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THE INTERSECT PROJECT — MITIGATING BARRIERS IN GIS USAGE FOR INTERDISCIPLINARY ARCHAEOLOGICAL RESEARCH

ABSTRACT

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While geographic information systems (GIS) are used in many aspects of archaeological research there are several barriers preventing larger scale and more sophisticated use beyond simple viewing of spatial data. A questionnaire survey of environmental archaeologists has been conducted to identify those barriers and gather information about general familiarity with GIS. The results suggest that the problem lies especially in the lack of funding, insufficient practical skills and inadequate data sources. A solution is proposed in the form of a Web-GIS framework that should mitigate some of the barriers, and facilitate interdisciplinary research. This paper presents the results of the first stage of the InterSecT project.

Keywords: Web-GIS, interdisciplinary research, software, environmental archaeology
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INTRODUCTION

Spatial information in environmental archaeology is used extensively at every stage — from the choice of study area, through fieldwork and analysis, to the presentation of results (Conolly & Lake 2006). When used in geographic information systems (GIS), loca-

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tional data can be used to merge the information from many fields of research, which would not be possible otherwise. However, interdisciplinary approaches often introduce heterogeneity in spatial data. This is hardly surprising, given the fact that the information comes from different sources that may not be compatible in respect of file formats, level of detail, accuracy and precision as well as, most importantly, the perception of geographical space. The latter is particularly diverse as space is given unequal weight, and many archaeologists, for example, emphasise time rather than location (Wagtendonk *et al.* 2009) and this is described in ontology specific to a given domain. Thus to use spatial information to its full potential it should be gathered, sorted and ordered in the most homogeneous and standard form possible.

The domain of GIS incorporates spatial data gathering, processing and presentation (Longley *et al.* 2006). They are used with great success in many aspects of everyday life and in the process of scientific knowledge production — either as a tool or the subject of research. Archaeology, environmental and classical alike, extensively uses GIS. In the next section the authors describe numerous such uses illustrating that GIS is hardly a novelty in archaeology.

One can therefore formulate an open question about whether the potential of GIS tools are fully utilised. It seems they are mainly used as a source of data or for viewing the results, and much less often in analysis, where they could be most beneficial. What is needed to change this situation is a better form of spatial communication where the spatial information becomes a *lingua franca* of interdisciplinary research. This process is not without many barriers and it is worth pointing out that many of them are due to the nature of GIS itself; this issue will be also discussed in more detail in one of the following sections.

This paper presents the main assumptions, objectives and results of the first stage of the InterSecT project which aims to facilitate the use of GIS in interdisciplinary research with particular reference to environmental archaeology. It is worth mentioning that GIS is perceived and described here as a set of tools and techniques used in the management of spatial data, rather than as a science on its own. This view, however limited (Wright *et al.* 1997), is much clearer in the given context and also popular among archaeologists (Conolly and Lake 2006).

GIS IN ENVIRONMENTAL ARCHAEOLOGY

GIS technology is extremely flexible and can be used in any spatial context. In archaeology GIS methods were first used at the turn of the 1970s and 1980s for statistical analyses, creation of databases and digital mapping. Due to the nature of GIS and the use of environmental data (i.e. geographic coordinates for organising spatial information, terrain models for analysis, etc.) most applications of GIS in archaeology are related to the environment.

In general, the use of GIS in archaeology can be classified as either inter-site or intra-site. The inter-site analyses focus on the broader category of geographical settlement regions. Very often they are used to produce predictive models (Gillings and Wheatley 2002). Intra-site analyses of local archaeological sites include the analyses of distributions of residual material at the site with reference to its environmental parameters, such as slope, wetness or fossil surface.

Environmental archaeology uses spatial analyses most widely. Initially, they were used mainly for the artistic visualisation of archaeological sites (Kvamme 1998, 1999; Van Leusen 2002). Over time, GIS has become an analytical tool supported by statistical tests and software for the analyses of archaeological sites. Currently, GIS is very often applied to the spatial analyses of regional settlement and land use patterns as well as the selected environmental factors over time (Llobera 2001; Winterbottom and Longham 2006). Another use of GIS is to study the relationship between environmental parameters (variable environmental conditions) and settlement patterns. In most cases, the next step of such research is the development of predictive models in general, which in turn can be used in practice to help the search for archaeological sites (Kvamme 1989; Stančič and Veljanowski 2000; Fry *et al.* 2004; Howey 2007; Kay and Storm 2009). Such studies involve determining the correlation between the distribution of archaeological sites and the environmental variables of the region. Knowledge of environmental variables and the regression or discriminant functions helps determine the distribution of archaeological sites in unexplored areas, their cartographic visualisation and the testing of models on the basis of independent samples.

Other methods utilising GIS are cost-surface and viewshed analyses. These methods are more often used in Europe than the USA, although this is where the first publications originated. The literature indicates that the reasons for this situation are different approaches to the study of the past in Europe and North America. The American school of human-environment relations pays more attention to the characteristics of the physical environment, while European studies often emphasise social determinants that are closely linked to the concept of territoriality (site catchment analysis) (Kvamme 1998; 1999).

In both methods the starting point of the analyses is a digital terrain model, which is used for identifying obstacles (i.e. “frictions”) as part of the cost-surface. In most cases, these are physical parameters of the environment, such as watercourses, wetlands, steep slopes, etc. Using this method makes it possible to determine old migration routes. Viewshed analysis determines the area seen from particular locations, such as places of worship or burial mounds (Wheatley and Gillings 2000; Kay and Sly 2001; Lake and Woodman 2003; Ogburn 2006).

Today, an important aspect of research is four-dimensional GIS, which uses the fourth dimension — time, in addition to the coordinates x, y, z. Such analyses are not common as they require an archaeological and environmental database for several time intervals. The most frequent problem is obtaining the palaeo-geographical data for the time period of the archaeological cultures under consideration. Most of these studies analyse the variability of settlement distributions and land use changes over time (Spikins *et al.* 2002).

The countries with the greatest GIS usage include the USA, UK, Australia, New Zealand, the Scandinavian countries (60% of the projects), and the Netherlands, followed by Mediterranean countries (i.e. Italy, Spain and France). In the countries of Central and Eastern Europe the use of GIS projects in archaeological research is estimated at 15% (Djindjian 1998). Over time, however, the structure of participation in research projects has not changed much.

GIS is mainly used in archaeological heritage management (*cultural resource management* — CRM). However, projects analysing the relations between settlement, landscape and culture within the broader framework of environmental archaeology, have only a slightly smaller participation. Such projects are usually carried out in the USA, Australia and Scandinavian countries.

In Poland, despite the interest in the possibilities of GIS, especially among students and young archaeologists, there are few articles based on GIS analyses. The use of digital terrain models to visualise archaeological sites is most common (Dobrowolski *et al.* 2011; Zagórski 2009). More advanced studies include the analysis of prehistoric settlement preferences in relation to hydrological and topographic features of a site, which were obtained from the transformation of the digital terrain model (Jasiewicz and Hildebrandt-Radke 2008 a, b, 2009). In addition to settlement preferences, for the same set of the data, settlement analyses were performed to derive density and trends over a number of time intervals (Jasiewicz and Hildebrandt-Radke 2011). However, development of the viewshed analysis and the cost-surface analyses are at their initial phase (Jasiewicz and Makohonienko 2009).

This situation is mainly due to the fact that much of the documentation of archaeological research, from both the surface and from excavation, is still stored in analogue form. This situation should gradually improve as the construction and development of a geospatial database of monuments has been identified as one of the functions of the National Heritage Board of Poland. The new strategy of this institution implies moving away from the previous passive model in the administration of monuments towards active management of the heritage. This is related to the implementation of the INSPIRE Directive in Poland, whose task will be primarily the collection and integration of natural and geographical data (Kołodziej 2011; Banaszek 2010).

An example of activities in this regard is the computerisation of the data of the Polish Archaeological Record Project (*Archeologiczne Zdjęcie Polski* — AZP). The project is still in progress, criticised and recently converted into a spatial database. The previous actions led to the creation of a computer program AzpMax which was to be used to enter and analyse the AZP's data (Prinke 1996; 1997; 1998; 2002). Practically, however, on a larger scale, it has not been realised. Today, it does not meet the criterion of a geospatial database. Therefore, there are local attempts to develop new programs for introducing and processing the AZP's data as GIS databases (Gawrysiak and Reder 2011).

The digitisation of both the data and the results of archaeological research are a necessary first step to make it possible to take a full advantage of geospatial environmental data. This is especially important as such data is constantly growing and gaining wider access via Internet platforms.

Having archaeological and geospatial data supports the proposition and solving of scientific problems, using a variety of queries and, most importantly, allows for use of GIS methods and geostatistical analysis, which will produce a completely new quality of research results.

INTERSECT PROJECT

The aim of the InterSecT (*Inter*disciplinary *S*ci*e*ntific *T*ool) is to create a software framework that will facilitate the use of GIS in interdisciplinary research. The main goal is to allow scientists from various disciplines to use spatial information easily, regardless of their backgrounds and lack of geoinformation knowledge, without the need for extensive training and with existing hardware and software infrastructures. The latter is particularly important in the initial stages of scientific collaboration, when funds are often limited. Therefore, InterSecT is trying to overcome two barriers to GIS use, namely software interoperability and disciplinary interoperability.

These aims may be achieved by using web-based GIS (Web-GIS). These have been developed in recent years and become a viable alternative to more traditional desktop solutions (Dragićević 2004; Rzeszewski and Jasiewicz 2009). Most everyday tasks of traditional GIS packages can be achieved in the web environment (Anderson and Moreno-Sanchez 2003) alongside more complicated geospatial analyses possible thanks to the Web Processing Service (Díaz *et al.* 2008; Meng *et al.* 2010). Moreover, some feature exclusive to Web-GIS are capable of overcoming software interoperability:

• Modularity: GIS in a web environment are not complete and closed solutions. They are rather described as conglomerates of multiple, often independent modules. This allows for customisation of the features provided by a given framework according to the users' needs and the existing hardware infrastructure. But, this kind of software architecture is also entirely dependent on smooth cooperation between different software packages, which may not be easy to achieve.

• Open Source Software: Web-GIS is one of the branches of GIS rooted in the Free and Open Source Software for Geoinformation (FOSS4G) movement and the available software packages are amongst the most advanced (Brovelli *et al.* 2012). By utilising the FOSS4G packages one can drastically decrease the initial costs of GIS system development (Anderson and Moreno-Sanchez 2003). Thus, spatial information can be distributed more easily and to a greater number of users. There is also a higher probability that a non-geographer will know at least one Open Source software item, the one accompanying any professional package. However, there are risks involved: many Open Source solutions do not include proper support or documentation, and the available training is limited. Few vendors offer commercial support, Ubuntu by Canonical being a notable exception.

• Browser based interface: Web-GIS software can be based around a thin-client concept, where the main software and data is located on a remote server and users access the required features through a web site. It is fairly safe to assume that the browser graphical interface is well known to the average computer user and thus the training period can be short. One disadvantage of this solution is that adding non-standard features often requires extensive programming effort. Also, developers must always pay additional attention to security issues.

The second barrier between disciplines is much harder to overcome because it is the result of ontological differences in the perception of space. Differently perceived phenomena are also differently described, which can easily lead to misunderstanding. To avoid this, spatial information should be as syntactically homogeneous as possible. The transformation and conversion of data streams are therefore necessary and should be carried out in the background, invisibly to most users, to eliminate the human error factor. Only in this way can spatial communication mitigate disciplinary barriers.

This framework will be first tested and introduced in environmental archaeology because of the wide range of sciences in this field and its strong connection to geographical space. The project will be conducted in five phases:

1. Designing and disseminating a questionnaire to understand the needs and expectations of prospective users, electronically distributed to members of the Polish Association of Environmental Archaeology (*Stowarzyszenie Archeologii Środowiskowej* — SAS).

2. Constructing a spatial database that will encompass most of the potential data.

3. Choosing software and designing the framework; adding missing functionality and interoperability routines.

4. Testing the project in a real-life application.

5. Documenting and distributing.

The first stage of the project has been completed. The results and conclusions are described below.

QUESTIONNAIRE SURVEY RESULTS

The first stage of the project was carried out from January to May 2012, comprising a questionnaire survey sent to Polish environmental archaeologists. There were 39 responses, of which 33 were used for further analysis. The rejected ones were either inadequately filled in or were from people who had previous knowledge of the purpose of the research and it was believed that this might have introduced bias. The overall number of the respondents was relatively small but it must be taken into account that every questionnaire represents a research group or institution rather than a single person. The full content of the questionnaire is available at *http://intersect-gis.pl/ankieta*.

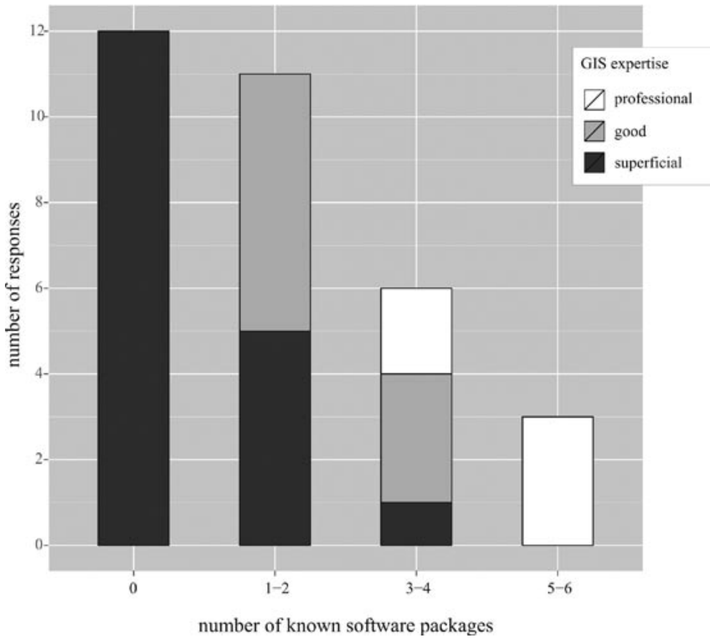

Fig. 1. Comparison of self-evaluated GIS expertise with the number of known software packages

One of the main goals of the questionnaire was to assess general knowledge of GIS among environmental archaeologists. Firstly, the respondents were asked to evaluate their own GIS expertise using a threefold scale: *professional*, *good* or *superficial*. Some of the further questions were designed to verify this evaluation by asking about more detailed aspects of GIS. Figure 1 cross references the self-evaluation and the number of known GIS software packages. The latter question was open and participants were allowed to list any number of names. As can be seen in the figure, both questions correlate positively and strongly. The respondents declaring superficial GIS expertise listed no more than 1–2 packages, while those perceiving themselves as professionals were able to list at least 3–4 and mostly 5–6 different software names. There were some cases where people who declared superficial knowledge were able to enumerate more than three packages. This may be due to either an inaccurate estimation of the knowledge or confusion between knowledge and proficiency in software. The latter seems more probable because there were no opposite cases. Not only is the number of packages interesting but also their names. The three most popular were Quantum GIS (14), ArcGIS (13) and Saga GIS (7). Significantly less popular were Mapinfo (3), gvSIG(3) and AutoCAD (2), and only single respondents mentioned Geomedia, GeoMap, Global Mapper, GRASS, ILWIS, Microstation, PostGIS, Spatialite and Surfer. A clear popularity of the Open Source Software is not surprising, as it reflects the increasing use of this kind of software by the research community at large (Steiniger and Bocher 2009). This also bodes well for the assumptions of the InterSecT project, which will be entirely based on FOSS4G.

The declared GIS expertise was also compared to the frequency of using spatial data (Fig. 2). The correlation is similar — the greater the expertise the more frequent spatial data usage, but not nearly as strong. There are groups of people using GIS data very frequently who only have a superficial knowledge of GIS. Again, this may be the result of wrong self-estimation, but there are other possible explanations. For example, this could be a sign that there are scientists who use spatial data in research or even just perceive the potential of using it but, at the same time, are unable to fully utilise GIS tools due to existing barriers, lack of knowledge or skill. This would confirm the hypothesis that there is a need for GIS tools in disciplines other than geography or geoinformation, and that there is a niche for projects like the one presented here.

In the next part of the questionnaire the respondents indicated most frequently used data types (Fig. 3). Our hypothesis was that "simpler" types of data, like scanned maps and GPS points, would be used more often. This proved to be the case, with topographic maps and measurement data among the most frequently used, ranked at the first and third place respectively. But the differences between data types are almost negligible and statistically insignificant. Only six less respondents listed *text data*, ranked in last place, than *topographic maps*. These results show that there is a wide variety of data types and formats that must be taken into consideration in the framework database design. The authors hoped for the distribution to be more skewed towards a particular type, but the variety

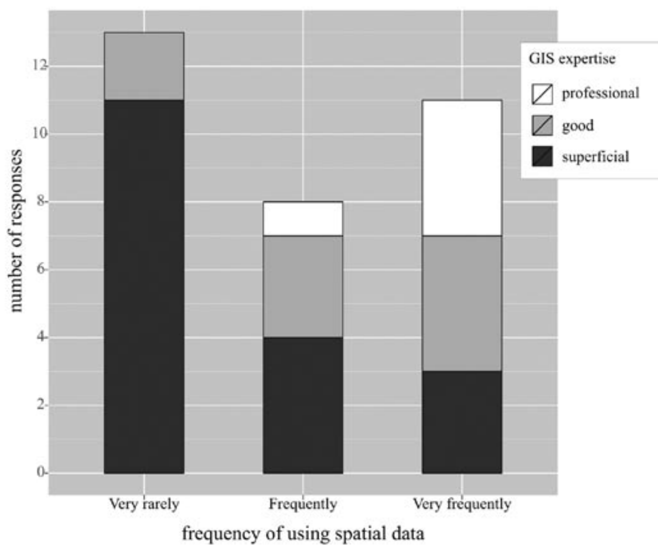

Fig. 2. Comparison of self-evaluated GIS expertise with frequency of using spatial data

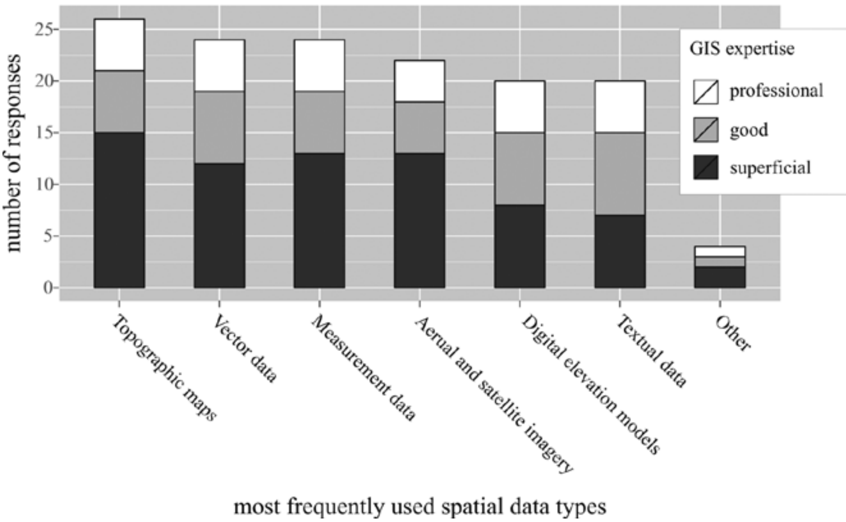

Fig. 3. Comparison of self-evaluated GIS expertise with the most frequently used data types

means that technically it will be more difficult to encompass all the possible data inputs. It may be even necessary to narrow down the choices available to future users. Lack of any prevalent standard whatsoever signifies that it is important to provide some methods of translation.

The diverse data types are usually the result of equally diverse tasks performed using GIS. The respondents were asked to rank 13 common functions provided by GIS packages in a threefold scale: *necessary, useful* or *unnecessary* (Fig. 4). The choice of wording was deliberate, with the intention of obtaining as much information as possible. The two extreme choices required some previous experience, while the middle one was not so restrictive and therefore was probably more often selected in case of unfamiliar functions. Also, to mark the functions as *unnecessary*, one must have a complete knowledge of their GIS needs. The results show that only three functions were designated in this way by more than one person. Surprisingly, one of them was *editing vector objects*, which at the same time was described as *necessary* by the greatest number of respondents. The other two were *digital terrain models* and *web services*. Equally puzzling is that only 10 respondents gave *GPS data* the highest grade. It had been expected this would be one of the more useful tools for archaeologists. For an explanation it would be helpful to look into the workflows used to gather location data. Generally, it is clear that GIS in environmental archaeology is used in a rather basic way for vector data editing, georeferencing, map production and classification. Therefore, one of the goals of the proposed framework should be to introduce more advanced tools and better ways of utilising those already being used, for example, scanned and georeferenced maps could be replaced by remote data sources from web

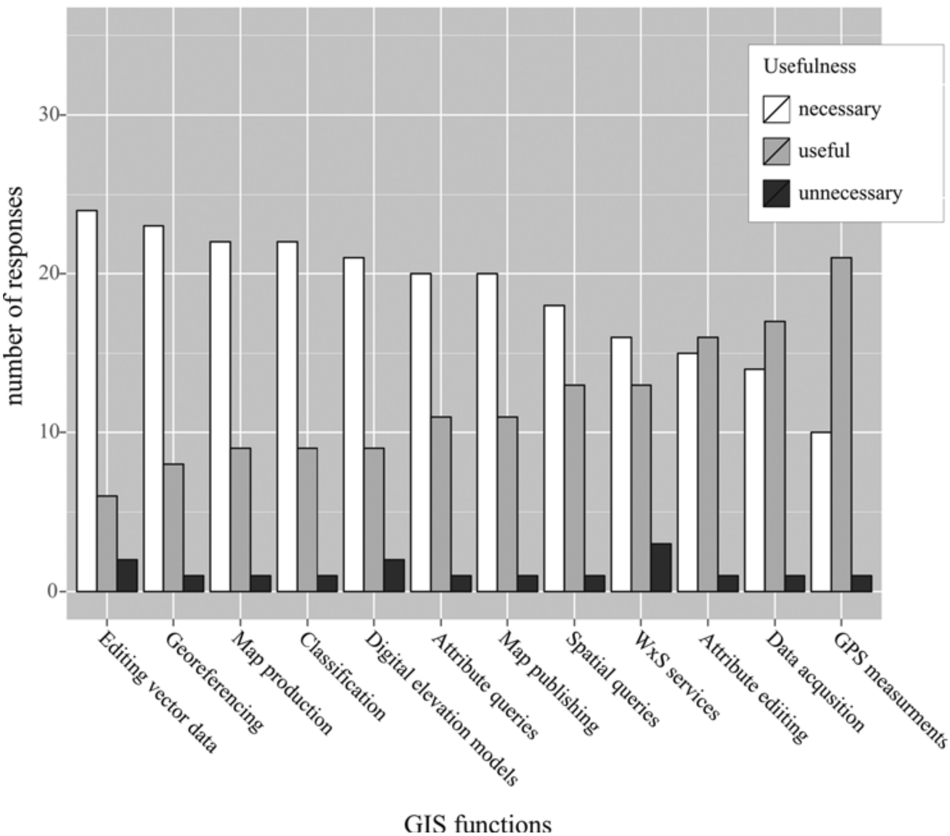

Fig. 4. Usefulness of various GIS functions as graded by the respondents

services like the WMS or WCS. This must be done with care however, to ensure that the simpler functions are still available. The respondents also had an opportunity to include their own desired functionalities and more than half of the respondents (22) took it. From the detailed descriptions given it was concluded that most of the suggestions can be classified in the domains of spatial analysis or better graphical interfaces that would allow for simpler workflows.

The last part of the questionnaire dealt with the barriers perceived in using GIS. This was an open question so the answers were classified into four categories: *funding and availability*, *lack of skill*, *quality and availability of data* and *lack of knowledge* (Fig. 5). It was hardly surprising that almost half of the answers (15) suggested lack of sufficient funding. The respondents complained that it was equally difficult to gain access to professional GIS software and hardware infrastructure. This partly explains the aforementioned popularity of the Open Source Software. The second significant barrier is the lack of skill in using GIS software. The reasons for this are manifold. Obviously, environmental archaeologists come from many different backgrounds, where GIS is not routinely taught and every skill must be learned by experience rather than formal training. But even among geographers, where the situation should be much better, this is still a relatively new subject. It was not until the late 1990s that GIS started playing a more than marginal role in geography (Kistowski 2001). This is also related to the first of the barriers — lack of funding severely limits the access to the GIS software and therefore impairs the GIS skills in the scientific community.

Two other barriers were more rarely mentioned but they are significant nonetheless. The first one is *Quality and availability of data*. Once more, it is strongly dependent on finances. Many datasets essential to archaeology, like detailed digital terrain models, are expensive and beyond the reach of many scholars in Poland. Thankfully, the situation is gradually improving due to the INSPIRE project and the evolving National Spatial Data Infrastructure. These initiatives, like the Polish Geoportal (htp://geoportal.gov.pl), make the spatial datasets available for viewing and even downloading by means of various web services (WMS, WFS). But, from the comments received from the respondents and the importance they placed on the web services in the questionnaire, it can be concluded that this source of data is still not widely recognised. Therefore, one of the goals of the InterSecT should be to propagate knowledge about remote data sources.

The lack of knowledge about GIS is the last category of the perceived barriers that was identified. It is interrelated to *lack of skill* but we chose to separate it to underline some

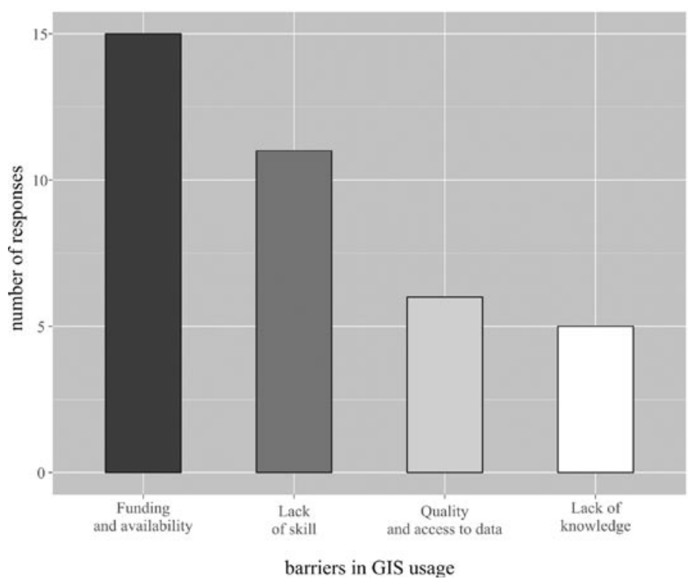

Fig. 5. Categorised barriers in using GIS

additional issues. The respondents drew attention to problems of general spatial literacy, e.g. lack of basic cartography skills needed for simple tasks like the transformation between coordinate systems or creating a readable diagram or a map. This group also includes people who have never had contact with any GIS software.

CONCLUSIONS — IMPROVING GIS USAGE WITH WEB-GIS

It is clear that Web-GIS can be used to mitigate barriers existing between environmental archaeology and a wider use of GIS tools. The proposed framework will be entirely based on the FOSS4G software and therefore the initial costs will be minimal. Without a large data load all the components of Web-GIS can work relatively smoothly even on low-tech hardware. Therefore, it is possible for interested users to conduct preliminary test-runs on existing computer architecture. This will reduce funding problems indicated as important for the majority of the respondents. Still, knowledge and skill barriers remain. Therefore, the project goals were modified to address this problem.

Based on the results of the questionnaire it seems that the proposed framework should fulfil both an educational and practical role as it may be equally important to introduce certain tools as it is to provide easy access to them. This issue will be addressed in two ways. Firstly, installation and data integration will be streamlined to the bare minimum. The finished framework will be published as a downloadable, preconfigured Linux distribution that can be either installed on a separate server machine or as a virtual machine. In this way users will not be required to install any software components on their own. Secondly, detailed documentation with tutorials for basic tasks will be provided. The comments from the survey suggest that even a simple introduction to data models and spatial analysis would be beneficial. This is of course not without costs. Simpler, clearer and better documented workflows require time that could be otherwise allocated to the development of more advanced geoprocessing tasks. This means that the final project will not deliver all the planned functionality but hopefully it will be better suited to the needs of the potential end-users.

The only important barrier that will be partially addressed is the accessibility and quality of the data. The framework will include various types and formats of exemplary data and this should introduce users to the many possible data sources, not only in the form of locally stored files but also to the remote services, like the WMS or WFS. But the quality of the currently available datasets and their accessibility are still not sufficient for many tasks. The situation is improving thanks to various institutional efforts, like *http://geoportal.gov.pl* or *http://geoserwis.gdos.gov.pl*, but the majority of data is still in analogue form. However, the authors hope that this project will make the use of Web-GIS for research more popular and, since it is relatively easy to publish data gathered in this way, it could lead to more resources being available in the public domain.

The status of the project and all the data and software gathered so far are available at the project website *http://intersect-gis.pl/*.

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