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Expanding Scales in GIS Analysis

Abstract: I propose to argue that the widely perceived opposition between a “site scale” and “regional scale” in GIS analysis is not an optimal classification in archaeological practice. While stressing the importance of the conceptual separation of terms describing the dead and the living cultures I will suggest that projects should be approached in accordance to their theoretical background rather than their geographical extent. Since archaeological data is usually severely biased in diverse aspects, new analytical “scales” will be introduced into the debate, which allow to address questions previously inaccessible in GIS analysis. This approach is based on descriptive databases viewed as multi-dimensional spaces, regardless of the presence or absence of geographic coordinates. This paper concludes that useful GIS outputs need not look like decorative maps of the physical landscape, or distribution maps of finds, but that they can also present formalized abstract models built by the framework of a newly-coined term “fact space”.

A Dichotomy between Intra- and Inter-Site Approaches?

Various meanings and definitions of the term “scale” have been introduced into archaeological literature (e.g. STEIN / LINSE 1993; RAMENOFKY / STEFFEN 1998; LOCK / MOLYNEAUX 2006). The dichotomy between intra-site and regional approaches has often been recognized and is usually the most obvious categorization of archaeological projects from the perspective of scale. Nevertheless, I would like to bring a slightly more complicated typology of spatially-oriented archaeology into discussion. I find the division between intra-site and large-scale approaches too simplistic while having no useful significance in both theory and methodology. The very concept of an archaeological site is nothing but an illusion produced by the former purely positivistic perception of the archaeological record. Today it is clear that the more appropriate way of speaking about empirical facts is in terms of their varying density in defined spatial units (KUNA 2000; IDEM 2004). Even if we find some striking concentrations of finds packed in a restricted area, we understand that in most cases these facts had accumulated over a period of time and that they cannot directly reflect the situation in the original living culture. In other words, the dead culture is static (NEUSTUPNÝ 1986a) and cannot serve as a basis for the research on the dynamic human past without taking into account effects of formation processes and the subsequent transformation of the archaeological record. If these correctives coming from archaeological theory are applied, we face

spatial distributions different from those observed empirically.

I do not deny that villages, hamlets, farmsteads, enclosures, cemeteries etc. existed as various focal places of the past human activities. Instead I would only point to the fact that their general inclusion of the term *site* is problematic as is the concepts of a dichotomy between *site* and *region* or *site* and *off-site*. Any attempt to draw a line around a set of empirical facts and label them as a site is inevitably an arbitrary construct because archaeological facts would be distributed nearly continually, in space, had they escaped destruction. Sometimes, abrupt edges can be discerned in for example the distribution of pits cut into the bedrock or distribution of pottery fragments. Nonetheless, other kinds of data may continue to occur in the same place (for instance botanical remains and pollen, production debris etc.), which indicates the gradual and overlapping character of individual activity areas and impact zones within the human world. The term *site* is therefore just a traditional element of an archaeological debate, which has only a vaguely defined content at present.

What Matters in Spatial Archaeology?

The debate about pros and cons of different geographic scales in archaeological investigation must be inevitably enriched by theoretical concerns reflecting the nature of the archaeological record. Above all, the strict division between the *dead cul-*

ture, which represents the empirical basis of archaeology and the past *living culture*, which is the ultimate object of archaeology as a discipline, must be clearly recognized (NEUSTUPNÝ 1986a; IDEM 1993). It is methodologically incorrect to search for patterns in the dead culture (archaeological finds) as if it would directly mirror the structure of the living culture. The relationship between these two distinct domains is mediated by archaeological theory. In a regional scale, so-called *settlement area theory* is particularly suitable in this respect (NEUSTUPNÝ 1986b; IDEM 1991; IDEM 1994).

A more elaborate classification of GIS approaches within archaeology should therefore be problem-oriented and arise from a careful consideration of the varying character of the archaeological record. Situations investigated by archaeologists differ substantially and their description is usually a multi-dimensional task. Therefore, I restrict myself to brief comments on several examples of GIS projects from my own experience. All are based on the Bronze Age evidence with some overlaps to other periods.

Holešov

The cemetery at Holešov represents an extremely valuable collection of mortuary record. Having been excavated four decades ago, it could not be analysed in detail until GIS became available (ONDRÁČEK / ŠEBELA 1985; ŠMEJDA 2003; IDEM 2004). This funerary area is a good example of an intentionally structured set of archaeological facts. It has been subject to reduction in some aspects (like organic materials and tissues, surface appearance of graves, potential superficial structures), but otherwise there still remains a lot of intact recorded ordering, which enables effective ways of extracting original patterns in the data to propose their possible meaning. Moreover, cemeteries frequently offer a good chronological control of individual find complexes. This is not fully the case at Holešov, where pottery and other chronologically significant finds are rare. Probably the most prohibitive factor for archaeologists is to interpret the symbolic nature of burial rituals, which can be decoded only in parts – and only then with some good fortune.

Prague-Hostivař

An excavation of the settlement at Prague-Hostivař (VAŘEKA 2003) is another example, that shows that

the archaeological description of a typical residential area in prehistoric Central Europe must be approached in quite a different way. The difference is especially due to the substantial lack of the functional order in preserved archaeological complexes, such as pits or remains of building structures. Deeper pits have been usually preserved in their primary position, but their precise dating remains problematic. Artefacts, refuse and other movable evidence usually have been accumulated, reduced and fragmented in the course of residential activity as well as afterwards; each transformation process having had its own rate of operation. We can be confident that there was some post-depositional spatial movement and mix-up of small objects and sediments. This has made the original structuring of human world blurred in the archaeological record and only indirectly accessible (ŠMEJDA / KOČÁR in press). Although here we face one “site” in the same way as in the case of the Holešov cemetery, our theoretical apparatus and methodology will certainly be quite different. Heavily transformed evidence in settlement sites restricts the range of possible research topics directed to the living culture confronting us mainly with selected aspects of economy and refuse management of local communities. Consequently burial and residential *sites* stand in even a more profound opposition when it comes to the application of formalized methods including GIS than, for instance, one settlement and some region.

Vladař

In this last example I am going to draw your attention to a prominent hill with a multi-period occupation and a very extensive fortification system, which encloses an area of 120 ha (1.2 km²) (CHYTRÁČEK / ŠMEJDA 2005; IDEM 2006). Systematic archaeological investigation of the region where Vladař hillfort is located started only several years ago and this work still continues. Although plenty of evidence has already been collected from the fieldwork, it is difficult to use the data in a really sound formal analysis. There are several reasons for this situation:

- patchy spatial distribution of data. Some areas having been recorded very meticulously (like excavated trenches), while others only by rough description (fieldwalking, metal detector survey); Many parts of the landscape remain totally blank due to the absence of any survey material.



Fig. 1. Holešov cemetery: the distribution of copper daggers (black dots) in the geographical space.
Created in ArcGIS 9.1.

- erratic quantity and quality of individual segments in our dataset.
- low chronological control of the great portion of finds.
- the heavily modified terrain relief in the vicinity of the hillfort, through the processes of soil erosion, transport and accumulation, has been partly destroyed. The evidence from the accessible surfaces has also been partly removed.

Often, data in such “large-scale projects” is usually not very consistent and is hard to compare in a rigorous way. In such a situation I use a metaphor – borrowing the statistical terminology – that they have “too many degrees of freedom”. Necessary control points in the process of archaeological inference are lacking. This is magnified in the case of projects covering very large geographic extent, especially if we want to proceed to other more sophisticated outputs than basic distribution maps.

Possible Solutions

Two major problems connected with the application of the GIS in archaeology exist in my opinion. I am going to identify them and suggest some proposed solutions.

- 1) **Available evidence is quite frequently not representative as a basis for solving questions that archaeologists are interested in.** I have tried to describe at least some of the biases of typical datasets above. The only reasonable way to overcome this problem involves theoretical modeling of processes that create these deformations. Therefore this point is mostly theoretical and I admit that many contributions have already touched this issue before (e.g. NEUSTUPNÝ 1993). For this reason I would like to concentrate rather on my second thesis in the remaining part of my paper:
- 2) **Even if our data is good with respect to the previous point and it can be demonstrated that they are structured meaningfully, these structures or patterns do not necessarily manifest themselves in a geographical space.** If so, the traditional way of using GIS is not productive. This second point is maybe very disappointing for the GIS users, but I want to suggest one methodological approach that opens new scales for GIS application in archaeology.

Descriptive Databases, Vector Space and GIS

Geographical information systems originated as tools designed for geographers and cartographers. They have developed substantially since the 1980s and today present extensive bundles of powerful modules. Let us put aside for a while that they are called *Geographic IS* and keep in mind that they are primarily tools for spatial research. I think we can agree that space has much broader content than geography. Space is an abstract term that takes on special meanings in different contexts.

Archaeologists, as well as specialists in other disciplines, work with theoretical spaces and their domains (= ranges of allowed values, terms) on a daily basis (NEUSTUPNÝ 1996). The most illustrative example is the common use of descriptive relational databases. Such databases consist of tables. Tables typically include the description of objects represented by table rows, whose task is accomplished through attribute values organized in table columns. Attributes can be defined as geographic coordinates, metric dimensions, ranks, counts, expressions and various types of qualities. Inevitably, many tables by their very nature represent a multi-dimensional analytical space. And *space* can be investigated in GIS. Traditionally the design of such investigation relied on the definition of space by means of geographic coordinates, but apparently this is no longer a necessary prerequisite. In fact, a GIS research conducted in geographical space is just one special instance of possible approaches.

However, many couples of fields of archaeological databases can potentially provide the definition of a new two-dimensional reference system. Analogically we can design even more-dimensional spaces from our databases and explore their content and inner relationships. Of course this is no new idea, it has already been done a million times before in the form of scatterplots in the realm of statistical exploration, but I am convinced that in the connection with the contemporary GIS software it develops a fresh dynamic application.

Simple Applications

Traditional GIS approach would display the Holešov cemetery as a distribution of the grave polygons or points in the geographical space. This output is naturally understood as the plan indicating *how far the individual graves are from each other* in the excavated area. Various attributes of the burials can be asso-

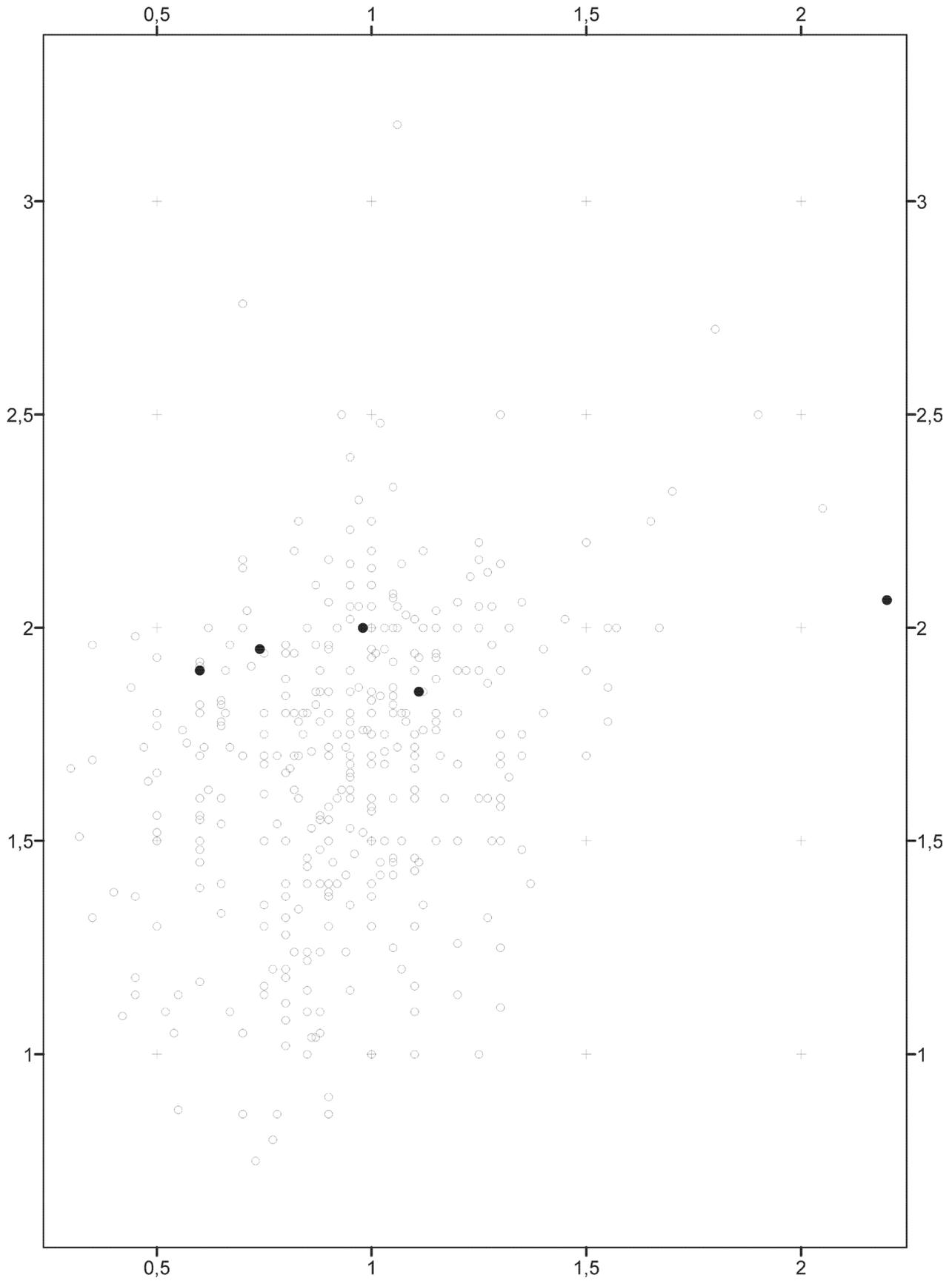


Fig. 2. Holešov cemetery: the distribution of copper daggers in an analytical space that is referenced by depths ('x-axis') and lengths ('y-axis') of the grave pits. Note the interestingly low variability of lengths, belonging to graves that contained daggers (1.85–2.0 m). Created in ArcGIS 9.1.

ciated with their point representation and investigated (Fig. 1).

The cemetery can also be represented by points located in an **abstract space**, for instance defined by axes corresponding to the depths and lengths of the grave pits. There is a plan of the same cemetery displayed in Fig. 2, showing the same objects, but viewed from a quite different perspective. Now, the points “mapped” in very close positions represent grave pits that are similar in terms of their dimensions and *vice versa*.

It is possible to display even more dimensions of the descriptive database in both of these spaces with the aid of symbology, contours, trends etc. It is clear that each plan has the ability to reveal different structures. To do this they must be connected with the geographical ordering in the first place to be followed by the dimensions of grave pits. Procedures of this kind can be elaborated and are open to flexible re-designing and numerous exploratory experiments. In some well-grounded configurations this methodological approach can also be used as a hypotheses-testing tool.

The following example is based on a more complex methodological background. This time we will compare the distribution of macrobotanical remains of precisely indeterminable *Cerealia* in settlement pits as recorded at the Hostivař settlement in the geographical space (Fig. 3) with the representation of the same features displayed in a new reference framework, defined by the PCA treatment of archaeobotanical data collected from the pit fills. The axes of spatial reference in this case correspond to factor scores extracted from the database of archaeobotanical determinations (Fig. 4). This becomes a graphical representation of the very complex spatial model, since the axes themselves already describe mutually independent latent structures of the archaeobotanical dataset.

From the above-mentioned (and still relatively simple) examples we can infer that many other theoretical models built in an abstract “analytical space” can be expressed in this abstract form as relationships in mathematical (vector) space. Although it is not primarily geographic, but can be explored *as if* it was. We can also discuss investigating traditional graphs as if they were maps of abstract analytical spaces. This is my new “scale” of GIS analysis, or to be precise, there are many “new potential scales”, which are capable of looking into questions inaccessible in GIS before. This change of thinking about spatial data perhaps seems to be trivial at the first

sight, but in fact it reveals whole new worlds in regards to formalization of archaeological reasoning. It also intensifies a welcome cohesion of the spatial and formal properties of archaeological facts, which are the only properties observable by archaeologists (note that time is not directly observable, it is always inferred from spatial and formal attributes). The introduction of a new general term “**fact space**” (in this context understood as *space of archaeological facts*) into archaeological debate, containing its geographical and formal components (see NEUSTUPNÝ 1996, 112–113), seems to be a good starting point for further expansion of archaeological theory and methodology.

Conclusion

I believe that future applications of GIS in archaeology should free themselves from plotting various phenomena in a strictly “geographical” space. The geographical approach represents only one part of the potential of GIS within archaeology. Modern GIS and statistical software can also be applied to the formal analysis of vector spaces (or data matrices), where the geographical location of investigated entities is no longer the most essential prerequisite. These types of inquiry have been traditionally limited to statistical software packages, yet both GIS and statistics programs are becoming increasingly integrated, combining immense computational power with diverse graphic presentation, data exploration, pattern recognition, and data visualization. In my view, current GIS software in the phase of data exploration can in many respects offer tools that are superior in their efficiency to standard statistical packages, especially when their use is driven by new theoretical concepts of handling archaeological data.

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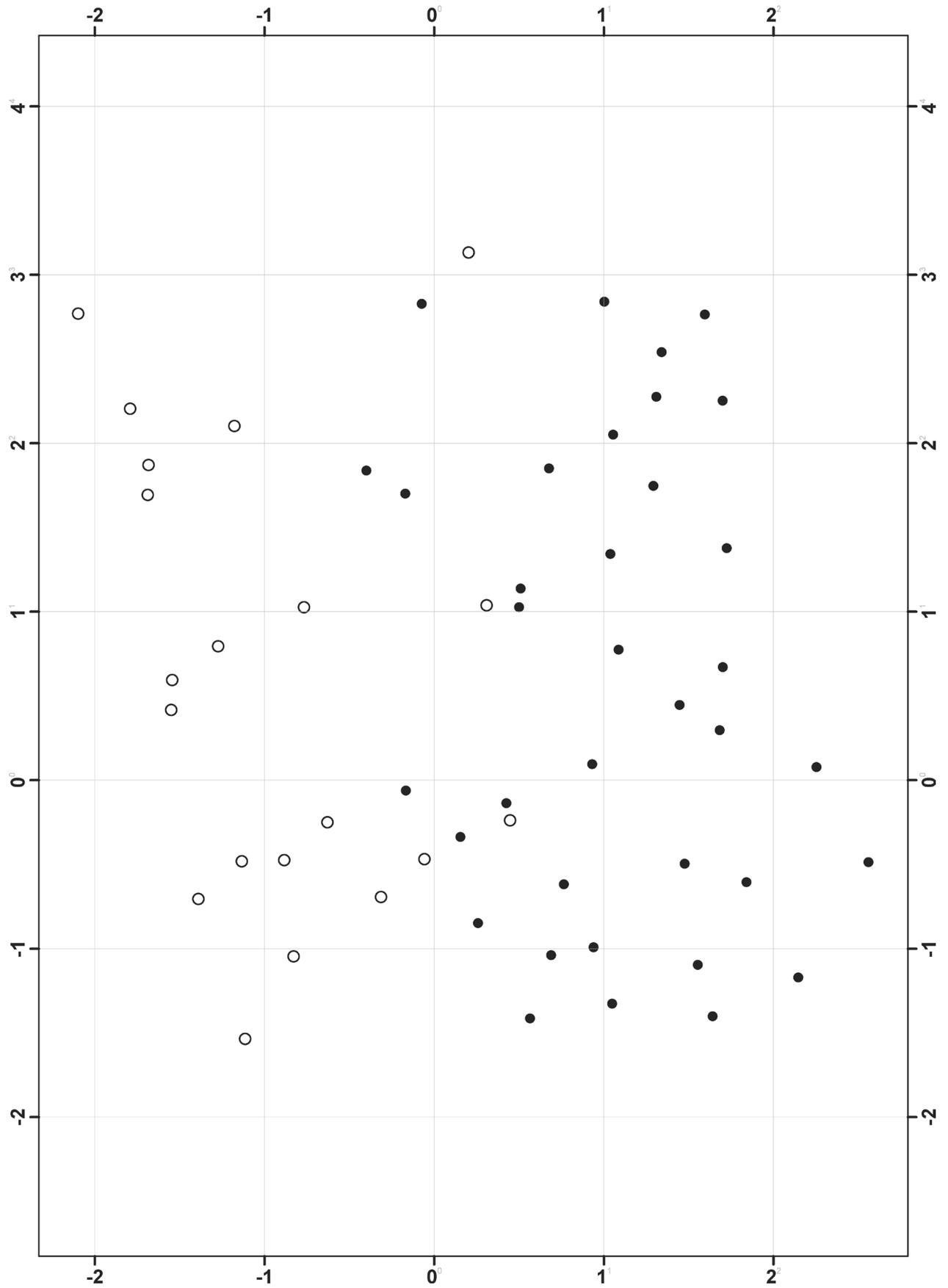


Fig. 4. Hostivar settlement: the distribution of pits containing *Cerealia* indetermined exactly (black dots) in an analytical space. This abstract space is referenced by factor loadings of the first two factors resulting from the PCA treatment of archaeobotanical data. Created in ArcGIS 9.1.

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