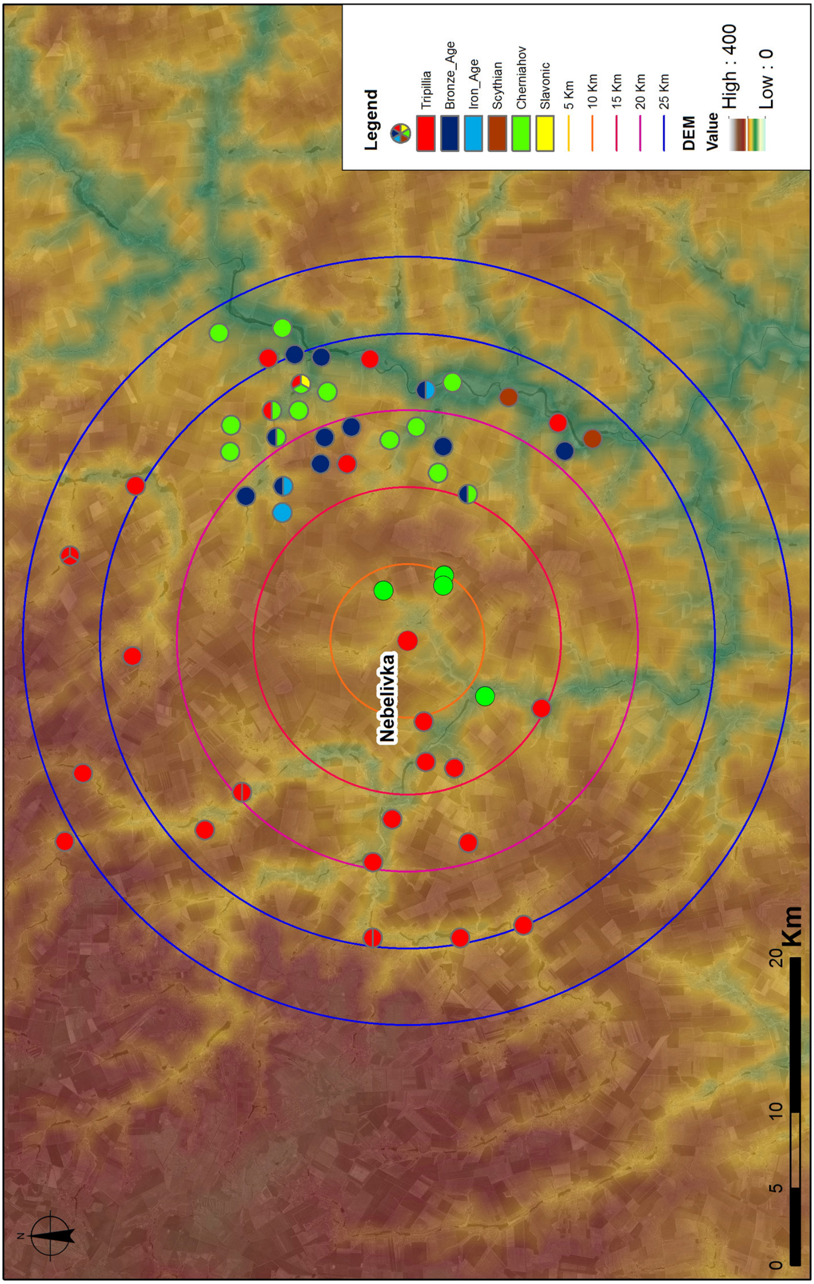


Figure 3.14: Distribution map of all sites recovered during the 2012–2014 field survey seasons, including the locations of known Trypillia sites in the Nebelivka macro-region (by M. Nebbia).

In 2014 and 2015, we surveyed a total of 158.5km along river courses covering an area of 574ha during a short three-week season, finding 30 sites[33] of all time periods (two of which were Trypillia) (Figs. 3.13–3.14). These results showed a shift from a site density of 0.001 per ha in the first season to 0.05 sites per ha in the fourth season. This result confirmed that settlement locational strategies were essentially the same from the Copper Age to the Post-Medieval period. The investigated area included a transect leading from Nebelivka towards the megasite of Volodymyrivka (Trypillia BII), situated to the South-East along the Synukha River.

This choice was dictated by the question of looking for Trypillia settlements between two contemporary megasites in an archaeologically understudied area. Furthermore, the territory covering 25 km radius from Nebelivka has been chosen as wider hinterland to be investigated in terms of Trypillia settlement patterns, thus defining the megasite macro-region.[34] The macro-region comprises the counties (Ukrainian = *oblast*) of Cherkassy and Kirovograd and the border between the two crosscuts the study area more or less diagonally from North-East to South-West. This left the South-East quadrant of the macro-region totally within the Kirovograd county, which has never been properly investigated archaeologically. Therefore, the field survey focussed on the right bank of the river Synukha and all the right tributaries, both active and dried out. In this way, the South-East quadrant of the macro-region represents a sample for both completing the knowledge on Trypillia presence and grasping insightful data on long-term settlement patterns trajectories (Fig. 3.14).

3.3.5 Site Sampling Strategy

Another goal of the field survey conducted along river courses has been to establish a method of sampling single sites, in order to understand their extension and gain some insights on the internal structure. Given that site scatters are clearly discernible from the background and they are mostly single phase (at least from the surface scatters), a sampling strategy intended to establish the shape, extent and internal organization of the site scatters has been adopted. Very few off-site materials have been found. The survey technique was a mix between extensive and intensive – a combination of extensive survey of long river branches and intensive sampling of each site scatter. The tight schedule and the limited manpower dictated the operative procedures. A first assessment of the scatter extent defined sampling intervals ranging from 20 metres, for small sites, to 80 metres, in the case of 1.8 km long sites located along the lower riverbank. In this way, it is still possible to compare the sherd density between

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33 See https://doi.org/10.5284/1047599 Section 2.2.
34 This decision was driven mostly by cost and time factors.

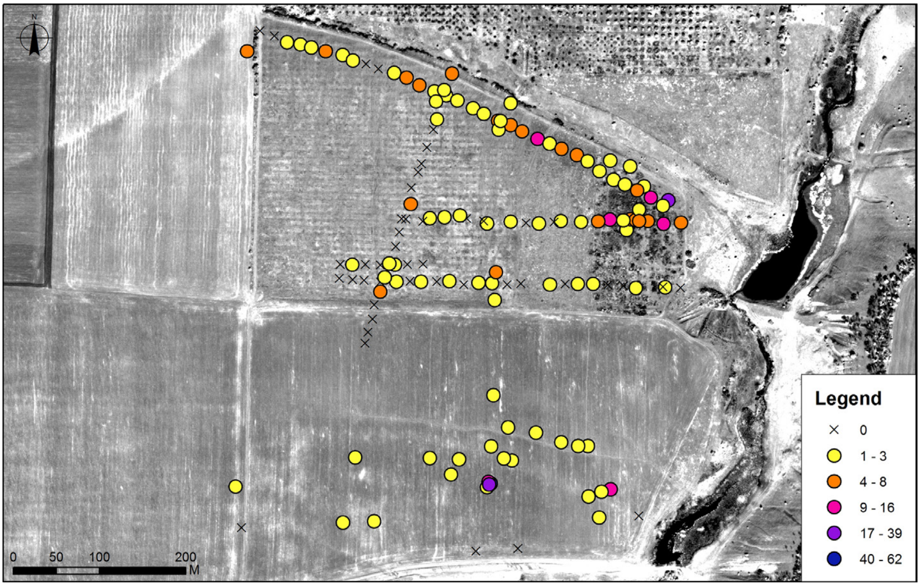

Figure 3.15: Surface material counts by site sampling transects at the newly discovered Trypillia settlement of Kutsa (20 km North-East of Nebelivka) (by M. Nebbia).

sites, by simply reducing the 20m sampling to 40m or 60m or 80m. We walked multiple transects across each scatter and picked up surface material within 3-metre radius samples until two consecutive samples were empty (Fig. 3.15). Samples were located using a hand-held GPS device and the finds database – with information regarding sample number, quantity and chronological horizon, type of material, part of the vessel (for potsherds), dimensions (for building material like daub) and comments for special finds – was merged with the points layer in GIS[35]. The plotting of samples with material quantities and material types enabled the definition of the edges of the scatter and therefore its shape, permitting the differentiation of core areas with a higher density of material from built-up areas from open spaces, with the additional comparison of the distribution and density of daub against sherds. For some Early Medieval sites, the distribution of metal slag enabled the location of production areas, usually at the downstream end of the settlement. Despite the low percentage of multiphase settlements, in some cases it was possible to detect expansions, contractions and shifts of the settlements through time.

35 See https://doi.org/10.5284/1047599 Section 2.2.

3.3.6 Assessing Site Sizes

The second way field survey contributed to Project research was through the assessment of information regarding site size derived from the literature. The major publication – the *Encyclopaedia of Trypillia Civilization* – contains all the Trypillia sites known in Ukraine compiled by gathering all available information; from unpublished amateur archaeological reports, to sporadic findings by local farmers, to scientific reports of excavated features (Videiko 2004). The sheer diversity of sources raised some issues about the reliability of the information reported. Therefore, it was crucial to make a thorough assessment of the reliability of the information regarding site size, with field survey playing a fundamental role in ground-truthing.

Very few Trypillia settlements have ever been excavated in their entirety, mostly because of their massive extent (the principal exceptions are Kolomiishchina I (Passek 1949a) and Ozheve-Ostriv (Chernovol & Radomskiy 2015). Therefore, the estimate of site size has always been derived from the dimensions of the surface scatter of material. Different techniques have been used to measure and to calculate the area of the halo. Generally, people have measured the two diagonals of the surface scatter and then calculated the extent by using the rectangle area formula. This method has been criticised when scholars realized that the shape of Trypillia settlements was oval rather than rectangular. Thereafter, archaeologists started calculating the sizes of surface scatters using the ellipse area formula, thus reducing previous estimations of site extent (Diachenko & Menotti 2012). Nevertheless, all these measurements, whether they were taken using a tape measure or GPS, do not take into account the density of the intra-site features and the effect that ploughing has had on the dispersal of surface material (Haselgrove et al. 1985). The first issue has been addressed in the first season of the project in 2009, when intra-site gridded collection on the megasite of Nebelivka found a good correspondence between surface material and sub-surface features (cross-validated with geomagnetic anomalies). The same results were obtained while surveying other, smaller Trypillia sites where the density of dwellings is lower and therefore each sub-surface structure shows up on the surface scatter quite neatly as a dense cluster of material. Even though we could not double-check the correspondence between surface and sub-surface features, we can argue that, overall for Trypillia sites, the surface material is an accurate proxy of the internal layout of the built-up area, based on the results of the gridded survey conducted at Nebelivka (Chapter 3.2.2) and visual assessment on the ground[36]. This is probably due to the fact that the deep ploughing reaches the shallow eroded top of the archaeological horizon, which is quite rich in material and therefore the sheer amount of sherds and daub that come to the surface is in strong contrast with the background soil. Therefore, since the micro-halo of surface material of a single buried

36 It was almost possible to see the rectangular shape of the structures from the surface scatter.

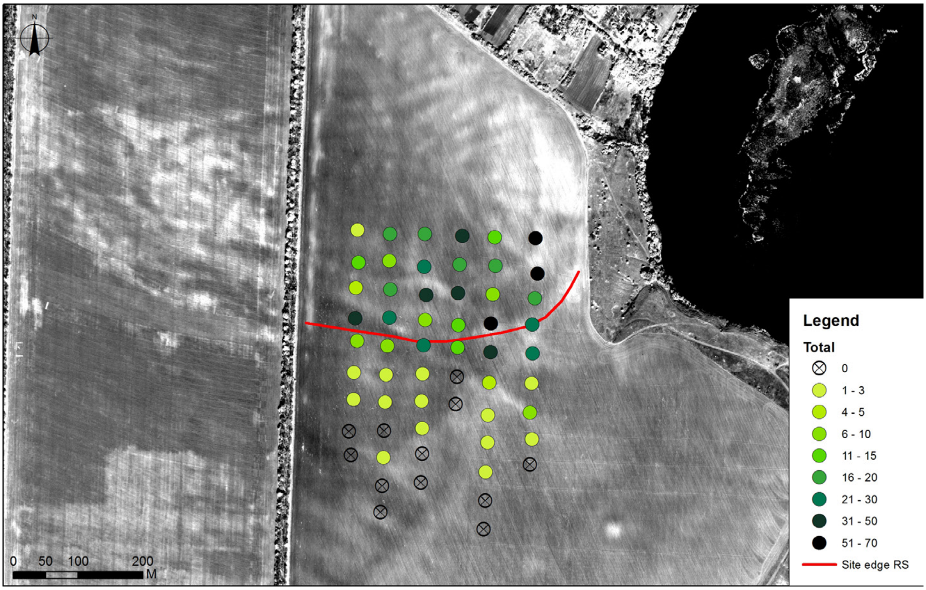

Figure 3.16: Sampling transects on the Trypillia site of Volodymyrivka. The colours indicate the quantity of both pottery and burnt daub collected at each sample. The red line shows the actual limit of the built-up area (by M. Nebbia).

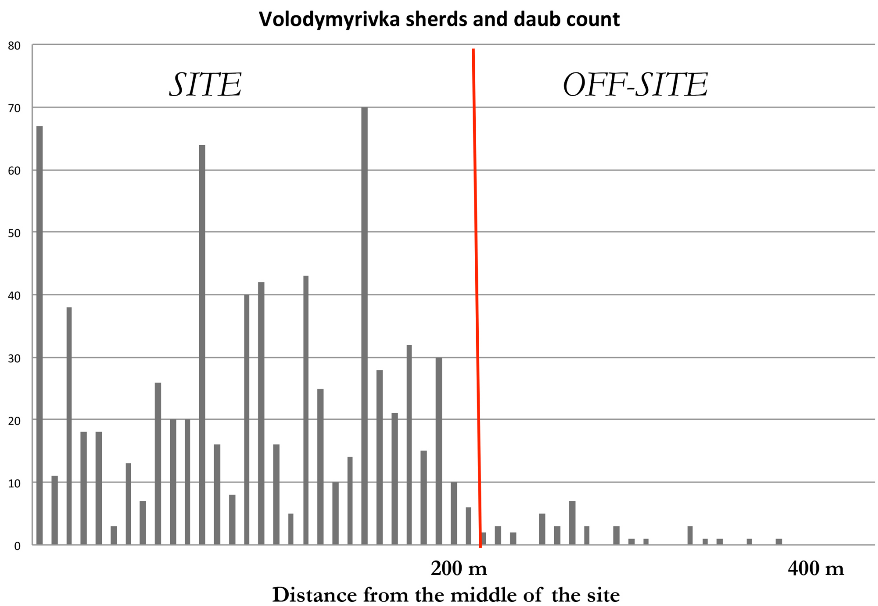

Figure 3.17: Material counts of the 6 transects walked on the BII megasite of Volodymyrivka (by M. Nebbia).

structure is generally very minimal, it is possible to work out a way of establishing the edge of the built-up area. This method was first tested on the site of Volodymyrivka, since the South-West limit of the site is quite clear from the satellite imagery and it has already been determined that the anomalies visible on the imagery are *in-situ* features. By walking six parallel transects from the middle of the site towards the outside, using a 40m spacing, we counted the number of sherds and daub in each sample (3m radius) (Fig. 3.16).

Plotting the results in a histogram showed different patterns in the middle of the site and the edge of the site. In the former, six transects crossed alternatively, but not regularly, both structures and open areas, producing an irregular trend in sherd and daub counts. By contrast, the off-site part of each transect saw a drastic drop in material counts and an overall descending trend towards the off-site (Fig. 3.17). The interface between these two trends can be considered as the limit of the built-up area, because, outside the site edge, the amount of ploughed/dragged surface finds gradually decreases further away from the in-situ archaeology. This also means that the overall halo of surface material goes well beyond the site limits, thus leading to a general over-estimation of the site size. After testing this method on two other Trypillia megasites (Nebelivka and Perehonivka) under different geomorphological conditions, it is clear that the over-estimation is not consistent and not dependent only on the size of the built-up areas. Arguably, multiple factors can affect the spread of material on the surface and therefore it is hard to define a fixed percentage of over-estimation. In conclusion, as much as the surface artefacts are a good proxy for the definition of a single dwelling and therefore the internal layout of the settlement, they are not reliable for the estimation of the built-up area without the use of systematic, intensive sampling.

3.3.7 From Space to Field: Ground-Truthing Remote Sensing Interpretations

The last contribution of the field survey activity to the project concerns the cross-validation on the ground of the features detected and mapped from the satellite imagery. When looking at a satellite image, a great variety of features are seen but no one is completely sure of what one is looking at – hence the term “interpretation” of the aerial image. The only secure way of defining the nature of a feature is to go and visit it on the ground. Then, future interpretations of a similar feature on a satellite image may be more accurate. If this rule is valid even for a well-known region, because the same feature can change the ways of manifesting itself on the image, depending on a number of factors discussed in Section 3.2.1, it must be endorsed even more for a completely unknown territory. The latter was the case of the Ukrainian forest-steppe zone of Nebelivka.

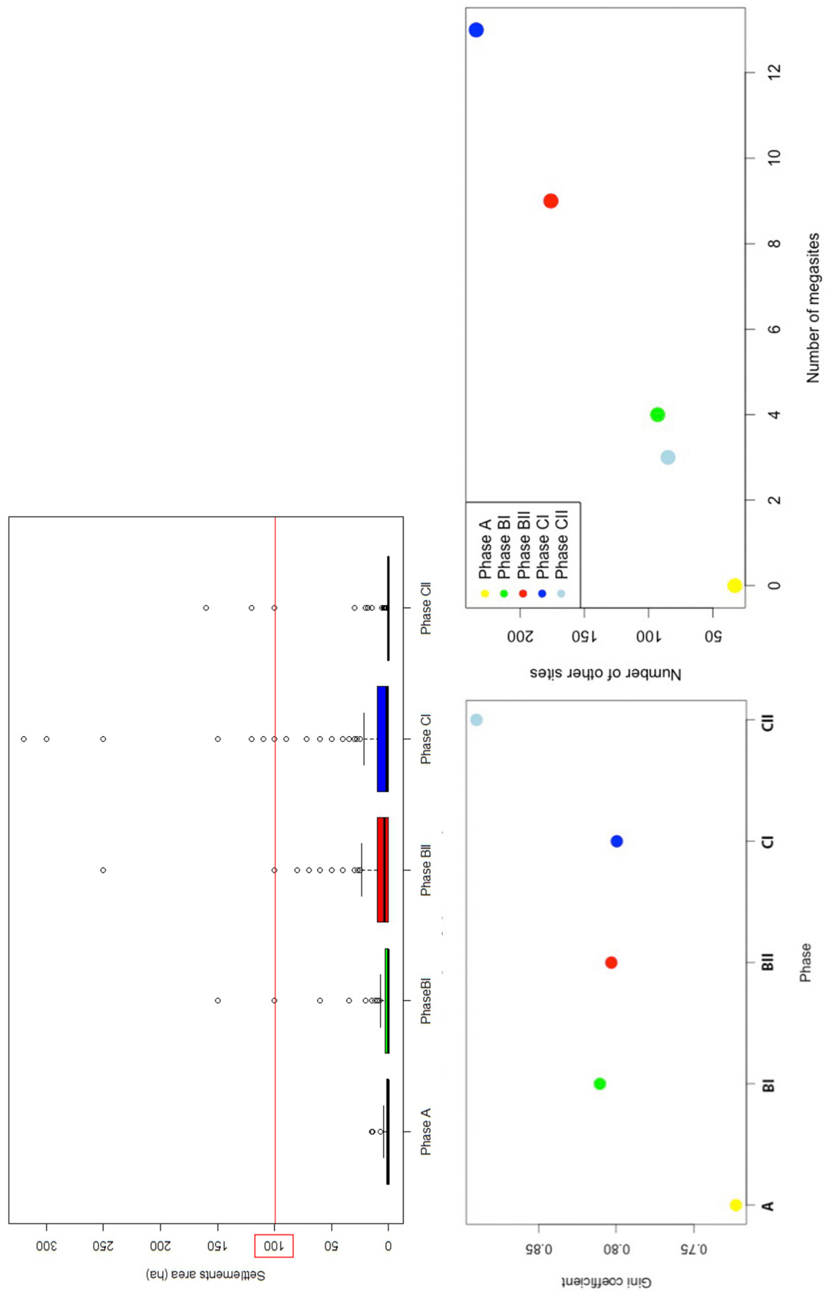

Figure 3.18: Upper: Boxplot of site areas reported in the Encyclopaedia by phase, showing the megasites sizes as outliers; Lower left: plot of GINI coefficients of Trypillia site sizes by phase; Lower right: plot of Trypillia megasites vs. smaller sites by phase (by M. Nebbia).

After a first mapping and interpretation exercise, based on the knowledge of fundamental concepts of archaeological photo-interpretation and with the experience of having worked with a range of different datasets, the team needed to check on the ground the number of features detected on the satellite imagery. The ground-truthing exercise served for the assessment of the potential of the different available remote sensing datasets and to understand what has been mapped.

Since the choice of the best dataset has already been broadly discussed in Section 3.2, I shall concentrate here on the understanding of what is visible from space.

In the 2012 season, ground-truthing was attempted for seven sites identified by Mr. Stefan Smith from the Project's set of CORONA images. Not one site turned out to be of archaeological significance, highlighting the problematic nature of CORONA images for forest-steppe research.

Trypillia sites are only visible in a very limited range of land use conditions, satellite sensors and soil moisture. The fieldwalking results showed that there is a number of smaller and larger Trypillia sites, which are not visible on the World-View images, but very much detectable from surface collection. Nevertheless, when visible, Trypillia sites are quite unmistakable features on satellite imagery.

Moreover, there are a number of other features that can be seen on the imagery which depend on understanding the geomorphological characteristics and the general archaeological characteristics of a territory (see Section 3.2.5 for detection of palaeo-channels). Furthermore, some bright patches that look like archaeological sites on the images, and are situated along river courses – like the large majority of sites, turned out to be outcrops of the brighter clayish chernozem C horizon that is exposed by the effect of the constant water and soil erosion.

One positive result of this investigation is the great potential of remote sensing for the recognition of burial mounds as characteristic archaeological features of the study area. After the first season of field survey, it was clear how mounds of different diameters and heights (ranging from 0.3m to 5m) are highly visible on satellite imagery, both multispectral and panchromatic. This result yielded a database of nearly 800 barrows mapped within the macro-region (Fig. 3.9). Of course, the limitation of remote sensing does not allow for an estimation of the real height of these features, but it helped enormously, during the second season, in targeting specific field visits aimed at the recording of even very subtle mounds, almost invisible from a ground perspective.

In summary, the field survey represented one of the key aspects of the field methodology developed within the Project and its results contributed enormously to a number of research aspects. The project benefitted from the field survey in four principal ways: 1) in establishing the layout of Trypillia megasites, 2) in establishing improved ways of determining site size, 3) in assessing site densities within the Nebelivka micro-region and a sample of the macro-region; and 4) in establishing the immediate hinterland of a megasite such as Nebelivka and the implications that this information had for the understanding of the settlement's formation and development.

Marco Nebbia

3.4 GIS Settlement Patterns – Trypillia

3.4.1 Introduction

The theoretical definition of megasites has neither been changed nor updated since the 1970s, when the first complete geomagnetic plans were produced (Shmaglij 1980). Since then, scholars have termed as 'megasites' those settlements whose areas extend beyond 100ha (Fig. 3.18 Upper) and whose layout is defined by concentric circuits of dwellings, radial rows of structures and a more or less extensive empty space in the middle (Chapman et al. 2014a; Rassmann et al. 2014; see above, Chapter 2.1.2). Further insights into the internal structure of megasites developed out of the "second phase of the methodological revolution" in Trypillia studies (Chapman et al. 2014b), which contributed to the discussion on how social structure was materialized inside these large settlements, thus providing new understandings within the wider discussion regarding their possible 'urban' nature.

For many years, the focus of the research remained at the megasite level, trying to gather more information and data for the whole settlement. Only recently have archaeologists started to look at these large settlements in the wider context of the Southern Bug-Dnieper interfluve 'system' or "Western Trypillia Culture" (WTC) (Diachenko 2010). Diachenko modelled movements and migrations within the Southern Bug-Dnieper interfluve – though including a limited number of sites in his network analysis – in an attempt to revise the chronological sequence of megasites occupation (Diachenko & Menotti 2012, 2015). Manzura studied Cucuteni-Trypillia settlement dynamics within the framework of the "colonisation" of the North Pontic steppe territory, but referred to megasites (or "super-centres") as evidence of a shift from an egalitarian tribal system towards a more complex societal organization in control of restricted resources from intensified production and exchange (Manzura 2005).

Technological and methodological advances improved our understanding of the layout and internal structure of megasites, but what Manzura and Diachenko demonstrated is the importance of considering the megasite phenomenon in the broader context of coeval sites, rather than considering it as a separate social development. Unfortunately, we have not yet reached the same level of detail for the other Trypillia sites as we have for the biggest of the megasites. Nevertheless, it is worthwhile including in the research agenda the final database of sites derived from 'cleaning' and selecting the information contained in the *Encyclopaedia of Trypillia Civilization* (Videiko 2004).

This hints at a new definition of megasites based on their spatial relationship with other settlements. Since the quality of the database is temporally consistent over the five Trypillia phases, and recalling that Cherkassy (where the majority of the megasites is located) is not the only region with a good dataset, we can assume that diachronic analysis of settlement patterns for the two millennia of the Trypillia period are to be taken as real patterns and not excessively biased by data collection and data quality. The chronological resolution based on pottery typology is 300–400 years (Kruts & Ryzhov 1985; Ryzhov 1990, 1993, 1999, 2000, 2007), the site location accuracy is within 1–2 km, and the site size accuracy is difficult to assess but is random across the sample. A useful heuristic device to be adopted in order to overcome a number of problems in the survey data is a trans-scale strategy where patterns in the data are analysed at both different temporal and spatial scales and where the continuity across scales is considered and respected, even when using scalar categories such as *macro-meso-micro* to facilitate the analysis (Knappett 2011, p. 10). The scale of analysis helped to control for inaccuracies in the data, just as the final interpretative model has been designed to be dynamic so as to allow the possibility of the inclusion of new data coming from future research.

Using an inter-scalar approach, four lines of investigation have been pursued in order to define the spatial relationship and the formation processes of the megasites in the territory of Ukraine:

1. Megasite locational strategies: is there a correlation between the locations of megasites and the locations of smaller Trypillia settlements?
2. Size hierarchies: does the first appearance of megasites in phase BI introduce a level of hierarchy in site sizes and what changes occurred during phases BII and CI as the megasite phenomenon itself developed?
3. Size clustering: are the settlements nucleating with the appearance of the megasites and at what scale is the clustering statistically occurring?
4. Megasite micro-hinterland patterns: what is the settlement pattern within a megasite's micro-hinterland (5 km)?

Overall, a regional and contextual perspective (Kantner 2008) is the only approach that allows for a full understanding of settlement patterns and, most importantly, the underpinning settlement systems of a specific social entity (Flannery 1976, p. 162).

3.4.2 The Data from the Encyclopaedia of Trypillia Civilization

The core set of data derives from the publication of all the known Trypillia sites in modern Ukraine up to 2004. The collection of data has been built up since the 19th century when the first register and map of archaeological remains in Ukraine have been compiled. In the early 20th century, an official register of archaeological monuments was collected in 1925 (V.U.A.K) and then updated until 1950, but never published. The first publication of Trypillia sites was in the middle of the 20th century, when Passek listed 94 entries (Passek 1949a; Childe 1951). A decade later, Passek published an updated version which included some sites along the Dniester in Moldova, making a total of 125 Trypillia sites (Passek 1961).

A few years later, the first broad collection of archaeological sites in the country, including 960 Trypillia sites out of a total 7,000 recorded, was published as 'Archaeological Monuments of Ukraine' (Zbenovich et al. 1966). From the 1960s to the early 1990s, a national programme of recording archaeological sites developed a standard protocol of data collection by preparing a document for each site (the site 'Passport') including basic information regarding the type of site (settlement, burial mound, surface scatter), period and dimensions. During this period of investigation, many previously unrecorded Trypillia sites were found, although some counties, such as Vinnitsa, Cherkassy and Kirovograd, remained poorly investigated. In 1971, the first map of 171 Trypillia sites was published within the 'Arheologia Ukrainskoi RSR' volume (Berezanskaya 1971). Since the fall of the Berlin Wall and the end of the Soviet era, the national programme of archaeological investigations has been decentralized and each county has developed its own plan for site recording and mapping. In 1995, a series of regional maps was published for the counties of Chernivtsi, Vinnitsa, Ternopil, Khmelnits and Odessa. This included the plotting of site locations on a map as well as recording other basic information. From this moment, the development of registers of archaeological monuments has been under the control of each county, with some central monitoring by the Institute of Archaeology in Kyiv. The non-systematic and decentralized way of managing the archaeological heritage has led to a level of uncertainty regarding the number of known Trypillia sites, so that some archaeologists (e.g., Videiko) proposed a total of 1,500, whereas others (e.g., Ryzhov) are more optimistic, with around 5,000 Trypillia sites (Videiko 2004, p. 564).

Finally, in 2004, a comprehensive collection of all the information regarding known Trypillia evidence has been published as an edited volume called the *Encyclopaedia of Trypillia Civilization* (Videiko 2004). The maximum information has been taken from all possible sources and updated with new discoveries from 19 counties, to constitute a total of 2,042 Trypillia entries; however, some Ukrainian archaeologists claim that they are up to 4,400 sites including both Cucuteni and Trypillia sites (Videiko 2004, p. 565). Unfortunately, the information collected since the beginning of the 20^{th} century has not been assessed nor evaluated with field visits or excavations but rather taken as granted and reported while the main focus has been devoted to finding more (and possibly bigger!) sites. Meanwhile, as field methodologies and theories advanced and developed, the information collected since the 19^{th} century has not been double-checked or updated with improved recording procedures. Therefore, the *Encyclopaedia* represents a massive amount of information compiled using a varied range of methods and field procedures that has produced an uneven and inconsistent dataset.

The information reported consists of: 1) a description of the site location; 2) a brief history of site investigations; 3) an estimation of the size of the site; and 4) the chronological horizon of the material found on site. Unfortunately, these data are not provided for every site – indeed, the information is often piecemeal and we have full and detailed information for only a few entries of the *Encyclopaedia*. Moreover, the inaccuracies, derived from the adoption of old and, by now generally obsolete, field methods and theories, have been transmitted into the final version of the publication. The compilation of metadata regarding how data have been collected in the field is lacking for almost all the entries. It was, therefore, necessary to evaluate the reliability of the information by trying to understand how people recorded sites in the field and elaborated reports.

A long and severe data cleaning process assessed the accuracy as well as the reliability of the information reported and resulted in a strict selection of "usable" data. The entries that have been deemed sufficiently reliable for the research have been plotted on the map. A total of 499 sites (from the complete list of 2,042 contained in the *Encyclopaedia*) has been considered and mapped with a location accuracy that ranges from few metres to 2 km, depending on the details provided in the descriptions. The overall distribution of known Trypillia sites in modern Ukraine is shown below (Fig. 3.19) (for list, DOI https://doi.org/10.5284/1047599 Section 2.1). The figure itself shows how site densities changes across the whole territory of occupation, and the data cleaning process confirmed that these differences are actually reflecting diverse research intensity rates. In fact, the two counties which are archaeologically best investigated are Vinnitsa and Cherkassy. For this reason, most of the spatial analysis and interpretations have been conducted diachronically and on a large scale.

The database[37] represents the data that have been used for the research on Trypillia settlement patterns and the table (Table 3.2) here displayed reports the type of information that has been recovered from the Encyclopaedia and how it has been organised.

An initial data mining process 'extracts' patterns in the data collected and managed, which constitutes the basis for the interpretative model that provides a nuanced explanation of the nature and function of Trypillia megasites.

37 The database can be accessed at: http://archaeologydataservice.ac.uk/archives/view/trypillia_ahrc_2018/downloads.cfm?group=1244

Table 3.2: List of all the fields of the attribute table of the Trypillia database (by M. Nebbia).

FIELD	DESCRIPTION
ID	Unique ID identification number.
Name	Name of the nearest village or main watercourse (as it appears in the Encyclopaedia).
Oblast	Name of the county where the site is located.
Region	Name of the municipality where the site is located.
Phase	Trypillia phase attributed to the site.
Area (ha)	Site area as reported in the Encyclopaedia for the majority of the sites and corrected where possible.
A	Boolean value of presence/absence.
BI	Boolean value of presence/absence.
BII	Boolean value of presence/absence.
CI	Boolean value of presence/absence.
CII	Boolean value of presence/absence.
Remote_sensing	Level of certainty for site visibility on satellite imagery (from 0 to 1).
Stage_code	A numerical value for the assigned Trypillia phase.
Location_certainty	Level of certainty for the location assigned to the point (from 0 to 1).
Elevation	Elevation of the point derived from the SRTM data (30m) in metres.
Notes	Notes on the pottery group assigned to the site (if present) and other general notes.
Annotations	Annotation on where the area value has been derived from that specific site.

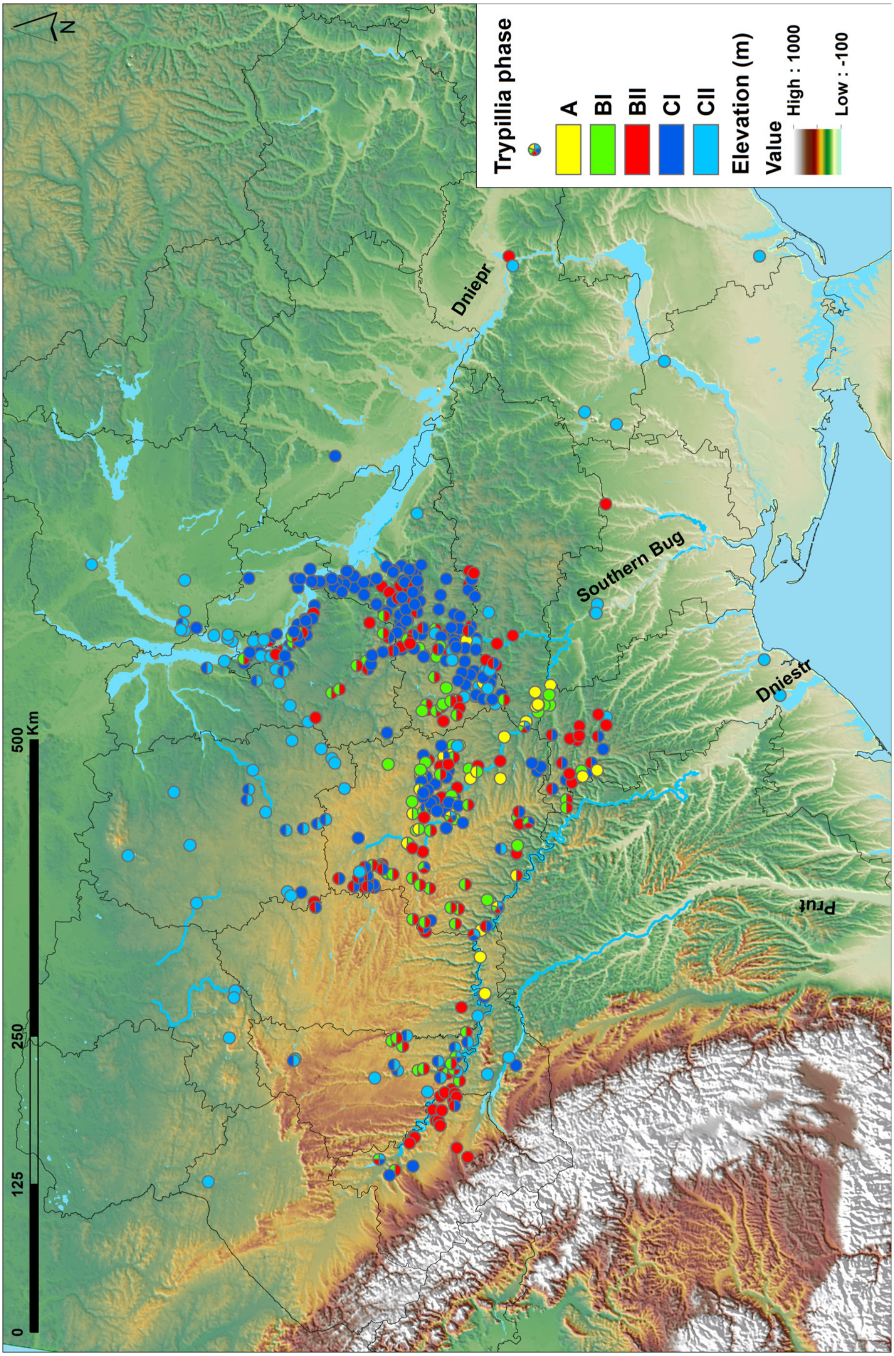

Figure 3.19: Distribution of the 499 Trypillia sites used in the study, derived from the Encyclopaedia (Videiko 2004) (by M. Nebbia).

3.4.3 Megasite Locational Strategies: Why Were They Where They Were?

A simple plot of all the Trypillia settlement data on a map shows that there is a concentration of megasites in the Southern Bug-Dnieper (henceforth SBD) interfluve, within the region of Cherkassy (Fig. 3.20). A total of 20 out of 23 megasites are located in a megasite cluster (henceforth *mega-cluster*), whereas 3 are situated in a more marginal[38] area spanning the whole Trypillia territory. At first glance, it would seem that the SBD interfluve constitutes the "core" of the Trypillia people, whereas the rest of the sites represent the "periphery"[39], and probably that is one of the reasons why archaeologists focussed their attention mostly on the cluster rather than considering the whole volume of available data.

Regardless of the nature of the relationship between the two macro-patterns, it is clear that there is a predominant locational strategy for the development of megasites, which prompts the question: why were they where they were? Is there an environmental reason why they developed in that specific territory? Or maybe other explanations are possible?

A two-step logistic regression test has been performed on the datasets, based on four comprehensive and general environmental variables; elevation, slope, distance from rivers, and soil type.

At first, all Trypillia sites have been tested against the four independent environmental variables and the results showed how their locations are statistically dependent on the variables. Secondly, the locations of SBD sites have been compared against the rest of the Trypillia settlements and the results of the regression show how the settlement strategies inside and outside of the SBD interfluve are the same when tested against environmental variables. Overall, the results of the combined logistic regression test suggested that the settlement strategies that megasites and small sites followed in the SBD territory are to be sought in the social rather than the environmental sphere.

3.4.4 Site Size Hierarchies

Most archaeologists have talked about site size hierarchies in the context of synchronous variability in site sizes within the same 'cultural' and 'political' context, and, in the absence of monumental architecture, took this as evidence for political or social stratification or hierarchy (Creamer & Haas 1985; Earle 1987;

38 Here the term marginal is conceived as "not part of the cluster" and not in terms of overall importance.

39 See Wallerstein (1974) for core-periphery theory and Friedman and Rowlands (1977) for the first applications to archaeological research.

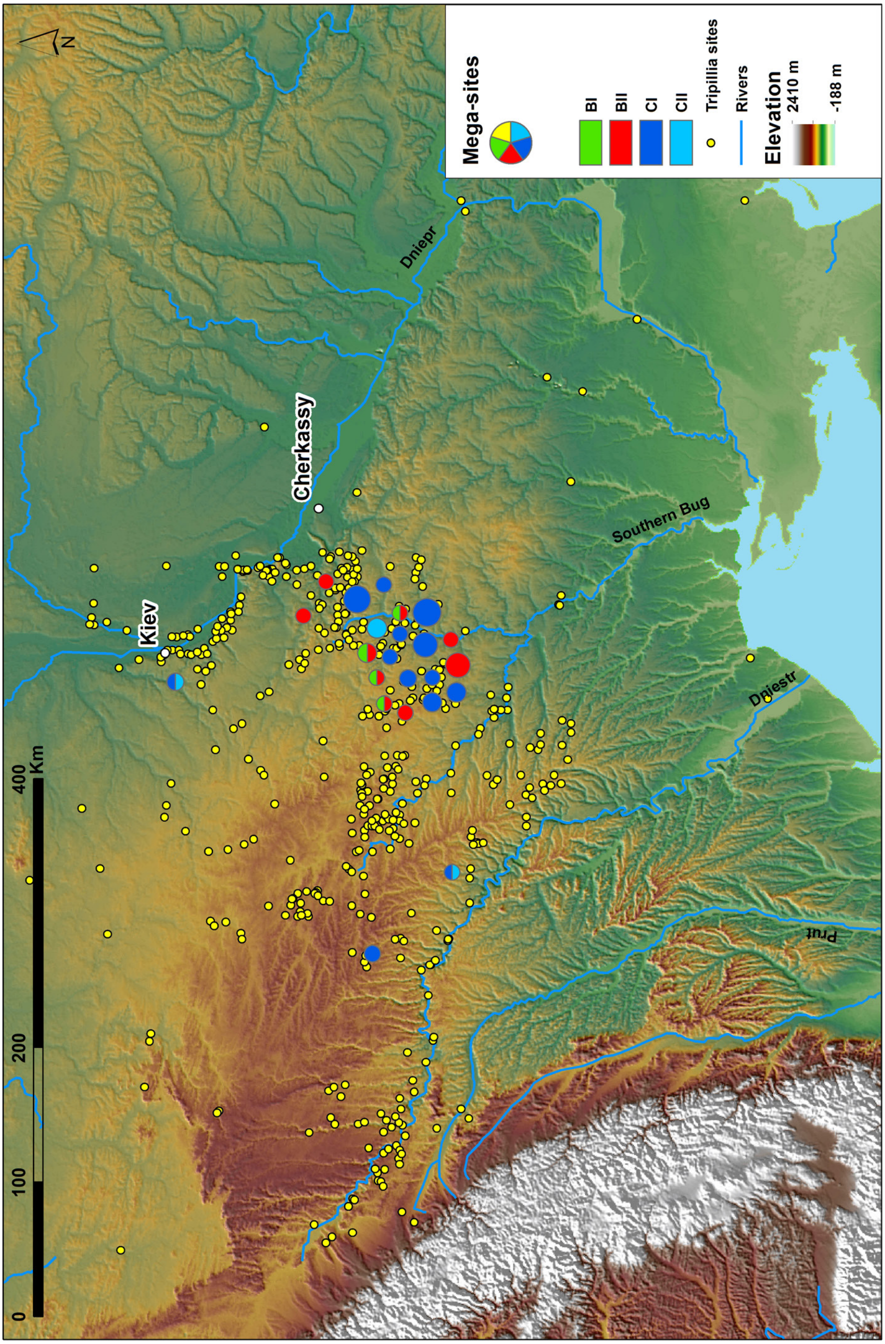

Figure 3.20: Distribution map of known Trypillia settlements, highlighting the location of megasites in the Southern Bug-Dnieper interfluve (by M. Nebbia).

Gilman et al. 1981; Johnson 1977; Liu 1996; Peregrine 2004; Ellis 1984). More recently, scholars have moved away from this static and consolidated paradigm, and argued for multiple explanations for the formation of site size hierarchies, thus moving beyond a constraining correlation between size and centrality (Flannery 1976, 1976a; Keswani 1996; McIntosh, R. 2005; Parkinson 2002; Peterson & Drennan 2012). The development of alternatives for explaining site size hierarchies is also fundamental for a more thorough understanding of Eastern European settlement patterns (Galaty 2005; Kowalewski 2008), and new theoretical frameworks alongside new methods are needed in order to fully comprehend settlement patterns as more primary data is produced. As Duffy clearly shows in his synthesis of settlement data, there can be a number of different reasons and processes that can lead to the development of a site size hierarchy within the same cultural and political framework (Duffy 2015). In this research, the analysis of site size hierarchies has been used for data exploratory purposes and the definition of different settlement patterns in the SBD interfluve and the rest of the Ukrainian forest-steppe territory, particularly in relation to megasites development. The key questions are: have megasites affected site hierarchies? And if so, how?

A series of histograms representing site sizes for the five Trypillia phases indicates how each phase, at different scales[40], shows a degree of size hierarchy (Fig. 3.21).

The data appear to follow a "Primate Pattern" distribution – a typical indicator of social hierarchy and of regional centralization, where there is a peak for small areas and a long tail of fewer, larger sites (Milisauskas & Kruk 1986, p. 25; Drennan & Peterson 2008, p. 360). It seems that, for each phase, there are one or more very large sites (i.e., the megasites) which stand out from the "expected" unimodal Poisson distribution. Simple visual inspection of the histograms prompts the conclusion that, from a system theory viewpoint, those are the centres of the system (Bentley & Maschner 2003). Drennan and Peterson criticise the fact that this interpretation is generally adopted without any statistical testing of whether the largest values "depart" from the normal Poisson distribution enough to be considered 'dominant centres' (Drennan & Peterson 2008, p. 361).

The approach followed in this research is to consider broader patterns in the data at different scales across the Trypillia phases. The starting point is to consider the megasites as statistical outliers in the overall site hierarchies. Furthermore, histograms show the gap between the high frequency of smaller sites and the very large ones with the absence of middle 'tiers'.

40 Xlims and binwidths are optimised and therefore different for each plot.

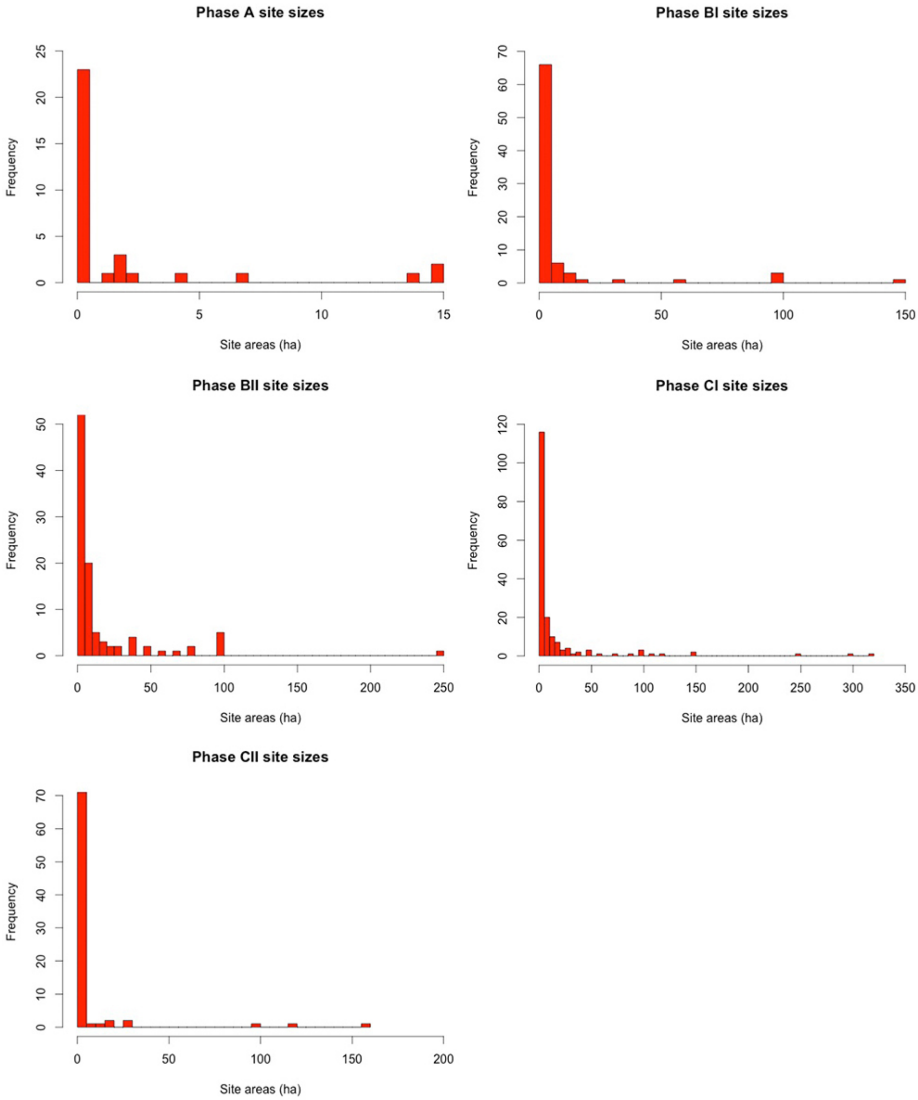

Figure 3.21: Histograms displaying Trypillia site sizes by phase. Phase A (N=33 sites); Phase BI (N=46); Phase BII (N=176); Phase CI (N=234); Phase CII (N=85) (by M. Nebbia).

The next step is to assess the effect that the development of megasites had in terms of site size hierarchies. In order to do that, we used the GINI coefficient as a measure of data ‘inequality’ (Gini 1912). The coefficient has been applied in archaeology in recent years mostly to estimate social inequality within a single site or between sites, based on grave goods as a proxy of wealth (Bowles et al. 2010; Windler et al. 2013). In the present case, it has been used to assess the influence of the megasites over size variability/hierarchy in each phase (Fig. 3.18 Lower left). The graph shows how the initial development of megasites during Trypillia BI prompted an increase in size ‘inequality’, thus establishing a hierarchical pattern in site sizes. Throughout Trypillia Phases BI, BII and CI, size ‘inequality’ remains quite stable if not showing a slight decrease, even though the number of megasites increases exponentially and proportionally to the number of smaller settlements (Fig. 3.18 Lower right).

This suggests that, during the middle Trypillia period (~ 4100–3400 BC), the appearance and development of such large sites did not coincide with a parallel development of a strong hierarchy in settlement sizes. Regardless of whether site size hierarchies are considered evidence of political organization in the case of the Trypillia, we are not facing a materialization at the regional level of any supra-local political or administrative structure.

This pattern is visible at a global scale, but, within the SBD interfluve, there is a *cluster* of megasites which are not ‘at the centre’ of a traditional hierarchical scenario of smaller sites where sparse ‘central places’ create a landscape of multi-tiered settlements. Instead, the SBD interfluve represents a unique panorama of ‘central places’ whose ‘hinterland’ has yet to be identified.

3.4.5 Spatial Distribution of Trypillia Settlements: Site Clustering and Megasite ‘Centrality’

Following the exploratory spatial data analysis, we can now discuss the distribution patterns of Trypillia sites across the landscape, how they change at different scales and how they changed in time. In order to do that, the followed approach analysed the data by using two basic principles of point pattern analysis (PPA); namely the analysis of the first and second orders characteristics of a given point pattern (Bailey & Gatrell 1995, pp. 32–35). In brief, the first order characteristics describe the average point density (or intensity) and distribution patterns across the whole region under investigation; whereas the second order characteristics describe the density of points relatively to their internal spatial organization, reflecting internal interactions of attraction and inhibition (Bevan et al. 2013 p. 31). Understanding the behaviour of data at different scales and their internal interactions provides insights for the archaeologist who has the major challenge of interpreting these patterns, by providing an explanatory historical narrative.

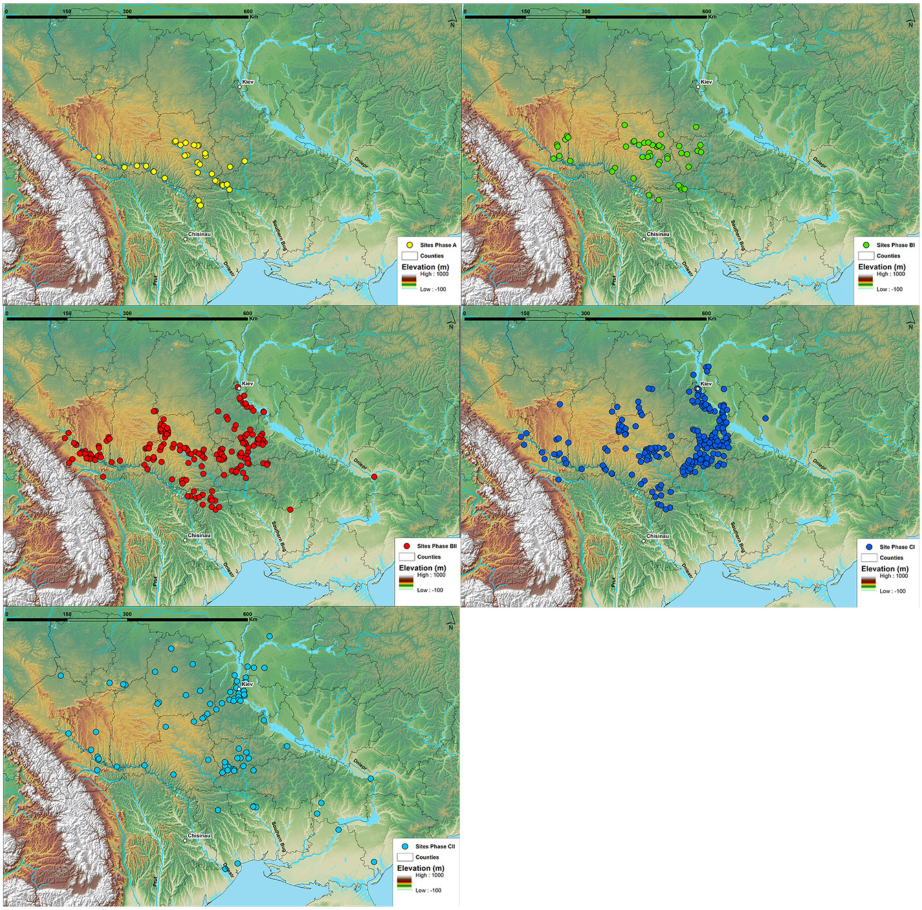

Figure 3.22: Spatial distribution of Trypillia settlements by Phase: upper left – Phase A; upper right – Phase BI; middle left – Phase BII; middle right – Phase CI; lower left – Phase CII (by M. Nebbia).

The simple visual assessment of the five distribution maps of Trypillia sites shows an increasing level of settlement clustering until phase CI – especially after the appearance of the first megasites in phase BI – and a trend to a more dispersed settlement pattern in phase CII (Fig. 3.22). Moreover, by phase BII, the full Dniester-Dnieper interfluve is occupied by Trypillia settlements and remarkable further expansions are not visible until phase CII. During phase CI (the period of the maximum size of megasites), the level of site clustering reaches its peak, but the areas occupied remain roughly the same. It is only with phase CII – the time of the end of megasites – that a remarkable overall dispersal can be observed and the Trypillia area of influence reaches its maximum extent.

Bearing in mind the development of the overall site patterns throughout the five Trypillia phases, attention should now be focused on the internal characteristics of the data and the variation of the variable 'size' across the landscape. This analysis will provide insights into the scale at which certain phenomena are occurring and will suggest the perhaps surprisingly large distances at which we need to look for understanding the range of Trypillia human interactions.

The study of data spatial variability or data spatial autocorrelation was incorporated into archaeology in the late 1980s to early 1990s, when it was adopted to investigate the spatial distributions of tombs (Attwell & Fletcher 1987), settlement locational strategies (Kvamme 1990), the origins and spread of languages (Piazza et al. 1995), and the "collapse" of the Classic Maya 'state' (Neiman 1997; Bevan et al. 2013a). The fundamental tenet underpinning spatial autocorrelation analysis is Tobler's first Law of Geography, which states that "*everything is related to everything else, but near things are more related than distant things*" (Tobler 1970). On this basis, the analysis of the spatial dependency of archaeological data – in this case Trypillia settlement size – could help in understanding the spatial relationship of megasites with other smaller settlements.

One of the most commonly used methods of analysing spatial autocorrelation of a given value is Moran's I index, developed by Patrick Moran (1950). The index describes the combined behaviour of point location (viz., site location) and point value (viz., site size) and whether the pattern is random, clustered or dispersed. Moran's index calculates the global spatial autocorrelation of the data, thus measuring the overall clustering of a given point dataset. A further development of the test has been suggested by Luc Anselin (1995), who proposes "local indicators of spatial association" (LISA) in order for a statistical evaluation of the clustering occurring in a local spatial unit, starting from the principle that, if there is no statistical evidence for global clustering, this does not exclude the possibility of local clustering. Moreover, Anselin's local Moran's I statistics allows for the differentiation of clusters of low and high values and of spatial outliers. In this way, it is possible, for instance, to identify a high value (in this case a big site or megasite) within a Neighbourhood of low values (viz., smaller Trypillia settlements) and measure the statistically significant scale of the Neighbourhood[41]. In other words, the data will set the scale at which a site becomes statistically 'mega' compared to its neighbouring sites.

An incremental Global Moran's I test has been performed on the dataset by phase, and at 'incremental' scales. The results indicate that the optimal distance at which the data show a clustered behaviour is around 100 km for each phase but different levels of clustering are suggested by z-scores. Considering the difference in number of sites and megasites (see Fig. 3.18 Lower) in each phase, the almost consistent optimal

41 In this Chapter, the term 'Neighbourhood' is used in its spatial-statistical meaning of the space surrounding a given point or feature.

distance acquires an even higher significance as a common pattern between the three phases that cover almost 1,000 years. We can, therefore, argue that ~ 100 km has a statistical significance in terms of settlement pattern nucleation and will be used in the next set of analyses aimed at showing where these clusters are and how they behave in the presence of megasites.

The Anselin's local Moran's I test performed on each phase shows how the megasites in Trypillia BI, BII and CI represent spatial 'outliers' that are significantly bigger compared to their coeval smaller site outside the SBD territory at the scale of ~ 100 km, which suggests the human scale at which these settlements could be seen as 'central/special' places. But what was happening closer to the megasites, within what we can call their micro-hinterland?

3.4.6 Megasite Micro-Hinterlands

The reason for investigation of the immediate hinterland of such massive settlements is that of site sustainability. Thus, if we argue for a large coeval population living in megasites (e.g., Rassmann et al. 2014; Müller et al. 2016), they would have exploited the surrounding territory for a number of economic activities. Several scholars have studied the Trypillian economy (Bibikov 1965; Gaydarska 2003; Harper 2011; Nikolova & Pashkevich 2003; Pashkevych 2012; Shukurov et al. 2015; Ohlrau et al. 2016) and all the models propose an agro-pastoral mixed economy based on archaeological evidence. Carrying capacity models, however, propose that in order for such massive sites to be sustained by land products, even in a mixed economy, they needed the help of manuring and ard tillage (Shukurov et al. 2015, p. 280). Ethnographic data suggests that the maximal limit of arable land around a site remains within 1.5–2 hours of walking distance (Jarman et al. 1982, pp. 30–31), which translates to approximately 5 km in terrain such as the Ukrainian forest-steppe. This distance is also the estimate proposed for the size of infields and outfields around Bronze Age tell sites in Mesopotamia (Widell et al. 2013). The most recent carrying capacity model developed by Ohlrau et al. (2016) also proposes a minimal radius of approximately 5 km for arable land around megasites like Majdanetske and Taljanki (with respective sizes of 200 and 320ha). All the models recently developed are based on the contemporaneous occupation of the majority of the dwellings in the megasites (Ohlrau et al. 2016, Table 5; Shukorov et al. 2015, pp. 239–240), thus relying on a maximalist population estimation for each site. Shukurov et al. (2015) argue that even a fertile soil like chernozem needs manuring and ard tillage to support the agricultural regime needed to supply even small sites (10–20ha).

Therefore, the investigation of the immediate (5 km) hinterland of Nebelivka has been conducted in order to check any archaeological evidence of farming activities and more specifically, manuring practices. Evidence of manuring has been identified in scatters of worn potsherds spread on the fields as part of debris coming from the settlement (Bowen 1962, p. 6; Wilkinson 1982, 1989; Gaffney et al. 1985; Bintliff & Snodgrass 1988; Alcock & Cherry 2004; Chapman et al. 2010). The ability to identify manuring scatters was built into survey methodology at Nebelivka.

The first systematic field survey ever conducted in Ukraine has been carried out in the near hinterland of the site of Nebelivka (Trypillia BII), covering around the 42% of the available fields (Fig. 3.12). During the 2009 season, we adopted a non-site sampling strategy (Thomas, D. 1975) in order to assess the definition of 'site' derived from surface material. This involved picking up and positioning every single small find with an accuracy of 3 metres in the 55ha coverage. The results show four major surface scatters, which can be identified as archaeological sites (Fig. 3.12) among a huge quantity of *off-site* material. Of approximately 1,000 potsherds collected in the 30 km^2 covered in the megasite hinterland, only a single sherd can be reported as dating to the Trypillia period.

The results of the field survey show that there is very little, if any, archaeological material presence in the immediate surroundings of a 238ha settlement with almost 1,500 dwellings. Therefore, it can be argued that this is negative evidence for such intensive land exploitation as proposed by the carrying capacity models developed by Ohlrau et al. (2016) and Shukurov et al. (2015). In particular, there was no evidence for manuring scatters in the Nebelivka micro-hinterland.

Finally, looking at the immediate hinterlands of the other megasites in the SBD interfluve, it is noticeable how the absence of other coeval sites is a common characteristic for phases BI, BII and CI (Fig. 3.23). This could suggest that those territories were devoted to farming, although the systematic, intensive survey of the Nebelivka micro-region seems to contradict this hypothesis. More systematic field survey around megasites would help understanding whether this is an isolated pattern or a common trait for these big settlements. As for Nebelivka, further evidence demonstrating a very small impact of the settlement on the local environment derives from the results of the pollen sequence obtained by a core located 250m North-East of the edge of the megasite at the bottom of the river valley (https://doi.org/10.5284/1047599 Section 3.4). The results show how, during the occupation of the settlement, the quantities of cereals are even lower than during either the pre- or post-occupation period of Nebelivka (Albert et al. 2020).

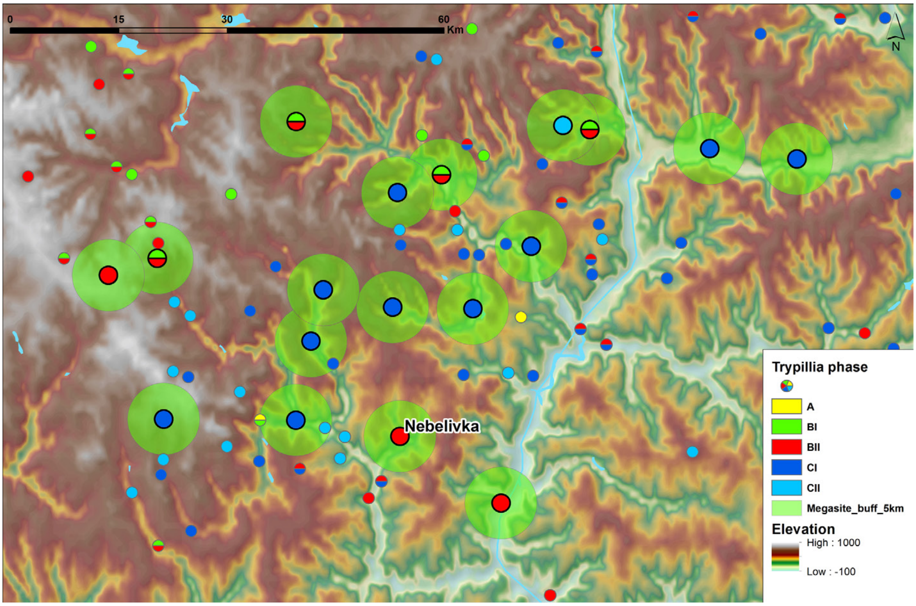

Figure 3.23: 5-km hinterlands of megasites in the Southern Bug-Dnieper interfluve (by M. Nebbia).

Only more data derived from further systematic fieldwalking around other megasites combined with more pollen analysis conducted on core locations near megasites as well as smaller sites could confirm or reject this pattern. The two models developed by Ohlrau et al. (2016) and Shukurov et al. (2015) assume that the single megasite or smaller settlement is entirely occupied at the same time, but this is a 'mega-assumption' since no-one yet has established a fine-grained chronological sequence of megasite development. Most of the arguments in favour of the coeval occupation of all the dwellings derive from the assumption that the formal layout of these settlements (including the whole range of archaeological features, such as kilns, mega-structures and house rows) has to be developed by a single top-down decision-making process (Müller et al. 2016a). Nonetheless, other possibilities for explaining the formation processes of such structured layouts can be derived from a broader context of Trypillia settlements in general (Nebbia et al. 2018). The extraordinary dimension and density of megasites cannot be really appreciated if we do not include their relative capacity for accommodating people coming from coeval smaller settlements.

Marco Nebbia

3.5 Concluding Remarks

The aim of this Chapter was to explore a range of possible formal analyses of the Trypillia datasets, newly included in the discussion on megasites. The aim was to provide new perspectives derived from the investigation of settlement data from different points of view, which can be summarized as follows:

1. There are no clear environmental-related reasons why the megasites are located in the *mega-cluster* within the Southern Bug-Dnieper interfluve; hence motivations must be sought in the social sphere.
2. With the development of megasites, there are two clear macro-settlement patterns that are established by the beginning of phase CI, clearly identifiable in the SBD *mega-cluster* of megasites and the rest of the Trypillia settlement distribution. With the increasing number of sites, including megasites, and the development of site nucleation throughout Phases BI, BII and CI, there is no evidence for the development of a single, structured settlement hierarchy. On the contrary, the megasites stand out as exceptionally bigger than the rest of the Trypillia settlements, without a solid middle tier of sites.
3. There is a global and developing nucleation process of Trypillia settlements during the first four Phases A, BI, BII and CI, whereas the last CII phase is characterized by a return to a more dispersed settlement pattern. On a local scale, the 'centrality' of megasites is measured by a statistically significant difference in site size at a scale of approximately 100 km. This figure seems to be consistent for around 1,000 years, without being affected by the increasing number of sites and their development and nucleation.
4. The immediate hinterlands of megasites seem archaeologically 'empty' and the human impact on the local environmental very marginal.

In conclusion, the great potential of the landscape approach has been shown for the first time in Trypillia studies. The main contributions of this Chapter are both methodological and interpretative:

- It represents the first systematic assessment of the potential that remote sensing can have in the recovery of Trypillia sites (mega- and non).
- It proposes a new agenda for field investigation in Ukraine where systematic field survey is applied for the first time.
- It represents the first attempt to use the remarkable amount of legacy data in the study of Trypillia megasites.
- New insights on the immediate hinterland of Nebelivka demonstrated the peculiar nature of such a big settlement that seems to exist within a thinly occupied landscape. The implications become more striking when the exploration of the

broader hinterland (macro-region) shows how other similarly large settlements are located (and possibly co-existed, see p. 255) within a few kilometres.
- A remarkable large-scale effect of site clustering alongside the emergence of megasites cluster is highlighted for the BII–CI phases, thanks to the inclusion of a larger settlement dataset.
- A probable scale (100km) of people's movements across the landscape is proposed and the implications that this has on the wider interpretation of the nature of megasites will be discussed in depth in Chapter 6.

Overall, the combination of large-scale landscape analysis with detailed site-based investigation can only bring to a wider and more accurate picture the archaeologist is constantly seeking when trying to answer their research questions. In this case, the contribution of the landscape side of the project will be integrated with a fine-grained analysis of the site of Nebelivka to produce a better understanding of the Trypillia megasite phenomenon.