A GIS BASED SPATIAL DATA ANALYSIS IN KNIDIAN AMPHORA WORKSHOPS IN REŞADİYE

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ABSTRACT

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The main objective of this study is to determine main activity locations and correlation between different artifact types in an archaeological site with geographical information systems (GIS) and spatial data analyses.

Knidian amphora workshops in Datça peninsula are studied in order to apply GIS and spatial statistical techniques. GIS capabilities are coupled with some spatial statistical software and spatial data analysis steps are followed. Both point and area datasets are examined for the effective analysis of the same set of spatial phenomena.

Visualizing the artifact distribution with the help of GIS tools enables proposing hypotheses about the study area. In exploration part of the study, those assumptions are tested and developed with the help of explorative methods and GIS. The results are discussed and assessed in terms of archaeological framework. Finally the results are compared with the archeo-geophysical anomalies and excavation results.

Keyword: GIS, Spatial archaeology, Spatial Data Analysis, Knidian ceramic workshops

ÖZ

REŞADİYE KNİDOS AMPHORA İŞLİKLERİNDE BİR CBS TABANLI MEKANSAL VERİ ANALİZİ

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Bu çalışmanın temel amacı, arkeolojik bir alanda coğrafi bilgi sistemleri (CBS) ve mekansal veri analizleriyle etkinlik lokasyonlarının ve farklı buluntular arasındaki ilişkilerin belirlenmesidir.

CBS ve mekansal istatistik tekniklerini uygulamak için Datça yarımadasındaki Knidos amphora işlikleri çalışılmıştır. CBS olanakları, mekansal istatistik teknikleri ile entegre edilerek kullanılmış ve mekansal veri analizinin temel basamakları izlenmiştir. Nokta ve alan veri kümeleri aynı mekansal olguların etkin analizi için test edilmiştir.

CBS yardımıyla buluntu dağılımının görüntülenmesi, çalışma alanı hakkında varsayımlar üretilmesini sağlamaktadır. Çalışmanın keşif seviyesindeki analiz kısmında ise, varsayımlar keşifsel yöntemler ve CBS ile test edilmiş ve geliştirilmiştir. Sonuçlar arkeolojik açıdan tartışılmış ve değerlendirilmiştir. En son olarak, elde edilen sonuçlar arkeo-jeofiziksel anomaliler ve kazı sonuçları ile karşılaştırılmıştır.

Anahtar Kelimeler: CBS, Mekansal Arkeoloji, Mekansal veri analizi, Knidos seramik işlikleri

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1. Introduction

The relation between man and its environment is studied under many disciplines. Archaeologists ask similar spatial questions (Green, 1990) in order to analyse and explain socioeconomic life of human in the past, GIS (Geographical Information System) becomes an essential tool to find the answers.

GIS as a spatial analysis tool in archaeological inquiry provides more accurate and rational planning for further researches. Unfortunately, GIS and archaeology are brought together mostly for administrative purposes. Since use of GIS techniques needs strong financial resources, individual usage is limited. Therefore, most of the former studies relate to "regional" level archaeological research financed by central or local governmental agencies. Hence, GIS is rarely used as a spatial analysis tool in an intrasite archaeological study. In these schemas, GIS is not used as an analysis tool, creating GIS for data storing purposes is dominant. GIS became popular around 90's in Turkey. However, it is limited to the governmental agencies and disciplines which deal with relatively more geographical issues. Archaeological society in Turkey, except for few exceptions, is unfamiliar with GIS in their field studies. Quantitative techniques are also disregarded because of the domination of "classical" approach in Turkey. Though some projects of TAÇDAM (Center for Research and Assessment of Historic Environment), and projects like Kerkenes (an archaeological excavation study in Central Anatolia) within the Middle East

Technical University, are good examples of utilization level of GIS in archaeological researches. So, both in global and local scale, the implementation of GIS as a spatial analysis is limited.

The main objective of this study is to determine the main activity locations and correlation between different artifact types in an archaeological site based on GIS coupled with spatial data analyses. Interrelation between the artifacts and meaningful clusterings are investigated with the help of integration of GIS and spatial statistical techniques. These analyses provide a tool to guide archaeological excavation since they help to identify the locations of activities. Moreover, different kinds of datasets are tested to reach useful results for archaeological analysis such as point area.

A Knidian pottery production center in Datça which is located in south-western Turkey is selected as a study area. The study area is surveyed and excavated by Turkish-French archaeologists during 80's under the supervision of Prof. Dr. Tuna. The source data comprise the results of the ground surveys. These ground surveys are led to a systematic collection of artifacts by 5x5 m grids and to their taxonomic classification.

We assume that the artifacts distribution of surface reflects activity locations underneath. Hence, studies pertaining to surface artifact distribution would enable archaeologists to identify the location of facilities and the correlation between artifacts. This would eventually lead to the discovery of production sites in the study area. The results of spatial analysis undertaken go hand in hand and support excavation results and also are consistent with detected archeo-geophysical signal anomalies. The discussion on the results of different spatial data analyses are carried out as well.

This study comprises three components: the GIS, archaeology and spatial analysis.

1.2. Overview of the Chapters

In Chapter II, a brief history of GIS and archaeology is explained including some milestones. In the following parts of the chapter, the conceptual structure of the literature is investigated and an alternative classification is proposed. In the light of these classifications some examples of earlier studies are presented.

In chapter III, the theoretical structure of the GIS based spatial data analyses for point and area data are given. Moreover, detailed descriptions of the techniques used in this methodology are introduced.

In chapter IV, first, the site and its characteristics are presented. Then the structure of the former studies documented

In chapter V, the theoretical structure presented in chapter III, is implemented to case study data. Processes of transformations of source data for further analyses and the results of spatial analyses are given. Finally, results of the methods are compared and assessed.

The last chapter produces a summary of the survey results and a general assessment of spatial analysis carried out, as well as recommendations and proposals for further studies.

CHAPTER II

GIS & ARCHAEOLOGY

2.1. Brief History

Implementation of GIS in Archaeology is approximately two decades old (Kvamme, 1995). However, analyzing the archaeological data quantitatively starts with "New Archaeology" approach in 60's which includes an analytical perspective (Aldenderfer, 1996). It can be defined as diffusion of "spatial analysis" techniques - borrowed from other disciplines such as geography, geology etc. (Hodder and Orton, 1976) - into archaeology. Demands on prediction models for undiscovered sites and needs for the analysis of archaeological sites, where complexity of artifact distribution doesn't provide clear results force professionals use to statistical techniques. Any kind of distribution maps in archaeological context has an important role for understanding of the main issues of socio-economic structure of the past (Hodder and Orton, 1976). "Environmental determinism" and "deductive reasoning" approaches in the archaeological societies supported the effective usage of quantitative techniques with "landscape" layers like topography, slope, geology etc. Those techniques to be carried out were going to be needed for the utilization of computer technology. Therefore, GIS started play some role in Archaeology in the late 70's (Kvamme, 1995). Predictive archaeological site location modeling analyses are taking the central place of GIS studies from the beginning (Kvamme, 1989).

In the second half of the 80's computers and softwares were still hard to buy or use for most of the individual archaeologists, but national or regional level governmental agencies (especially agencies in North America) started to use GIS as a management tool (Kvamme, 1995). Since personal computers and GIS softwares have become affordable, from 90's to the recent day many studies have being done.

Subtitles of studies related to GIS and Archaeology has been classified by many researchers. These subtitles are important for understanding where this thesis stands in the literature. A classification proposal of the literature on this subject will be tried to be created in the following part of the chapter as well.

2.2. Classification Models

Classification of the studies on this subject became important as scientific researches and publications increased. Many books and proceedings are bringing studies of different branches of the subject together and a classification was essential. Some scientists studying this field have tried to organize those works in a systematic way.

Savage (1990), one of the most known names in this field, identified three headlines for GIS studies in archaeology. These headlines are:

1) Location modeling
2) "GIS procedure related studies"
3) GIS in "Landscape archaeology"

Location Modeling studies can be called as "Predictive Archaeological Site Modeling". Many of the governmental agencies in North America have been using these studies as a decision supporting system from the late 70's (Kvamme, 1995). The main objective of this approach has been started in order to locate archaeologically sensitive areas at planning stages of some development projects (Savage, 1990). Therefore, in fact this headline involves the management characteristics of GIS tool too.

The accuracy or precision of the GIS analyses and data are the basic concern of GIS procedure related studies. Data obtained from various resources could have missing or erroneous detailed information (Kvamme, 1995). This information can be crucial for results of many analyses. The extent of the accuracy or precision in the data must be studied and set for the results of analyses. Studying the accuracy of the data in statistical terms is a contemporary field in all of the GIS community too. Savage pays attention to the results of these analyses which mustn't be taken as "facts" before they are archaeologically tested and proved.

Landscape Archaeology is defined as "...study of spatial relationships among humans and their physical, social and cognitive environments" (Savage, 1990). As the definition reflects, this approach and GIS together can be used as a "spatial analysis" or "theory building" tool in archaeological researches and create a combination of theory and methodology (Savage, 1990).

"Landscape archaeology" heading was emphasized by Savage (1990) as the real potential of GIS in archaeological studies. The classification however has overlapping parts and doesn't clear the image of the literature structure enough. It has fuzzy points which don't involve in the classification. The modeling part is a level at spatial statistics analyses. So, it cannot be sharply separated from "spatial analysis" characteristics of GIS. Some missing functions of GIS that has being used in the literature are missed too like the visualization and mapping capabilities of GIS.

Harris and Lock (1995) classified GIS and Archaeology studies under 3 themes which are affected by 3 existing archaeological traditions. They are cultural resource management, spatial statistics, landscape archaeology (Harris and Lock, 1995).

The function of the cultural resource management (CRM) is developed in national or regional governmental agencies as databases and digital mapping (Harris and Lock, 1995). So, they are mainly recording systems, but later used for prediction models too. Harris and Lock (1995) draw attention to differentiation of North America and European CRM traditions in which they are associated with spatial statistics and landscape archaeology, respectively.

The usage of spatial statistics with GIS in archaeology started in the USA for predictive models of site locations which are given highest priority (Harris and Lock, 1995). However, a small amount of instances of integration of spatial statistical techniques into GIS are carried out (Harris and Lock, 1995). In future, exploratory data analysis in GIS will provide wide horizons (Harris and Lock, 1995).

Landscape Archaeology tradition differs from spatial statistics tradition in its concentration on extracting a cultural meaning of different landscape elements and their spatial relations (Harris and Lock, 1995). In other words this tradition not only produces a spatial structure of archaeological features also relates it with a social, economic or political model in order to build a theory.

Harris and Lock (1995) accepted the overlaps of contents of these 3 themes. They emphasized the database part of CRM. Landscape Archaeology trends in GIS has a semantic level separation from spatial statistics. In fact, in terms of use of GIS, there are not much differences between each other.

Classification of applications of GIS in archaeological studies according to Kvamme (1989) has 5 main themes:

1) Regional data management
2) Management of remotely sensed data
3) Regional environmental analysis
4) Simulation
5) Locational modeling

Aldenderfer (1996) formed this classification in 'Anthropology, Space and Geographic Systems', but he also accepted that there are overlapping parts between them.

Creating regional databases by governmental agencies are highly related to the efforts of historic preservation (Aldenderfer, 1996). Management is the key word for explanation of these GIS usage. However, there is a trend of specific GIS applications for this purpose too (Kvamme, 1989).

The environmental structure could be best visualized by integration of RS within GIS (Loker, 1996). Management of remotely sensed data has been seen only for monitoring tool. This theme of study has not been taken into consideration as a parameter for predictive modeling applications.

Regional environmental analyses coincide to landscape archaeology approaches of former classification examples.

Simulation studies seek the answer of the "what if" questions (Aldenderfer, 1996). Studies on this subject are not as much as others. Creating models of historic socio-economic life is the duty of these studies. GIS is crucial for that kind of analyses in order to be in a systematic way (Aldenderfer, 1996).

Locational modeling is explained above in other classifications too. The most emphasizing point is almost in every classification is that the issue is taken into considerations for regional analyses. Micro level (intra-site) locational predictive modeling is not mentioned.

2.3. Proposed classification of literature in this study

Above mentioned classifications include a theory component. In other words they are classified according to some approaches in archaeology not functional methods of GIS. Because of that approach many of the techniques used in different headlines are overlapping and diffusing to each other. In the thesis, a classification is proposed according to the implementation types of GIS into the studies. That kind of classification enables to set the methods in the case study.

Another missing point is the scale of the studies which differentiate from regional or national scale to the intrasite or excavation scale. GIS's role or position changes in those scales. Using GIS as a decision making tool in an excavation requires different techniques and also has different problems from using GIS as a data management tool at regional level. So, the classification must have another dimension which defines the content and nature of the data too. Hence, the following classification schema is proposed for the investigation of studies in the literature in the following subsections. The diagrammatic illustration of this classification may help to see the classification more clearly (Figure 2.1). The classification path where this thesis is located is highlighted in order to help to make clear the relevance of the following studies to this study.

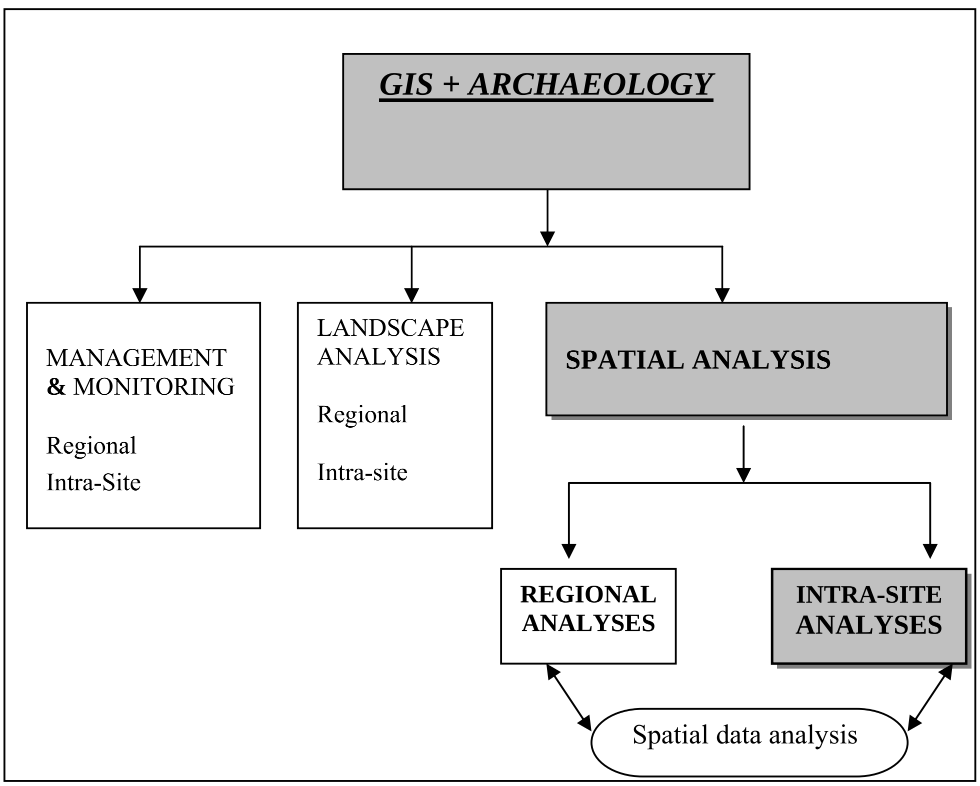


Figure 2.1. Diagram of the classification proposal

Management & monitoring studies are based on only creating a recording system and visualization tool of the data. As like other headlines it has 2 different levels of content which is regional and intrasite levels. Using GIS as further analyses are not the main goal in these applications. Many of the governmental agencies are involved in this group. They have an importance of being "base maps" for further studies that's why their database structure and mapping standards take the central place of attention.

On the other hand these studies in the literature have the minimum relevance to the thesis. Database designs for archeological features, visualizing techniques of them are another study field. So, the instances of that kind of applications don't take much part in the case studies. Especially, regional level studies are related to the state agencies such as "Maryland Historical Trust".

The Maryland Historical Trust is the state agency responsible for the identification, preservation and interpretation of historical and cultural resources for the state of Maryland. Located within the Maryland Department of Housing and Community Development, the Trust is the federally designated State Historic Preservation Office.

The Trust includes a library which includes information on 30,000 standing structures, 9,000 archeological sites, and 400 historic maps.

A GIS project is developed for both management and research needs. There are 3 basic requirements of the project:

1) Create a computerized database of information on state-inventoried archeological sites;
2) Complete the digital mapping of archeological site and survey locations;
3) Create an index of keywords and terms in the database for flexible search and query.

Project includes those steps to be carried out.

- Base maps
- Historic Sites layer
- Database design
- Other Digital layers
- Interface Design

Five data sets were identified for digitizing as part of the data conversion:

1) The Maryland Inventory of Historic Properties (Buildings, historic districts, and structures, with approximately 36,000 individual resources).
2) Archeological sites, with approximately 9,500 resources;
3) Areas surveyed for archeological sites, approximately 1,500;
4) Historic properties listed on the National Register of Historic Places, approximately 1,100 resources;
5) Historic properties with a Maryland Historical Trust Historic Preservation Easement, approximately 350 resources.

Data sets were digitized as polygons defining the boundaries of the sites.

Databases in the GIS serve two functions: tracking and managing the digitized data, and describing the properties themselves. The database is designed according to a basic data table and other tables related to it. These tables are prehistoric table, historic data table, management table which have the attribute data of the features.

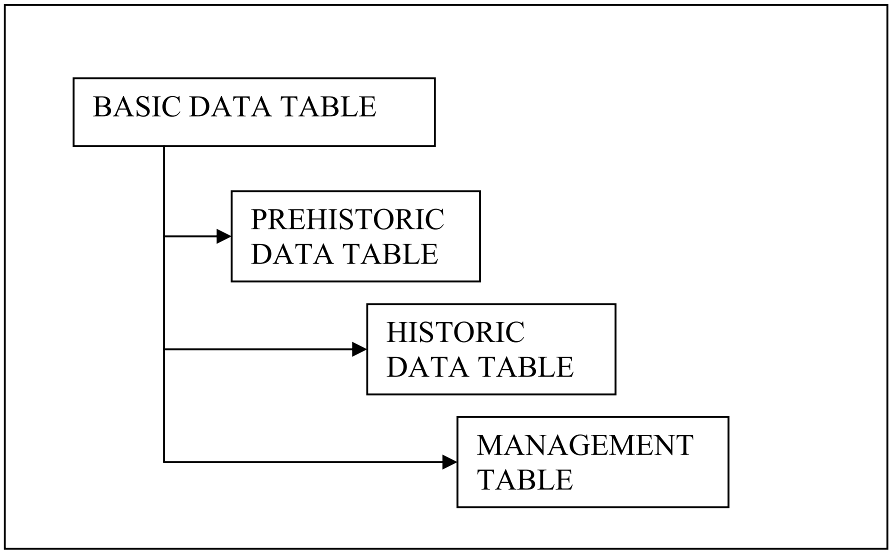


Figure 2.2. Database structure of the project

Other kind of digital data is used to complete the GIS. These data sets are:

SPOT Satellite Imagery

Infrared Digital Orthophoto Quarter Quads

Property Parcel Database, Parcel Maps, and Parcel Centroids

Black and White Orthophoto Quadrangles developed from NAPP Photography

Digitized Historic Shorelines

Wetlands Areas

Flood plain

The archeological sites database was designed to contain information for both site management and site research. A relational table structure incorporates data relating to both of these goals.

Digital mapping of archeological sites was completed, and the archeological survey locations were also digitized as part of this grant. A survey database was also developed and linked to the survey layer. These layers have been integrated into the GIS along with the National Register layer, easement layer, and state inventory of standing structures. An index was created of all terms in the database, which allows the user great flexibility in the format of searches.

These materials have been integrated into a geographic information system at the Maryland Historical Trust. The GIS information is currently accessible at a user's workstation, and the index, now operational on a development computer, will be loaded onto a library computer within the next few months to be accessible to library researchers. The conversion of these records has resulted in a data set that is flexible and comprehensive, and staff and outside researchers are already using the benefits of improved searching capabilities.

Intrasite level studies, on the contrary, are carried out usually by academic professionals. Archaeology departments of universities that are organizing excavations or survey studies on field are the main user group at this level. Next instance study for intrasite level management and monitoring class is an excavation level recording and visualizing GIS project in Jordan in an Iron Age Settlement called Jabal Hamrat Fidan by UCSD Anthropology department (http://weber.ucsd.edu/Depts/Anthro/classes/tlevy/Fidan/JHF).

This program integrates many of the latest digital technologies to facilitate archaeological research and publication. It starts with the excavation, stores and manipulates digital survey and photography information in a GIS program and is accessible to the global community in a relational database on the WWW.

The following figure (Figure 2.3) can be considered as diagrammatic structure of the recording system.

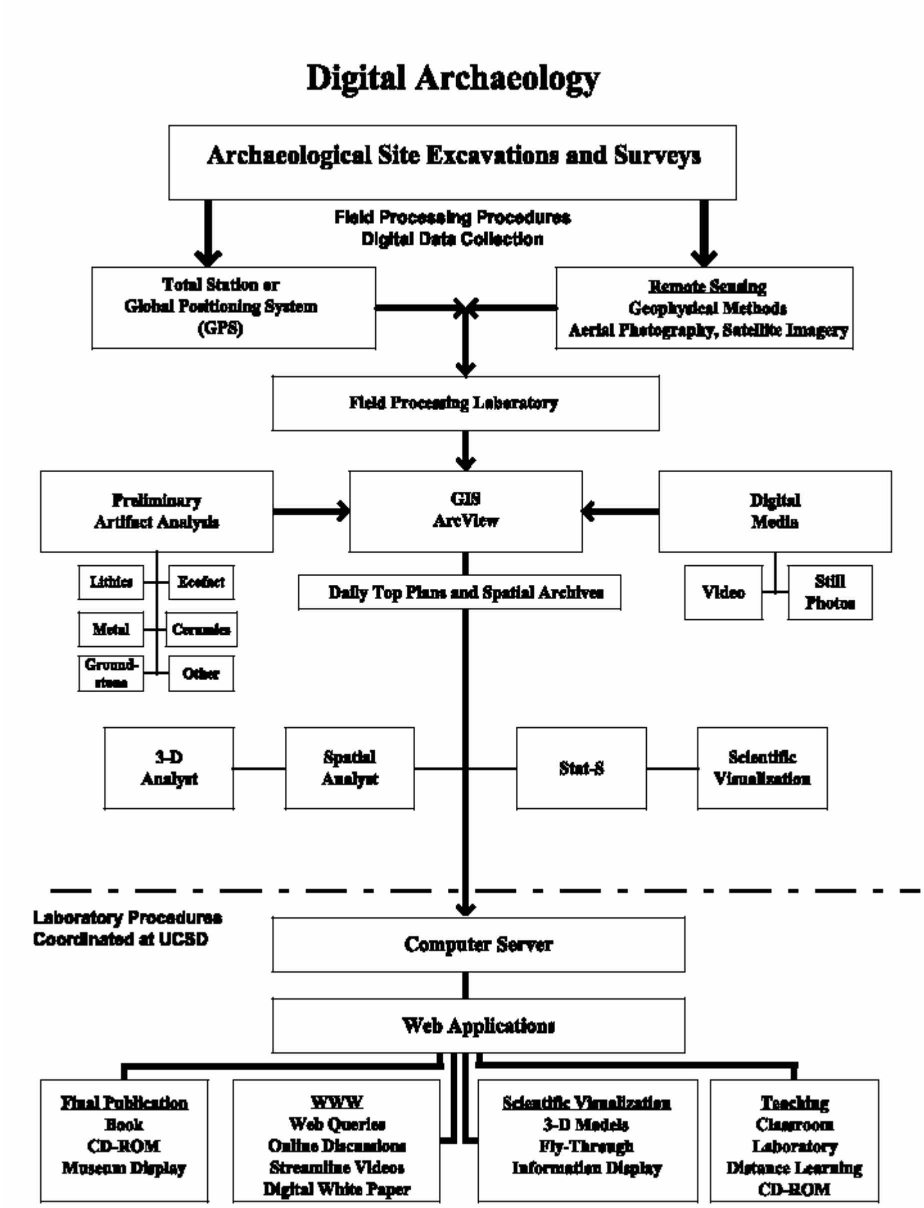


Figure 2.3. Flowchart of the processes of GIS database

Source: http://weber.ucsd.edu/Depts/Anthro/classes/tlevy/Fidan/JHF, 2003

In the field processing procedures,the base maps obtained through using GPS and RS are used. Moreover, the data about the artifacts, sediment layers, physical structures are converted into X, Y and Z coordinates in order to create a 3D GIS database. Videos and digital photography are also used –integrated to

GIS- for documentation. The coordinates are collected daily by “Total Station”. Each artifacts coordinates, digital photo and attribute data is combined to the GIS for further studies (Figure 2.4).

This information is evaluated with some analysis modules of the software (spatial analyst, 3D analyst etc.).

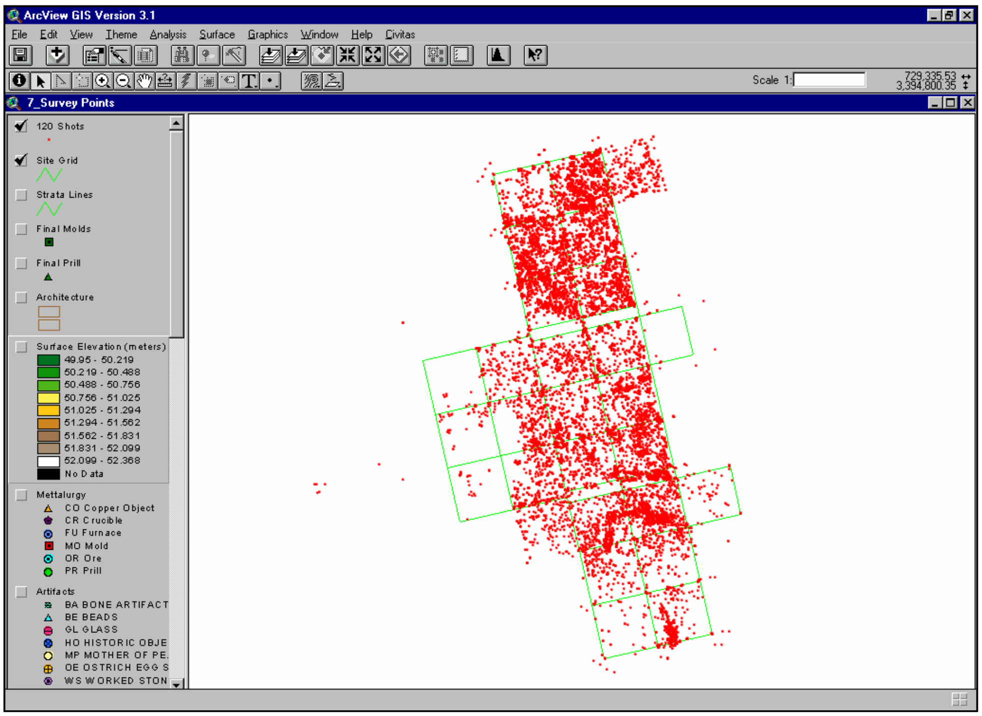


Figure 2.4. Distribution of artifacts within the excavation grids

Source: http://weber.ucsd.edu/Depts/Anthro/classes/tlevy/Fidan/JHF, 2003

A database is built on the basis of the geographic distribution of artifacts and structures for the purpose of publications, web queries, scientific visualisation, teaching in laboratuary processes. Collected data are converted into a GIS based database. 3D Views are created and collested artifacts are visualized in their 3D position (Figure 2.5).

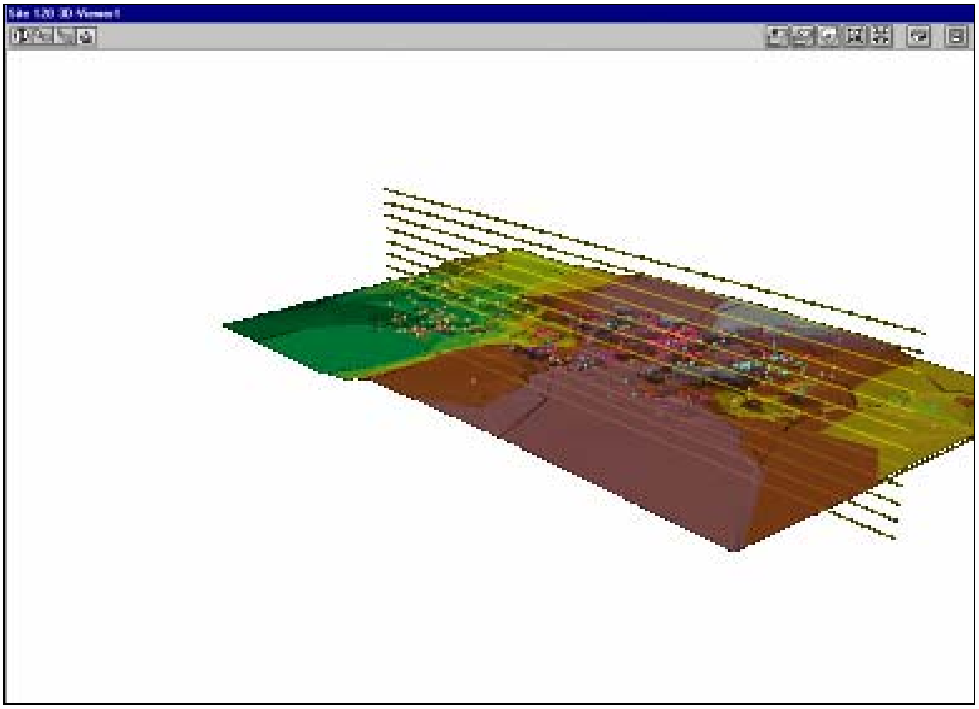


Figure 2.5. 3D positions of artifacts over 3D landscape view
Source: http://weber.ucsd.edu/Depts/Anthro/classes/tlevy/Fidan/JHF, 2003

Landscape Analyses are not much different from spatial statistics. In fact, they use the techniques of that part too. But they have a different motivation which includes mainly correlating the environmental effects and human geography. It also investigates the relation between geological, geomorphological environment and ancient settlement pattern. In the literature, the studies intensify mainly on the regional level. Intrasite level studies-investigating the relation of an individual settlement and its environmental parameters- are still rare.

Store Valley Project in Britain is a good example for the investigation of the landscape of the settlements at regional level [1]. Using the landscape they also performed some Viewshed analyses in order to see the correlation of ancient settlements and ancient inter-visibility between them (Figure 2.7). Air

[1] (http://aarg.univie.ac.at/aerarch/ stour_valley /stour_valley.html)

photographs, DTMs (Digital Terrain Model), locations of sites and some geology maps are used as basemaps of the study (Figure 2.6).

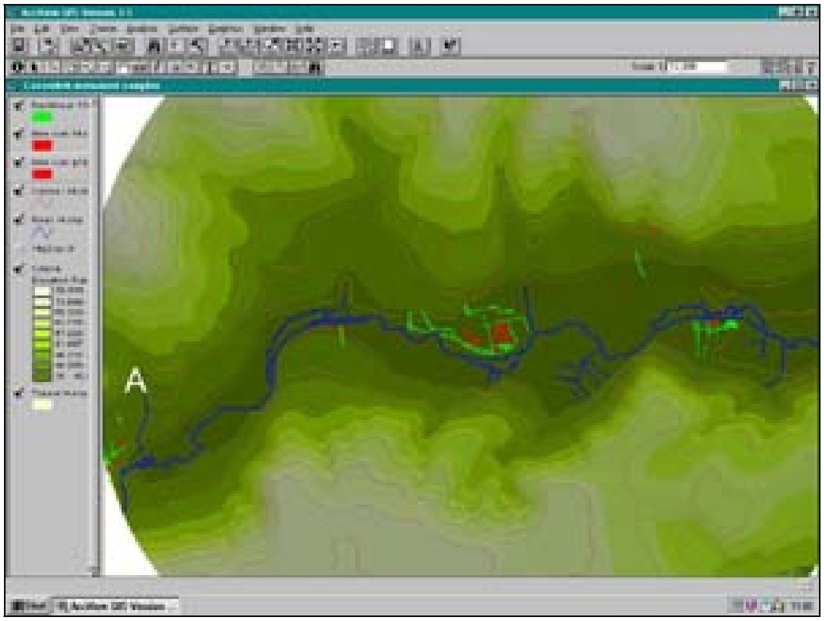


Figure 2.6. Environmental setting and sites

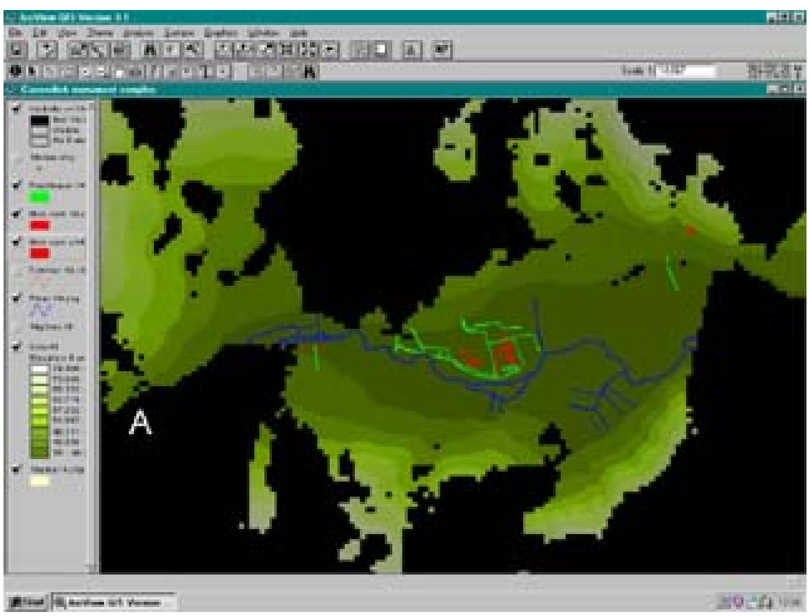


Figure 2.7. Viewshed Analysis of an archaeological site

Source: (http://aarg.univie.ac.at/aerarch/stour_valley/stour_valley.html

Like landscape analyses, much of the spatial analyses are based on regional level. Moreover they are "modeling" level studies which are classified as "locational modeling" in Kvamme's classification. Exploratory analyses are not emphasized enough in the literature. "Predictive locational site modeling" or "site catchment analyses" –sometimes supported by settlement location theories- are very popular from the beginning of utilization of GIS in archaeological researches.

In the earlier part of the chapter, the main usage of spatial statistics in regional level studies was emphasized as predictive modeling. A predictive model for Minnesota is developed as Mn Model in USA. The project is documented in its website in a very detailed manner (http://www.mnmodel.dot.state.mn.us). The main headlines of the project can be summed as follows:

Minnesota Department of Transportation financed a prediction model which is a statewide GIS-based model for pre-1837 archaeological site locations for archaeological sites for further avoidance in construction facilities. The project is called as Mn/Model. Logistic regression is selected as statistical technique for modeling.

UNIX, NT platform, ARC/INFO, ArcView are used on personal computer, moreover, Spatial Analyst, Grid Modules for analyses, S-Plus, SPSS for statistical analyses, AutoCad for digitization procedures are utilized.

Especially environmental data are collected by variety of governmental agencies (1/24.000.000 DEM's (USGS)). Essential geographical data for archaeological sites are obtained by other governmental agencies mostly by State Historic Preservation Office. On the other hand, some of the data were digitized as well. Detailed methodology and standard definitions were determined during the project and they are documented too. Those layers are used in order to constitute independent and dependent layers of the model. All of these layers, their attribute data and other non-graphic data are organized in a relational database.

In this project both GRID Module and S-Plus is used for statistical analysis. However it is emphasized that GRID Module is very limited in respect to the utilities of S-Plus. So S-Plus is used in the crucial parts of the study including final results. Especially defining the best variables (stepwise regression) and their weights in the third line are the most important usage area of the software.

The technique for modeling is selected as logistic regression. In this technique they used environmental layers as independent variables of regression and prior results of archaeological studies as dependent variables (presence of sites, exclusion of single artifacts, lithic scatters, site absence). Known sites and known non-sites (negative survey points) are used for formulating and testing the model as well.

The logistic regression analysis's ability of processing a very large number of independent variables is used as 40 variables in Phase 1, up to 85 in Phase 2, and 43 in Phase 3 (Table 2.3.).

Table 2.1. Phases of Project

Models were built in three phases:
Phase 1 models (1996) were run for only 27 counties. They predict sites 22%-54% better than by random chance alone.
Phase 2 models (1997) were run for the entire state. They predict sites 28%-89% better than by random chance alone.
The Phase 3 Survey Implementation Model (1998) predicts sites 44%-90% better than by random chance alone. It also indicates areas where the potential for sites is unknown because of inadequate survey information.

Source: http://www.mnmodel.dot.state.mn.us, 2003

At the end of the each phase probability values for existence of archaeological sites are obtained differently (Table2.2)

Table 2.2. Assessment of Phases

Model statistic	Phase 1	Phase 2	Phase 3
Percent area in high/medium probability class	55.5	24	23
Percent sites predicted	84	77	85
Gain	0.37	0.68	0.71

Source: http://www.mnmodel.dot.state.mn.us,2003

Final product of this study becomes a probability map as seen in Figure 2.8.

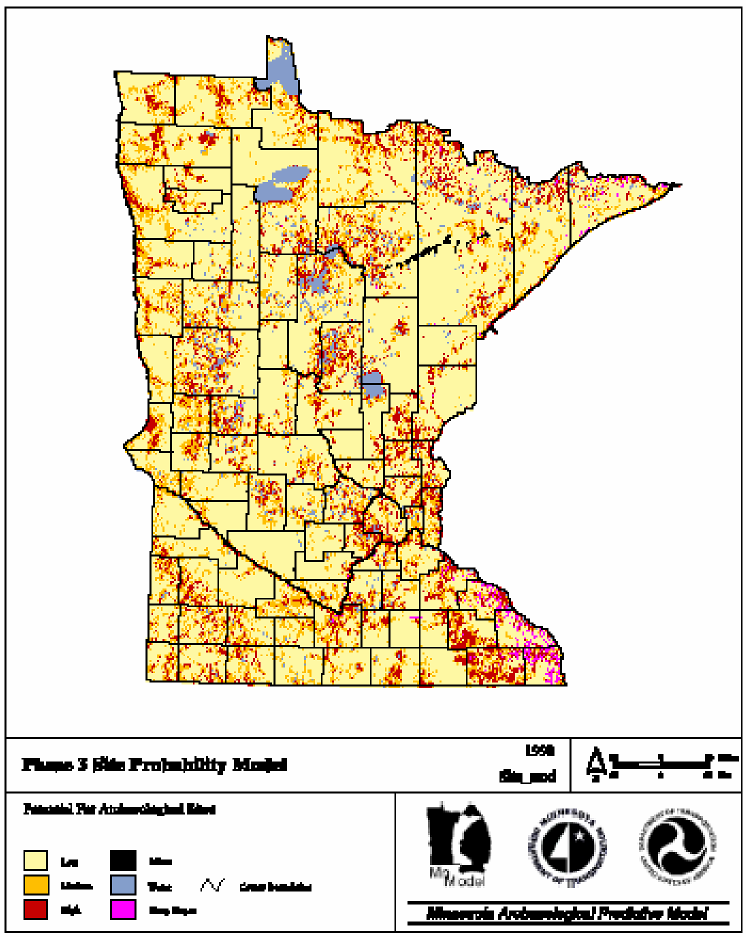


Figure 2.8. Phase 3 Probability Map

Source: http://www.mnmodel.dot.state.mn.us, 2003

Intrasite level study for spatial analysis heading of the classification includes mainly again archaeologists performing analyses about their field studies. This level of implementation of GIS as a spatial analysis tool is not as frequent as regional level studies. The instances of studies are not as complicated as regional level studies either. Following studies are most relevant of them.

In the project of Penaflor (http://www.arch.soton.ac.uk/Research/Penaflor/ch3), the potential usage of GIS in intrasite analyses in archaeology is emphasized. It can be more than a tool for thematic maps, an analysis tool for combined datasets like environmental data, architecture and artifact distribution.

The areal data is converted into point dataset by taking their center points. A table is created including site coordinates, period information, weight and count of the artifacts.

There is an unavoidable loss of data because of the method of taking the centroid of the squares for the locations of finds. There can be misleading information like “pseudoclustering”. Although artifacts are scattered to the corners of the square they are represented located on the centroid.

A trend surface is created for the site and correlated with the geophysics results by overlaying them. 3D models are generated for some kind of artifacts throughout the site by interpolation. But it is expressed that these results should not be taken as predictive model for future occurrences only as a summary model of the existing study (Figures 2.9.-2.11.).

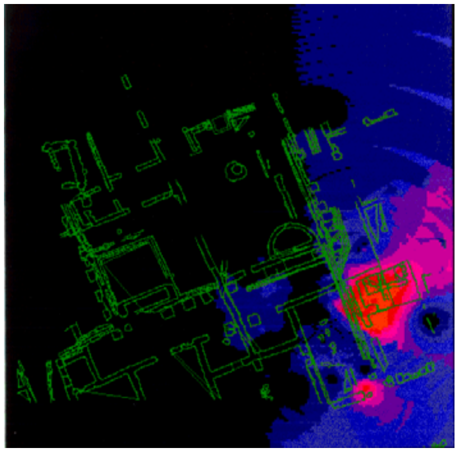


Figure 2.9. Amphora distribution surfaces in different time Periods

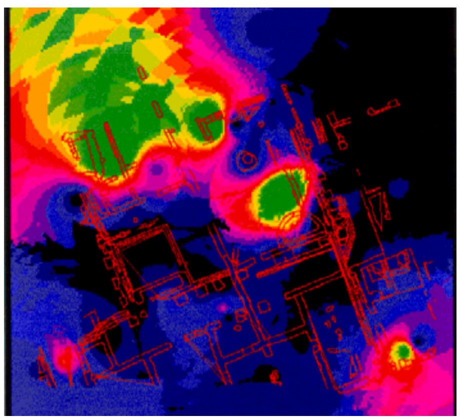


Figure 2.10. Amphora distribution surfaces in different time Periods

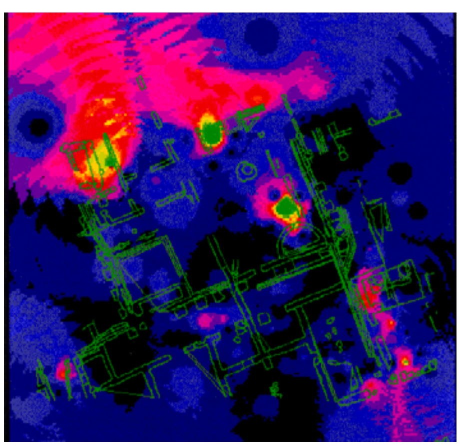


Figure 2.11. Amphora distribution surfaces in different time Periods

Source: (http://www.arch.soton.ac.uk/Research/Penaflor/ch3, 2003)

Another example for this is the survey and excavation project in Tell-Jalul (http://gis.esri.com/library/userconf/proc96). This study based on analyses in Jordan in an Iron Age settlement. It includes site probability model, erosion model (in order to understand terrace agriculture) at regional level, and analysis of surface pottery sherds for further archaeological research at intrasite level which is the main focus point for this thesis. There are 3 steps in this study.

In the first step the relations between environmental effects and archaeological sites. Soil types, elevation, slope, aspect etc. are analysed in GRID Module of ArcInfo. The environmental data is related with the methodology of Kvamme (1989) and finally set up a probability model for site.

In the second step, erosion models are used. Theoretically, lands with higher rates of erosion are accepted as more difficult to be cultivated. Differences of preferences to settlement, differences of soil types and differences of erosions are observed in different 2 periods.

In the third step, ceramic distribution is considered. This step is the last before the excavation. So the results will orient the excavation strategies. The changing population levels, residence patterns and social differentiation are supposed to be decided through following methods.

All of the area is divided into 6x6m squares (45 rows, 55 columns), elevation readings from center of each cell, sherds are classified according to their types, time-periods (43199 totals, 2791 diagnostic), numbers and weights are put in a table. In order to create a topographic layer the center point readings are used for point coverage.

In programming process, they created a menu to select type or period of the sherds. So a new table is created where total number of sherds in each cell and weights are included.

The sherds from each grid cell are assigned to their center point. Through those center points point coverage is created in order to have the distribution surfaces for pottery distribution (Figure 2.12).

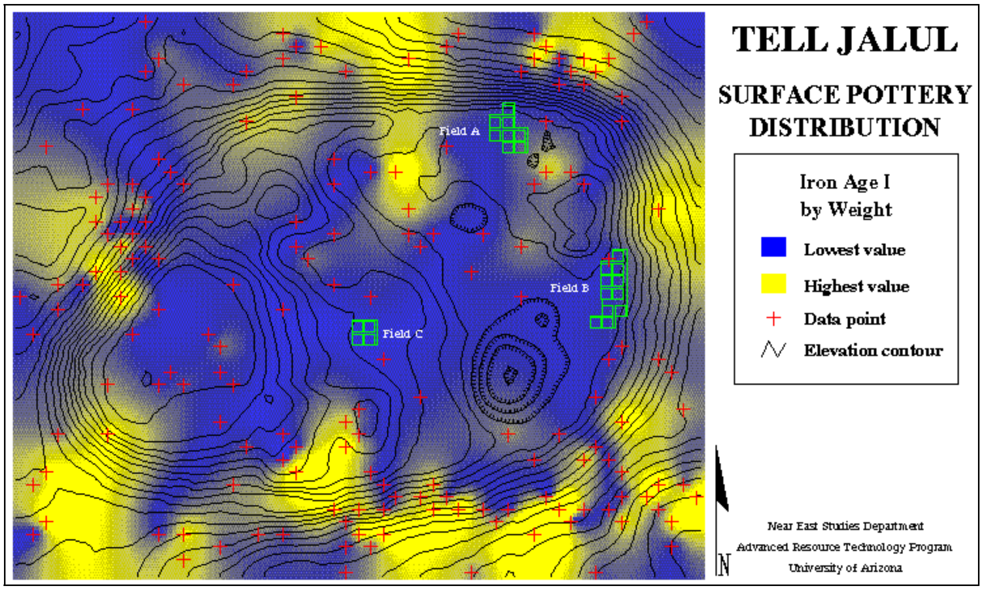


Figure 2.12. Pottery Surface
Source: http://gis.esri.com/library/userconf/proc96, 2003

GIS also allows a researcher to see and examine intra-site patterns and make inquiries into how people lived. Although the strengths of GIS lie more naturally with regional studies, the final example shows that it is robust enough to answer site-based questions as well. So, as they are locating in the "highlighted" area of classification too, they can be defined as "equivalent" to this thesis. The location of this thesis is explained both theoretically and on the basis of similar studies. It is supposed that these explanations may help to asses the conceptual framework of the following chapters.

CHAPTER III

THEORETICAL BACKGROUND OF THE STUDY

3.1. Introduction

Capabilities of GIS are not sufficient for all types of spatial analysis techniques. In order to overcome this deficiency some application solutions are developed to integrate them. There are 3 main headlines of integration models (Bailey and Gatrell, 1995). They are loose coupling, close coupling and full integration. In loose coupling method data is handled in some spatial statistical software and then transferred into a GIS package to display results. Close coupling method on the contrary requires some programming in a macro language of GIS software and creating some routines for specific spatial analysis purposes. Full Integration method -as the name implies- includes spatial analysis capabilities of GIS software alone which is not very common.

Each method has its own advantages and disadvantages. In close coupling method there are many transfer processes between the GIS and spatial statistics softwares, and there is a limitation of the capabilities of the used statistics software. On the other hand close coupling method has and advantage of time in other words when required softwares are achieved the analysis part become faster. Close coupling method is most functional method because suitable technique and proper platform is used for integration. However, it needs a good knowledge of a macro language of GIS software like VBA, MapBasic, Avenue etc. Full integration method is the most limited one into narrow space of commercial softwares of GIS packages which are mostly do not include detailed spatial analysis techniques for specific problems or datasets like archaeology.

But it provides high-speed solutions for practical problems. Although all of the methods are used in this study, close coupling method becomes dominant. Some free spatial statistical packages are used for the analyses and the results are imported into GIS software. However, some routines and some "internal" methods within GIS are also used.

Integration of GIS and spatial analysis techniques are used in a systematic structure. This structure of the study borrows its backbone from spatial statistical techniques. Analysing spatial data through a hierarchical order from "blurred" to "clear" steps is provided by visualisation, exploration and modeling stages (Bailey and Gatrell, 1995). Visualisation of spatial data is the first step to have a visual impression of the data and generating hypotheses from it. Exploration part which is the main focus point of this study is an attempt to see the data without the affects of the "outliers" to help the analysts in improving hypotheses and proper models (Bailey and Gatrell, 1995). It eases to catch trends, patterns or peak values in the data (Bailey and Gatrell, 1995). In modeling stage -partly in this study- some estimations can be inferred (Figure 3.1).

Besides, the techniques of spatial analysis are varying according to the characteristics of the spatial phenomena which they are adapted to. Those spatial phenomena can be point, line or area. In the case study area dataset is treated as both point and area and their results are compared. In other words visualization and exploration stages are performed for point and area dataset separately. This comparison will help us to obtain proper results for archaeological framework (Figure 3.1).

The concept of first order and second order effects of a spatial distribution is another important issue. In most of the spatial analyses the result is affected by either former or the latter one. First order effects reflect the global trend, second order effects, however, are intra-event or local trends in the dataset. These effects can be illustrated as iron filing in order to help understand the phenomena (Bailey and Gatrell, 1995). If iron filings are scattered over a surface they are distributed purely random. But if some magnets are put under the surface, iron fillings gather around the magnets that can be described as first order effect. Then if the iron fillings are collected and scattered again, there will be local small groupings around some filings which are magnetized from the former process. This is the second order effect. If the magnets are put again under the sheet first and second order effects are illustrated together (Bailey and Gatrell, 1995).

Another kind of analysis is the "conventional" data analysis which is performed in order to support the methodology in terms of seeing the correlation between the types of artifacts.

3.2. Systematic structure of the study

The proposed structure consists of 3 main parts such as; Integrated GIS and spatial statistical techniques, conventional data analysis techniques and inference.

The integrated GIS and spatial statistical techniques involve two stages such as visualization an exploration for the first order and second order effects. This part mainly focuses on detecting the spatial distribution of artifacts as well as spatial autocorrelation among them in the study region. The conventional data analysis part is for assessing the correlation between the types of several artifacts. In the last step, results from the previously mentioned stages are combined in order to make inferences for archaeology (Figure 3.1).

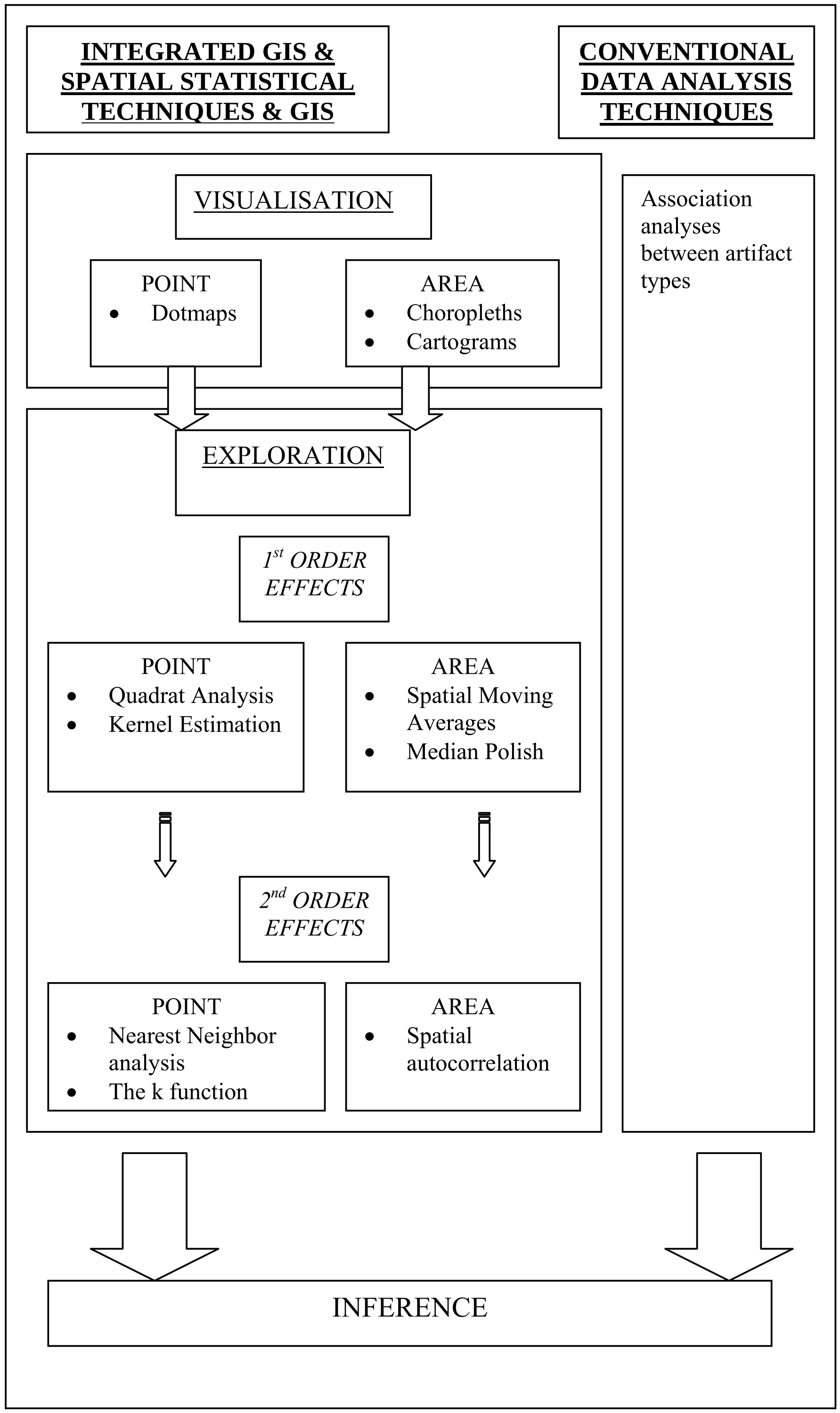


Figure 3.1. The diagrammatic structure of the study

3.2.1. Visualisation in integrated GIS & spatial statistical techniques

The techniques for visualising areal and point data are different. For point pattern dot maps are created. Areal data on the other hand is visualized by either choropleth maps, graduated symbol maps or cartograms.

In most areal data analyses visualization is performed through choropleth mapping (Bailey and Gatrell, 1995). The choropleth mapping is based on classifying the attribute values of the geographic features and then rendering them according to these classes. As Bailey and Gatrell (1995) emphasized the selection of the class size and number is important which can lead into wrong indication of results.

Another important issue about choropleth mapping is the effect of sizes of polygons over the attribute values. The values are expected to be higher in the larger areas and it will show wrong results in the maps (Bailey and Gatrell, 1995). The simple way of recovering that effect is normalization of attributes by the area in other words taking the densities into consideration instead of occurrences. This can be carried out in many types of software (ESRI ArcMap). 3D views can be used for increasing the dramatic effect of choropleth maps as well (Figure 3.2).

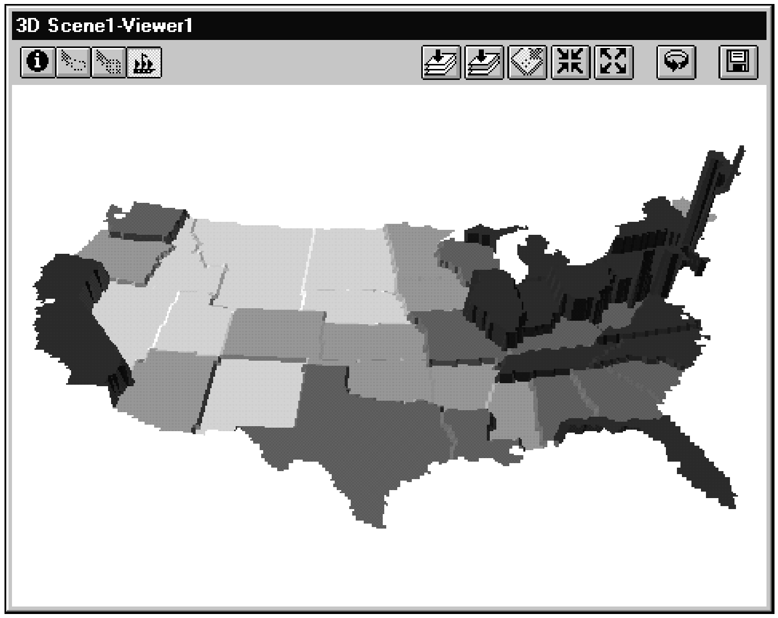


Figure 3.2. 3D View Choropleth Map
Source: http://gis.washington.edu/cfr250/lessons/3d, 2003

Cartograms can be defined as diagrammatic maps. Another naming convention for them is value-by-area mapping as they depict attributes of geographic objects as the object's area.

The advantage of cartograms is that values are not only mapped with the help of colors but also areas. The effect of emphasizing the differences of values is becoming more dramatic. Problem of overlapping areas is the one disadvantage, and if areas are regular, the distortion of areas makes the results unreadable.

3.2.2. Exploration in integrated GIS & spatial statistical techniques

The first order effect which indicates the global trend is explored for point data by using quadrat method and Kernel estimation.

Quadrat method is used for testing the probability of random distribution of the point datasets. It provides a global (first order) coefficient for the spatial distribution of the events. A square grid is applied over the study area and points are counted in each grid. Their frequency distribution is compared with Poisson distribution which indicates complete spatial randomness (CSR). If there is approximation of observed values to the Poisson distribution values, it is accepted as random distributed, else clustered or regular depending on the value of variance-mean ratio (VMR). The null hypothesis (H_0) states existence of CSR. In other words, VMR= 1

$$\text{VMR ratio} = \frac{s^2}{\lambda} \tag{3.1}$$

Where s^2 = variance and λ =mean.

VMR > 1 Clustering
VMR = 1 Complete spatial randomness
VMR < 1 Regularity

Null hypothesis is tested by x^2 test:

$$x^2 = (k-1)\frac{s^2}{\lambda} \tag{3.2}$$

k = Number of grids

The main deficiency of quadrat method is its dependency on grid size. The second handicap of this method is its disability of visualizing the distribution's characteristics. In other words, it only gives a measure about the distribution of the data but not the locations of them. Kernel estimation method solves this problem.

Kernel Estimation is a probability density map. A density map is created around the points. It enables the analysts to recognize the trends in the point dataset distribution over the study region. It is applied implementing a circular "window" over the dataset which has a determined radius (Figure 3.3).

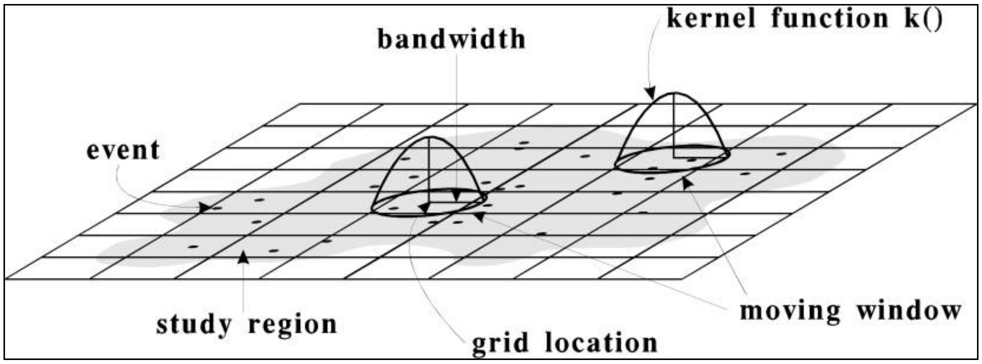


Figure 3.3. Visual definition of Kernel Estimation
Source: (http://web.gc.cuny.edu/cur/NIJbook, 2003)

$$\hat{\lambda}_{\tau}(s) = \sum_{i=1}^{n} \frac{1}{\tau^{2}} k\left(\frac{(s - s_i)}{\tau}\right) \tag{3.3}$$

Each s_i denotes an event, where s is the center of the Kernel function. τ is the bandwidth, λ_s is the density value at the point of s. k(h) is the probability density function which is called *kernel* (Bailey and Gatrell,1995).

A bandwidth is selected and then for each location of s a density value is obtained. A raster or vector dataset is suitable for that kind of result.

Dual Kernel is a spatial analysis technique where kernel estimations of more than one dataset are calculated and visualized together. This kind of analysis provides the analysts to see locational relations of different event distributions within the study area.

Kernel estimation method provides meaningful visual density distributions over the study area. Only shortage is absence of testing the significance of the results.

Second order effects which illustrate inter-event attraction are explored by the nearest neighbor distances and the K function for point pattern.

The nearest neighbor analysis focuses on the distances between the events. It gives an idea about clustering of events caused by intra-event interaction. It is based on comparison of observed and mean minimum distances between points and calculated by their ratio R.

$$R = \frac{r_o}{r_e} \tag{3.4}$$

r_0 = Observed mean minimum distance
r_e = Expected density

0<R< 2.1491

R= 0 Perfect clustered pattern
R=1.0 Perfect random pattern
R=2.1491 Perfect regular pattern

$$r_e = 0.5\sqrt{\frac{A}{N}} \tag{3.5}$$

A= Area
N=Number of points

$$s_d = \frac{0.26136}{\sqrt{N(N/A)}} \tag{3.6}$$

Equation 3.6 shows the calculation of standard error d

$$z = \frac{|r_o - r_e|}{s_d} \tag{3.7}$$

Equation 3.7 is the calculation of Z index.

The K-Function analysis is “superior” to nearest neighbour distance analysis, since it does not only consider nearest distances but also events in every distance. It is an index for measuring non-randomness of the events for defined distance intervals (Figure 3.3). Local trends can be measured through this analysis. R is the area of the study field and n is the number of events.

$$K(h) = \frac{R}{n^2} \sum_{i \neq j} \sum \frac{I_h(d_{ij})}{w_{ij}} \qquad (3.8)$$

If d_{ij} is the distance between event i and event j, I (d_{ij}) is an indicator function which results in 1 if $d_{ij} \leq h$ and 0 if $d_{ij} > h$ where h is the distance set to be analysed. w_{ij} is the edge correction factor. If a circle is centered on event i and passing through event j, then w_{ij} is the proportion of the perimeter of this circle which lies in study area.

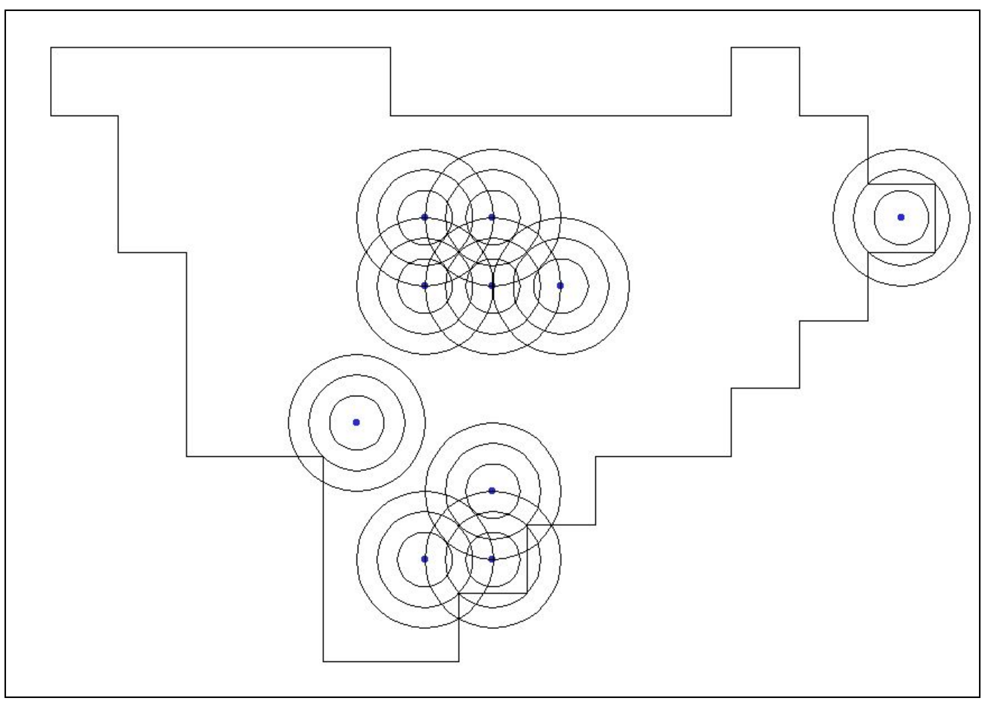


Figure 3.3. Example of different distance intervals

Plotting the K values against different d values enables analysts to see the clustering or dispersion at different distances. In order to have such a linear graph, K(h) values must be transformed into a square root function L(h).

$$\widehat{L}(h) = \sqrt{\frac{\hat{K}(h)}{\pi}} - h \qquad (3.9.)$$

In a typical L(h) graph, positive peaks are indicators of clustering and negative troughs are of regularity.

The first order effects for areal data are explored by median polish and spatial moving averages methods

The median polish technique is used usually for regular lattice type areal data such as pixels in satellite images in order to see the global spatial trends, so, this technique is applied to regular lattice areal data (pixels, in the satellite image example).

$$y_{ij} = \mu + \mu_i + \mu_j + \varepsilon_{ij} \qquad (3.10)$$

μ is fixed overall effect, μ_i and μ_j are row and column effects and ε_{ij} is a random error and y_{ij} is the new value for i^{th} row and j^{th} column (Bailey and Gatrell, 1995). In order to estimate the effects Median Polish uses Medians of rows or columns which is more powerful to eliminate extreme values (Bailey and Gatrell, 1995).

Median polishing is a iterative process. It operates in a stepwise algorithm as follows:

1) An extra (r+1)th row and (s+1)th column is added to the matrix of lattice and given value of 0.

2) Each cell value is replaced with the subtraction of the values of itself and the median of the row. The added row's [(s+1)] pixel values-that was set to 0 at step1- are replaced with addition of itself and the median value of the row.
3) The same process in the step 2 is repeated for columns including for the (s+1)th row. In other words each column's median value is calculated and each cell value is replaced by the result of subtraction of the column median and cell's value. (r+1)th row is replaced with addition of itself and the median value of the column.
4) The matrix become (r+1) X (s+1). The step2 and step3 is repeated for each cell repeatedly until the values of matrix doesn't change (or only some acceptable small changes).
5) The extra column and row contains the values of estimation. The {(r+1),(s+1)} cell contains $\hat{\mu}$ value, for each "***i***" value {***i***,(s+1)}cell contains $\hat{\mu}_i$ and for each "***j***" value {(r+1),***j***}cell contains $\hat{\mu}_j$.
6) A new matrix is generated calculating new values of cells with the help of the above mentioned formula ($\hat{y}_{ij} = \hat{\mu} + \hat{\mu}_i + \hat{\mu}_j$).

(Bailey and Gatrell, 1995)

The spatial moving averages method is another smoothing technique for areal data. The technique is based on assigning averages of areal units within a certain proximity to the each areal unit. Different Proximity Matrices are used for attaining better results.

$$\mu_i = \frac{\sum_{j=1}^{n} w_{ij} y_j}{\sum_{j=1}^{n} w_{ij}} \tag{3.11}$$

w_{ij} denotes the elements of proximity matrix of A_i and A_j (Bailey and Gatrell, 1995). y_j denotes the attribute value of the area. There are many techniques of constructing spatial proximity between areas according to different criteria.

2 different proximity matrixes are used in this study:

1) Distance between centroids: All of the values of areal units within a certain distance to each areal unit's centroid are calculated.
(If centroid of A_i is within some specified distance of that of A_j then w_{ij}= 1, Otherwise w_{ij} = 0) (Bailey and Gatrell, 1995) (Figure 3.4)

2) Neighborhood Proximity: In this matrix the neighborhood of polygons are involved in the calculation of average value.
(If Aj shares a common boundary with Ai then w_{ij} = 1,Otherwise w_{ij} = 0) (Bailey and Gatrell, 1995) (Figure 3.5)

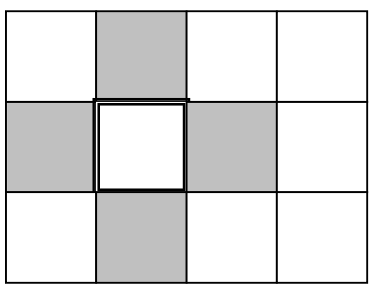


Figure3.4. Neighbourhood Distance

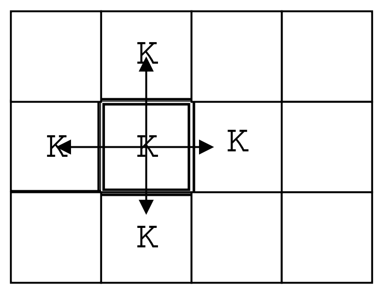


Figure 3.5. Centroid Distances

The second order effects for areal data are explored by correlograms which indicates spatial correlation. Correlograms provide a measure for the auto correlation between the areas. Moran's I, which is given in equation 3.12 is used for autocorrelation measure.

$$I = \frac{n\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (y_{i-}\bar{y})(y_{j-}\bar{y})}{\left(\sum_{i=1}^{n}(y_i - \bar{y})^2\right)\left(\sum_{i \neq j}\sum w_{ij}\right)} \tag{3.12}$$

where; n = number of values, $y_{i/j}$ = value at location i & j , $\bar{y}$ = mean value, and w_{ij} is the weight at distance d, that is, w_{ij}=1 if point j is within distance class d from point i, else w_{ij}=0

3.2.3. Conventional data analyses

The spatial relation of different types or different period artifacts is analyzed in the former sections. The archaeological semantic level of the study is structured in this section where the usage of artifacts or, usage of area in different time periods could be analyzed. For this purpose correlation of occurrences of different types of artifacts, in different time periods are analysed in the same quadrates (Figure 3.9). This will help us to explore land-use pattern at micro scale. This level of study is carried out using the presence and absence information of type of artifact groups in each quadrat (Hodder and Orton, 1976). Two different type of artifacts correlation is tested by creating contingency tables (Table 3.1)

Table 3.1. Contingency table of Presence/Absence

		Type A		
		Present	Absent	
Type B	Present	*a*	*b*	*e* = *a* + *b*
	Absent	*c*	*d*	*f* = *c* + *d*
		g = *a* + *c*	*h* = *b* + *d*	

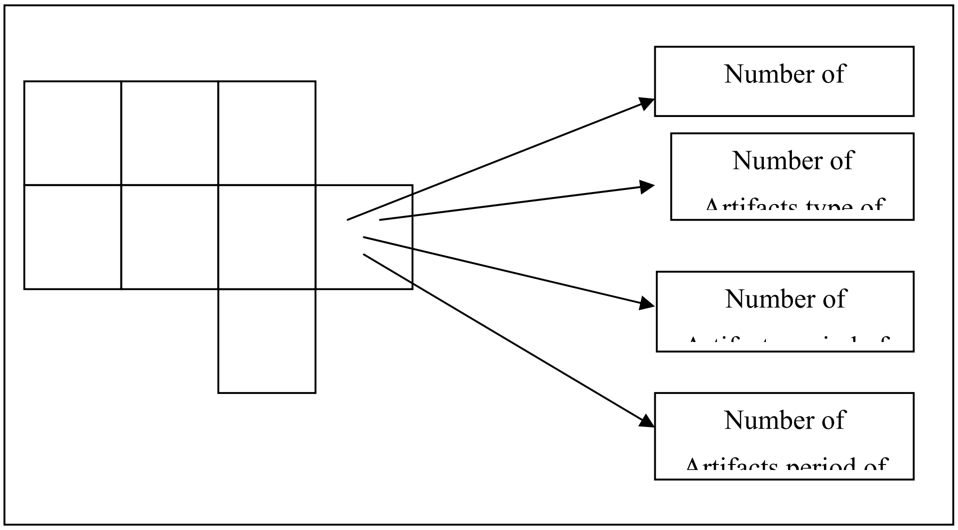


Figure 3.6. Different kind of artifacts in grids

$$\gamma = \frac{ad - bc}{+\left(efgh\right)^{1/2}} \qquad (3.13)$$

γ coefficient is calculated for measuring correlation between some groups of artifacts. In fact this is the same ϕ coefficient which can be converted into x^2 index for significance testing by;

$$x^2 = \phi^2 N \qquad (3.14)$$

where N is the number of observed events.

3.2.4. Inference

Analysing the study area with all of the methods mentioned in former sections, enables the archaeologists to make interpretations about the locations of the activity areas. The methods also indicate the land use pattern in the different time periods and they can be evaluated with the knowledge of ancient history in that region. The integrated GIS with spatial analyses can help to orient the excavation strategies in the field where conventional data analysis can be used in making archaeological researches about the site.

CHAPTER IV

STUDY AREA & FORMER STUDIES

4.1. General Information about the site

The study area is a site of ancient pottery workshops located on Datça Peninsula near the township Reşadiye which is 3 kilometers north of modern town Datça in southwestern Turkey (Figure 4.1). It is considered as the amphora production center for Knidos which was one of the major city of wine production in antiquity in Eastern Mediterranean (Tuna, 1996). So, exploration of the pattern of the production in this territory is crucial for sociopolitical and commercial relations in antiquity.

Figure 4.1. Study area location

Archaeological context of the area is discovered in 1980 (Tuna et al, 1987). The archaeological surveys under the supervision of Prof. Dr. Numan Tuna at the central part of the Knidian territory have revealed several ceramic workshops which were active from the middle of 4th century BC to the 6th century AD (http://www.metu.edu.tr/home/wwwmuze/ knidian.html, 2003). The workshop area had been studied by Turkish and French collaboration with the partnership of Prof. N. Tuna and Prof. J.-Y. Empereur from 1986 to 1992 that includes intensive ground surveys, geophysics studies and finally excavations (Tuna, 1996). Since, the amphora types found in this area are already known as the most common types around Mediterranean, organisation of the production facilities is important to study for archaeology. After the excavations, some ceramic kilns, refuse deposits are discovered. It is estimated that there are more than 10 amphora/pottery producers at a time of II. century BC in that area. Presently, the area is used and terraced for agricultural activities by local farmers. The area of the workshops is around 1 kilometer square.

4.2. Structure of the former studies

The studies can be evaluated hierarchically and chronologically. Both orders have the same structure. In other words, the field studies are developed from “extensive” to “intensive” during the 1986-1992 period. Firstly the area was surveyed on the basis of cadastral zones, then in some subsections the ground surveys are carried out on 5x5 m grids, and finally excavated.

All of the area is spatially set in terraces that indicate also present-day field boundaries subdivided by a cadastral plan shown in the Figure 4.2. Each cadastral unit is given a code and a table is created related to these codes, which consist of some archaeological and geomorphological attribute data per terrace. The fields of the table are as follows: terrace code, cadastral parcel no, land use, geological and geomorphological structure, cultural remains on ground, ground artifact density (10x10m), time periods of artifacts are provided in Appendix A.

The data about the artifacts are limited by the number, general information and rough time periods. There is no specific information about type of the potsherds. These studies give a global idea about the geological and geomorphological setting of the area and general intensity of artifacts on ground.

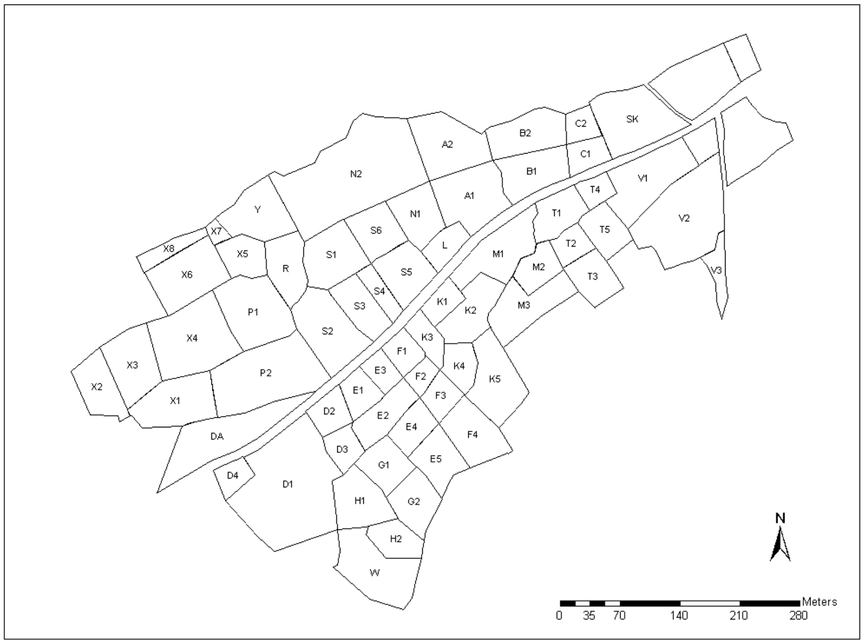


Figure 4.2. Cadastral Zones with ID codes

More detailed and intensive ground surveys are carried out in selected sub-regions in the study area. This survey studies in terraces were performed at the specified locations on 5x5 m grids. After collecting rough information all over the area some sub-sections are selected for more systematic ground surveys. This survey is based on systematic collecting, recording and taxonomic classification of the artifacts from the area that has been divided into sub-areas and sub-areas into 5 x 5 m grids (Figure 4.3).

Each one of the grid is given a unique ID code which includes their analytic positions in the area (NE.005.008). Each artifact that can give information for recording system is recorded in a detailed table with its Grid ID, time period, type and part attributes (Table 4.1).

In the ground survey studies in grids, around 8000 pot sherds are collected and they are classified according to the product groups like amphoras, fine ceramics, common ceramics. It is assumed that these ground distribution of artifacts are reflecting the kiln facility distribution and their periodic development (Tuna, 1996).

Table 4.1. Example of artifact records

Square	**d1**	**d2**	**d3**	**d4**	**d5**
NE.004.004	A	H			T
NE.004.004	A	H			T
NE.004.004	A	P	7		
NE.004.004	L				
NE.004.004	T		2		
NE.004.004	T		2		
NE.004.004	B			Y	

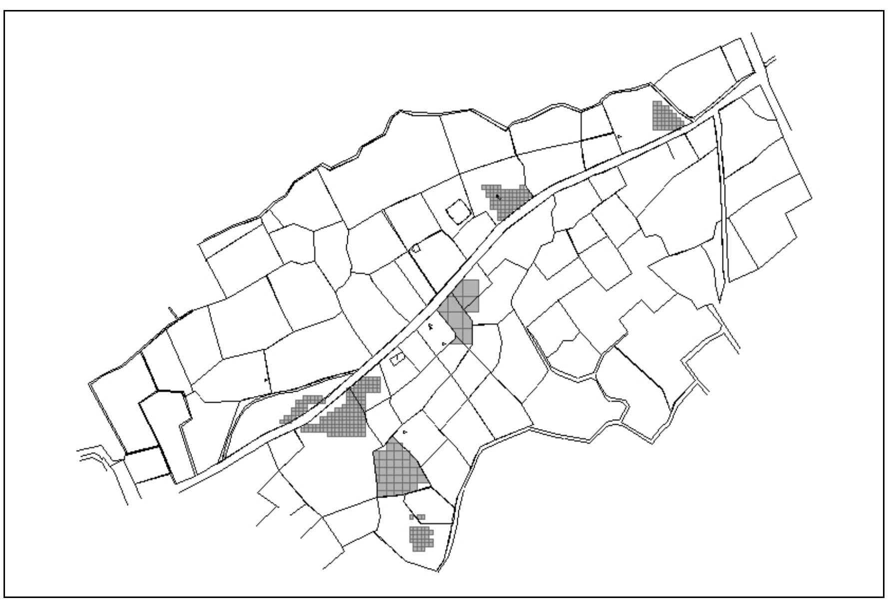


Figure 4.3. Subsections of surveying units

There are some sub-groupings of the artifacts formerly constructed by Prof. Dr. N. Tuna according to their types and related time periods (Table 4.2). All of the analyses are implemented to these sub-groups separately and all of the relationships are built between them. The number of artifact sub-groups in this subsection of survey area is listed in table 4.2.

Table 4.2. Artifact subgrouping in the subsection of the survey area

Sub-groupings of artifacts	Type / Period
A1	Amphora, late IV. Century BC
A2	Amphora, early III. Century BC
A3	Amphora, III. Century BC
A4	Amphora, II. Century BC
A5	Amphora, I. Century BC- I. Century AC
A6	Amphora, Dressel 6/Coan type, I. Century BC
A7	Amphora, late II.-I. Century BC, Rhodian type
B	Kiln brick
CC	Coarse ware
CF	Fine ware
F	Dumped kiln refuse, slag
T	Tile

The 1/1000 paper map (UTM projection) of study area was digitized and layers of cadastral zones, contour lines and other topographic features (road, building, etc.) are created by TAÇDAM (Center for research and Assessment of the Historic Environment). MapGrafix for Macintosh is used for cartography and GIS functions. The grids are implemented into the digital format by using MapGrafix again (Figure 4.4). The attribute data of grids is in 4D format and kept related to the MapGrafix database system.

CHAPTER V

CASE STUDY

5.1. Data Processing

The data is needed to be converted into some other formats in order to use proper softwares for spatial analyses. Firstly, since during the analyses mainly ESRI products are used, features of MapGrafix are converted into ESRI's shape file format. Areal dataset is already created as the grids in MapGrafix format, but the structure of the artifact tables in the grids is based on the each artifact. Statistical analyses using quadrats are based on the numbers of artifacts in the grids (Table 5.1). Therefore the structures of the tables are reconstructed according to the number of the artifacts for areal analyses. The sub-groups are treated as a field of the grid shape file's table (Table 5.2).

Table 5.1. Original table based on each artifact

Square	d1	D2	d3	d4	d5
NE.004.004	A	H			T
NE.004.004	A	H			T
NE.004.004	A	P	7		
NE.004.004	L				
NE.004.004	T		2		
NE.004.004	T		2		
NE.004.004	B			Y	

Table 5.2. Reconstructed table based on grids

ID	A1	A2	A3	A4	A5	A6	A7	B	CC	CF	F	T
NE.001.002	1	0	0	12	1	0	0	2	0	0	0	3
NE.001.003	0	0	0	2	3	0	0	1	3	0	0	3
NE.001.004	0	0	1	22	1	0	0	6	1	1	2	4
NE.001.005	0	0	2	15	2	1	0	53	1	3	19	3
NE.001.006	1	1	2	46	3	0	0	4	2	5	26	7
NE.001.007	1	0	3	36	1	0	0	3	0	0	13	1

Table 5.1 is the initial table that includes the characteristics of each artifact, where Table 5.2 is the new table that includes the number of artifacts by types in each grid. The structure was artifact-based tables, for analysing the grids.

In order to perform point dataset analyses in the study area, the grid data are converted to a point dataset by assigning to the grid centroids of each 5x5m grid (Figure 5.1). A script for Arc Map is used to perform this operation[2].

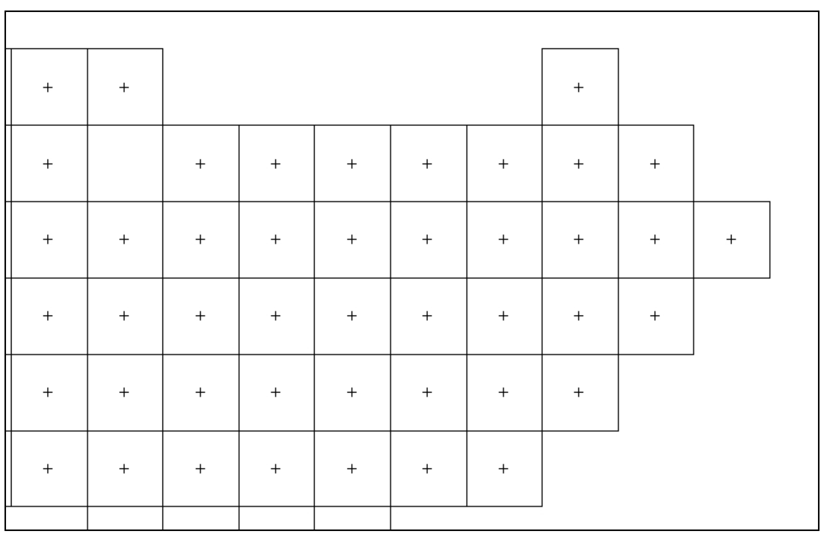


Figure 5.1. Centroids of the grids

[2]"Calculate XY" written in Visual Basic by Jon Barlett (http://support.esri.com, 2003)

A point dataset is created for each artifact group. Hence, if there are, say, 30 artifacts in a grid, all of them are assigned to the centroid of that grid. The main table of artifacts is rearranged under 12 sub-group tables so that they are used in the analyses separately. Then for each sub-group, a point dataset is created as ESRI's shape file.

As a summary, while graphical data is converted from MapGrafix format to ESRI format the areal data is transformed into point format. Non-graphical data are converted into artifact based tables depicting frequencies. Those contingency tables are based on the number of each artifact type which is set in the previous chapter. The number of the each artifact group in the study area is given in Table 5.3.

Table 5.3. Percentage labels and artifact types

Sub-group	Type / period	Amount	Percentage
A1	(Amphora, late IV. Century BC)	62	4,01
A2	(Amphora, early III. Century BC)	48	3,10
A3	(Amphora, III. Century BC)	173	11,18
A4	(Amphora, II. Century BC)	465	30,06
A5	(Amphora, I. Century BC- I. Century AC)	69	4,46
A6	(Amphora, Dressel 6/Coan type, I. Century BC)	16	1,03
A7	(Amphora, late II.-I. Century BC, Rhodian type)	11	0,71
B	(Kiln brick)	265	17,13
CC	(Coarse ware)	16	1,03
CF	(Fine ware)	82	5,30
F	(Dumped kiln refuse, slag)	158	10,21
T	(Tile)	182	11,76
TOTAL		1547	100,00

5.2. Integrated GIS and spatial analyses

Figure 5.2 depicts six sub-regions where detailed surveying is carried out. Consultations with the field director Prof. Dr. N. Tuna revealed that only one sub-sector could be suitable for this study.

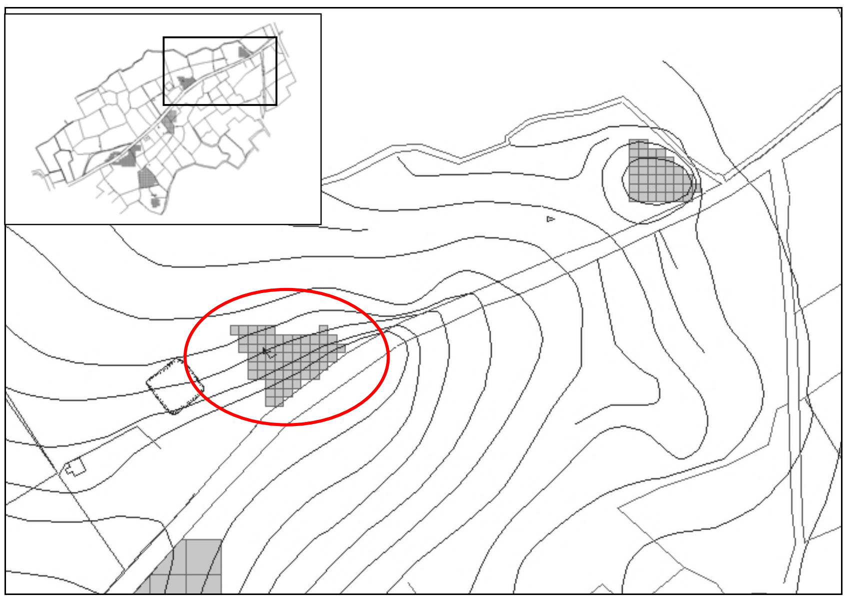


Figure 5.2. Selected sub-section of the survey area

This sub section is located at north-eastern sector of the pottery workshop area and near the road to village Hızırşah.

5.2.1. Visualisation

The transition from areal data to point dataset limited the visualization to regularly spaced grid centroids (Figure 5.3.). And in this case, dot maps are not effective for visualizing the point pattern. Therefore the exploration emerges as a crucial phase for the visualization of the materials

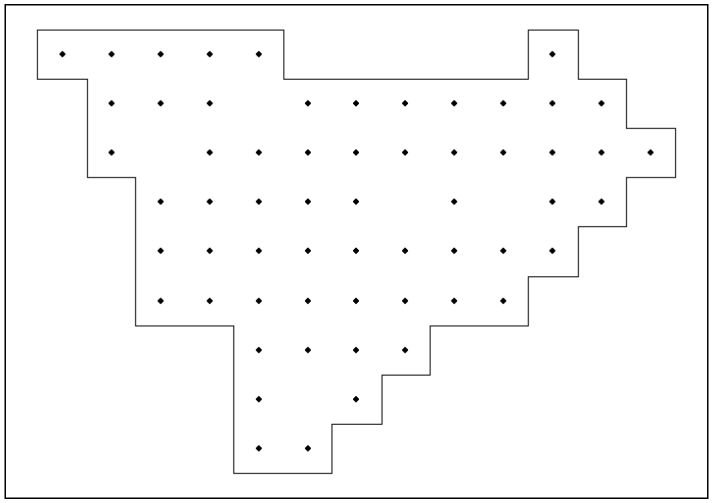


Figure 5.3. Dot map example of the study area

On the other hand, visualization for areal data, by means of choropleth maps would produce a “rough picture” about the spatial distribution of the artifacts.

Classes are based on natural groupings of data values. The software identifies break points by seeking groupings and structure inherent in the data. The features are divided into classes where there are relatively large changes in the data values (ESRI-ArcMap). Because of the advantages of this method, natural breaks are used in all of the choropleths (Figures 5.4 to 5.8).

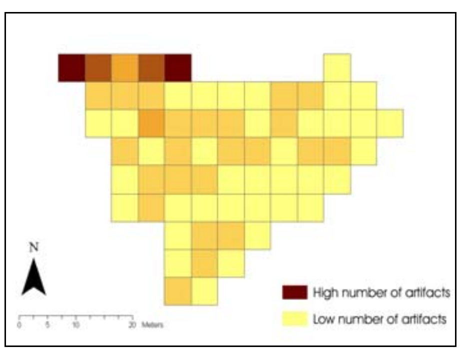


Figure 5.4. Choropleth of group A1

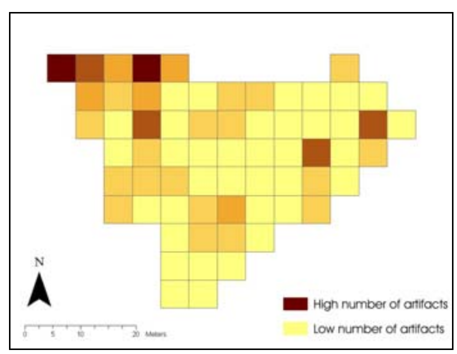


Figure 5.5. Choropleth of group A2

The choropleth maps depict the general pattern of the artifact distribution. Oldest amphoras (Groups A1 and A2) concentrate on the north-western corner of the study area (Figure 5.4, 5.5). Their location suggests a concentration of production activity at these grids. The distribution of group A4 depicts a trend to the central-west (Figure 5.6). II. century BC amphoras depict a clear shift of density from north-western corner towards mid-west of the study area. This sector is endowed with the largest concentration accounts for artifacts which suggest an eventual proximity to kilns.

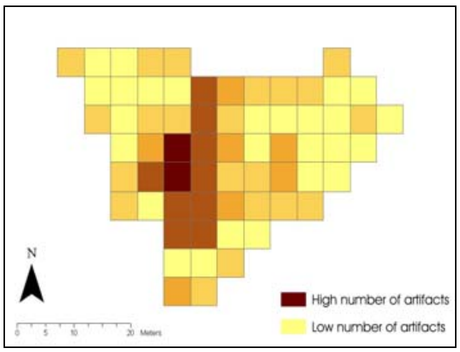


Figure 5.6. Choropleth map for group A4

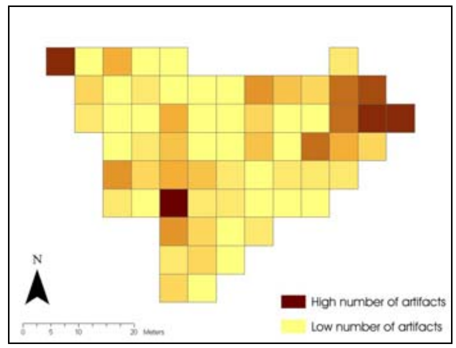


Figure 5.7. Choropleth map for group B

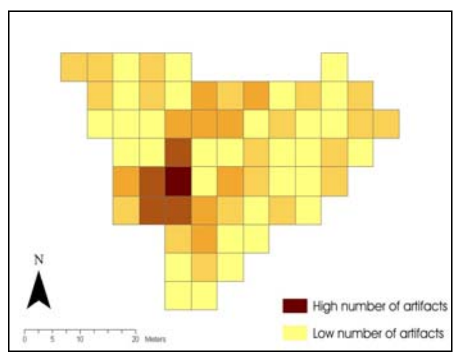


Figure 5.8. Choropleth map for group F

This sector is also rich in terms of defected products and kiln refuse which constitute an additional support to the assumption of a kiln location. On the other hand, the concentration of kiln bricks at the north-eastern corner of the study area (Figure 5.7) points out to a concentration of kiln activity. Grids in mid-west part and north-western corner of study area display another sector of concentration.

Other choropleth maps depicting the distribution of the artifacts are produced in Appendix B. The concentrations are not as clear as those above. In order to clarify these results, explorative analyses are needed.

The second visualisation technique used for areal data is cartograms (Figures 5.9– 5.10).

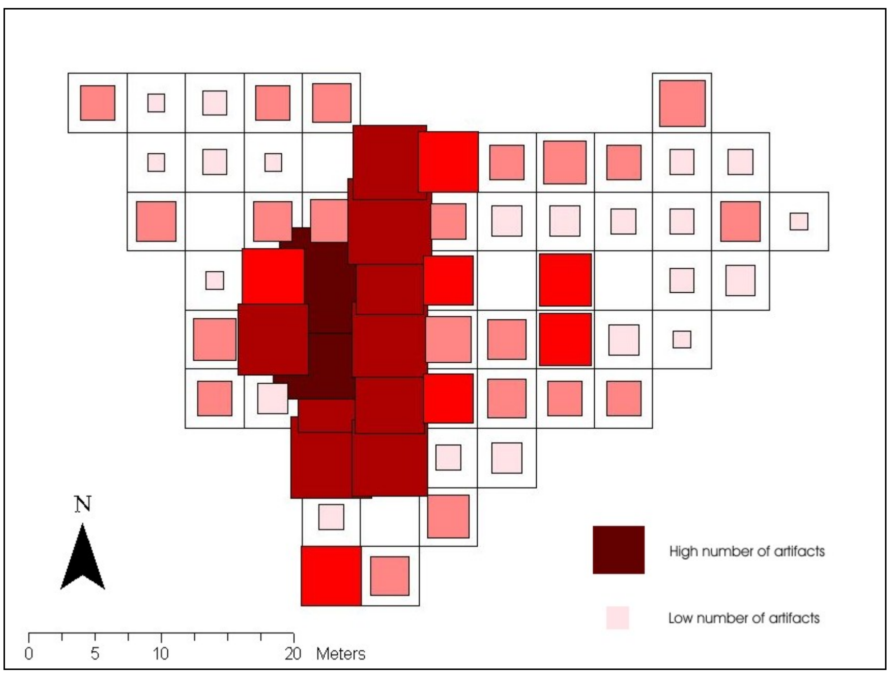


Figure 5.9. Cartogram of A4

The same artifact groups are analysed by using a routine in ArcView 3.2. Especially; amphoras in II. Century BC in Figure 5.9 showing their locations of density more dramatically in mid west part again. Figure 5.10, however, shows a clearer result than the choropleth for group A7.

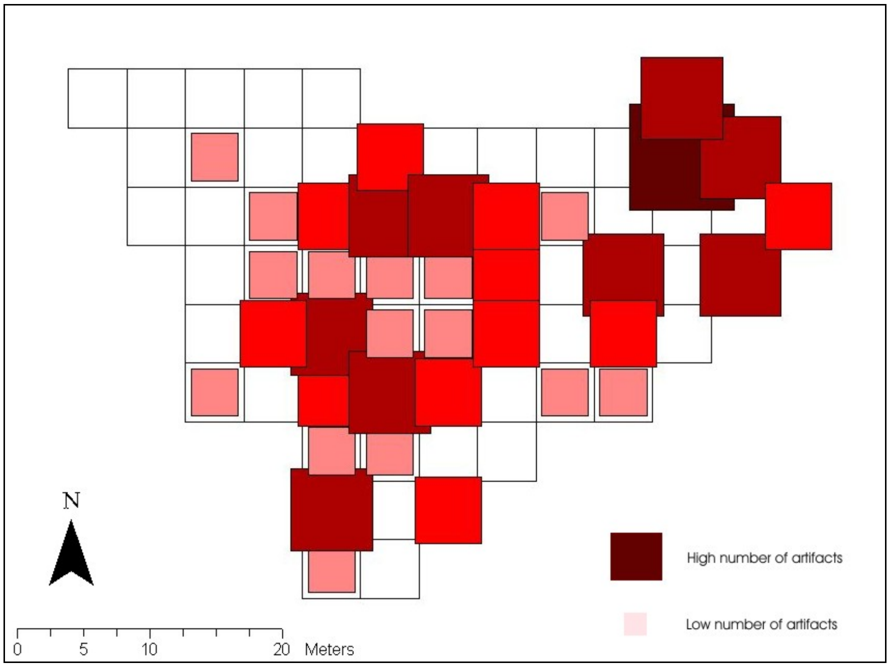


Figure 5.10. Cartogram for A5

These visualization exercises indicate that:

- Artifact concentrate on the north-western corner
- Artifact concentrate on the mid-west
- Artifact concentrate on the north-eastern corner

Artifacts display significant local concentrations suggesting the presence of some "centers" of production. However, these results are "a prior" considerations which are unsubstantiated and need further statistical evidence. In what follows we will concentrate on trends that are not analysed in choropleth maps and cartograms.

5.2.2. Exploration

In the first phase of exploration aimed to detect whether there is any clustering in any part of the study area. In other words, the global trends of the artifact distribution are studied.

This is tested first through Quadrat test. The VMR values are calculated to test the global distribution of artifacts in the study (See section 3.3.2). Then Z test is performed to test the significance of the VMR value at 0,01 significance level (Table 5.4).

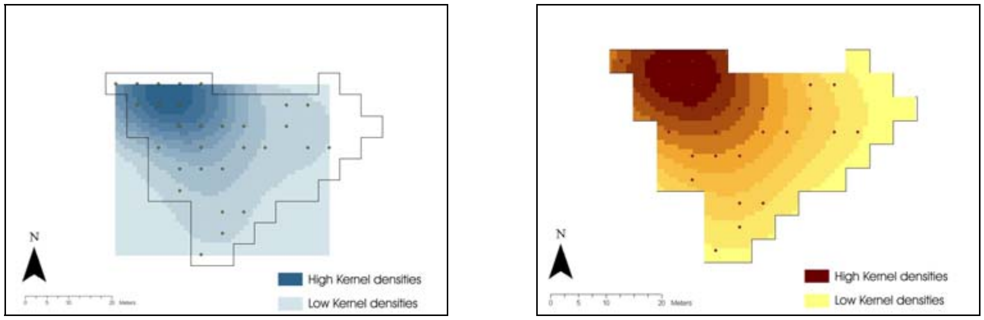
Table 5.4. Quadrat analysis result

	Average	Variance	V.M.R	Z test
A1	0,954	3,595	3,595	417,02
A2	0,738	1,085	1,470	170,5049
A3	2,662	8,224	3,090	358,4296
A4	6,892	71,450	10,367	1202,526
A5	1,062	1,412	1,330	154,2533
A6	0,244	0,493	2,004	232,4466
A7	0,169	0,171	1,013	117,4604
CC	0,246	0,309	1,254	145,4466
CF	1,077	2,933	2,723	315,8773
F	2,431	22,891	9,417	1092,41
B	4,077	82,502	20,236	2347,411
T	2,800	27,760	9,914	1150,058
A	12,723	100,200	7,875	913,5545

For all of the artifact sub-groupings computed Z values are very high for 0.01 significance level.. Hence H_0 is rejected, and all artifact groups display a clustering. The highest 5 VMR values relate to bricks (B), II. Century BC amphoras (A4), tiles (T) and kiln refuses (F) and all amphoras (A). Bricks, tiles and kiln refuses are expected to cluster around kilns and/or its dump areas. They don’t scatter too much over the study area, because they are directly related to the structure of kiln and its dumping area. The group labeled A4 shows high VMR values in spite of its high population. Like other ceramic artifact groups, assemblage labeled A4 was expected to be more evenly distributed over the study area, but it takes the second highest VMR value. This can be interpreted as amphora production in II. century BC (A4) was at a specific location. Although choropleth maps do not depict other groups' distribution pattern, Quadrat analysis shows us that the latter are clustered too. It is important for the rest of the analyses to detect the clustering for all artifact groups. This would indicate the position of production facilities in the study region. But still the locations of the clusterings are not known for us. Quadrat Analysis only gives answers of YES/NO questions. It doesn't provide any answer to questions of "WHERE" or "HOW", in other words the clusterings could not be detected.

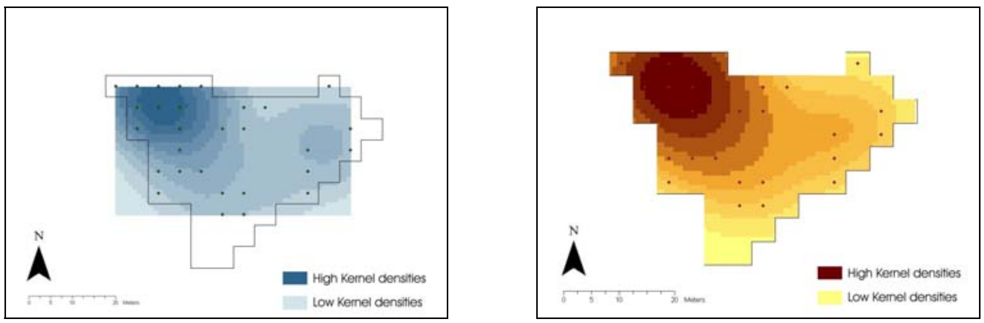
Kernel Estimation answers such questions. With using this technique students could detect the locations and shapes of the densities. Kernel estimation is performed with the help of Spatial Analyst Extension of ArcMap and Crimestat. Results would contribute to 1st order effects exploration. Different bandwidth sizes are tested and 10 m interval is selected as giving best result with the constant pixel size of 1.

The analyses are carried out for 12 sub-groups with Arcmap and Crimestat. The normal distribution function and fixed interval preferences are used in Crimestat. The maps of ESRI and Crimestat differ in their density smoothing because Crimestat is using Normal distribution, especially in Figure 5.13. The hypotheses set in visualisation process are somehow justified by the Kernel estimation. Since the output pixel size is around 1m, the results can be seen more clearly.



(a) (b)

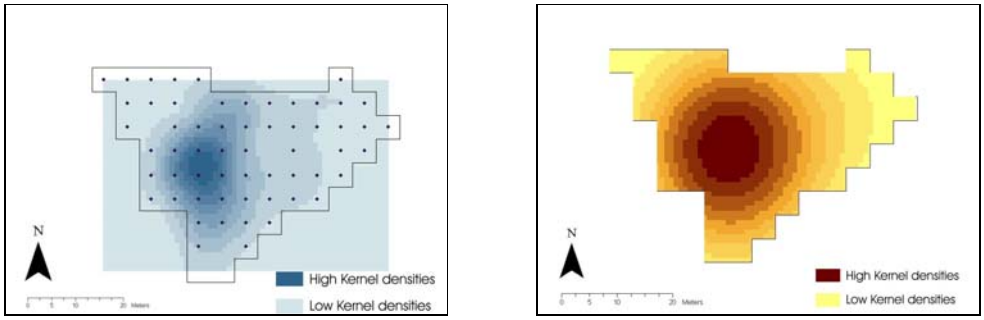
Figure 5.11. (a) Kernel estimation of Group A1 in Spatial Analyst, (b) Kernel estimation of Group A1 in Crimestat



(a) (b)

Figure 5.12. (a) Kernel estimation of Group A2 in Spatial Analyst, (b) Kernel estimation of Group A2 in Crimestat

Notice that the distribution of assemblages points out to the same locations detected through choropleth maps (Figures 5.11, 5.12 and 5.13).



(a) (b)

Figure 5.13. (a) Kernel estimation of Group A4 in spatial analyst, (b) Kernel estimation of Group A4 in crimestat

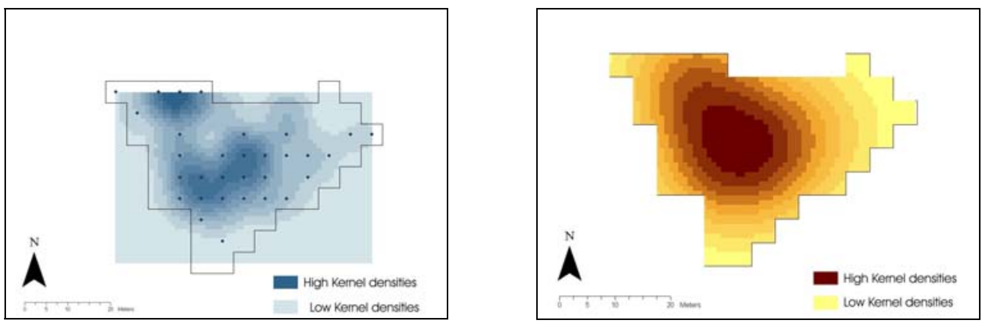


Figure 5.14. (a) Kernel estimation of Group CF in spatial analyst, (b) Kernel estimation of Group CF in crimestat

Another important outcome is the density map of fine ceramic artifacts (CF) which are concentrated in midwestern part and northwestern sectors of Figure 5.14. These locations overlap the concentration areas of assemblages labeled A1 (late IV. century), A2 (III. century BC) and A4 (II. century BC) as well. The archaeological expectation of these overlapping concentration locations can be the fine ceramic production during late IV century BC-II century BC.

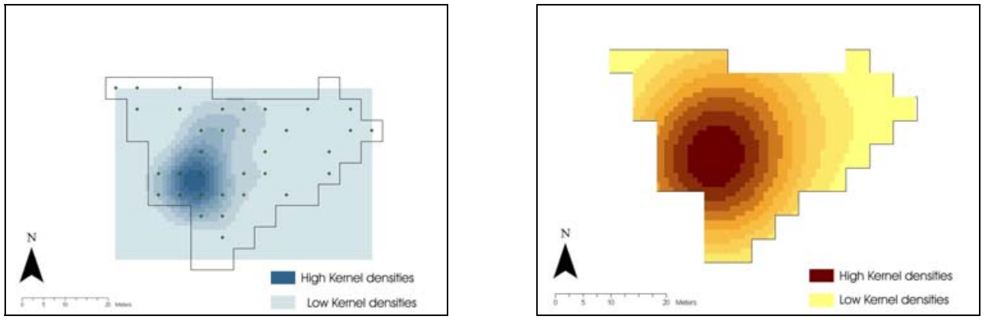


Figure 5.15. (a) Kernel estimation of Group F in spatial analyst, (b) Kernel estimation of Group F in crimestat

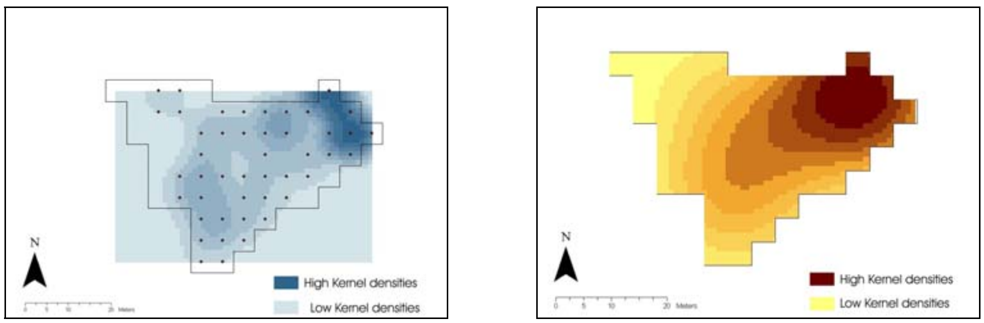


Figure 5.16. (a) Kernel estimation of Group T in spatial analyst, (b) Kernel estimation of Group T in crimestat

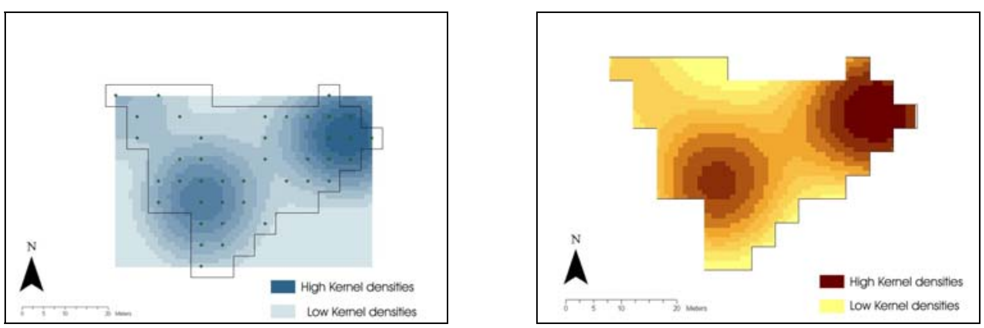


Figure 5.17. (a) Kernel estimation of Group B in spatial analyst, (b) Kernel estimation of Group B in crimestat

The Kernel estimation maps in Figures 5.15-5.17 relate to assemblage groups directly related to the kiln activities such as kiln refuses, tiles and kiln bricks. The general outlook of the density map for Bricks is similar to the composition of the refuse and tile maps.

"Bricks" concentrate in and around the northwestern sectors of the choropleth maps. Notice that, Figure 5.17 depicts a concentration at the mid-west. This corroborates with our hypothesis pertaining to the densities of the Brick map. The location of this second concentration overlaps with that of assemblage A4. The location of density at northwestern corner can be related to the density of group A5 which is documented in Appendix C.

The distribution of Group T related to tiles too, depict a concentration at the northwest. This would indicate is pointing another activity location (Figure 5.16). Group F's density map is similar to map of A4. These findings point out to earlier kiln activities around this sector.

Landuse pattern of the study area is explored by Kernel estimations. Dual kernels are performed with Crimestat to explore the relative difference of Kernel estimations.

To observe the global trend of two variables at a time Dual Kernel estimation analyses are performed. In Dual Kernel only the artifact groups of amphoras in different time periods are used. Relative differences of the kernel estimates of distributions are carried out to understand earlier land uses. This analysis aimed to detect a variation of densities of artifacts from different time periods. This would shed light on density variation in the study area.

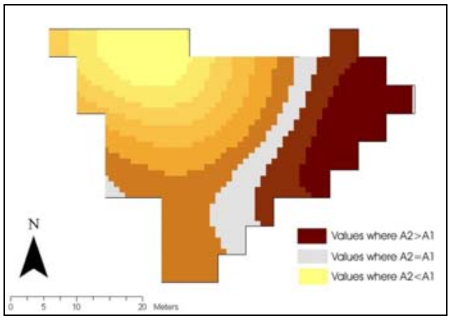


Figure 5.18. Difference between Kernel density of A2-A1

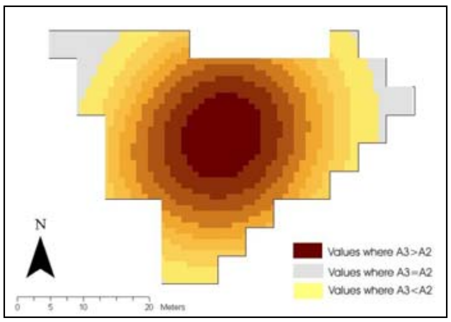


Figure 5.19. Difference between Kernel density of A3-A2

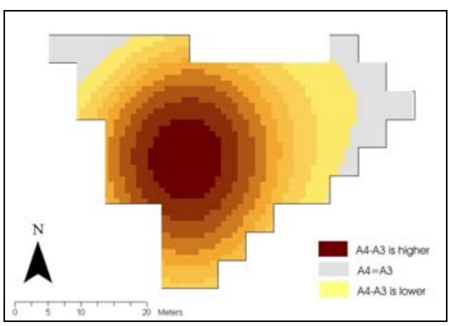


Figure 5.20. Difference between Kernel density of A4-A3

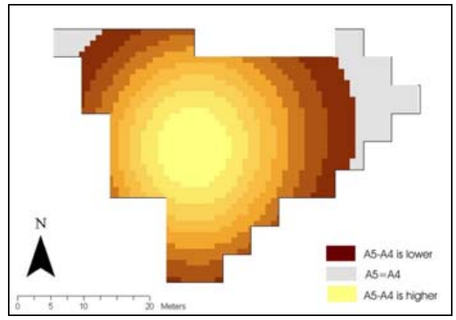


Figure 5.21. Difference between Kernel density of A5-A4

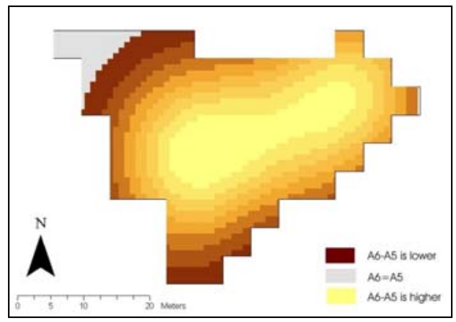


Figure 5.22. Difference between Kernel density of A6-A5

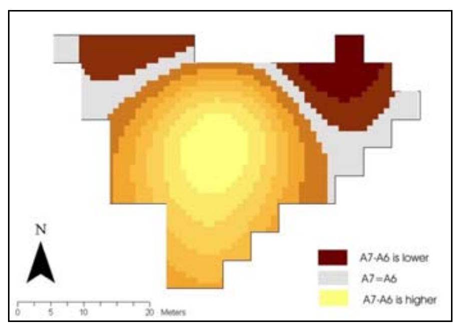


Figure 5.23. Difference between Kernel density of A7-A6

Relative difference of the kernel estimates are calculated in the dual kernel analyses in Figures 5.18- 5.24. It is implemented only to the artifact groupings A1-A7 because they are only groups that can give information about time periods.

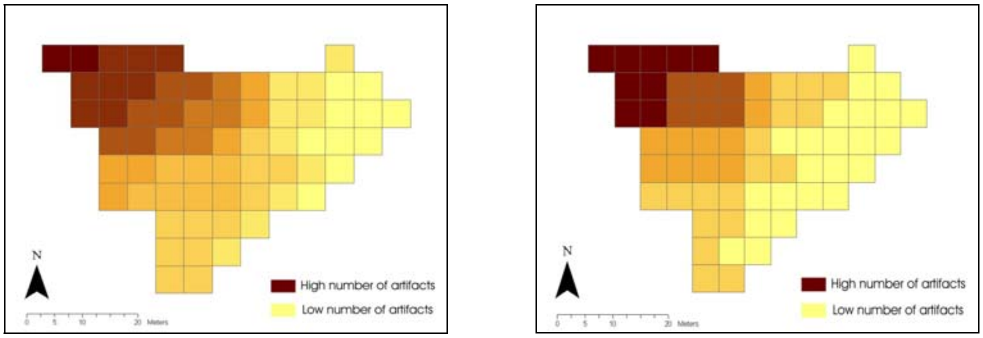
For each artifact group's relative kernel density is subtracted from the artifact group's that are referred to earlier time period like A7-A6 or A5-A4. In this analysis the differences between densities of different time periods are mapped quantitatively.

With the knowledge of locations of groups A1 and A2, the difference is seen that there is decrease in the density of A2 relative to A1 (Figure 5.18). And the concentration is moving to west. In the following time period the density is increasing and moving to the central part of the study area. In group A4, the density is rising again with small shift to eastern side (Figure 5.20). Group A5 is decreasing but with no change of location (Figure 5.21). In group A6 the density is moving to northeastern part and still decreasing (Figure 5.22). At last group A7 is increasing in the northeast and northwest parts (Figure 5.23). The movement of concentrations starts from northeastern corner to the mid-central part and then continues to move to northeastern corner.

The previous assumptions pertaining to three probable kiln locations can be evaluated with these results. The oldest kiln location is at northwestern corner, the kiln in mid-western part relate to the most intensive period of production and the last kiln should be located in northeastern corner.

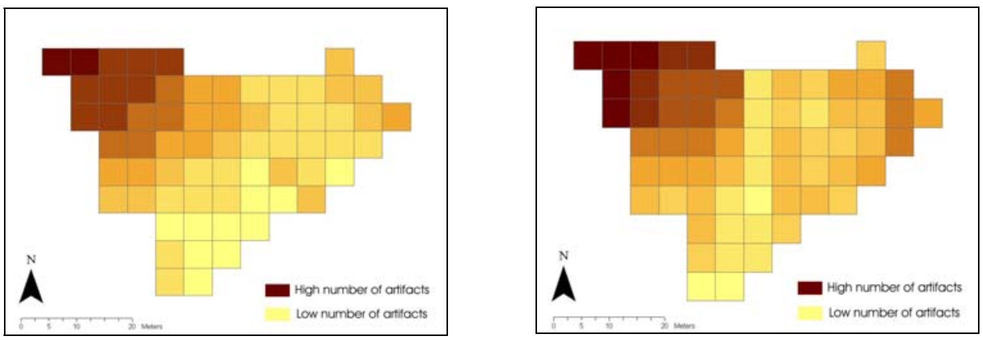
The areal data is first explored by spatial moving averages. Two different proximity matrices are implemented as mentioned in Chapter 3. Results of calculations of the proximity matrix based on the distances between the centroids are transferred into the attribute table of grids. The second proximity measure is the relation of the boundaries that are shared between two polygons. Those analyses are performed with ESRI ArcView 3.2 and XFilter[3]. This tool performed operations on neighborhood relations of grids. 1st degree is based on the neighbors around a polygon which share boundaries according to Rook case. 2nd degree neighborhood comprises the first and second neighbors of a grid cell.

[3] A script, created for ArcView written in Avenue by Klaus Neudecker,



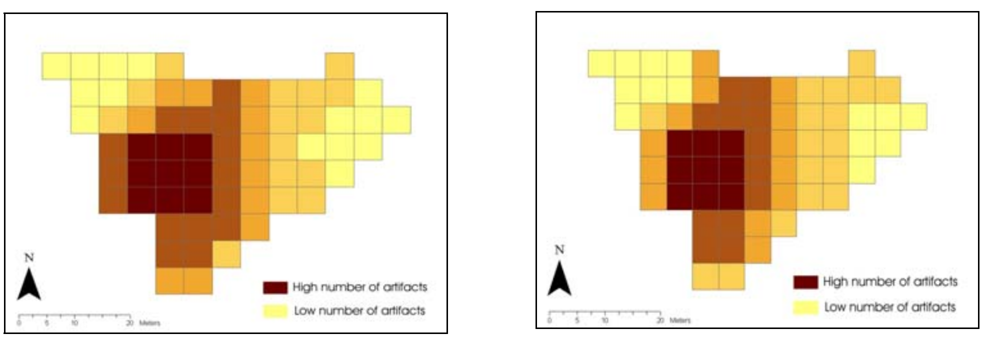
(a) (b)

Figure 5.24. (a) Spatial moving average for A1-20m, (b) Spatial moving average for A1-2nd neighbour



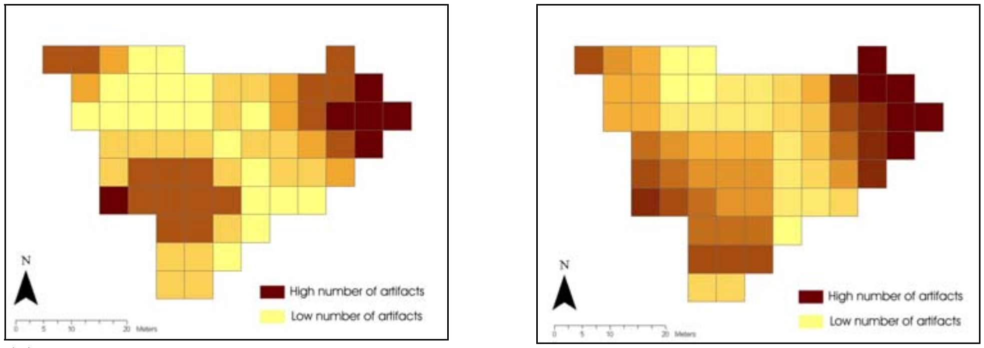
(a) (b)

Figure 5.25. (a) Spatial moving average for A2-20m, (b) Spatial moving average for A2-2nd neighbour



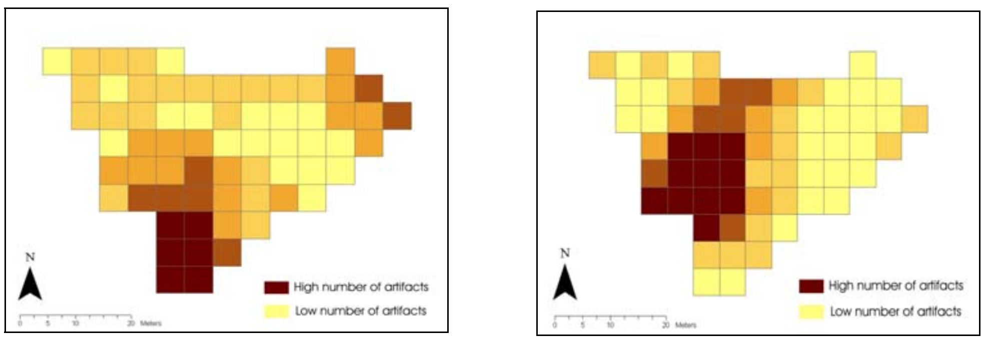
(a) (b)

Figure 5.26. (a) Spatial moving average for A4-10m, (b) Spatial moving average for A4-1st neighbour



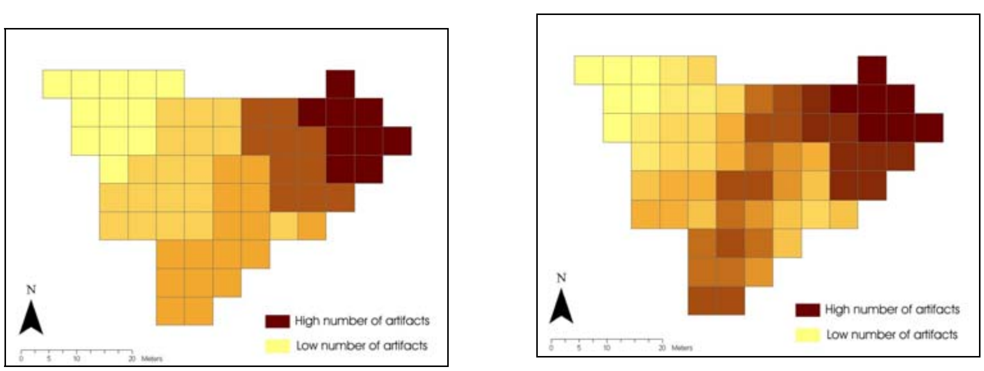
(a) (b)

Figure 5.27. (a) Spatial moving average for B-10m, (b) Spatial moving average for B-2nd neighbour



(a) (b)

Figure 5.28. (a) Spatial moving average for F-10m, (b) Spatial moving average for F-1st neighbour



(a) (b)

Figure 5.29. (a) Spatial moving average for T-20m, (b) Spatial moving average for T-2nd neighbour

The trends for all type of artifact groups become clearer in these analyses. If we interpret them one by one; Figure 5.25 and 5.26 show the same trend which is oriented to the northwest corner. Groups of A4 are clustered in the west center of the area in Figure 5.27. Figures 5.28, 5.29 and 5.30 reflect the same distribution as kernel estimations, three different locations of densities. The results are not as clear as Kernel estimations because of the low resolution at level 5 m.

The second exploration method for areal data is median polish. The aim of median polishing is the same as spatial moving averages. It clears the noises in the distribution scheme in order see the trends more clearly. Being already in a grid format, the surveying units don't need to be converted into the raster format. However, because of the low number of the grid cells (n=63) the trends cannot be seen as clear as in the spatial moving average technique. It is applied generally to thousands of raster cells. That's why few smoothed column and rows are displayed in this analysis. The results can be seen in Appendix D.

The second order effects for the point data are first explored by nearest neighbor analysis. R values and Z tests show a regular pattern between the events because of their regular spacing, The nature of the conversion from polygon data is the main reason of this pattern (Table 5.5). As a consequence of these effects this analysis is inappropriate for this case. The results are misleading

Table 5.5. Nearest neighbour analysis

Artifact Groups	R values	Z values
A1	1,976	14,7077
A2	1,762	10,984
A3	3,266	57,006

Unlike former analyses, “K function analysis” is performed for some of groups where sufficient number of events are available. In order to calculate K, L ,Lmin and Lmax values, Crimestat is used and the graphs are created in MS Excel.

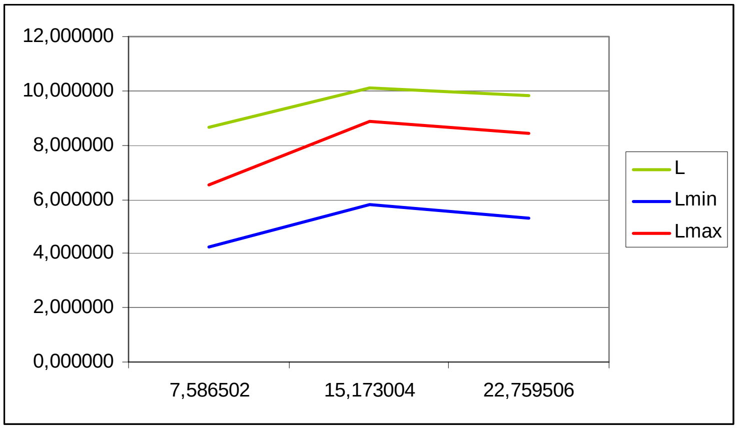


Figure 5.30. Graph of L values of CF distribution

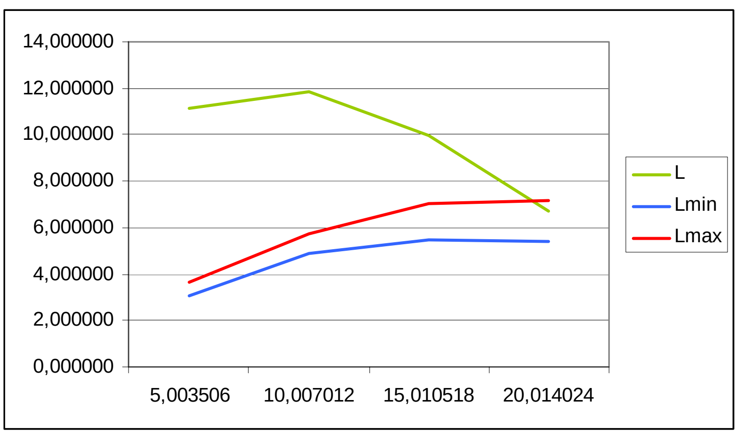


Figure 5.31. Graph of L values of B distribution

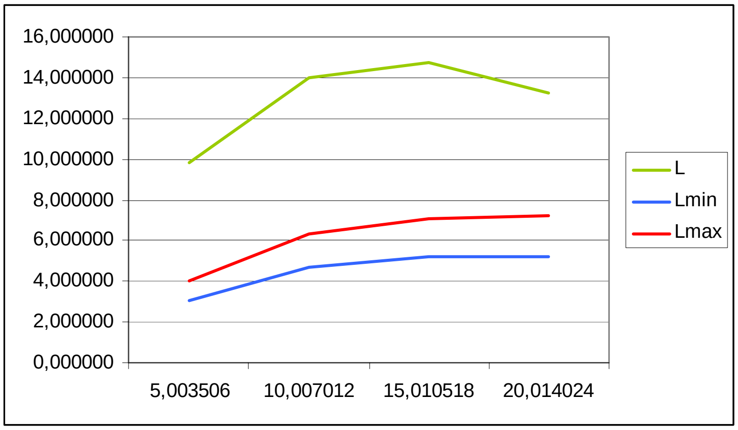


Figure 5.32. Graph of L values of F distribution

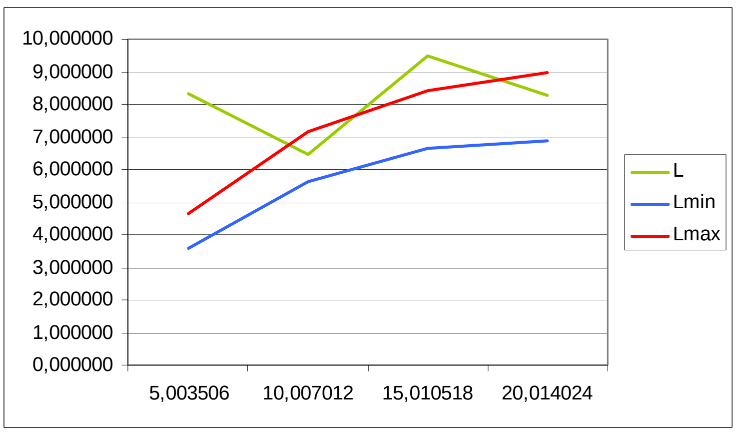


Figure 5.33. Graph of L values of T distribution

The graphs showing L values against distances shows the distances where the artifacts are clustered and the envelopes of Lmin and Lmax helps to understand if it is statistically significant or not by showing the statistically significant area between or above them.

In all of the graphs the values are positive, so there is a clustering not dispersion of values (Figures 5.30-5.33). The positive peak values point specific distances of clustered points. Group CF is clustered at 10 m and significant (Figure 5.30).

Group B is clustered at distance of around 7 m and significant (Figure 5.31). In group F there are two different clustering at the distance of 7m and 17 m, both are significant (Figure 5.32). Finally group T is clustered at around 17 m which is statistically significant (Figure 5.33). Other artifact groups are not significantly clustered, so they are given in Appendix E. The results of this analyses can be interpreted as some group of artifacts are clustering locally.

The clustered groups can be interpreted archaeologically since they should be clustered because of the same production facility. To put it another way, that kind of artifact is present because of another kind of artifact at the specific distance. This can help to find specific locations of production of artifact groups. This part of the interpretation has to be performed by the archaeologists.

In order to explore spatial autocorrelation, second order effects for areal data analysis are performed by using correlograms.

Correlogram analyses are carried out with special routine named “Rookcase” written for MS Excel. Proximity calculations for lag distances are set according to the distances between centroids of terraces. The Moran’s I values are computed.

Generally, the correlogram show higher values in shorter distances, negative values in long distances. The negative values in long distances can be interpreted as being more than one intensity location within the study area (Hodder and Orton,1976) which can be supported with the prior analyses too (Kernel estimation, spatial moving averages). Each lag in the analysis is 5m.

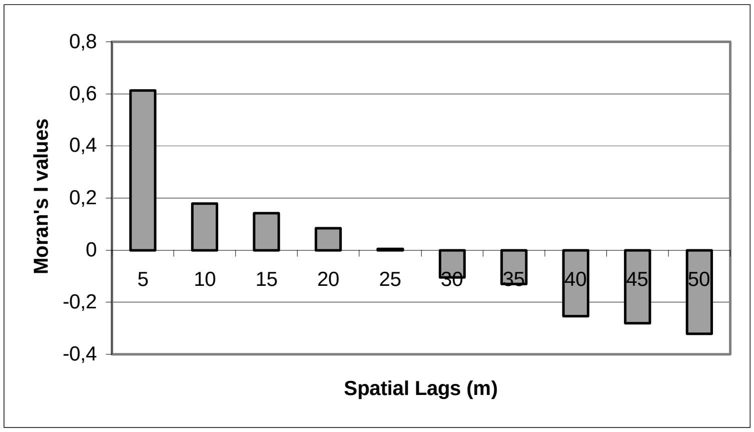


Figure 5.34. Correlogram for A1

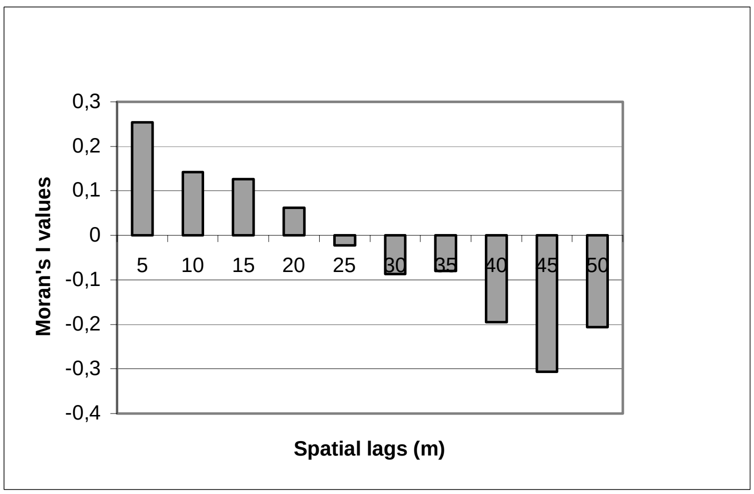


Figure 5.35. Correlogram for A2

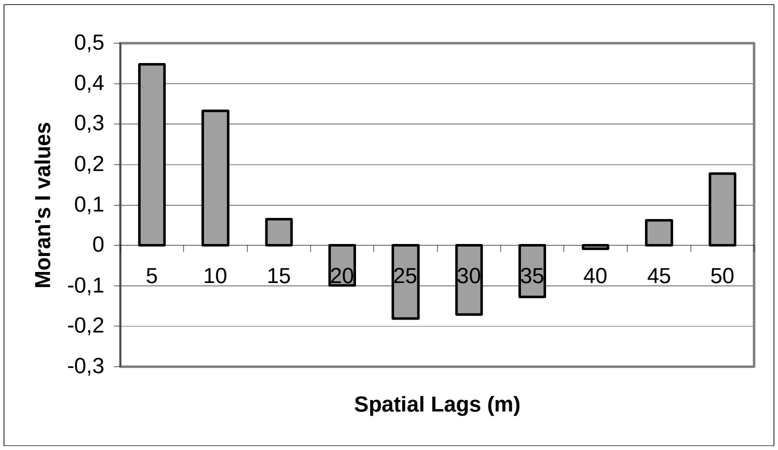


Figure 5.36. Correlogram for A4

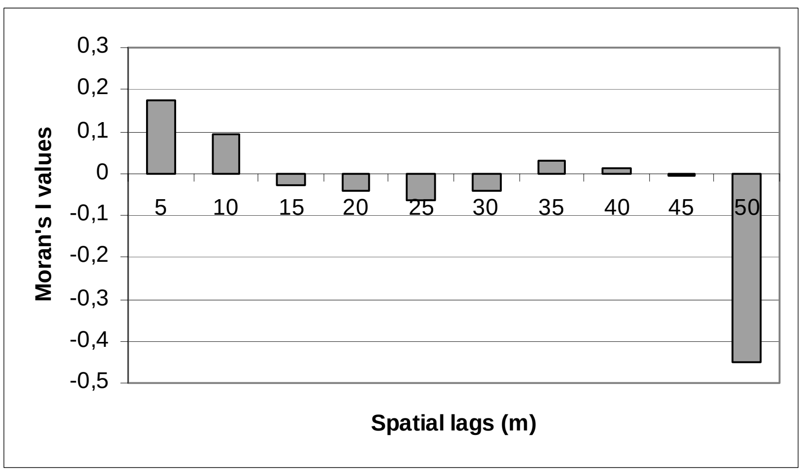


Figure 5.37. Correlogram for B

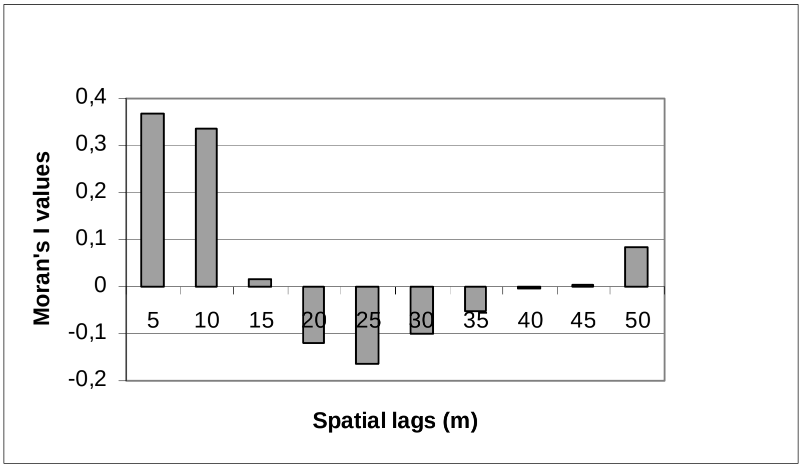


Figure 5.38. Correlogram for F

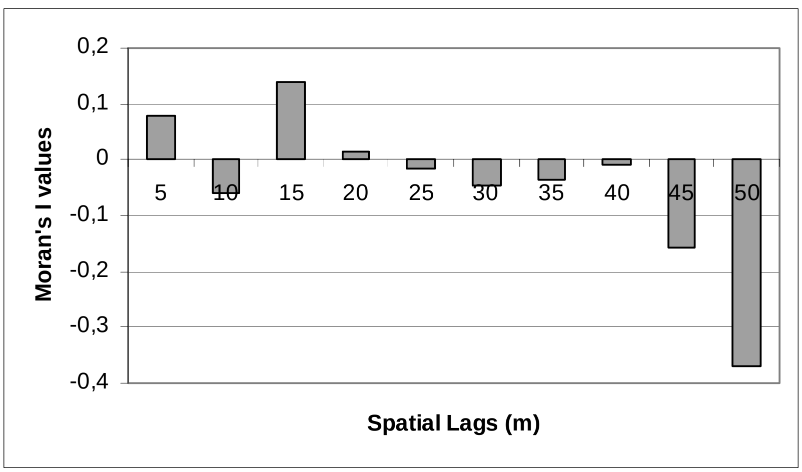


Figure 5.39. Correlogram for T

Figures 5.34-5.39 relate the intra event interaction on different distances. Like the K function in the point dataset, there is variation of clusters in different spatial lags. Especially group A1 and A2 are distributed very compact in a distance of 15m (Figures 5.34-5.35). However, group A4 has correlation in long distances such as 50m, considering the population density of group A4, it can be confusing as well (Figure 5.36). Group F is showing the same correlation parameter too, this can be interpreted as more than one density locations in the study area (Figure 5.38). At this point the density maps are very useful for seeing the density centers. On the other hand, in Figure 5.39, group T is reflecting a character of scattered phenomena overall of the area having any clusters on short distances.

5.2.3. Conventional data analysis

According to the consultations with Prof. Dr. N. Tuna, the meaningful couples of artifact groups are set for association analysis. There are 37 couples of artifact types which are tested for their degree of existence in the same quadrat. A transformation of combining the groups B and F is carried out as they are pointing the same characteristics for space.

Gamma coefficients generally are not very high or low, there are no sharp relations between the groups. In order to test the significance of the outcome of gamma coefficient $\chi 2$ test is applied for both 99% and 95% levels. In this scheme, the null hypothesis (H_0) is formulated as:

H_0: The correlation is due to random effects (The correlation coefficients are not statistically significant)

H_0 is rejected if the index is greater than the significance level, otherwise it is not rejected. For significance levels of 99% and 95%, there are only 7 couples are seems to be correlated (Table 5.6)

Table 5.6. Gamma coefficients for selected sub-groupings

Group1	Group2	Gamma	$\chi 2$	99%	95%
A1	A3	0,286	5,145	ACCEPTED	REJECTED
A1	A4	-0,242	3,693	ACCEPTED	REJECTED
A4	A6	-0,311	6,086	ACCEPTED	REJECTED
CF	A6	1,000	63,000	REJECTED	REJECTED
CF	A3	0,787	39,003	REJECTED	REJECTED
BF	T	0,372	8,723	REJECTED	REJECTED
BF	A3	0,352	7,805	REJECTED	REJECTED

5.2.4. Inference

Some of the analyses yield similar results others do not. In this step of the study, it is aimed to clarify the implication of analysis in archaeological point of view.

Quadrat analysis tells the archaeologists that the area is “worth” studying there is a global clustering in the all of the artifact groups. But it is limited only to this extent. In Kernel estimations, groups A1-A7 are clustered in different locations. They depict changes in land-use pattern in time (Figure 5.40). Group A6 and A7 are very low in population, so their locations can be disregarded. Other groups’ density distributions are similar to the groups A1-A7. These similarities can help to state the production dates of these groups (Figure 5.40). In other words, the landuse pattern for various time periods can be seen in Figure 5.40.

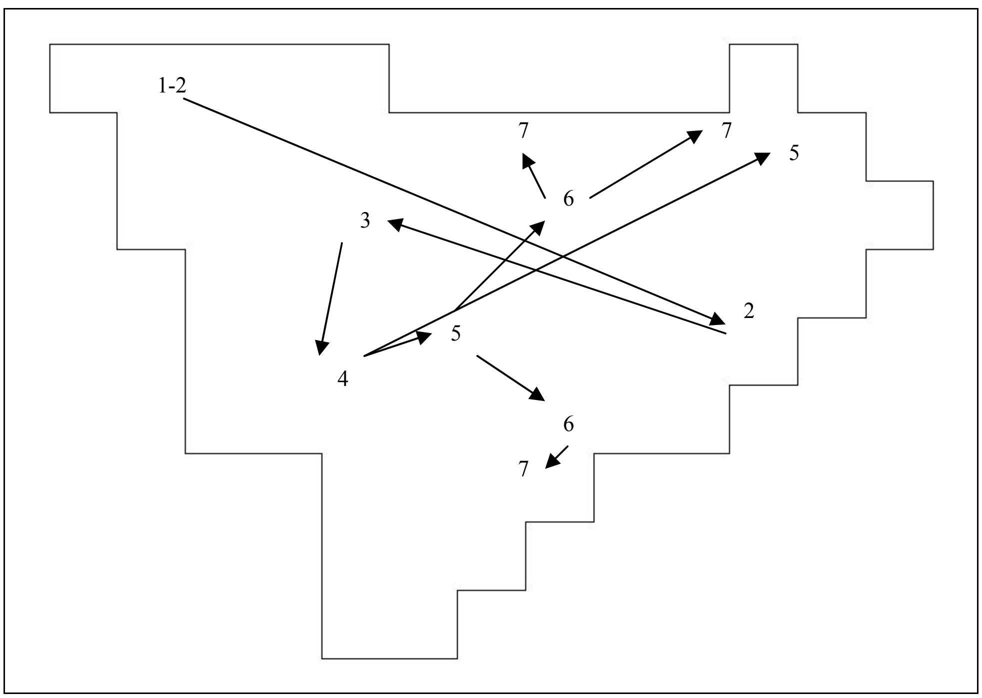


Figure 5.40. Diagram showing the movement of the densities in a chronological order derived from Kernel estimates

Group B, F and T illustrate kiln or dump area activity, such two locations of them are produced in Figure 5.41, one in the south-western part another in the northeastern corner. One of the most populated group, CF, is located with the location of groups A1, A2, A4, A5. Group CC's location is only near the group A4.

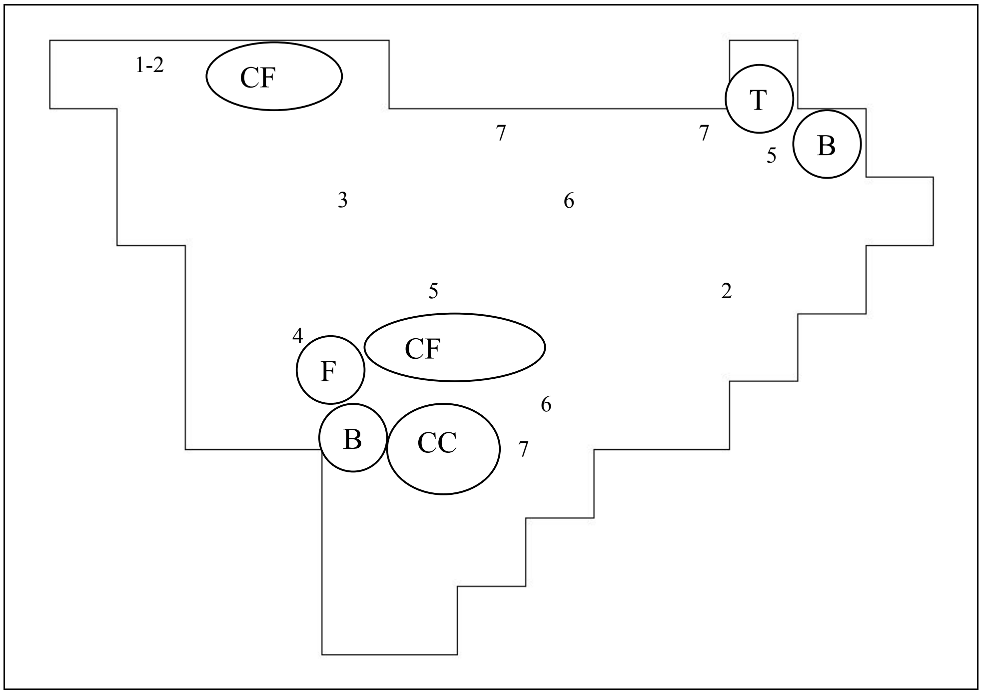
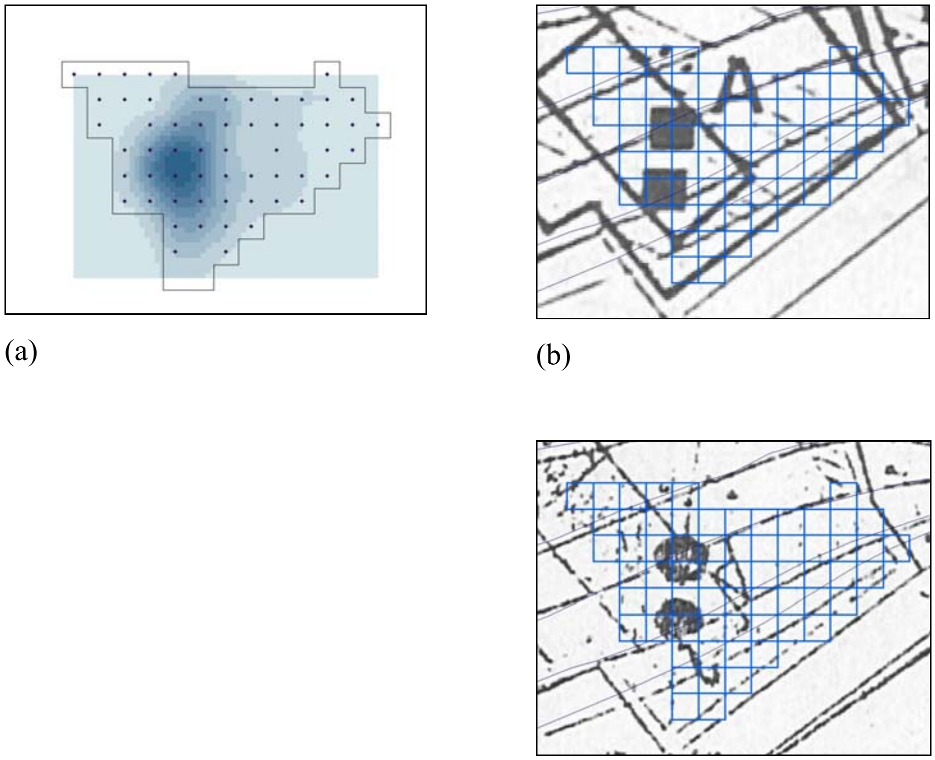


Figure 5.41. Locations of densities groups B, CC, CF, F, T with groups A1-A7

Dual Kernels show the difference of relative densities in different time periods. Their final interpretation can be the domination of group A4 in all of the sections. Besides, some density distributions such as A6 and A7 can be disregarded because of their low level of occurrence. In areal analyses the results are not as clear as it was the case with point distribution because of the grid size. Choropleths point out certain concentrations, but it is not clear. Cartograms for certain groups are meaningful. Results obtained for Spatial moving averages techniques are more or less similar those obtained in Kernel estimations.

The real assessment of the results of a statistical study is to know the pattern which is investigated. The information of excavation results and geophysical survey can be the real evaluator of the spatial statistical studies' reliability. A layer created from excavation results (Tuna, 1991) is used for comparison.



(a) (b) (c)

Figure 5.42. (a) Kernel density for group A4, (b) Locations of a kiln and its deposit, (c) locations of anomalies in geophysics survey

In the figure 5.42 (b), there are 2 squares which are denoting the location of a kiln and its dump area. (a) Part is the Kernel estimation of group A4 that is the most populated group in the area. They are seemed to be overlapping which is tested in an overlay map of them in Figure 5.43. The red ellipse is showing the density area of the group A4 and the locations of kiln and dump area (Figure 5.44).

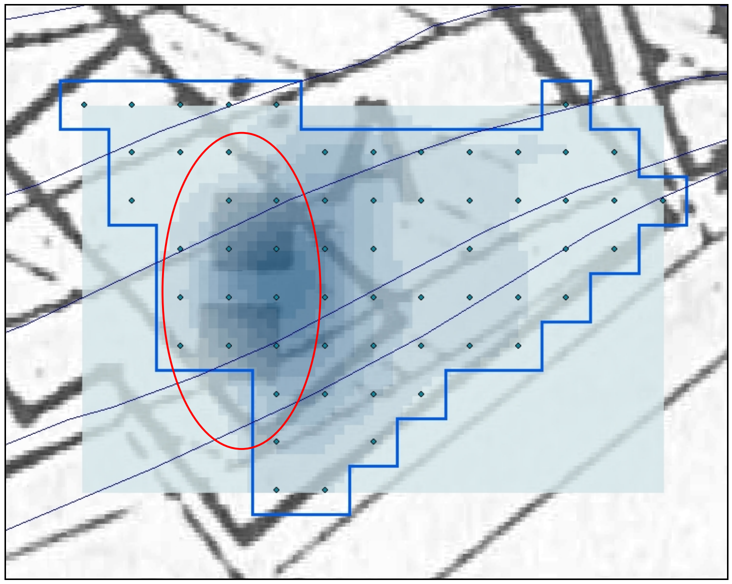


Figure 5.43. Overlay of kernel density of group A4 and location of the kiln

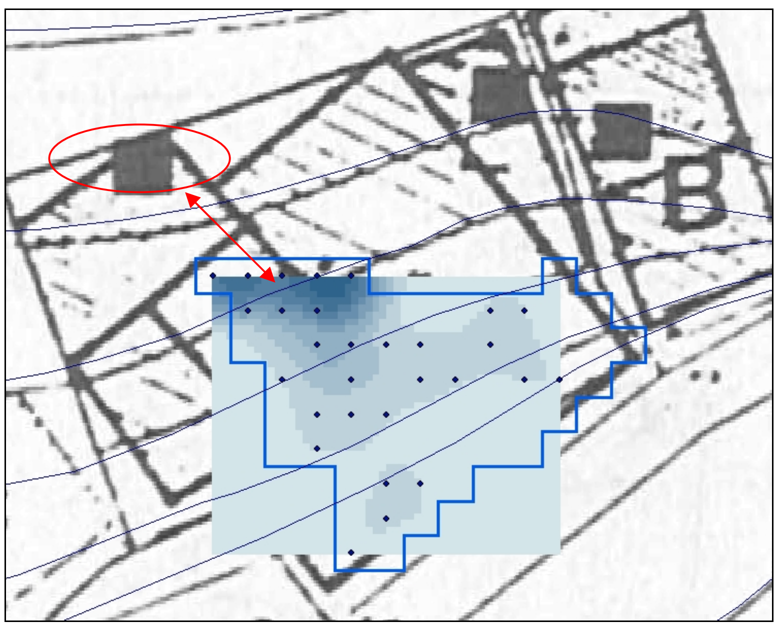


Figure 5.44. Overlay of kiln locations and kernel density of group A1

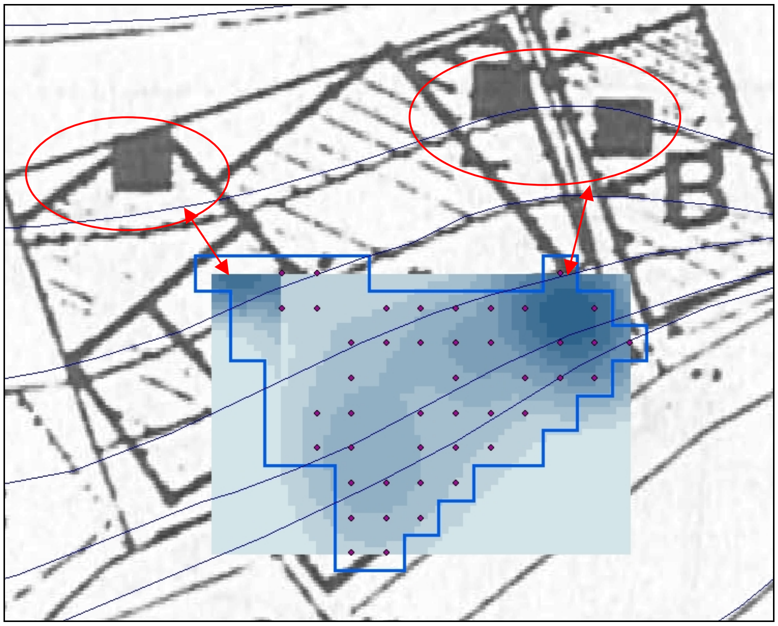


Figure 5.45. Overlay of kiln locations and kernel density of group T

Other concentrations such as group A1 and group T that took place in different parts of the study area could be caused by the another outside kiln around the survey area (Figure 5.44 and 5.45)

The results of all the spatial statistical techniques integrated with GIS capabilities generally seem to function efficiently, which are compared with excavation results.

5.3. Discussion of methods

It is obvious that the areal visualization techniques are the only way of visualizing such data. However, if the data is originally in point format dotmaps can give an idea about the distribution too. Techniques of choropleth and cartogram are both dimensioning the data according to the attribute of it, former according to color latter size. There are many cartogram techniques, but because the data is in a regular "cell" form, changes in the area of the polygons are not reflecting the distribution very well when the data is highly populated.

Choropleths are the most reliable technique for visualizing areal data collected in regular grid format.

Point dataset always has an advantage of variability of analyses in the field. However, it is not always possible to collect point data if number of artifacts is too high and the study region is relatively large. Another issue is the loss of information during the conversion to point data from area data. Although the artifacts are locating in the different part of a 5x5 square, they are considered as on a point, centroid of the grid. If the size of the study area is large enough this effect can be negligible. However, in very micro level studies like excavation data of housing unit, this loss must be considered.

In point dataset, especially the Kernel estimation and K Function gives very valuable results that can be interpreted. Kernel estimation results and Spatial Moving averages results overlap. Thus, Kernel estimates have the opportunity of changing resolution of the output. Kernel estimation results have grid size of 1m where spatial moving averages can only have 5m. So, point conversion does not disturb the results; also increase the efficiency in these analyses. Median polishing did not provide useful results mainly caused from insufficient number of cells. It is based on "polishing" the outliers in the rows and columns of grid data. In the result of this analysis limited rows or columns are affected and the trends cannot be seen. If many columns or rows are together like hundreds or thousands (may be pixels of an image) the result becomes more interpretable.

Second order analyses of point dataset were nearest neighbor and K function. As mentioned in the chapter III, being K function already amore advanced technique than nearest neighbor, in the study nearest neighbor yields misleading results because of the conversion. In catching global trend, conversion from area to point dataset did not affect the results but this time because the subject is about inter-event interactions the result become regular because of the above mentioned problem. In other words, minimum distance is always constant. K Function deals with not only minimum distance, all distances that are studied, that's why the proper second order analysis technique in this case becomes K Function. Correlogram and K Function are showing parallel results.

Calculating gamma coefficient has been used for many years by archaeologists; it is a valuable tool when testing the results of the spatial visual results of the analyses. It gives an idea of correlation between artifacts and the location of them can be estimated by the former analyses.

CHAPTER VI

CONCLUSION

The results of the analyses in this study at all levels are affected by the nature of the initial collected data. Some results give meaningful results for archaeologists, while others are not. Through all of the analyses just a part of the site is studied and meaningful and useful results for archaeologists can be achieved for further researches. No matter what kind of dataset is being used, GIS integrated with spatial statistical techniques assists usefully the field observations of archaeologists. In fact, some of the results of the analyses may be already known by the field observations. Thus, this limited study methodology can be implemented in broader terms in archaeological sites where field observation could be misleading because of the artifact intensity and extent of the site. In this framework, an instance of GIS based spatial analysis for archaeology is achieved and the capability of techniques is introduced. Some archaeological outcomes of the study can be listed as follows:

- The study area is a location for probable kilns
- 3 different locations of kilns are identified. They were active from late IV. century BC to II. century BC. Especially in II.century BC, the activities are intensified and located in the mid-west part of the study area.
- Fine ceramic as a side product is produced from late IV. century BC to II. century BC in two different kilns.
- Most dominant period of production is II. century BC.

The results for used methods are:

- The techniques in themselves are inadequate for analysing or directing an archaeological study alone, they should be taken up supplementary tools.
- Loose coupling method has a disadvantage of attaining most suitable results. In order to have proper technique to be applied close coupling method can be more appropriate.
- Both point and area gives useful results. However, as the point data has advantage of producing results in higher resolution, yield clearer results.
- Kernel Estimation and spatial moving averages give best results for catching global trends. Those techniques can be used as standard for distribution of artifacts.
- Median polish method is the most deficient and the validity of nearest neighbor analysis is dependent to the type of the data. However, they still can give meaningful results, with properly collected data.

Being an “explorative” study, analyses can be considered unfinished. On the other hand if the proper techniques are used, final stages of the analyses can be performed for modeling the distributions, in other words creating surfaces of probabilities of distributions which can be the subject of another study.

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APPENDIX A

SURVEY DATA OF FORMER STUDIES

Table A.1. Sample of original tables of artifacts

carre	d1	d2	d3	d4	d5
NE.001.002	B		2	V	
NE.001.002	B		2		
NE.001.002	T		2		
NE.001.002	T		2		
NE.001.002	T		2		
NE.001.002	A	H	4		
NE.001.002	A	H	4		
NE.001.002	A	H	4		
NE.001.002	A	H	4		
NE.001.002	A	H	4		
NE.001.002	A	H	4		
NE.001.002	A	H	5		T
NE.001.002	A	B	4	S	
NE.001.002	A	B	4		
NE.001.002	A	B	4		
NE.001.002	A	B	4		
NE.001.002	A	B	4		
NE.001.002	A	P	4		
NE.001.002	A	P	1		
NE.001.002	U	L	0	B	
NE.001.002	U	L	0	V	
NE.001.002	U	L	0		
NE.001.002	U	L	0		
NE.001.002	U	L	0		
NE.001.002	U	L	0		
NE.001.002	U	L	0		
NE.001.002	U	R	0	B	
NE.001.002	U	R	0	B	
NE.001.002	U	R	0	B	
NE.001.002	U	A	0		
NE.001.002	U	A	0		
NE.001.002	U	F	0		

d1 is denoting the type of the artifact, d2 is denoting the art of the artifact (base etc.) and d3 is denoting assigned time periods of them.

Table-A.2. Samples of original terminology for the coding system (in French)

d1
A (amphore)
B (brique)
C (couvercle)
D (disques
E (bol megarien)
F (coulee de four)
I (incertain)
J (cuvette jatte
K (coupe)
L (lampe)
M (monnaie)
N (lagynos)
O (oinochoe)
P (pithos)
R (ceramique
S (assiette)
T (tuile)
U (ceramique
V (vase a piedroit)
G (pot) pelike
H (jug)
S (metal slag)
W (pergamene terra sic.)
X (mangal)
Z (amphora base)

APPENDIX B

CHOROPLETH MAPS

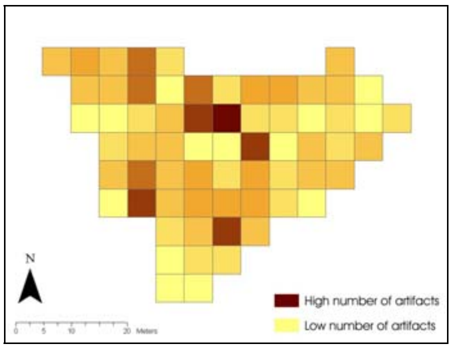


Figure B.1. Choropleth map of group A3

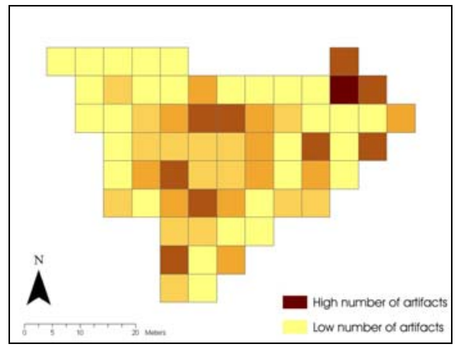


Figure B.2. Choropleth map of group A5

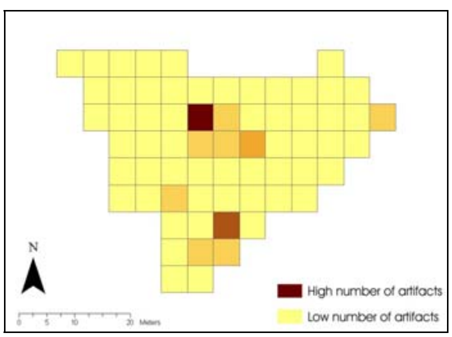


Figure B.3. Choropleth map of group A6

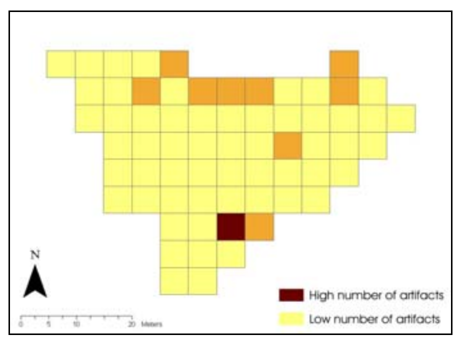


Figure B.4. Choropleth map of group A7

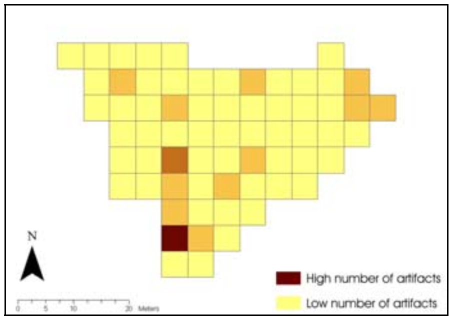


Figure B.5. Choropleth map of group CC

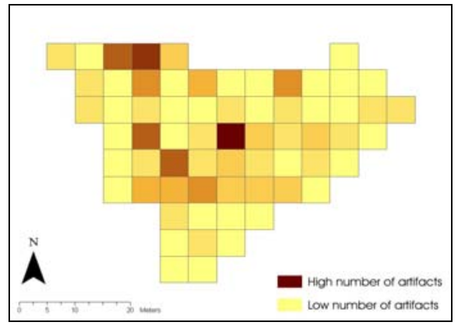


Figure B.6. Choropleth map of group CF

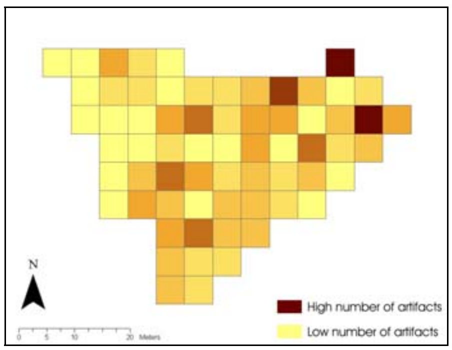
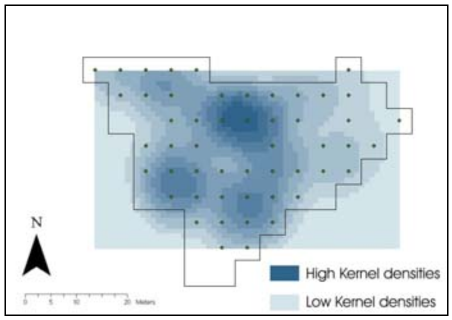


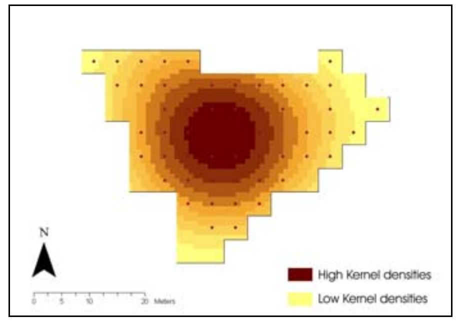
Figure B.7. Choropleth map of group T

APPENDIX C

KERNEL ESTIMATION MAPS

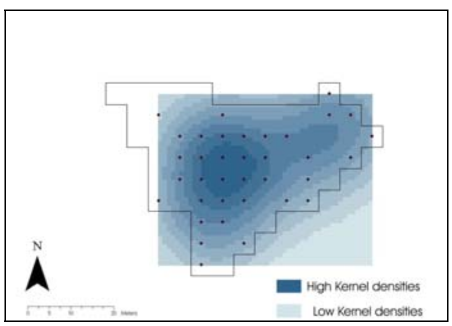


(a)

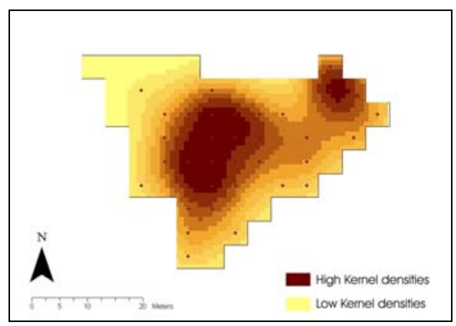


(b)

Figure C.1. (a) Kernel estimation of group A3 in spatial analyst, (b) Kernel estimation of group A3 in Crimestat

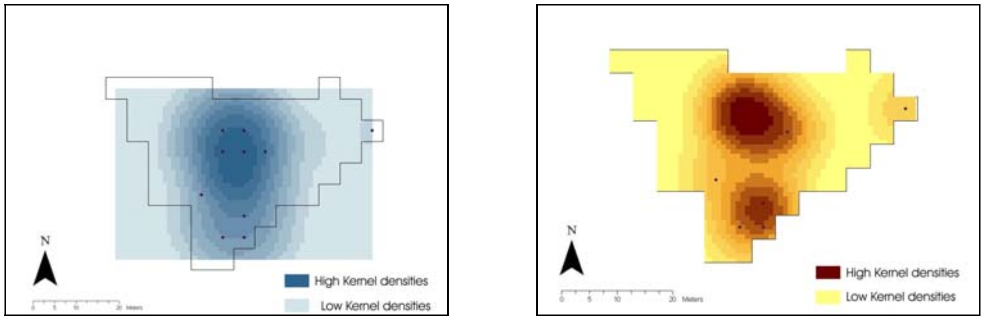


(a)



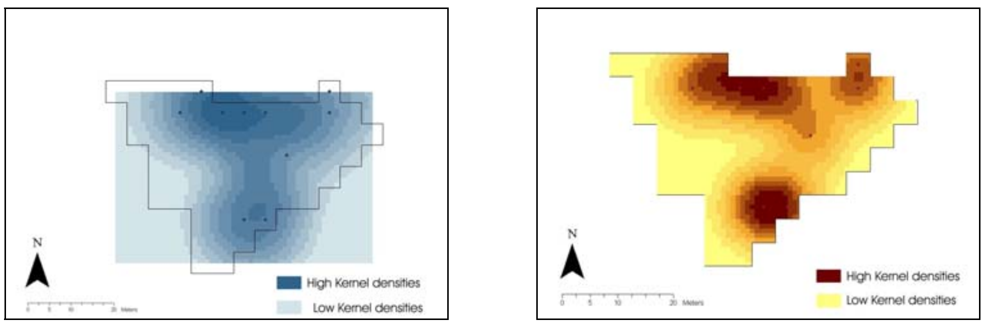
(b)

Figure C.2. (a) Kernel estimation of group A5 in spatial analyst, (b) Kernel estimation of group A5 in Crimestat



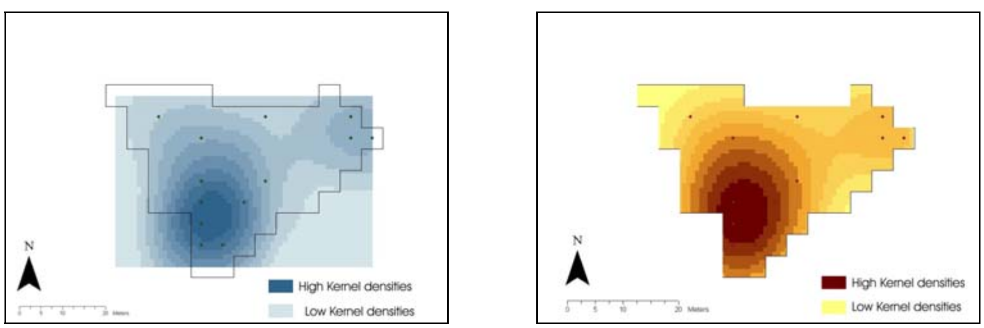
(a) (b)

Figure C.3. (a) Kernel estimation of group A6 in spatial analyst, (b) Kernel estimation of group A6 in Crimestat



(a) (b)

Figure C.4. (a) Kernel estimation of group A7 in spatial analyst, (b) Kernel estimation of group A7 in Crimestat



(a) (b)

Figure C.5. (a) Kernel estimation of group CC in spatial analyst, (b) Kernel estimation of group CC in crimestat

APPENDIX D

MEDIAN POLISHED MAPS

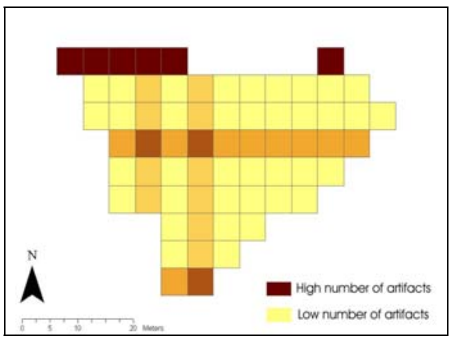


Figure D.1. Median Polished map of group A1

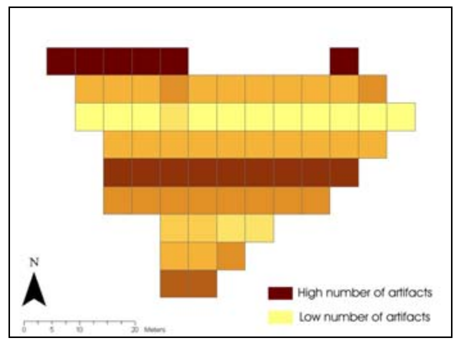


Figure D.2. Median Polished map of group A2

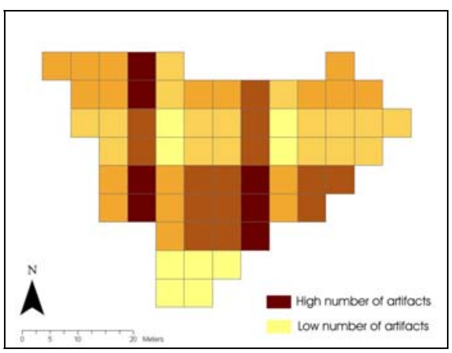


Figure D.3. Median Polished map of group A3

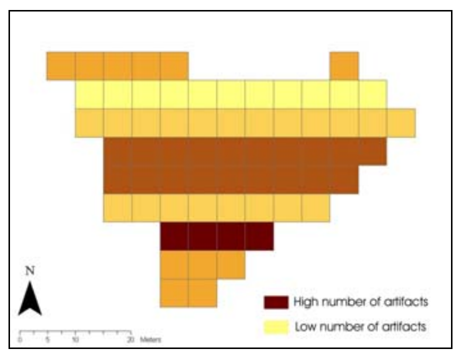


Figure D.4. Median Polished map of group A4

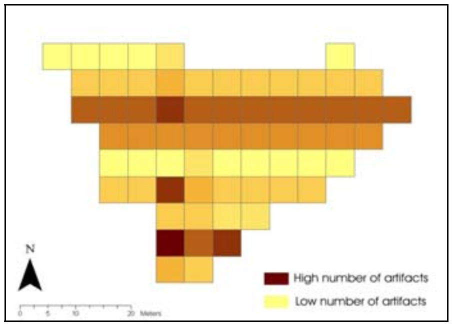


Figure D.5. Median Polished map of group A5

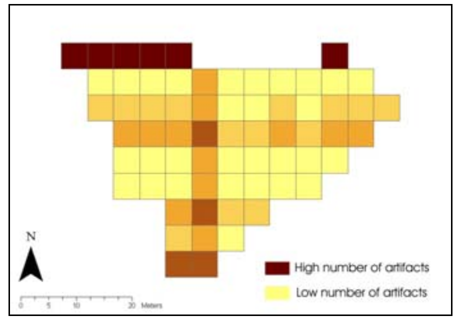


Figure D.6. Median Polished map of group F

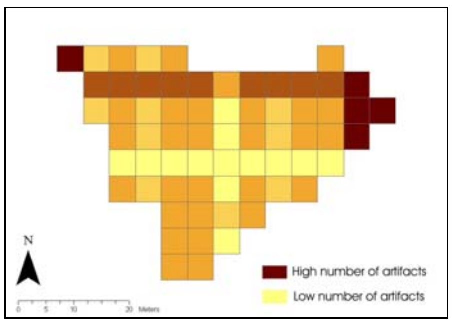


Figure D.7. Median Polished map of group B

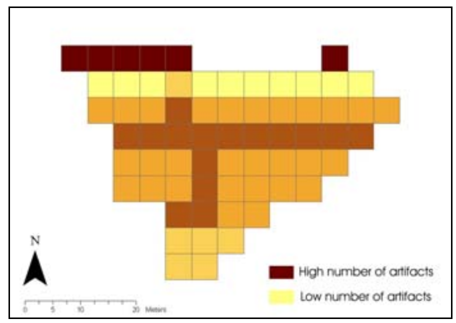


Figure D.8. Median Polished map of group T

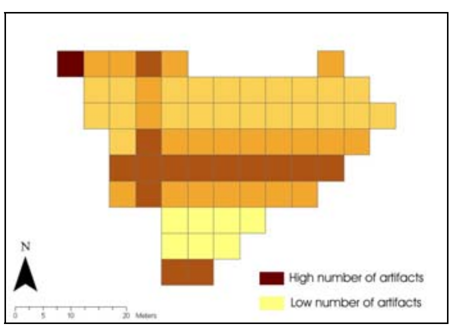


Figure D.9. Median Polished map of group CF

APPENDIX E

GRAPHS OF K- FUNCTION

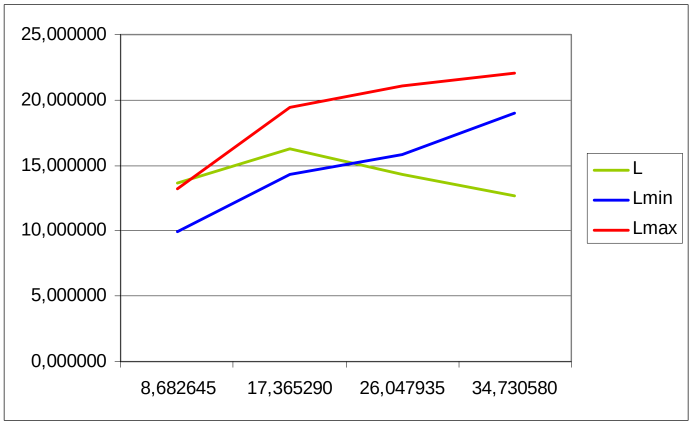


Figure E.1. Graph of L values of A1 distribution

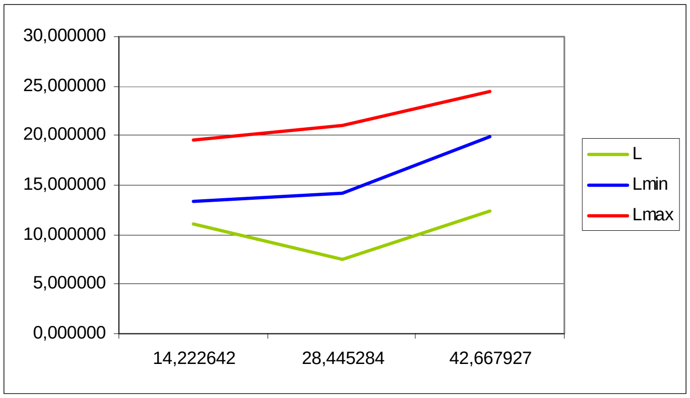


Figure E.2.Graph of L values of A2 distribution

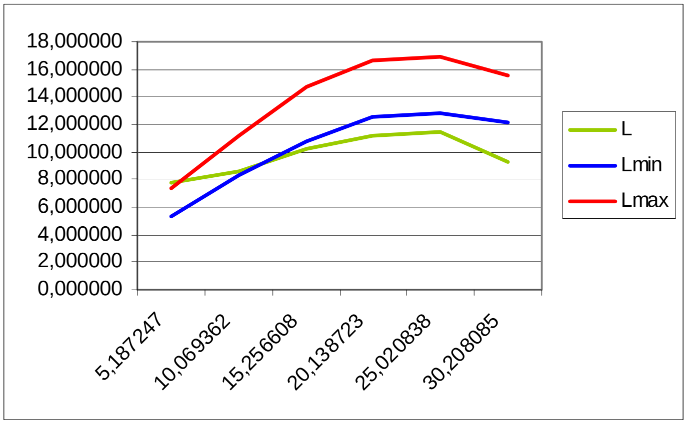


Figure E.3. Graph of L values of A3 distribution

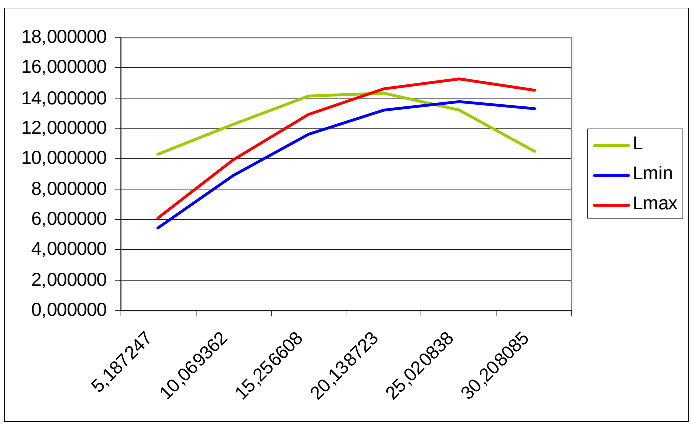


Figure E.4. Graph of L values of A4 distribution

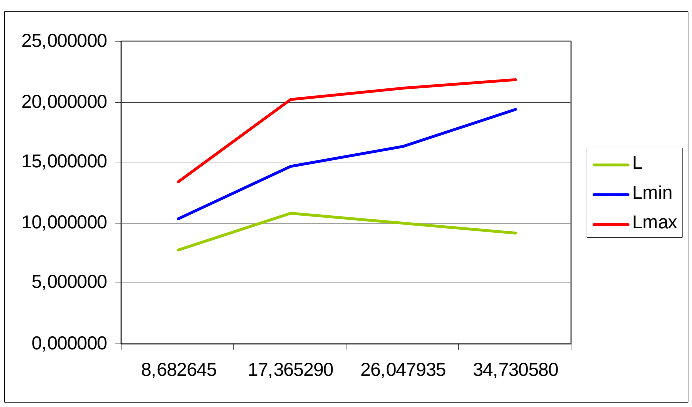


Figure E.5. Graph of L values of A5 distribution