Geographic Information Systems in Archaeological Analysis – GisArchaeo

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ABSTRACT

This summary sets out to synthesize work developed for a doctoral dissertation in the area of Territorial Engineering entitled: Geographic Information Systems in the Detection of Uillæ in Rural Roman Portugal: a Predictive Model.
This work was designed to analyze the suitability of Geographic Information Systems (GIS), for the purposes of archaeological research. To this end, firstly architectural surveying in the field of archaeology was described generically while examples of the implementation of SigArchaeo at international levels and in state of art contexts were collated, this in order to realize the proposed aim: the construction of a predictive model that might make it possible to infer the existence of Uillæ in rural settings. This sequence of procedures made it possible to establish phases of analysis of approach to the objective of the work.

1. ARCHAEOLOGICAL ANALYSIS AND GEOGRAPHIC INFORMATION SYSTEMS IN THE CONTEXT OF STATE-OF-ART

Geographic information can be defined as being the use of information associated with the location where it occurs then Geographic Information Systems can be seen as the optimization of the information resulting from the implementation of computer systems. These are systems which allow the receipt, analysis, selection and the numeric and graphic representation of that information. In turn, GIS in the area of archaeology, in addition to being based on the same assumptions, are suitable for the specific analysis to socio-historic structures and natural landscape and its evolution, taking into consideration, simultaneously, space, time and form (rarely so considered in traditional archaeological research) and, furthermore, allowing the association of descriptions of attributes or characteristics to a graphic survey.
In certain way, it can be said that, while GIS models – representations or abstrations of a phenomenon or process to be activated, which include arguments concerning the physical description of the space, which inter-relate spatially referenced facts with cartographic themes, and which describe, manipulate and analyze these themes and generate results, by superposition, in the form of new themes – seek to correspond to geographic descriptions of present phenomena. GisArchaeo models, which are also based on the same type of analysis of the space-form relationship, have, in time, a weighty component to take into consideration. They objectify the analysis of the present in order to understand the past and give orientation to future developments.
The ease with which traditional archaelogical analysis can be convert for use with GisArchaeo systems may be due to the sequence of archaeological processes used in fieldwork, in particular, the use of a multi-spatial grids, which serves to reference, simultaneously, the on-site excavation (using a larger scale grid) and the drawing (the smaller grid constructed by subdivision of the larger scale grid).
The standardization process is based on the placement of a central point, which makes it possible to geo-reference the survey on the national geodesic system, by using ortho-standardised axes, and on the points of reference that are to be established during the construction of the physical grid in the locations under analysis. This allows both the independence and the integration of the survey, which will be carried out only on sites to be examined, but, however, taking the whole into consideration as a single unit. This type of procedure makes it possible both to integrate separate surveys, with greater graphic rigour, and to make three-dimensional reconstructions of the structures in the environment in which they are found; it also makes for greater swiftness in processing the information – local and regional.
Of the diferent types of manipulation of information concerning archaelogical themes, three should be mentioned. These correspond to different approaches to the consideration of the information, which are reflected in the successive phases of GisArchaeo research and are, in hierarchical order:

- models for Site Localization and Management of Cultural Resources;
- Social Landscape models; and
- Reconstitution of Ancient Landscape models.

The models of Site Localization are based on inventory taking of the heritage in order to determine socio-historic scenarios, hypotheses of development and evolution of sites, to test for possible past populations, supported by field research, to select location based on environmental factors of the region, consistently defined in GIS and to determine patterns of sites, in order to identify locations where the same combination of environmental variables is verified, which may result in the identification of probable zones where new archaeological sites may be found.

Social Landscape models seek to infer the influence of human behaviour on the landscape through the objective determination of the limits of the areas of influence, which, in turn, allows the mean center and the center of gravity to be determined. They are models which seek to bring same order and sense to the cultural resource database, through the integration of social and environmental factors – determination of atypical locations. The construction of these models is based on the estimate of the constituent population of each center so that possible mobility through the archaeological space can be analyzed, taking into consideration a wider area, made up of various centers. This makes it possible to obtain hypotheses of previous occupations of the land from cartographic records of the limits of the areas and the axial thoroughfares of a region, as a function of probable connections which may be established between centres.

Reconstitution of Ancient Landscape models are the result of previous GisArchaeo analyses. They objectify the reconstruction of the "real-world landscape" of archaeological sites, and are based on the physical evidence extant in the present landscape, on the descriptions and other narratives of the sites under analysis and in the determination of the degree of disturbance to the landscape, in order to be able to carry out a comparison, through the overlaying of images, of different eras.

The types of modelling presented here correspond to the main strategies of research applied to archaeology, using GIS as a means of centralizing and managing great quantities of data, resulting in the implementation of archaeological models which are more consentient with the reality to which they refer, and therefore, with the more objective analyses of the unwritten past. Successive GisArchaeo projects, which may be developed, should contribute decisively to a greater divulgation of its implementation. In this context, it is hoped that the predictive model in the detection of *Uillæ* in rural settings in Roman Portugal, presented here, will make a contribution of unequivocal interest.

2. GEOGRAPHIC INFORMATION SYSTEMS IN THE DETECTION OF UILLÆ IN RURAL ROMAN PORTUGAL: A PREDICTIVE MODEL

The methodological process was based on the use of 10 case studies for the measurement and quantification of the respective morphological-environmental and socio-historical characteristics, and, on the basis of these values, indicators were established which were then used in the construction of the research model GisArchaeo. The aim was, when implementing it over a wider area, to detect other zones where the same occurrences of values might be verified, corresponding to sites of high archaeological potential. For this purpose, existing Roman heritage was considered and cases with the greatest affinity, in terms of time and space were chosen, so that a type of common pattern of occupation might be identified which would then be able to be used in automated research.

The choice of geo-referenced Roman heritage went beyond the consideration of the rural landscape, which presupposes the existence of an agricultural zone, to consider also, the typology and dimensions of building work, the existence of decorative elements, the state of conservation, the existence of documentation, especially in graphic form, and the accessibility of these data.

The planning and method of research was based on the collection of existing information, fundamentally historical, geographical and environmental in nature, on the determination of the area of influence – an area necessary for the natural balance of the *Uilla*; that is, one which would assure the basic necessities of its users – through determining the boundaries of the hydrographic sub-basin measured from the central point to the nearest water line, so that it was possible to measure the values of each theme under consideration as a function of this area and, consequently, to establish criteria for inference and comparison.

Based on the pre-established conditions, 10 rural properties with areas perfectly compatible with human walking were ascertained, which, according to the patterns of the time (before agricultural mechanization) can be classified as being one larger, three medium and six small properties. This delimitation made it possible to generate Digital Models of the Terrain, which, in turn, gave rise to the generation of Slope and Aspect Maps, for each of the case studies.

In this way, the measurement and comparison of data between different *Uillæ* were carried out, comparative tables of environmental factors were drawn up and the information was weighted in order to determine the indices which could be implemented by automated research. The information was studied by theme, in four dominant groups, in such a way that information could be superposed on each axis and later, between axes, and so that characteristic values could be determined, either for agricultural production and hydrologic resources, or for urban occupation, in order to attain the proposed objective.

After determining the indices by measuring the dominant environmental factors, the GisArchaeo research model was made. The superposition of information was carried out in two ways:

- by Binary Superpositions, which made it possible to determine the occurrence of related indicators such as might lead to the inference of potential sites;
- by Weighted Sums, which resulted in the ascertainment of areas of equal preference for the conjugation of weighted factors of the considered themes.

3. BINARY SUPERPOSITIONS

In the Binary Superposition Method the information, hierarchised in order to carry out overlay operations on and between axes, made it possible to obtain an area where an analysis was made of the aspects and slopes most favourable for the installation of a *Uilla* in a rural setting. With this process, six locations were identified, potencial archaeological sites, which corresponded to the environmental variables initially selected. The measurement of the environmental characteristics of archaeological sites makes it possible to identify new sites; but obtaining results implies the verification of the correlation between the model and reality, which can be done by the bibliographic research of existing facts and by on site confirmation.

With the results obtained, the overlay was made with the existing records, bibliographic, such as the Archaeological Map and the IPA data – the predominance of fortified *Uillæ* in the region having been verified – and graphic records, such as map-work and aerial imagery. This resulted in a great degree of correlation in the alignments between the model and the real-world site (indicating the probable existence of roads). The field-walk analysis of the most promising zones made it possible to observe that:

- the results excluded the zones corresponding to the vestiges of most recent occupation, namely Medieval-Islamic;
- the type of ground had decisive weighting in the research, since the zones with building work were also excluded;
- supporting rural infrastrucures were detected, probably of corresponding pre-existences;
- and that the alignments resulted from different growth patterns in local vegetation (different constitution of the layers closer to the surface of the subsoil).

The certainty of the existence of buried archaeological vestiges can only be confirmed by excavation work.

4. WEIGHTED SUMS METHOD

For the superposition of the information using the Weighted Sums Method, the variables were considered according to ranges of favourable values, by attributing weighting factors to each theme. In addition, the same structure and hierarchy of data were considered so intermediate results could be compared.

Implementing this type of analysis, in spite of the level of generalization of the information under consideration, allows areas of equal archaeological potential to be determined and a pre-selection of these areas to be made with the aim of providing research with a much greater degree of detail at a subsequent stage.

The themes were weighted according to the importance imputed to them for the cultural period in question, based on affinity and by direct consultation with specialists in this area who made themselves available for this purpose, so that an exhaustive classification could be made as well as intervals considered. The superpositon of the information made it possible to determine areas of equal preference for the co-occurrence of factors of the weighted themes (which were designated by archaeological isolines).

This weighting varied between 1 and 75, and for the purposes of the study, the first 20% were validated, which, in fact, were values between 60 and 75. The areas which corresponded to these first classifications were intersected with the cartographic division on a scale of 1: 25 000, which resulted in a superposition of 529 maps. Of these, again the first 10% with the highest classification were chosen, corresponding to 53 maps (2% of the total), so that experimentation with more detailed analysis could begin. The ultimate objective will be to establish procedures which may permit the analysis of all these areas. The intermediate result now obtained, in spite of relating to a much greater area than that of the first model, again validated, through binary superpositions, the same zones as being of great potencial.

These 53 maps were then examined for generic environmental characteristics for the period in question, particularly in terms of slope and aspect, and, with those that revealed greater affinity in factors such as predominately southerly and easterly orientations (maps 412, 539 and 574), research specification was carried out. This specification concerned the Roman environmental characteristics for the choice of the most propitious locations for the installation of a property (*pars rustica*), either in terms of soil quality for agricultural production or in terms of size, and, afterwards for the siting of a house (*pars urbana*), which would conform to the technical necessities of a construction of this nature.

Finally, the results were superimposed on the existing records. Consulting the database of the IPA made it possible to prove the existence of many Roman remains in the zone, especially tool-sheds. In turn, the field research made it possible to detect the existence of building work, carried out according to the tradicional construction methods of the region – shale masonry – difficult to date, and near one of the possible locations of the Roman house was found a small fortified Islamic structure (Relíquias), with surface spoil dating back to 5^{th} century BC, probably corresponding to the continuation of previous Roman occupation, a very common occurrence in the region. To validate these hypotheses, on site excavations had to be carried out.

5. COMPARISON OF THE INTERMEDIATE RESULTS

From the comparison of the intermediate results it can be concluded that, Binary Superpositions are suitable for the determination of sites – areas with specific environmental factors (archaeological research) – and that the Weighted Sums Method, at present, is preferentially placed within the hierarchy of archaeological potencial (archaeological planning), the two methods having led to similar results. In effect, the sites determined by binary superposition correspond to those with the greatest probability of occurrence in the weighted sums methods. This may be due to the following: the use of the same facts; their level of generalization or the need for better specification of the social component associated with each *Uilla* – agricultural, industrial or administrative – which could clarify the persistence of the results classifying, as being of high archaeological potencial, a region with such particular characteristics, where fortified *Uillæ* predominate.

CONCLUSIONS

It is believe that the development of this work has contributed to a new methodology for inferring the past, through the monitoring of remains in the time and space of which they are an integral part, specifically through the geo-referencing of structures and artifacts, through the determination of classes and types in the environment where they are set and through the measurement of densities and distributions of occurrences of spoil during the excavation process. Consequently, it is through to have contributed to the integrated management of cultural resources and to the archaeological research of different scenarios of the past.

In order to attain the proposed objectives, a set of procedures had to be established which, it is hoped, may become standard in any archaeological operation especially where the survey phase is concerned, so that information collected in different places and at different times can be collated, and information considered in the GisArchaeo model. It is to be noted that the sequence of operations which can be implemented in the model, which made it possible to obtain conclusions and to attain the proposed aim, whether in reference to hypotheses regarding archaeological occupations or in the sense of determining local and regional archaeological potencial, in addition to being innovative, is sufficiently flexible to be used and optimized in pieces of work of this nature, and so may eventually contribute also to the standardization process fundamental to being able to carry out comparisons between distinct developments.

This development, therefore, makes it possible to base decisions on impact analysis studies and environmental planning, whether in zones of urban expansion, in order to minimize the destruction of possible archaeological remains, or on Town Master Plans, as a form of safeguarding the disposition of territory and the use of land in the context of urban planning.

At local level, the wide use of GisArchaeo models can be predicted in drawing up virtual reconstructions, integrating the information collected, and for facilitating access to archaeological information, permitting new research according to new inferences, which may develop in the meantime.

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FIGURES

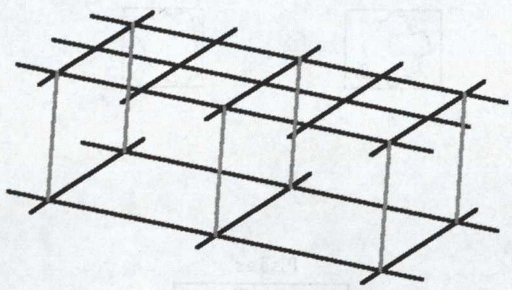
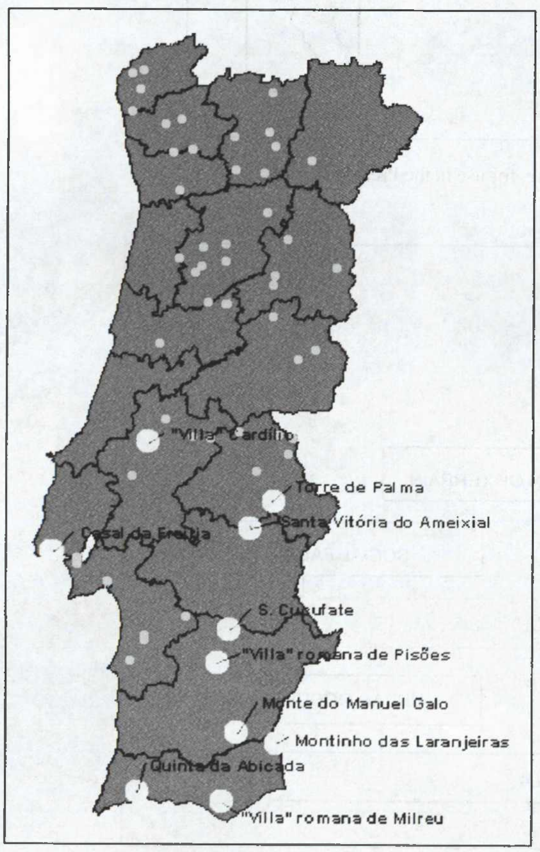


Fig. 1 – Diagram of a multiple-spatial grid, for simultaneous use with excavation and drawing.



Name	Features
Cardílio	*Uilla* (with important spa installations)
Freiria	*Uilla* (with granary and spa)
Torre de Palma	*Uilla* (with spa, temple and horse-installations breeding)
Santa Vitória do Ameixial	*Uilla* (with spa)
Abicada	*Uilla*
São Cucufate	*Uilla* (with spa, temple and farm)
Pisões	*Uilla* (with spa)
Manuel Galo	Fotified *Uilla*
Montinho das Laranjeiras	*Uilla*
Milreu	*Uilla* (with spa and temple)

Fig. 2 – Illustration of the geo-referencing of the classified Roman heritage and the identification of case studies.

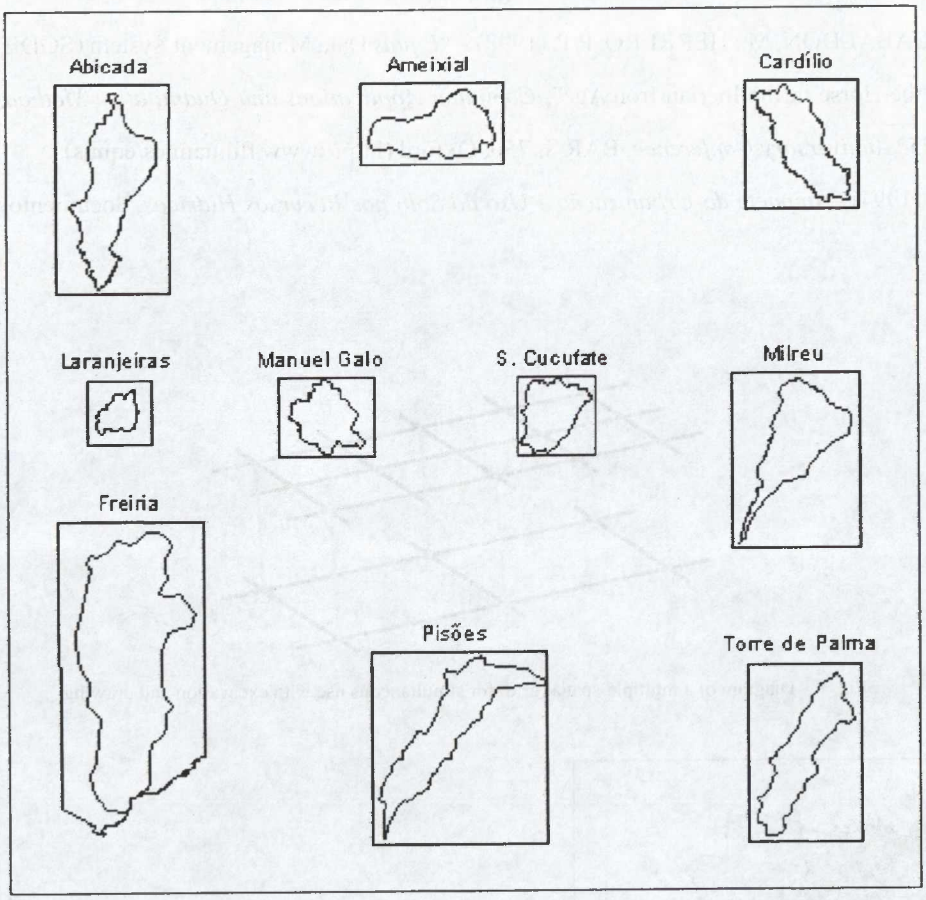


Fig. 3 – Areas of influence and limits attributed to each site, for use in the Predictive Model.

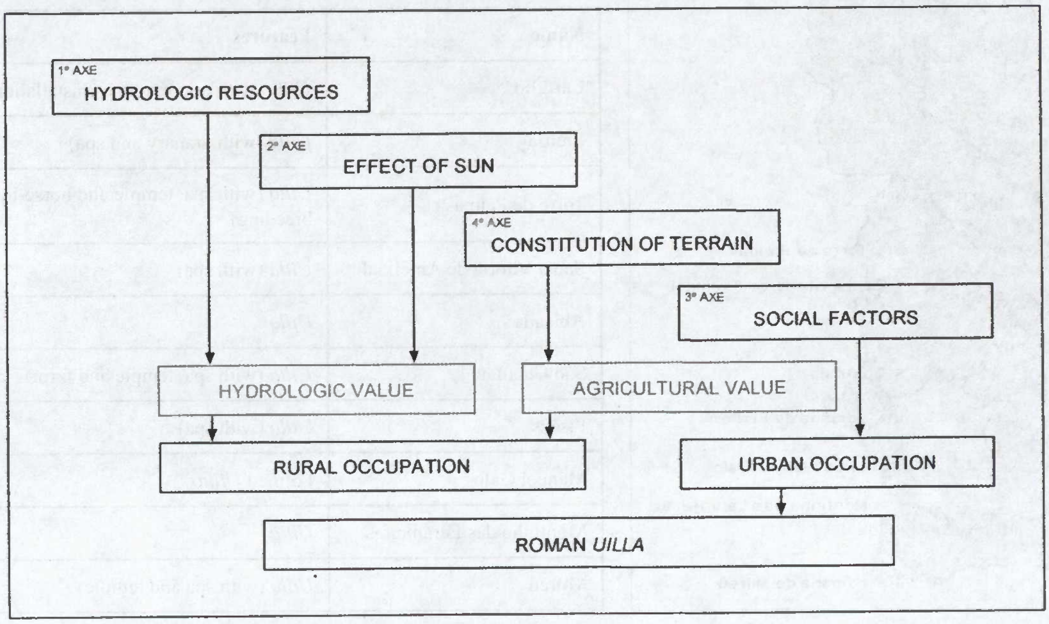


Fig. 4 – Diagram of the organisation.

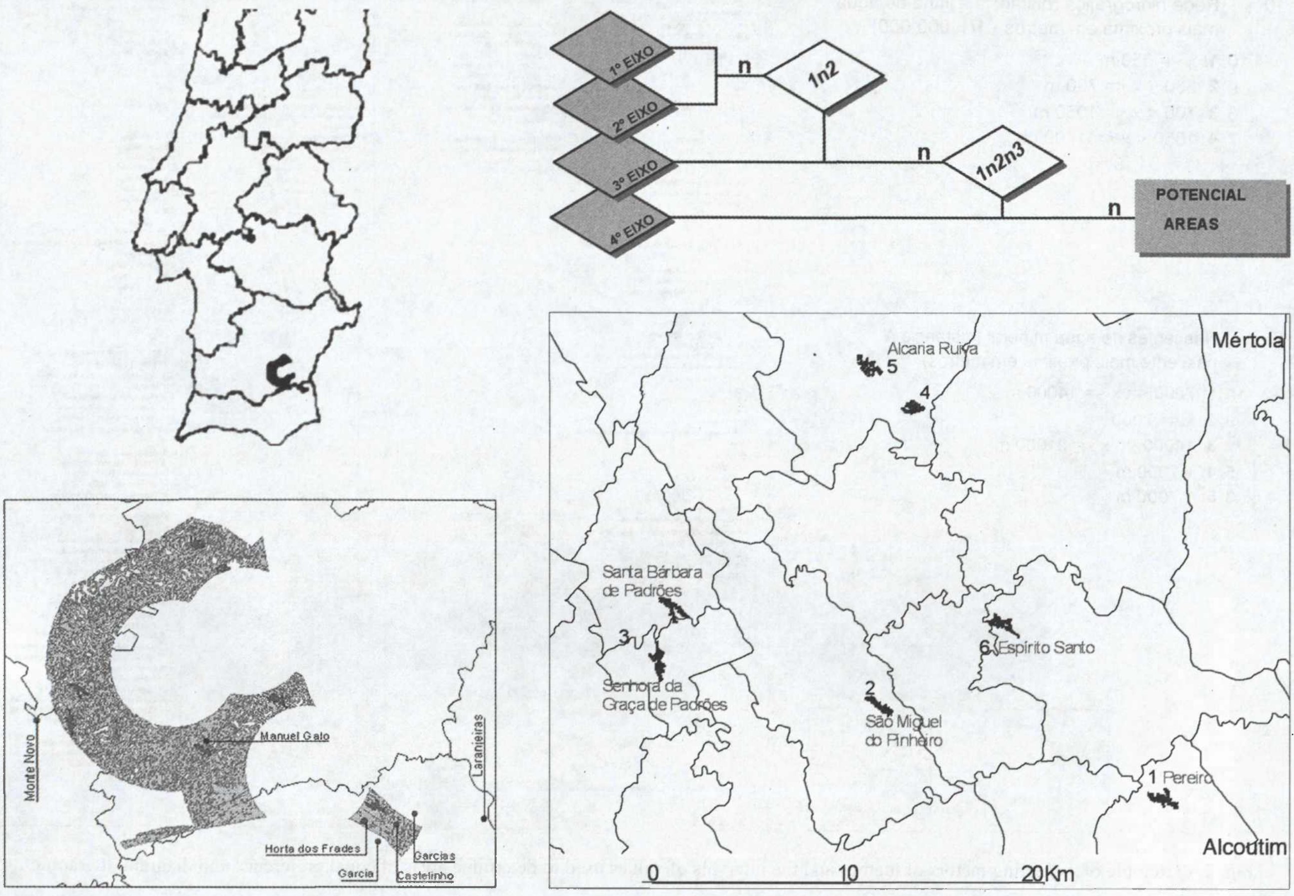


Fig. 5 – Result of the automated research: six sites to prospect.

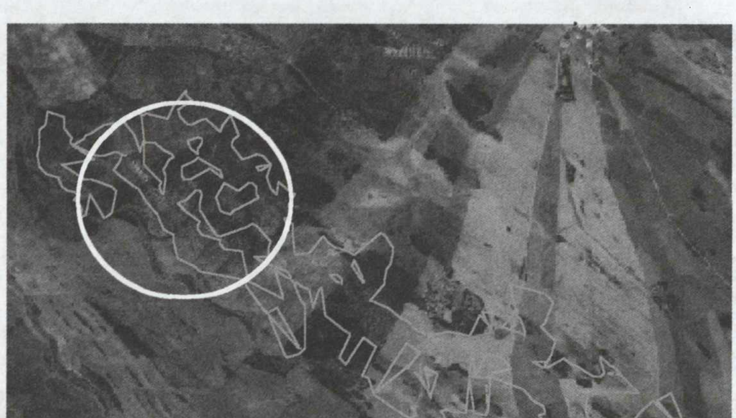


Fig. 6 – Superposition of potential areas of site location with respective orthophoto: a suggestion of areas to prospect.

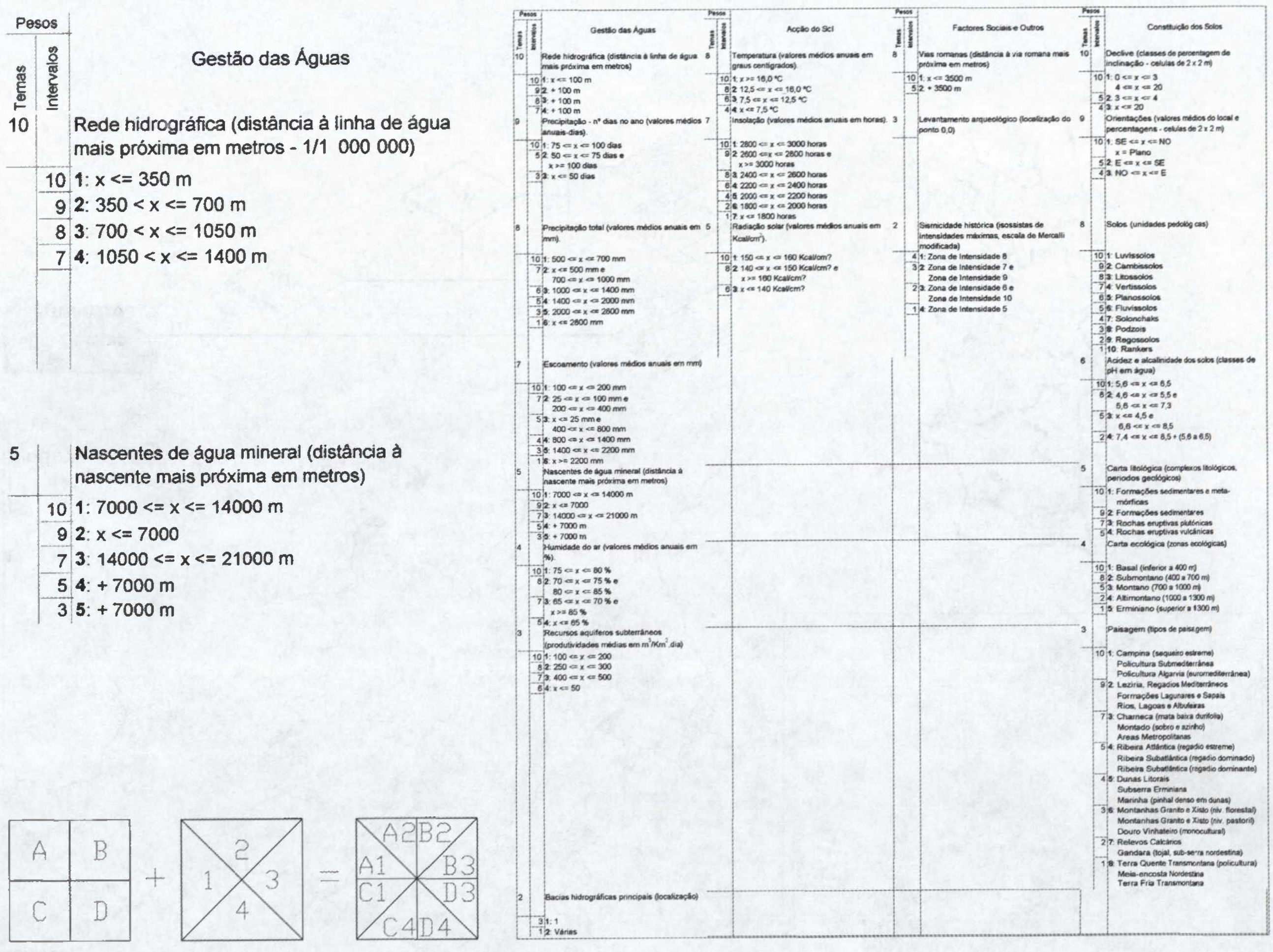


Fig. 7 – Exemple of weighting factors of themes and the intervals of values used to determine areas of equal preference and diagram of graphic equivalence of the Weighted Sums Method.

Fig. 8 – Result of the weighted values research, determination of areas of equal preference and selection of zones of greatest accumulation based on cartographic division on a scale of 1:25.000.