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FROM MICRO TO MACRO SPATIAL DYNAMICS IN THE VILLAGGIO DELLE MACINE BETWEEN XIX-XVI CENTURY BC

by
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Thesis submitted for the degree of Doctor in Prehistoric Archaeology

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9.GEOSTATISTIC INTRA-SITE SPATIAL ANALYSIS

The site of Villaggio delle Macine: the area surveyed in 2012

9.1 Introduction

This chapter is devoted to the analysis and results of intra-site spatial analyses of the areas surveyed in 2012 at the Villaggio delle Macine. We begin by analysing the absolute counts of archaeological observations, by mixed all identified materials together in the way of a palimpsest. It is used as null-hypothesis for the separated analysis of each archaeological category, according to the discussion in previous chapters. For a spatial correlation perspective, multidimensional analysis integrates all selected categories. The step-by-step procedure is the following one:

1) Plot of locations where some element has been detected (x, y coordinates of grid centroids)

2) Density analysis of single presences (Kernel Density Estimate) and Statistical Relevance of the null hypothesis of Spatial Randomness

4) Statistical Description of the Spatial Distribution. Measures of Central Tendency.

5) Plot of Spatial Frequencies (Lorenz curve, 3D Histogram). Weighted Measures of Central Tendency. Statistical Relevance of the Null Hypothesis of Spatial Randomness

6) Semivariance Modeling and Spatial Interpolation. Kriging

7) Spatial Correlation

In summer 2012, a further survey was carried out in the surrounding of areas already explored in 2009, reaching the lake's edge and a portion until that moment partially covered by flora, consisting of both reeds and small or medium bushes (for more details see Chapter 6). Such zones are included in this analysis. At South-West of sector surveyed in 2009 was spatially distributed a first sector (defined Zone 1); it was divided in 273 cells, summing u to 68.25 square meters (Convex Hull=881.63). On the North-East corner of zone surveyed in 2009 a further sector (defined Zone 2) was identified in 2012 and divided in 661 cells, summing up 165.25 square meters (Convex Hull=2009.4) (Figure 680).

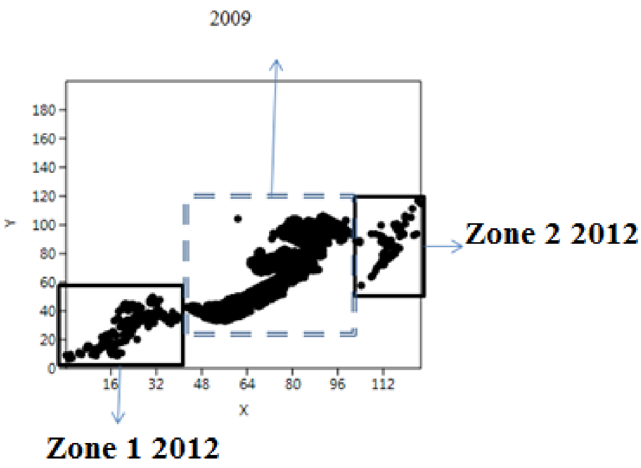


Figure 680 Spatial distribution of sectors surveyed during 2009 and 2012 (Area 1 and Area 2).

9.1.2 Absolute count of archaeological observations (palimpsest) within Zone 1

432 archaeological observations (ascribable to all the categories identified during survey of 2012) were identified and counted within Zone 1. 15 were the surveyed empty cells, while the sampling unit with more presence gave 6 archaeological remains. The spatial distribution of only those sampling units with material evidence is showed in Figure 681.

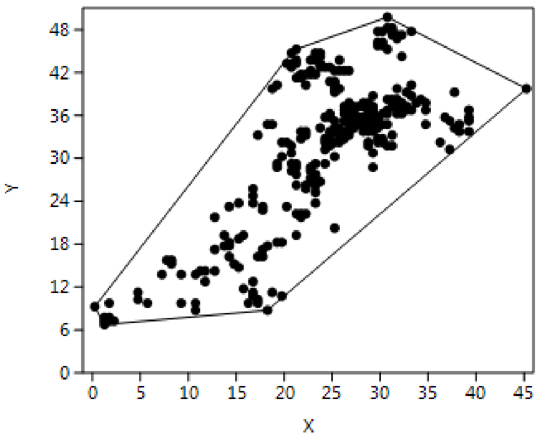


Figure 681 Spatial distribution of findings recovered in the area surveyed during 2012 (Past).

Ripley's *k* analysis on the distance between sampling units with all material evidence gives support to the hypothesis of spatial clustering in two main sub-sectors, within the reference area (Figure 682).

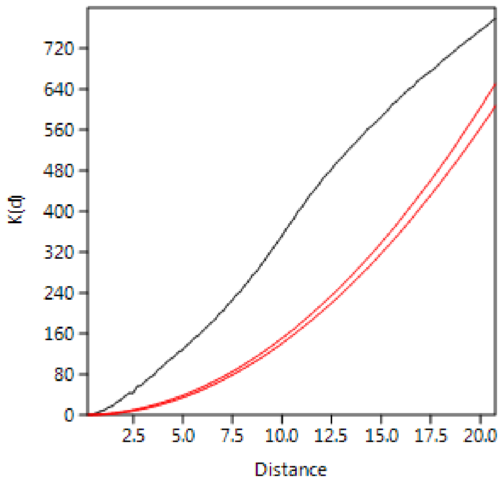


Figure 682 Ripley's *k* analysis on the distance between sampling units with all material evidence recorded in surveys of 2012 (Zone 1) (Past).

Within the convex hull defined by the effectively surveyed cells, the Kernel Density Estimation of non-empty cells (cells where a minimum of 1 single archaeological observation has been recorded) shows a predominant concentration between x=16-35 and y=25-45, with lower dense concentrations between x=10-15 and y=14-20 and between x=25-30 and y=44-50 (Figure 683). Such 258 surveyed non-empty cells are, according to Clark and Evans test, statistically significant clustered ($p<0$). Only 15 surveyed cells were proved to be empty and, according to Clark and Evans test, for them the null hypothesis of random pattern (Poisson process) can not be rejected at $p<0.05$.

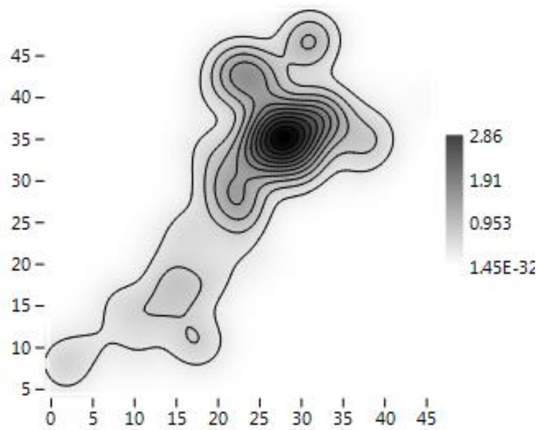


Figure 683 KDE of non-empty sampling units where any kind of archaeological evidence has been recorded in surveys 2012, within Zone 1 (Past).

When considering the raw quantity of archaeological observations at each cell, the probability density distribution of spatial frequencies clearly follows a J-shaped distribution. A majority of sampling units have raw counts of archaeological observations of less than 2 elements (global mean=1.67 observations per sampling unit). Three cells are distinguished from the majority with 4, 5 and 6 observations (interpretable as outliers). Both histogram and the box plot show a break point within the distribution corresponding to 3 frequencies for sampling unit (Figure 684).

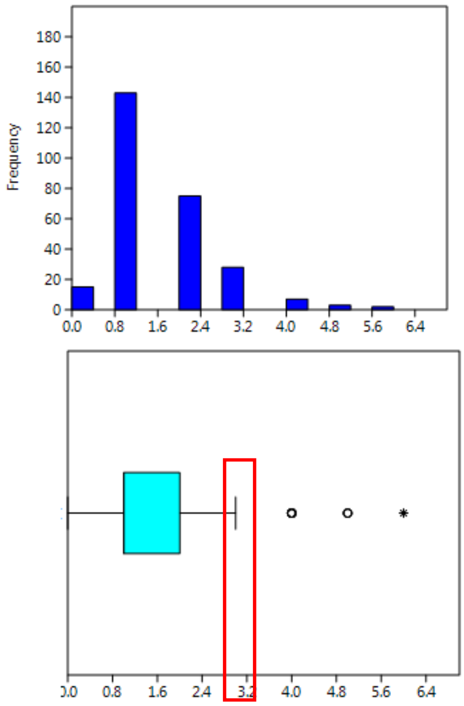


Figure 684 Histogram and box plot of frequencies observed for all material evidence summed up (Past).

A Lorenz Curve (Figure 685) gives a Gini Coefficient of 0.3084, with a 95% Bootstrap confidence interval between 0.274 and 0.330. The Coefficient of asymmetry is 0.9146, with a 95% Bootstrap confidence interval between 0.804 and 1.052. In general, we can see that 30% of all archaeological observations have been found at 80% of sampling units and the remaining 20% sampling units concentrate more than a half of the count data (70%). This result gives us an idea of the quantitative differences of materials accumulated at differentiated cells.

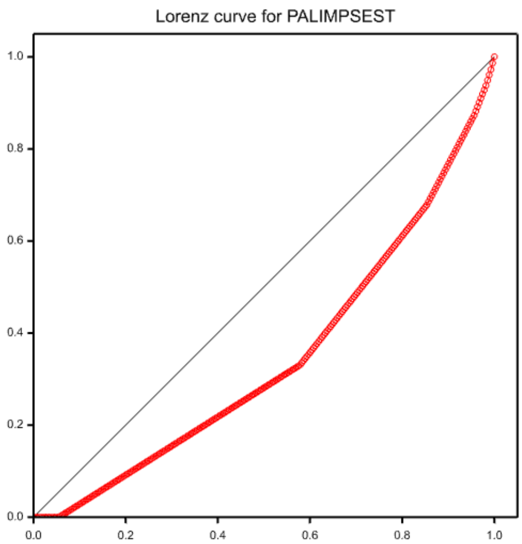


Figure 685 Lorenz Curve for all material evidence recovered during surveys of 2012 (Genstat).

A very irregular and scarcely homogeneous distribution is observed (Figure 686), which does not fit with an exponential theoretical model of intentional discard at a fixed center (tested using K-S tests, p<0 in all cases).

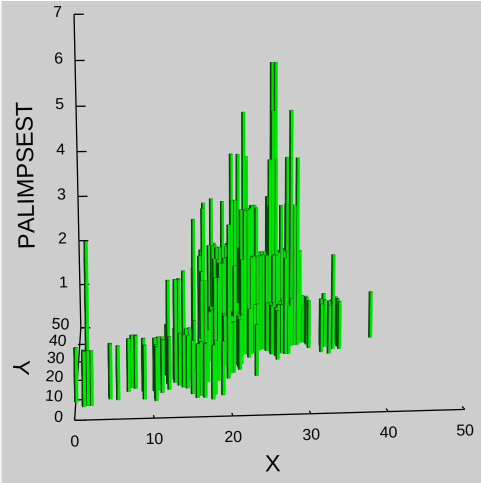


Figure 686 3D Histogram of all material evidence recovered during surveys of 2012, within Zone 1 (Systat 13).

87% of all archaeological observations are located in 95% of the effectively surveyed area, in such a way that only 5% of cells show more than 3 items and they are distributed in 13% of the effectively surveyed area.

The spatial distribution of count data per sampling unit shows a Global Moran's *I* of -0.003419. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is -0.003676 and the standard error of I is 0.003677. The test of significance using the normality assumption gave a highly non-significant z value of 0.070029. Consequently, we can accept that the spatial distribution of the general palimpsest could be only partially different than the expected value under a random distribution. However, the mixture of too much different intentionality mixed and summed up, could have produced such pattern. These results are comparable with those of the Geary statistics (1.000901) and Getis-Ord general G (=0.017763).

The Moran's *I* Correlogram (Figure 687) has been calculated for uniform class distance intervals of 1 meter and taking into account a 10 meters active lag distance. At the starting point *I* value is 0.529, above the expected value for randomness. When the distance between sampling units increases, *I* value drops off abruptly reaching values on the line (corresponding to spatial randomness) at 2 meters. Between the starting point of the function and until 3 meters is thus attested positive spatial autocorrelation. *I* values are above those expected for randomness at 3 and 4 meters and from such distance they are predominantly distributed on or below the line.
This result gives the possibility of identify positively spatially dependent areas of 3 meters of radius, what is suggestive working hypothesis for locating homogeneous activity areas.

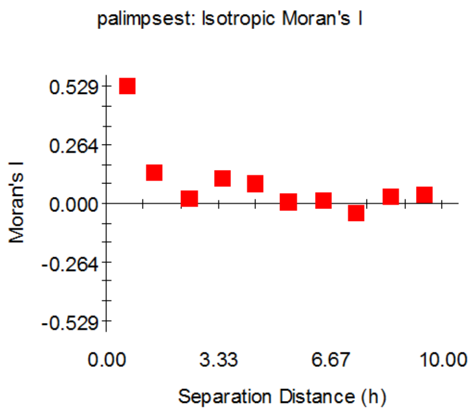


Figure 687 Moran's I Correlogram for all evidence recovered during surveys of 2012 (Zone 1) (GS+)

In order to verify if exists anisotropy, we have calculated anisotropic variograms at different directions (Figure 688).

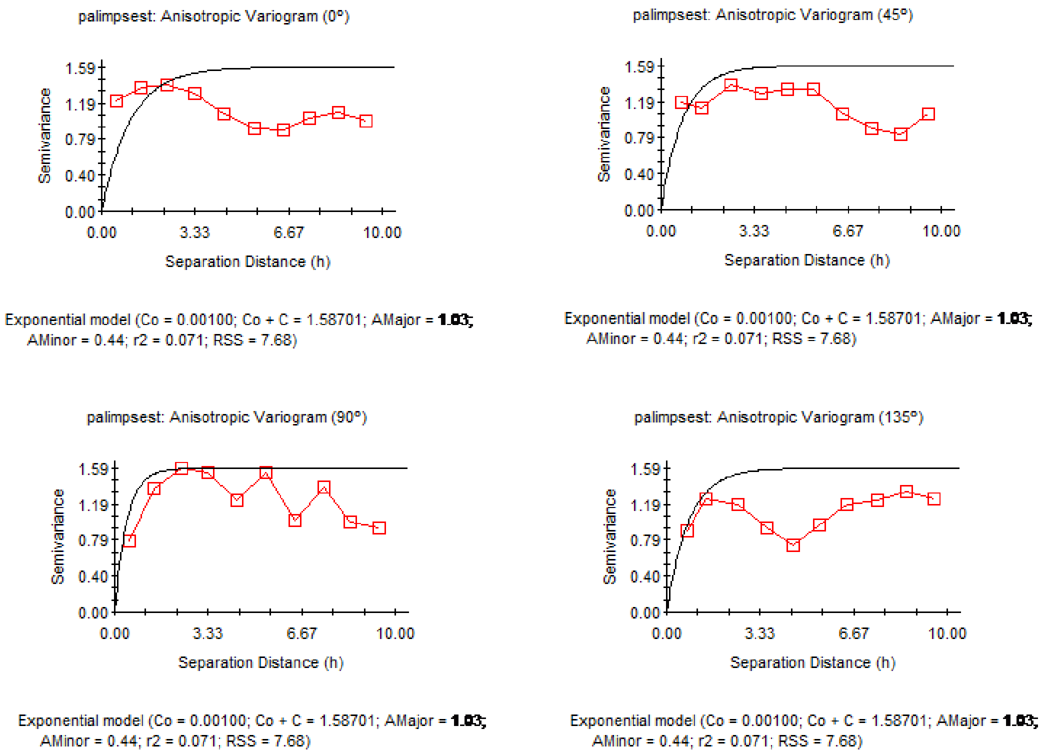


Figure 688 Anisotropic Variogram of all material evidence recovered during surveys of 2012, Zone 1 (GS+).

Results show that semivariance varies in different ways in the 0º, 45º, 90º and 135º; The Semivariance Surface or Variogram Map (Figure 689) shows a widespread anisotropy scattered within the surveyed area. It is quite absent spatial continuity.

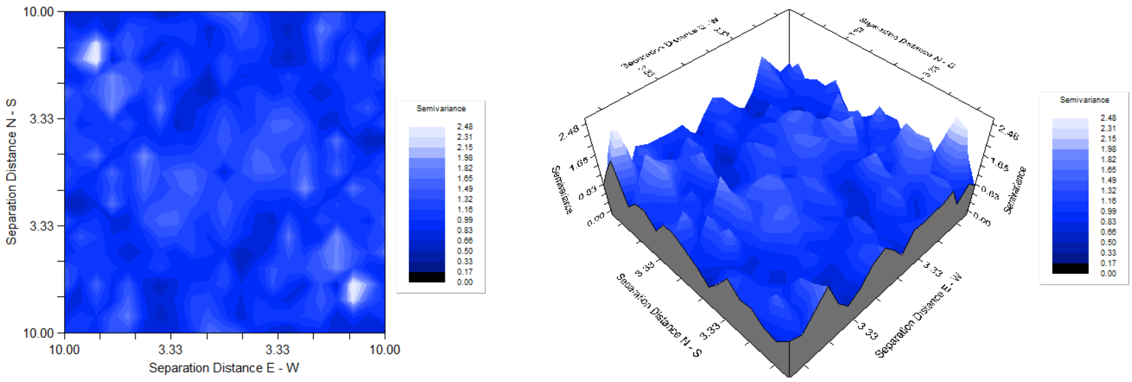


Figure 689 Variogram Map of all material evidence recovered during surveys of 2012 (Zone 1) (GS+).

An exponential isotropic variogram model (Figure 690) has been fitted to the empirical variogram. In this case C_0 (nugget variance) =0.30200, C_0+C (sill) =1.16900 and A_0 (Range) = 0.32.

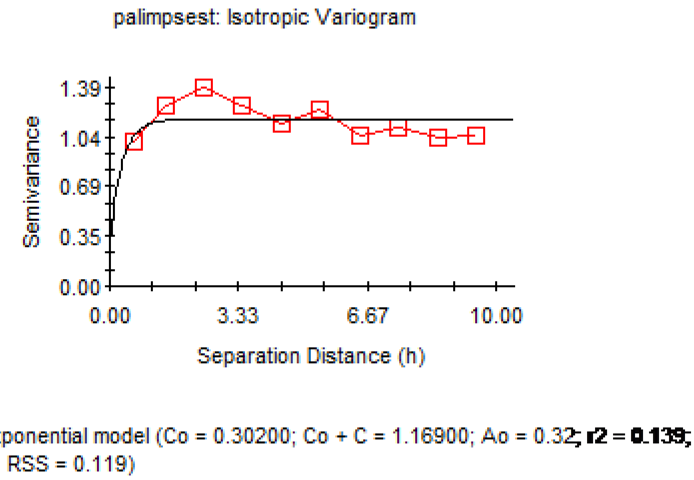


Figure 690 Exponential Isotropic Variogram for all material evidence recovered during surveys of 2012 (Zone 1) (GS+).

This model explains 13.9% of sample variance, showing a very poor goodness of fit. With this particular variogram, we have estimated the global variation of the total number of archaeological observations, using an Inverse Distance Weighting (Figure 691).

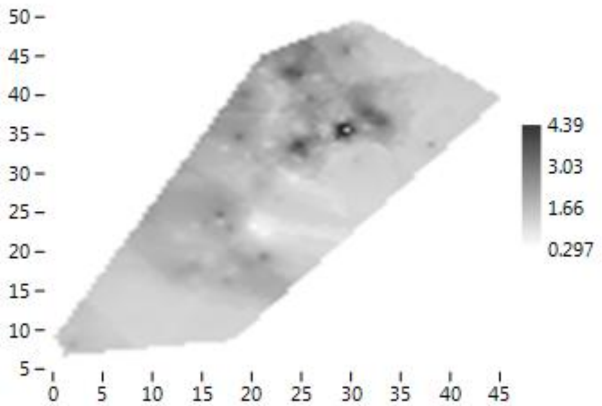


Figure 691 Graphic results of Inverse Distance Weighting calculated for all material evidence recovered during surveys of 2009 (Past).

This visualization shows the scarce spatial dependence between cells, that is observed particularly for those with highest frequencies, concentrated around the North-East corner of the surveyed area.

9.1. 3 Vertical posts within Zone 1

164 posts were identified and counted. 126 were the surveyed empty cells, while the sampling unit with more presence gave 3 posts. The spatial distribution of sampling units where posts have been identified is showed in Figure 692.

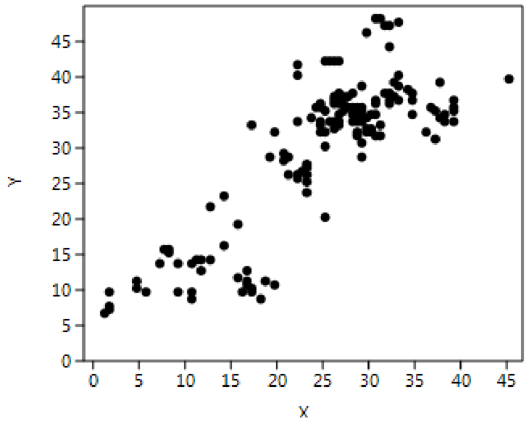


Figure 692 Spatial distribution of sampling units where posts have been recorded during surveys 2012 within Zone 1 (Past).

Ripley's *k* analysis, for all the reference area, on the distance between sampling units with posts evidence, suggests the possibility of some degree of spatial clustering (Figure 693).

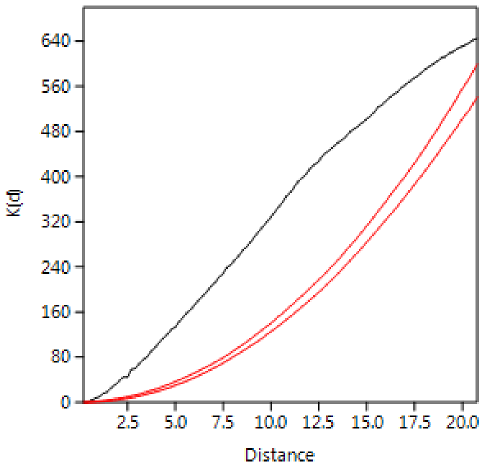


Figure 693 Ripley's *k* analysis on the distance between sampling units with posts recorded in surveys of 2012 within Zone 1 (Past).

Cells with posts are, according to Clark and Evans test, clustered. A Kernel Density Estimation (Figure 694) shows the presence of a main concentration observed between x=20-40 and y=27-44, and a lower dense further concentration between x=0-20 and y=5-17.

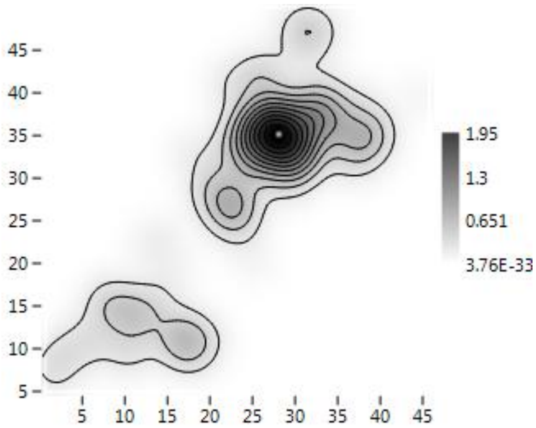


Figure 694 KDE of sampling units where posts have been recorded during surveys of 2012, within Zone 1 (Past).

Given that the majority of cells have only one or none, we have not considered here the probability density distribution of spatial frequencies. Cells with posts are spatially distributed, in relation to the frequencies of their occurrence within each sampling units, as showed in Figure 695.

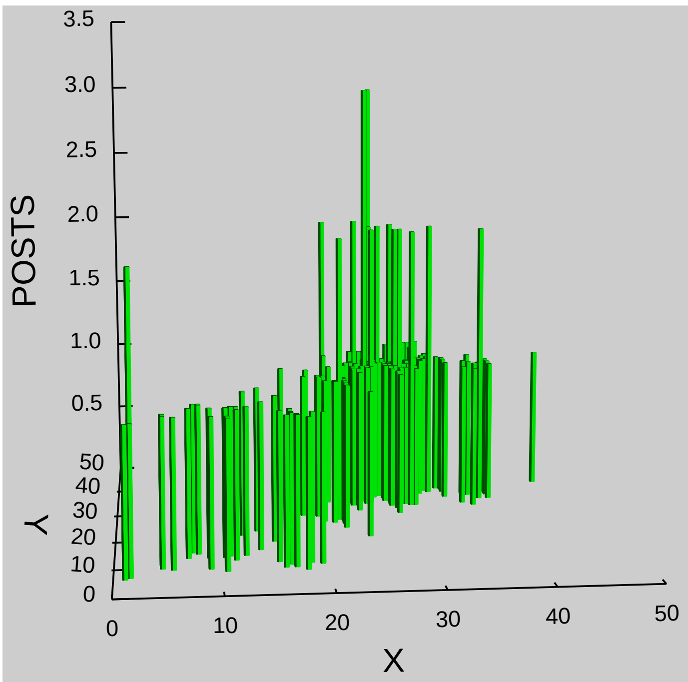


Figure 695 Spatial distribution of cells with posts and relative frequencies (surveys 2012, Zone 1) (Systat 3).

The spatial centroid of the area with posts, calculated using an abundance weighted mean spatial center is x= 24.951220, y= 30.292683, with 8.90 m of standard deviation along the *x* axis, and 10.51 m along the *y* axis.

The spatial distribution of the abundance of posts per sampling unit gives a Global Moran's I result of 0.070613. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is 0.003676 and the standard error is -0.008125. The test of significance using the normality assumption gave a highly significant z value of 9.143309. Consequently, we can accept that the spatial distribution of posts is significantly different than the expected value under a random distribution. This is what would be expected when not all spatial location have the same frequency of items. Those results are comparable with those of the Geary statistics (for this case C=1.027002) and Getis-Ord general G (G= 0.000000).

The Moran's *I* Correlogram (Figure 696) has been calculated for uniform class distance intervals of 1 meter, and taking into account a 10 meters active lag distance. *I* value at the starting point is about 0.319, above the expected value for randomness. As the distance between sampling units increases, *I* value drops off quite gently and continuously always above the expected value for randomness until 5 meter (between 6 and 10 I value is located on the line, corresponding to spatial randomness).

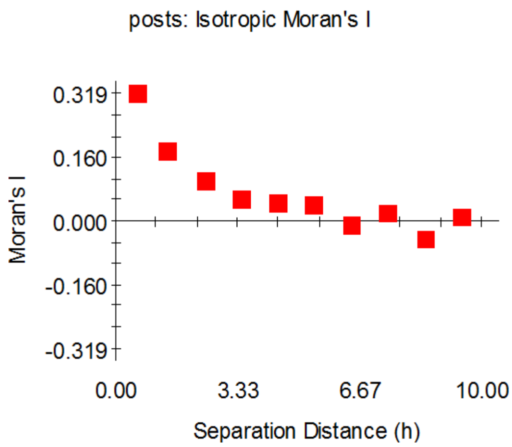


Figure 696 Moran's I Correlogram for posts recovered during surveys of 2012, within Zone 1 (GS+).

This result suggests the presence of positive spatial autocorrelation beween the starting point of the function and 5 meter; it is so possible to find out spatially dependent areas of 4-5 meter of radius, what is suggestive working hypothesis for locating homogeneous activity areas.

132 cells with one post are distributed in a statistically significant cluster (as showed by the Clark and Evans test) (Figure 697A). These constitute the 80% of all posts and are located in the 90% of the effectively surveyed area. Only 15 cells show more than 1 post (Figure 697B). In this case, the Clark and Evans test suggests that the null hypothesis of a random pattern (Poisson process) cannot be rejected at $p<0.05$.

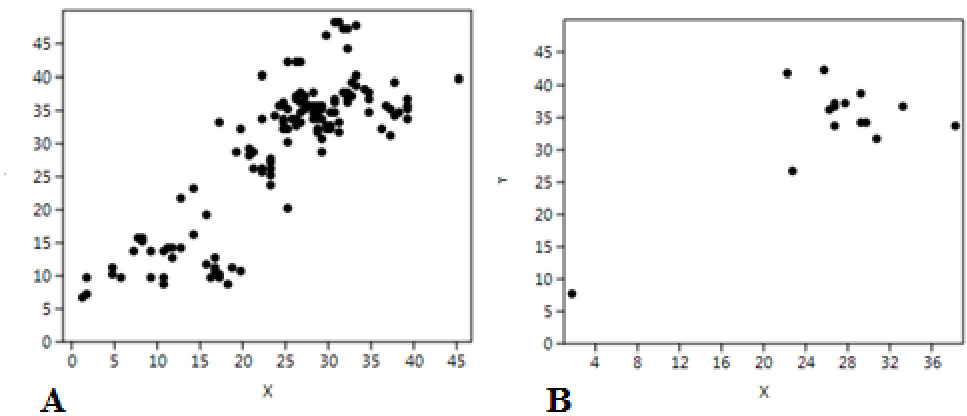


Figure 697 A)Spatial distribution of cells with 1 post B)Spatial distribution of cells with more than 1 post (Past).

Kernel Density estimate model of cells with 1 posts provides a clearer image (Figure 698).

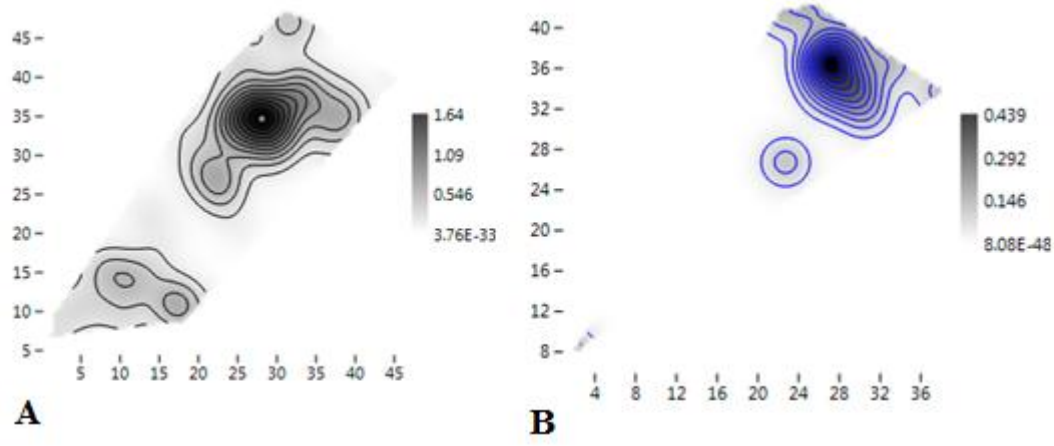


Figure 698 A)KDE of cells with 1 post; B) KDE of cells with more than 1 post (Past).

It is easy to see in the North-East corner of the surveyed area higher density points delimiting a less dense area. Following the South-West direction there is another area of lower dense posts. The similar spatial orientation is attested for sampling units with 2 or more presences, attesting a continuity and linearity in posts occurrence. However, in this case, the second concentration seems to be absent and smaller low dense points are concentrated between x=20-24 and y=24-28.

The possible presence of anisotropic variation was explored, studying the empirical variogram at different directions (Figure 699).

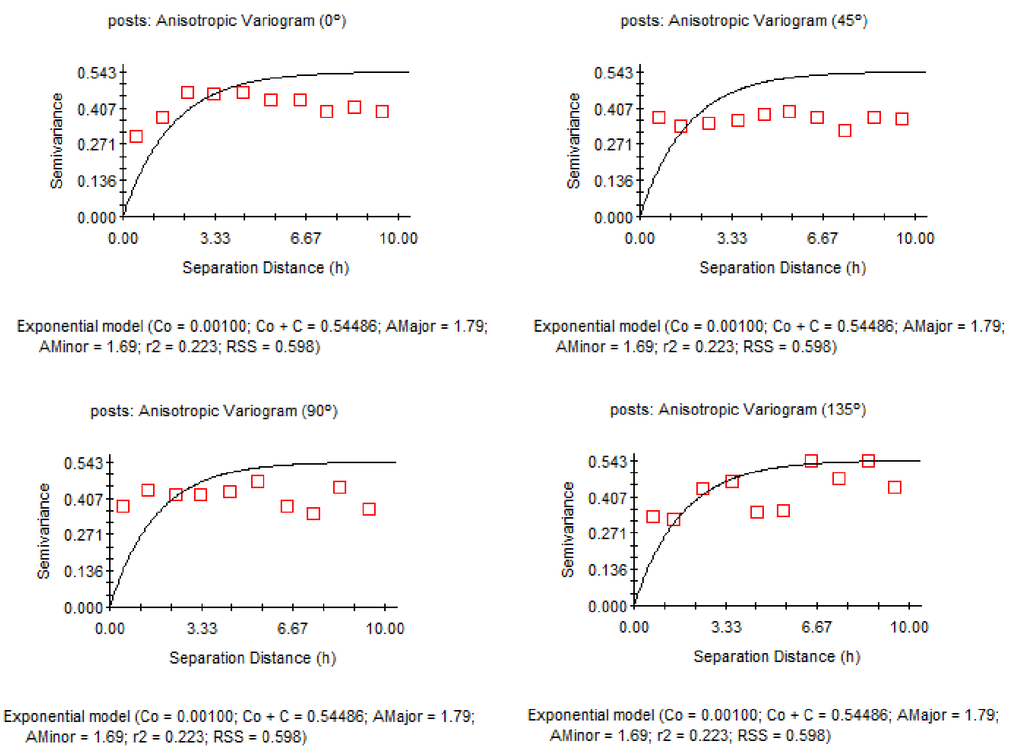


Figure 699 Anisotropic Variogram of posts recovered during surveys of 2012 within Zone 1 (GS+).

Results show the absence of homogeneous variations of semivariance at any distances. The graph of anisotropic Semivariance Surface or Variogram Map shows scarce spatial continuity which is interchanged to anisotropy particularly concentrated in the centre of the surveyed area and around the South-West and North-East corners (Figure 700).

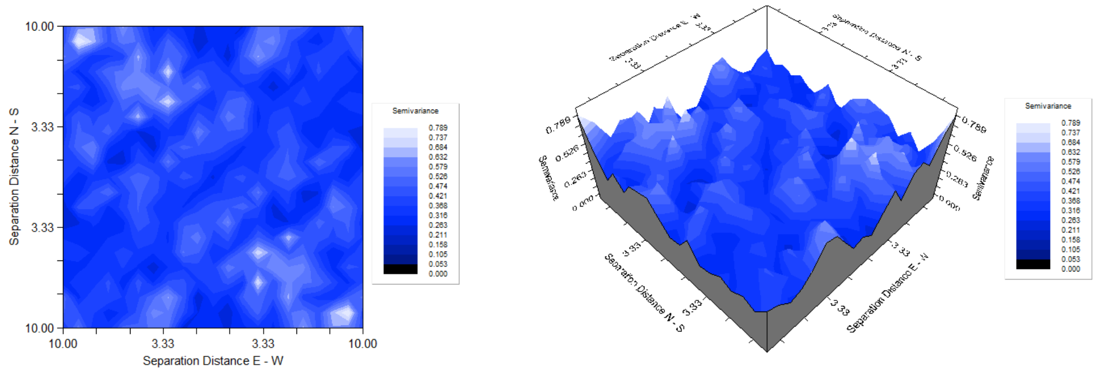


Figure 700 Variogram Map of posts recovered during surveys of 2012 within Zone 1 (GS+).

An exponential variogram model has been fitted to the empirical variogram. In this case C_0 (nugget variance) = 0.07400, C_0+C (sill) = 0.41000 and A_0 (Range) = 0.39 (Figure 701). This model explains 45.9% of spatial differences between the frequency of posts per sample unit.

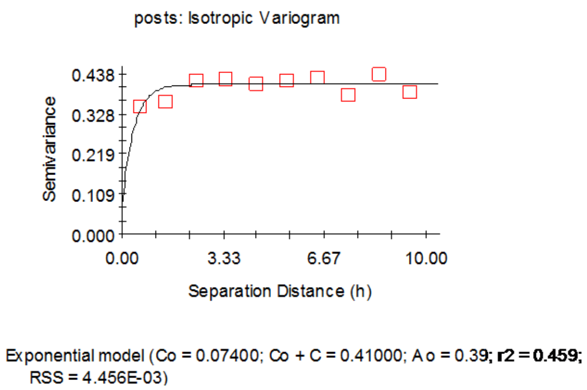


Figure 701 Exponential Isotropic Variogram for posts recovered during surveys of 2012 within Zone 1 (GS+).

The related inverse distance weighting interpolated model (Figure 702) stresses the alignment of a majority of vertical posts along the estimated ancient lake shoreline.

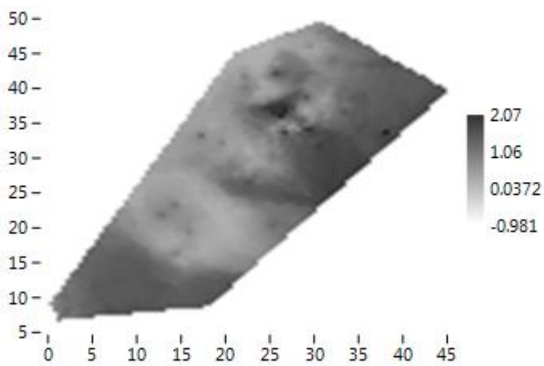


Figure 702 Graphic results of Inverse Distance Weighting calculated for posts recovered during surveys of 2012 within Zone 1 (Past).

9.1.4 Saddle querns

9 saddle querns were identified and counted. The spatial distribution of sampling units where saddle querns have been identified is showed in Figure 703.

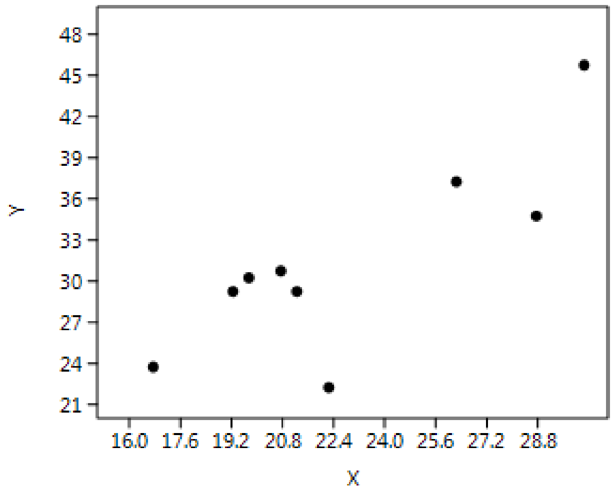


Figure 703 spatial distribution of cells with saddle querns

Ripley's *k* analysis on the distance between sampling units with saddle querns evidence, suggests the total absence of any kind of spatial clustering, since a predominant randomness characterizes such scarce saddle querns occurrences (**Figure 704**), as confirmed also by Clark and Evans test for the non-empty cells.

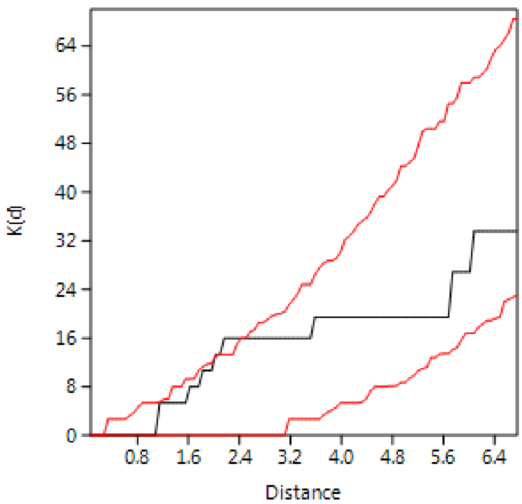


Figure 704 Ripley's K analyses on the distance between sampling units with posts recorded in surveys of 2012 within Zone 1 (Past).

9.1.5 Faunal remains (all taxa and all skeletal parts mixed together)

9 faunal remains were identified and counted; 264 were the surveyed empty cells, while only sampling unit with 1 presence are identified. The spatial distribution of centroid points of sampling units where faunal remains have been identified is showed in Figure 705.

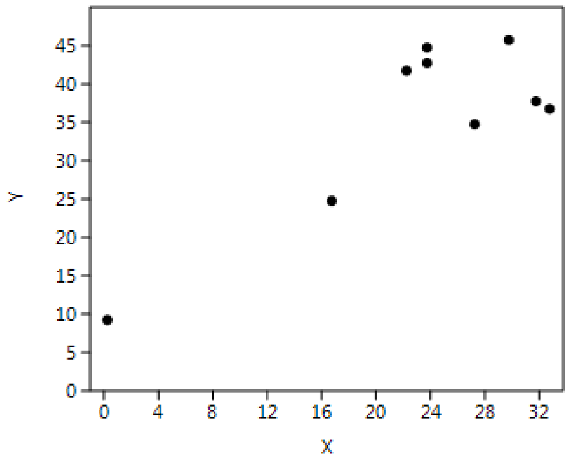


Figure 705 Spatial distribution of cells with faunal remains for surveys 2012, Zone 1 (Past).

Ripley's *k* analysis on the distance between sampling units with faunal remains evidence, suggests the presence of a restricted and really scarce spatial clustering, particularly potentially attested from 8 to 16 meters (Figure 706).

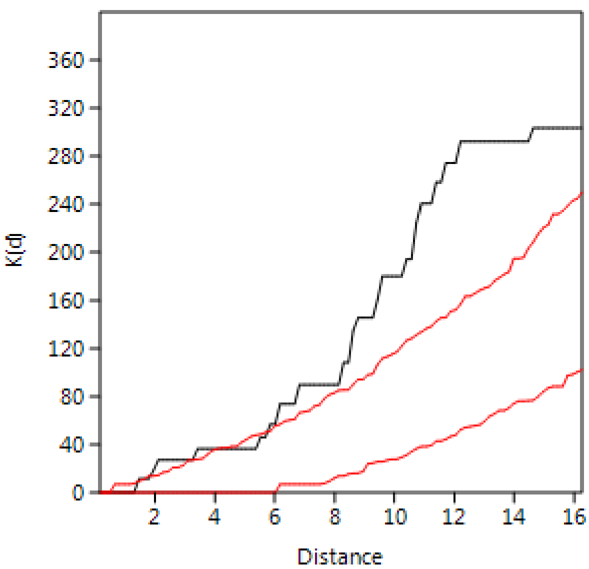


Figure 706 Ripley's*k* analysis on the distance between sampling units with faunal remains, recorded in surveys of 2012, within Zone 1 (Past).

9.1.6 Pottery

225 pottery fragments were identified and counted; 162 were the surveyed empty cells (that is, without any pottery) while the cell with more presence gave 6 items. The spatial distribution of sampling units where pottery has been identified is showed in Figure 707.

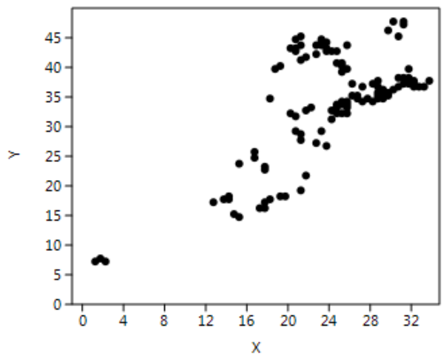


Figure707 Spatial distribution of cells with pottery within Zone 1 (surveys 2012) (Past).

Ripley's *k* analysis on the distance between sampling units with pottery evidence, suggests the possibility of some degree of spatial clustering, at the scale of the reference area (Figure 708).

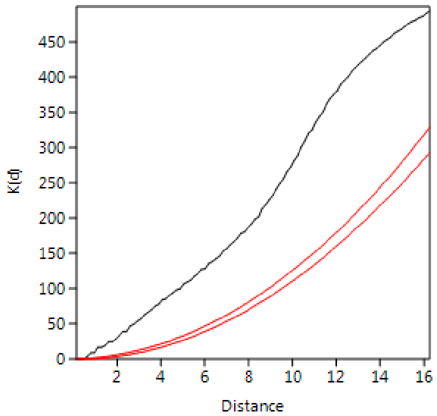


Figure 708 Ripley's *k* analysis on the distance between sampling units with pottery, recorded in surveys of 2012 within Zone 1 (Past).

Within the convex hull configured by those sampling units with some positive frequency of pottery, Clark and Evans test suggests clustering. A Kernel Density estimation of such cells shows the presence of two main different concentrations (between x=17-35 and y=29-45 and between x=12-22 and y=14-26 y. Two further lower dense points are observed between x=0-5 and y= 7-8 and between x=28-32 and y=43-45 (Figure 709).

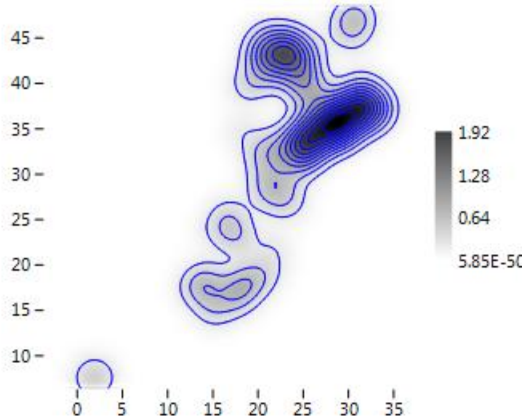


Figure 709 KDE of sampling units where pottery has been recovered during surveys of 2012, within Zone 1 (Past).

When considering the raw quantity of pottery at each cell, the probability density distribution of spatial frequencies does not follow a J-shaped distribution. A majority of sampling units have raw counts of archaeological observations of less than 2 elements (global mean= 2.02 observations per sampling unit). Histogram as well as box plot identify a break point in the distribution of frequencies corresponding to 2 presence, while 4 cells are distinguished from the majority with 1, 3, 4 and 6 observations (interpretable as outlier) (Figure 710).

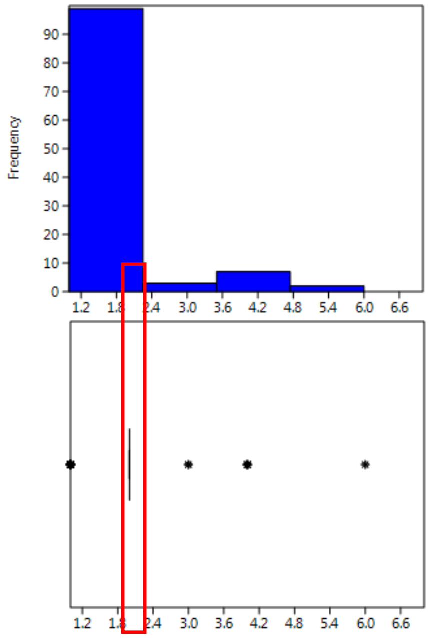


Figure 710 Histogram and box plot of frequencies observed for pottery (Past).

A very irregular and non-homogeneous distribution characterizes pottery (Figure 711) which does not fit with an exponential theoretical model of intentional discard at a fixed center (tested using a Kolmogorov Smirnov Tests, p<0 in all cases) nor of unintentional random dispersal.

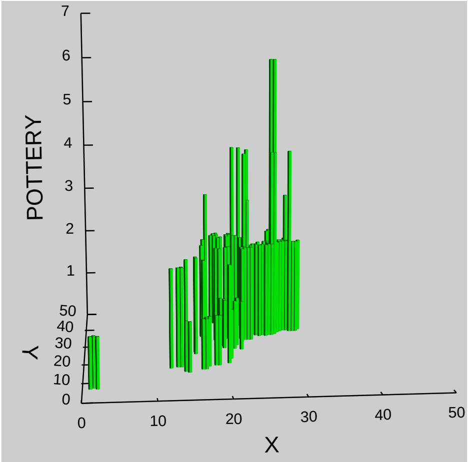


Figure 711 3D Histogram of pottery recovered during surveys of 2012, within Zone 1 (Systat 13).

The spatial centroid of the area with pottery, calculated using an abundance weighted mean spatial center is x= 24.883333, y= 35.092222, with 12.76 m of standard deviation along the *x* axis, and 5.68 m along the *y* axis. A standard deviation ellipse with a long axis of 25.52 m and a short one of 11.37 m delimits an area of 227.84 square meters, where most count data appear. It has been estimated an average density of 0.11 objects per square meter.

The spatial distribution of the abundance of pottery per sampling unit gives a Global Moran's I result of -0.00003419. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is -0-0003676 and the standard error is 0.003677. The test of significance using the normality assumption gave a highly non significant z value of 0.070148. Consequently, we can accept that the spatial distribution of pottery is not significantly different than the expected value under a random distribution. This is what would be expected in the case of the same frequency of pottery in quite every spatial location. Those results are comparable with those of the Geary statistics (for this case C=1.000725) and Getis-Ord general G (G= 0.031347).

The Moran's *I* Correlogram (Figure 712) has been calculated for uniform class distance intervals of 1 meter, and taking into account a 10 meters active lag distance. *I* value at the starting point is about 0.602, above the expected value for randomness. As the distance between sampling units increases, *I* value drops off quite gently and continuously always above the expected value for randomness until 2 meters (spatial autocorrelation), while from such distance I values are predominantly distributed on the line (corresponding to spatial randomness).

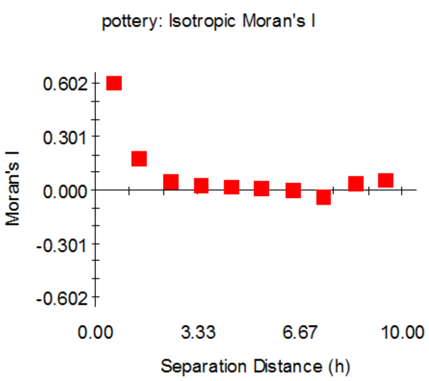


Figure 712 Moran's I Correlogram for pottery recovered during surveys of 2012, within Zone 1 (GS+).

This result gives the possibility of finding spatially dependent areas of 2 meters of radius, what is a suggestive working hypothesis for locating potential individual activity areas.

Taking into account what is suggested both by boxplot and histogram, that is the occurrence of a breaking point in the frequencies pottery in correspondence with a value of 2 items, sampling units with respectively more than 2 frequencies of fragments are analysed separately. 78% of pottery are located in the 89% of the effectively surveyed area, in such a way that 22% of pottery show more than 2 items located in 11% of the effectively surveyed area (Figure 713). According to Clark and Evans test, for such cells a null hypothesis of random pattern (Poisson process) cannot be rejected with $p<0.05$. However, it is interesting to observe that such cells are all located in the North-East portion of the Area 1 and they are not distributed according to the generally widespread North-East-South-West orientation, as even showed by Kernel Density Estimation (Figure 714).

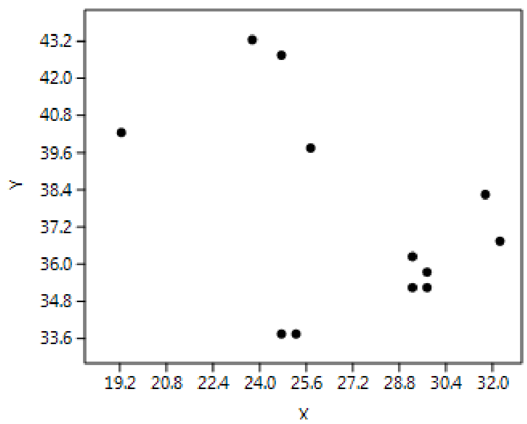


Figure 713 Spatial distribution of cells with more than 2 pottery fragments within Zone 1 (Past).

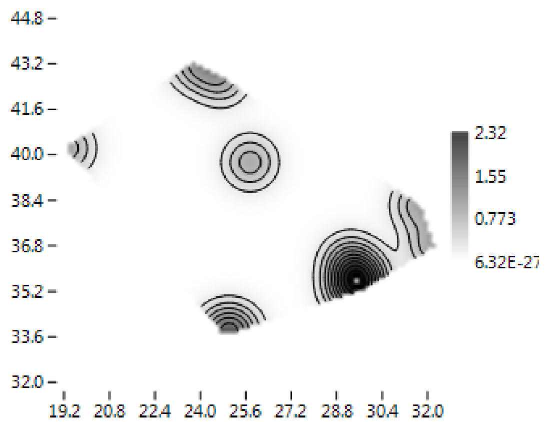


Figure 714 KDE of such cells (Past).

Moran’s *I* correlogram (Figure 715) of cells with more than 2 items fits with an irregular model between immediate sampling units, and some possible clustering between 7 and 9 meters, that is a main concentration zone, as showed above by KDE.

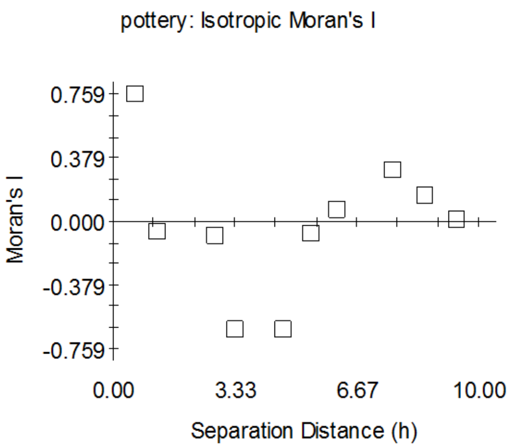


Figure 715 Moran's I Correlogram for sampling units with more than 2 potsherds recovered during surveys of 2012, within Zone 1 (GS+).

With this working hypothesis as starting point, we have explored the possible presence of anisotropic variation fitting a theoretical variogram at different directions (Figure 716). Results show that semivariance varies in predominantly in strong different way in 0º, 45º, 90º and 135º. Only in the first meters 0º and 45º show some scarce similarities.

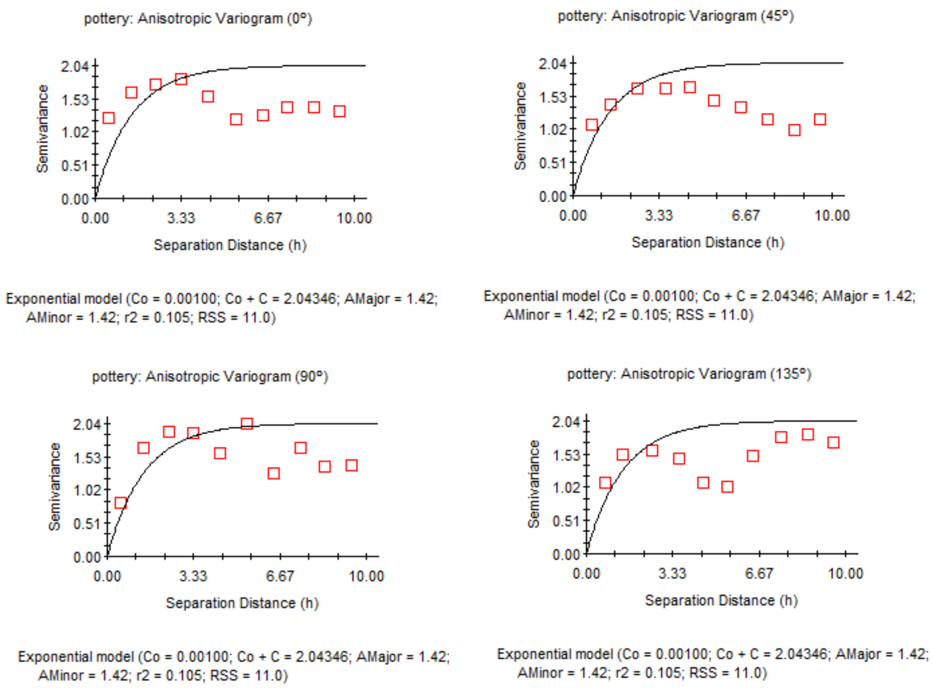


Figure 716 Anisotropic Variogram of pottery recovered during surveys of 2012 within Zone 1 (GS+).

The graph of anisotropic Semivariance Surface or Variogram Map (Figure717) shows that anisotropy seems to be widespread in all the surveyed area, although some peaks are concentrated near the North-West and South-East corners.

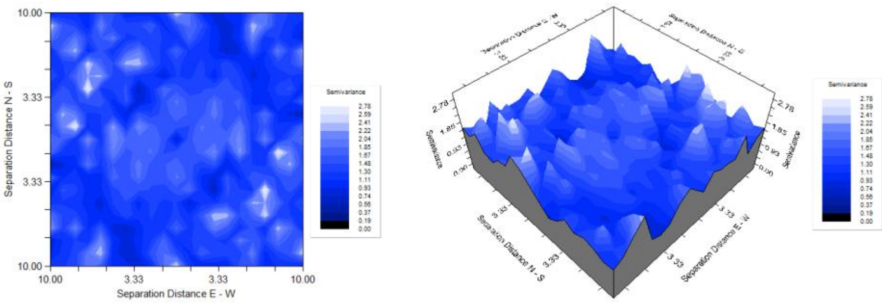


Figure 717 Variogram Map of pottery recovered during surveys of 2012 within Zone 1 (GS+).

An exponential variogram model (Figure 718) has been fitted to the empirical variogram. In this case C_0 (nugget variance) =0.07600, C_0+C (sill) = 1.51300 and A_0 (Range) = 0.47 showing a global fit of 51.7%.

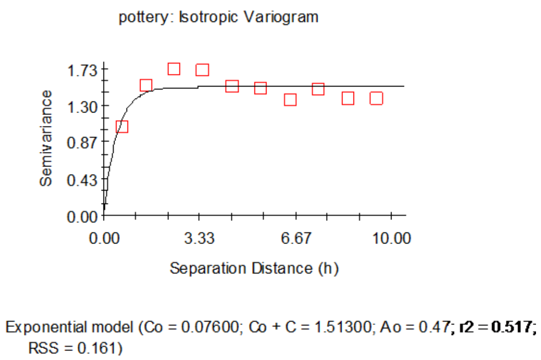


Figure 718 Exponential Isotropic Variogram for pottery recovered during surveys of 2012, within Zone 1 (GS+).

Using this model, a kriging algorithm has allowed building a spatial predictive model of pottery in this reference area (Figure 719). Such category seems to be distributed, without spatial continuity, around the Northern portion of the surveyed area, confirming what already suggested by KDE.

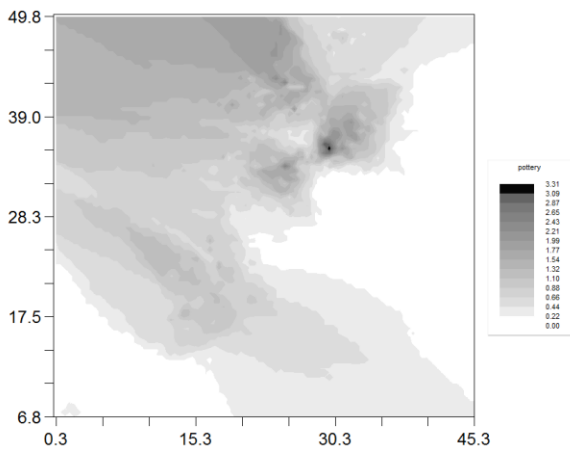


Figure 719 Graphic results of Inverse Distance Weighting calculated for pottery recovered during surveys of 2012 within Zone 1 (Past).

9.1.7 Concotto remains

This category includes both concotto remains and slabs. 18 fragments were identified and counted. 257 were the surveyed empty cells, while the sampling unit with more presence gave 3 items. Sampling units where concotto remains have been recovered are spatially distributed as showed in Figure 720.

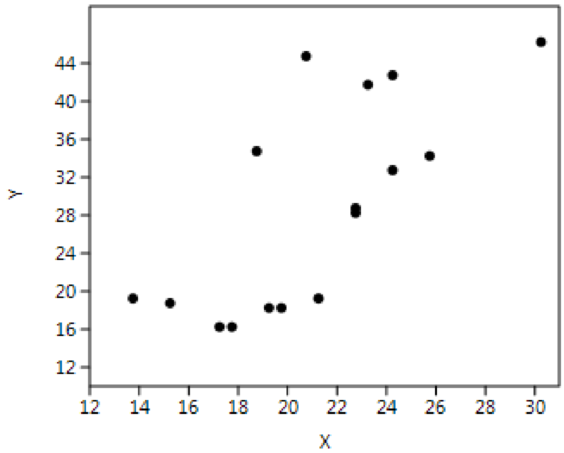


Figure 720 Spatial distribution of sampling units with concotto remains within Zone 1 (Past).

Ripley's *k* analysis (Figure 721) on the distance between sampling units with concotto evidence, suggests a predominant tendency to randomness along all the function, as even confirmed by Clark and Evans test.

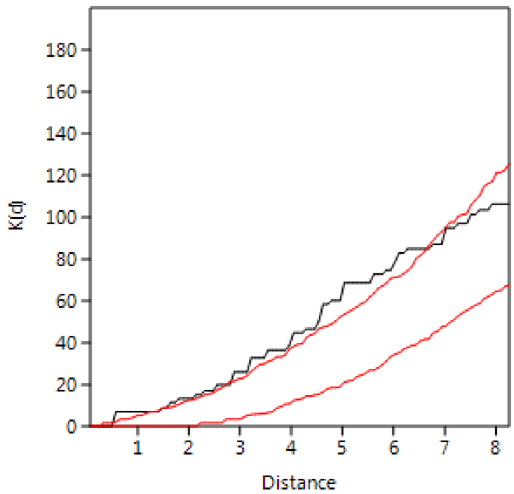


Figure 721 Ripley's k analysis on the distance between sampling units with concotto evidence. Surveys 2012, Zone 1 (Past).

9.2 Absolute count of archaeological observations (palimpsest) within Zone 2

1585 archaeological observations (ascribable to all the categories identified during survey of 2012) were identified and counted. The spatial distribution of only those sampling units with material evidence is showed in Figure 722.

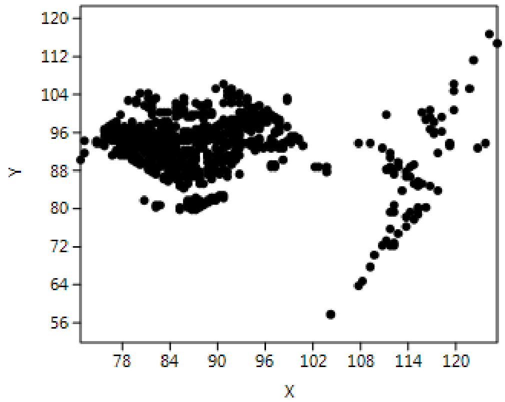


Figure 722 Spatial distribution of cells with material evidence (surveys 2012, Zone 2) (Past).

Ripley's *k* analysis on the distance between sampling units with all material evidence gives support to the hypothesis of spatial clustering in the reference area (Figure 723).

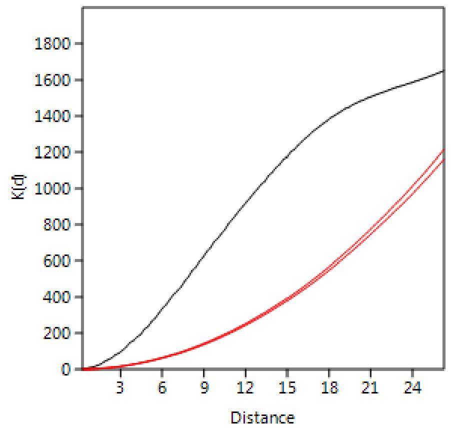


Figure 723 Ripley's k analysis on the distance between sampling units with all material evidence recorded in surveys of 2012 within Zone 2 (Past).

Within the convex hull defined by the effectively surveyed cells, a Kernel Density Estimation of non-empty cells (cells where a minimum of 1 archaeological observation has been recorded) shows the concentration of observables in two different sectors, respectively at the North-West and North-East corners of the surveyed area (Figure 724). Such non-empty cells are statistically significant clustered, according to Clark and Evans test However, as showed by KDE two different sub-zones are observed. The material evidence located in the Eastern corner of the surveyed area, partially underwater when these surveys have been carried out, are posts, recovered by total station.

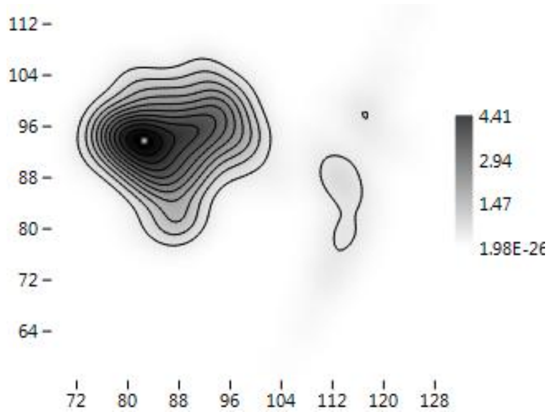


Figure 724 KDE of non-empty sampling units (surveys 2012, Zone 2) (Past).

When considering the raw quantity of archaeological observations at each cell, the probability density distribution of spatial frequencies clearly follows a J-shaped distribution. A majority of sampling units have raw counts of archaeological observations of less than 3 elements (global mean=2.56 observations per sampling unit). One cell is distinguished from the majority with 29 observations (interpretable as outlier). Both histogram and the box plot show a break point within the distribution corresponding to 6 frequencies for sampling unit (Figure 725).

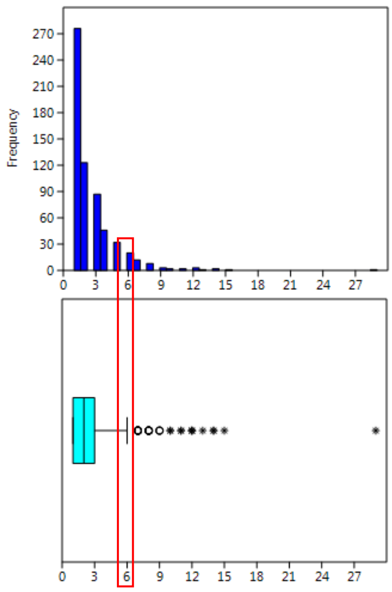


Figure 725 Histogram and box plot of frequencies observed for all material evidence summed up (Past).

A Lorenz Curve (Figure 726) gives a Gini Coefficient of 0.4466, with a 95% Bootstrap confidence interval between 0.419 and 0.472. The Coefficient of asymmetry is 0.9979, with a 95% Bootstrap confidence interval between 0.916 and 1.073. In general, we can see that 44% of all archaeological observations have been found at 80% of sampling units and the remaining 20% sampling units concentrate more than a half of the count data (56%). This result gives us an idea of the quantitative differences of evidence accumulated at differentiated cells.

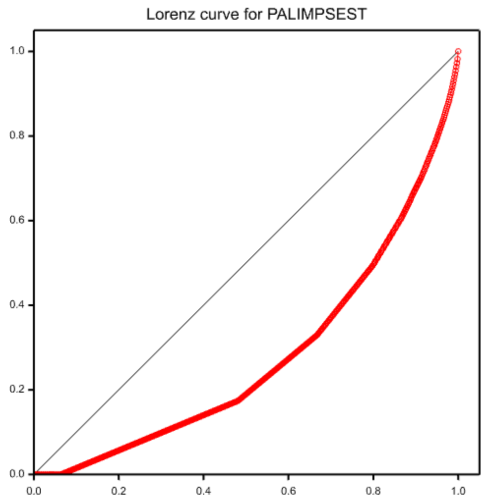


Figure 726 Lorenz Curve for all material evidence recovered during surveys of 2012, within Zone 2 (Genstat).

A very irregular and non-homogeneous distribution is observed (Figure 727), which does not fit with an exponential theoretical model of intentional discard at a fixed center (tested using K-S tests, $p<0$ in all cases).

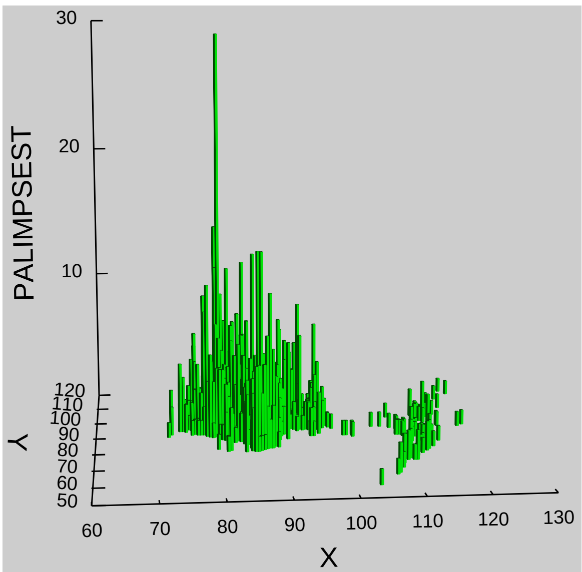


Figure 727 3D Histogram of all material evidence recovered during surveys of 2012, within Zone 2 (Systat 13).

79% of all archaeological observations are located in 94% of the effectively surveyed area, in such a way that only 35 cells show more than 6 items and they are distributed in 5% of the effectively surveyed area.

The spatial distribution of count data per sampling unit shows a Global Moran's *I* of -0.001362. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is -0.001515 and the standard error of *I* is 0.001515. The test of significance using the normality assumption gave a highly non significant z value of 0.100978. Consequently, we can accept that the spatial distribution of the general palimpsest is not particularly different than the expected value under a random distribution. The mixture of too much different intentionalities could produce such pattern, as would be expected in the case of a palimpsest. These results are comparable with those of the Geary statistics (1.000767) and Getis-Ord general G (=0.011077).

The Moran's *I* Correlogram (Figure 728) has been calculated for uniform class distance intervals of 1 meter and taking into account a 10 meters active lag distance. *I* value at the starting point of the function is at 0.216, above the expected value for randomness. Such condition is followed until 6 meters (between 6 and 10 meters I values are around 0), since within such distance *I* value drops off quite gently and continuously along the function.

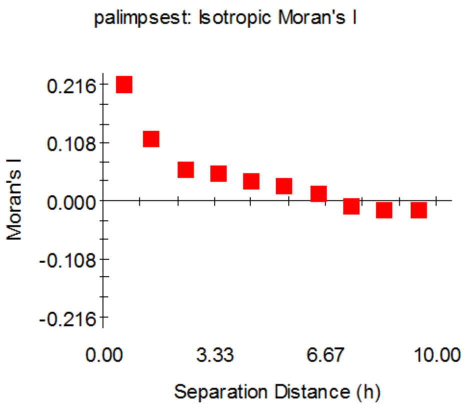


Figure 728 Moran's I Correlogram for all evidence recovered during surveys of 2012, within Zone 2 (GS+).

Thus, positive spatial autocorrelation is attested for the first 5 meters, suggesting the possibility of identifying spatially dependent areas of 5 meters of radius, what is a suggestive working hypothesis for locating homogenous activity areas.

We have explored the possible presence of anisotropic variation fitting a theoretical variogram at different directions (Figure 729).

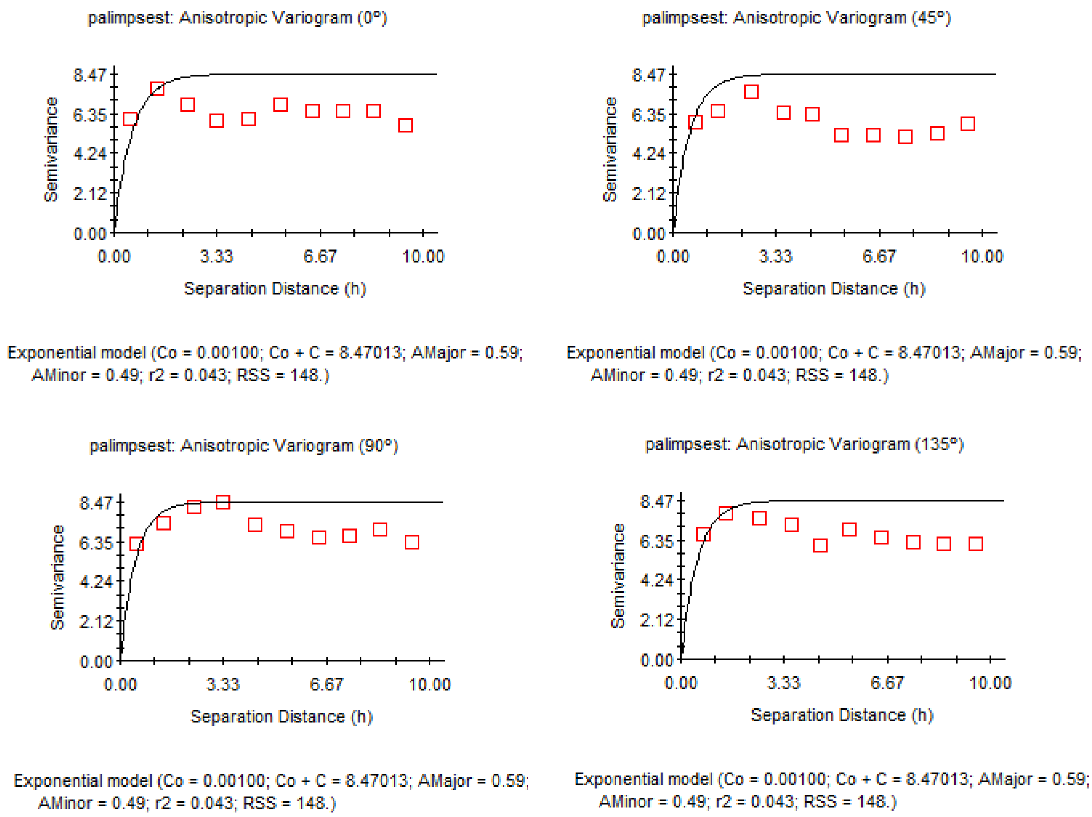


Figure 729 Anisotropic Variogram of all material evidence recovered during surveys of 2012, within Zone 2 (GS+).

Results show that semivariance varies in quite same way respectively in 0º, 45º and 90º only in the first meters of the function. The graph of anisotropic Semivariance Surface or Variogram Map (Figure 730) shows that anisotropy is widespread in the centre of the surveyed area, with particular presence around North-East and South-West corners.

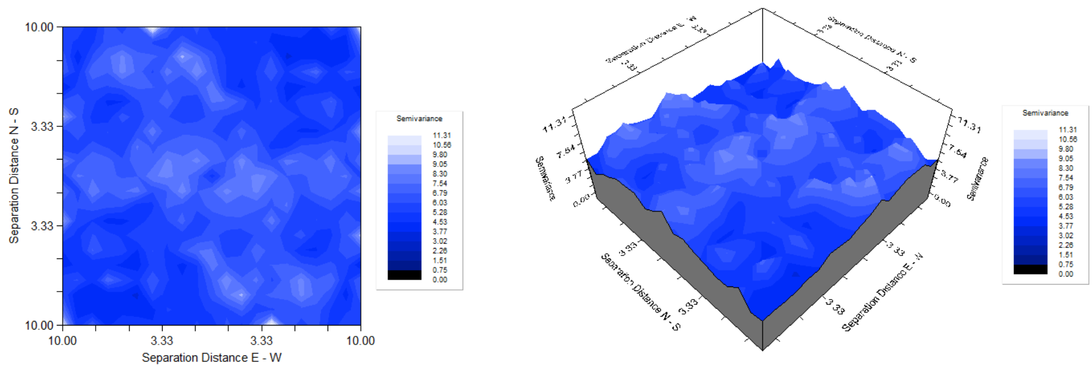


Figure 730 Variogram Map of all material evidence recovered during surveys of 2012, within Zone 2 (GS+).

An exponential isotropic variogram model has been best fitted to the empirical variogram (Figure 731). In this case C_0 (nugget variance) = 1.52000, C_0+C (sill) = 6.59800 and A_0 (Range) = 0.22.

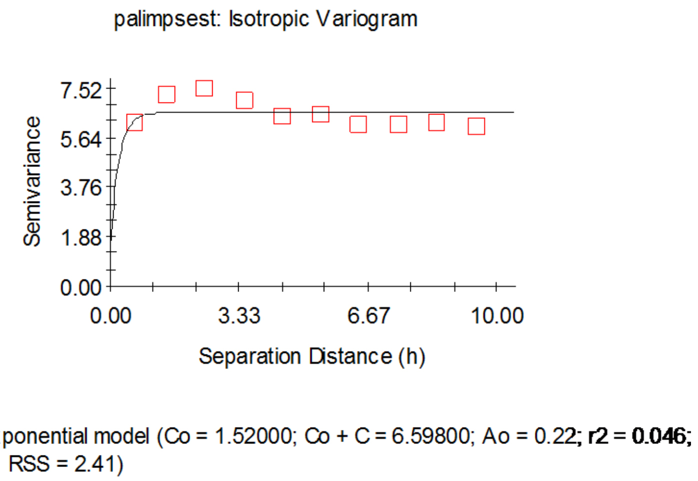


Figure 731 Exponential Isotropic Variogram for all material evidence recovered during surveys of 2012, within Zone 2 (GS+).

Since this wodel shows a scarce goodness of fit, it cannot be possible to continue with the interpolation.

9.2.1 Vertical posts within Zone 2

131 posts were identified and counted. 541 were the surveyed empty cells, while the sampling unit with more presence gave 2 posts. The spatial distribution of sampling units where posts have been identified is showed in Figure 732.

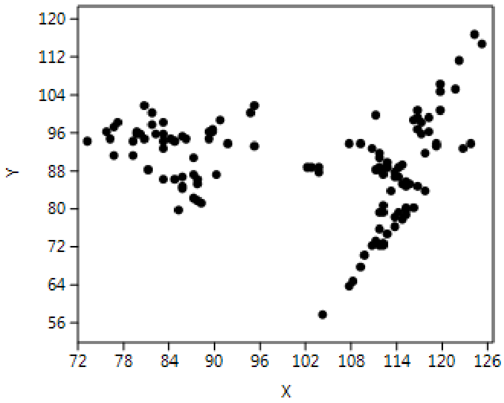


Figure 732 Spatial distribution of sampling units where posts have been recorded during surveys 2012, within Zone 2 (Past).

Ripley's k analysis on the distance between sampling units with posts evidence suggests the possibility of some degree of spatial clustering, particularly between the starting point of the function and until a distance of 22 meters (Figure733).

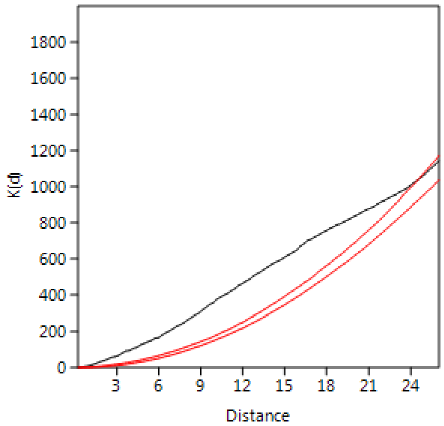


Figure 733 Ripley's k analysis on the distance between sampling units with posts recorded in surveys of 2012, within Zone 2 (Past).

Within the convex hull defined by the effectively surveyed area and according to a KDE two sub-areas within the same Zone (Zone 2) are observed, respectively identified between x=72-96 and y=78-103 and between x=100-126 and y=56-120 (Figure 734). According to the Clark and Evans test of nearest neighbour, posts are statistically significantly clustered, as well as the surveyed empty cells (in both cases p<0).

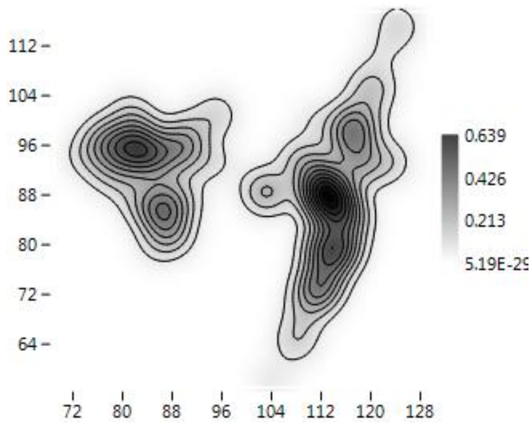


Figure 734 KDE of sampling units where posts have been recorded during surveys of 2012, within Zone 2 (Past)

Given that the majority of cells have only one or none, we have not considered here the probability density distribution of spatial frequencies.

The spatial distribution of cells with posts fits well with Poisson distribution with λ= 0.198 and Kolmogorov Smirnov Test=1. This condition suggests randomness in the spatial distribution of the abundance of posts per sampling unit (Figure 735).

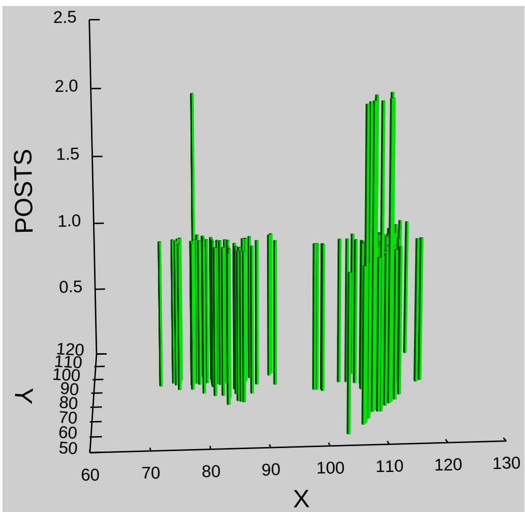


Figure 735 Spatial distribution of cells with posts and relative frequencies (Systat 13).

The spatial centroid of the area with posts, calculated using an abundance weighted mean spatial center is x=102.837786, y= 88.547710, with 14.42 m of standard deviation along the *x* axis, and 21.70 m along the *y* axis. A standard deviation ellipse with a long axis of 43.39 m and a short one of 28.83 m delimits an area of 982.55 square meters, where most count data appears. It has been estimated an average density of 0.034 posts per square meter.

The spatial distribution of the abundance of posts per sampling unit gives a Global Moran's *I* result of –0.000360. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is -0-001515 and the standard error *I* is 0.001515. The test of significance using the normality assumption gave a z value of 0.762557, a low significant value. Consequently, we can accept that the spatial distribution of posts is not significantly different than the expected value under a random distribution. This is what would be expected in the case of the same frequency of posts in every spatial location. These results are comparable with those of the Geary statistics (for this case C=0.993952) and Getis-Ord general G (G= 0.006350).

The Moran's *I* Correlogram (Figure 736) has been calculated for uniform class distance intervals of 1 meter, and taking into account a 10 meters active lag distance. *I* value at the starting point is about 0.166, above the expected value for randomness. As the distance between sampling units increases, *I* value drops off quite gently and continuously always above the expected value for randomness until along all the function.

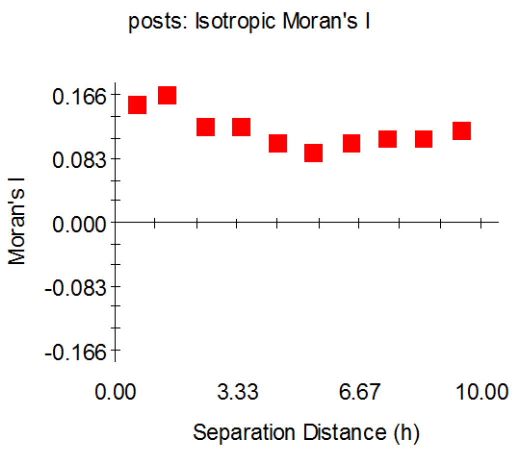


Figure 736 Moran's I Correlogram for posts recovered during surveys of 2012, within Zone 2 (GS+).

This result suggests the presence of positive spatial autocorrelation along all the function; it is so possible to find out spatially dependent areas of 10 meters of radius, what is suggestive working hypothesis for locating homogeneous activity areas.

Taking into consideration the scarce frequencies of posts within the surveyed area (ranging from 1 to 2) it is interesting to verify if there are attested differential spatial distributions between sampling units with more frequencies. Both 109 cells with one posts as well as 11 cells with two posts are clustered according to Clark and Evans test (p<0). Such cells are distributed as showed in Figure 737.

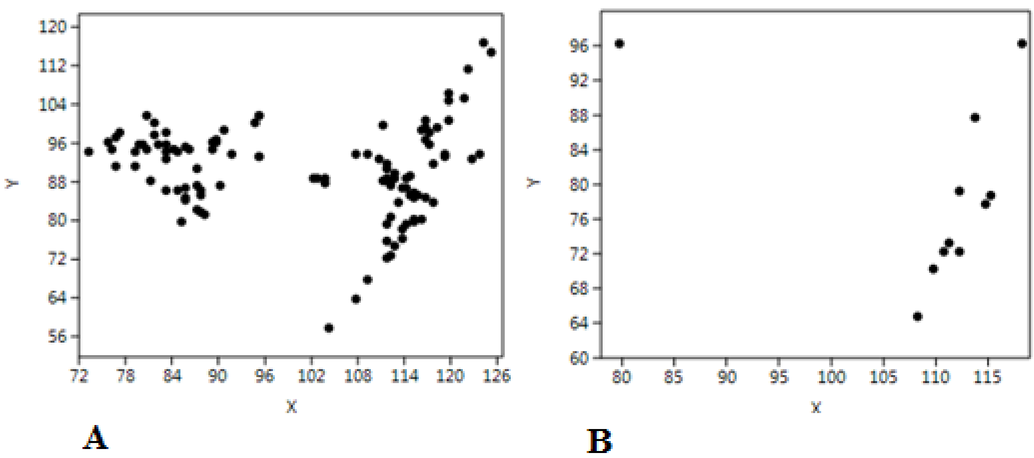


Figure 737 A) spatial distribution of cells with 1 post; B) spatial distribution of cells with 2 posts (Past).

The comparison between Kernel Density estimate model of cells with 1 or 2 posts provides a clearer image (Figure 738).

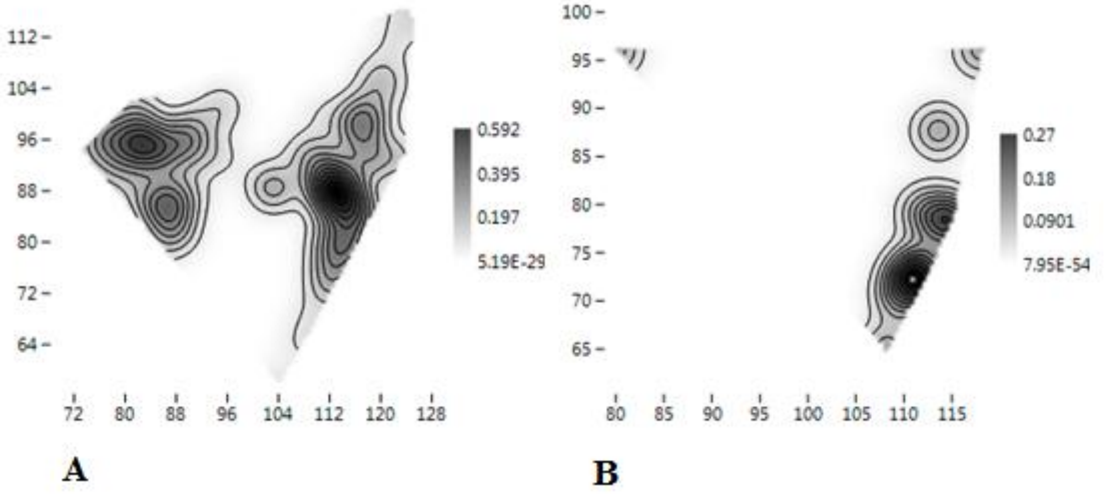


Figure 738 A)KDE of cells with 1 post. B)KDE of cells with 2 posts.

Such comparison shows how spatial distribution of cells with posts follows a South-West-North-East predominant orientation, parallel to the lakeshore, highlighting also a predominant concentration of posts within the Sub-Zone 2. We have explored the possible presence of anisotropic variation studying the empirical variogram at different directions (Figure 739).

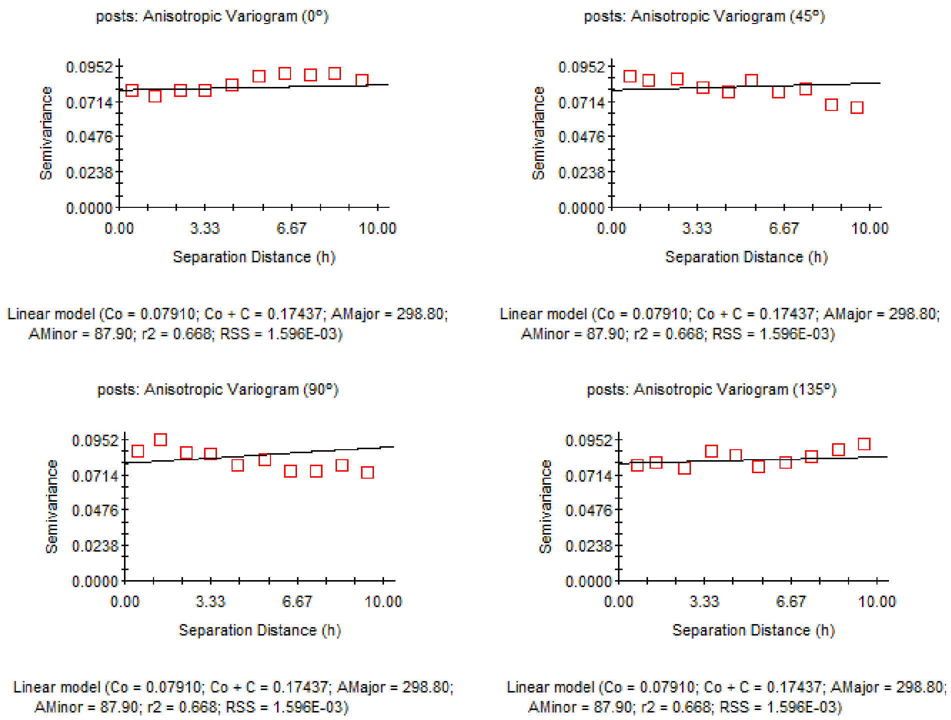


Figure 739 Anisotropic Variogram of posts recovered during surveys of 2012, within Zone 2 (GS+).

In general, results show that semivariance varies in the same way, particularly in the first meters, at 0° and 135° as well as at 45° and 90°. The graph of anisotropic Semivariance Surface or Variogram Map (Figure 740) shows that the appreciable difference can be observed predominantly observed around the North-East and South-West corners. Some spatial continuity between values at small-medium distances is attested.

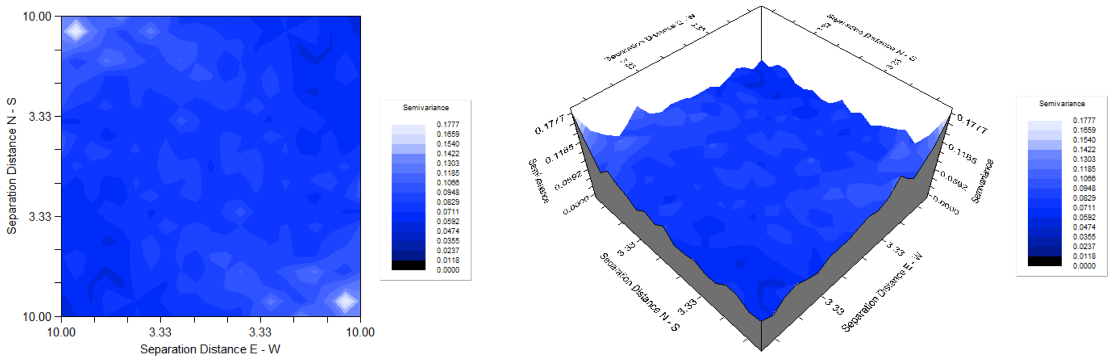


Figure 740 Variogram Map of posts recovered during surveys of 2012 within Zone 2 (GS+).

A linear variogram model with C_0 (nugget variance) = 0.08174, C_0+C (sill) = 0.08174 and A_0 (Range) = 9.45 is the best we can fit to the data (Figure 741). However, it does not explain the spatial differences between the frequency of posts per sample unit. Then, we cannot continue with the interpolation.

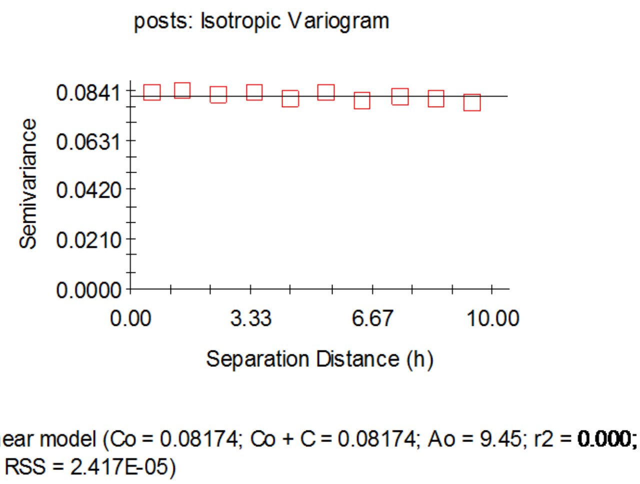


Figure 741 Exponential Isotropic Variogram for posts recovered during surveys of 2012, Zone 2 (GS+).

9.2.2 Saddle querns within Zone 2

58 saddle querns were identified and counted; they are sub-divided in 47 grindstones and 11 handstones. 606 were the surveyed empty cells (that is, without any saddle quern) while the cell with more presence gave 2 evidence. The spatial distribution of sampling units where saddle querns have been identified is showed in Figure 742.

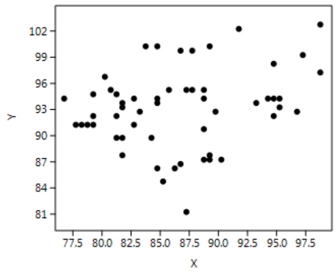


Figure 742 Spatial distribution of sampling units where saddle querns have been recorded during surveys 2012, within Zone 2 (Past).

Ripley's *k* analysis on the distance between sampling units with saddle querns evidence, suggests low possibility of clustering along all the function, since the curve seems to tend to the randomness, at the global scale of the reference area (Figure 743).

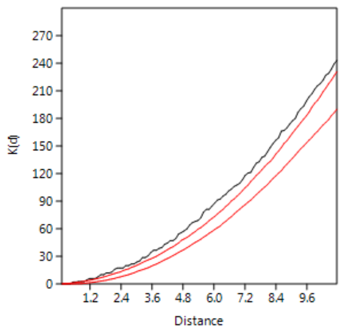


Figure 743 Ripley's K analysis on the distance between sampling units with saddle querns recorded in surveys of 2012, within Zone 2 (Past).

A Kernel Density Estimation (Figure 744) shows the presence of four different concentration areas (between x=84-91 and y=84-88, between x=77-90 and y=87-97, between x=92-97 and y=91-95 and the low denser between x=82-90 and y=98-100. However, for such cells the null hypothesis of a random pattern (Poisson process) cannot be rejected at $p<0.05$. This condition confirms what suggested by Ripley's k.

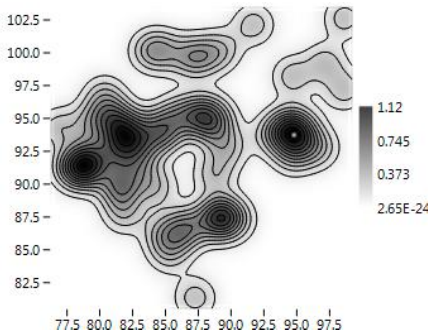


Figure 744 KDE of non-empty cells (surveys 2012, Zone 2) (Past).

9.2.2.1 Sub-categories of saddle querns: grindstones and handstones

Within the general category of saddle querns the sub-categories of grindstones and handstones have been identified during surveys of 2012.

9.2.2.1.1 Grindstones and handstones

Spatial distribution of sampling units where grindstones and handstones have been identified is showed in Figure 745.

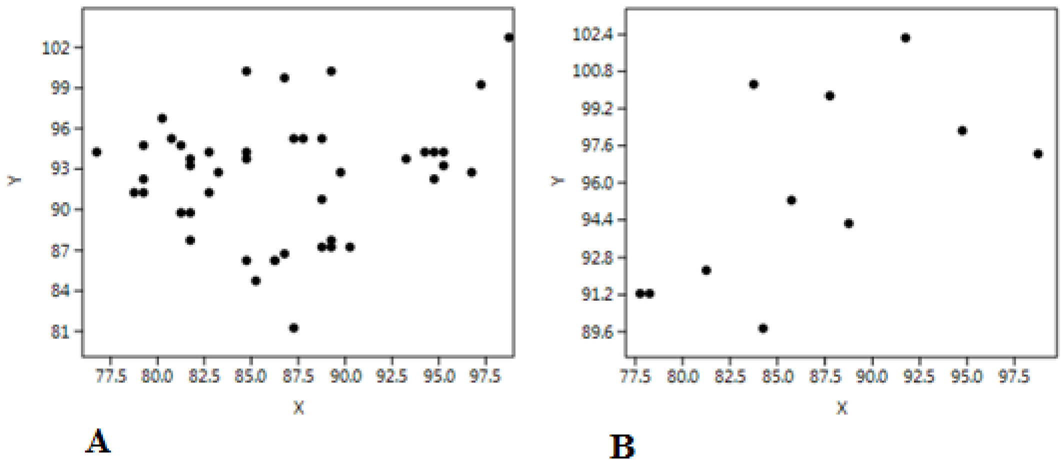


Figure 745 A)spatial distribution of cells with grindstones B)spatial distribution of cells where handstones have been recovered (surveys 2012, Zone 2) (Past).

Ripley's k analysis on the distance between sampling units with grindstones evidence suggest low possibility of clustering along all the function, since the curve seems to tend to the randomness. For handstones, it is observable a random pattern (Figure 746).

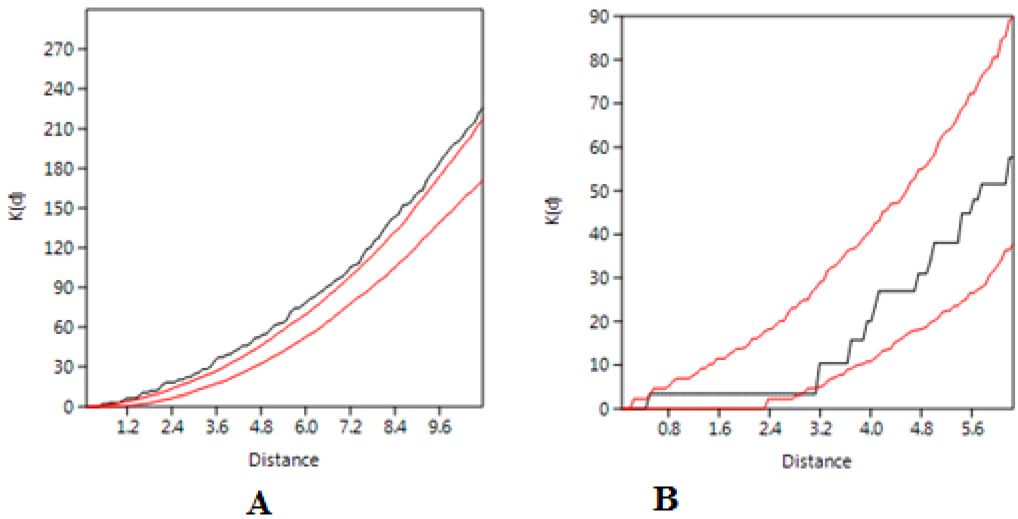


Figure 746 Ripley's k analysis on the distance between sampling units with grindstones (A) and handstones (B) recorded in surveys of 2012, within Zone 2 (Past).

9.2.3 Faunal remains within Zone 2

119 faunal remains were identified and counted; were the surveyed empty cells, while the sampling unit with more presence gave 4 items. The spatial distribution of centroid points of sampling units where faunal remains have been identified is showed in Figure 747.

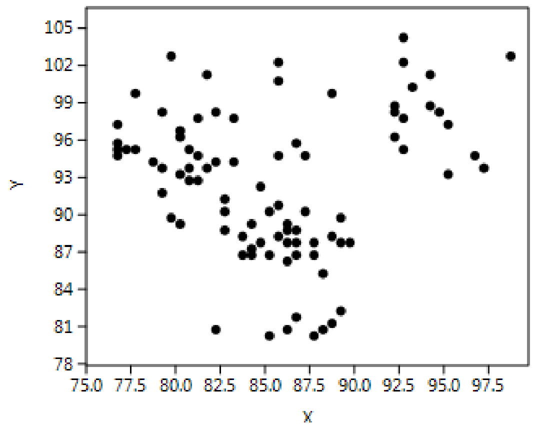


Figure 747 Spatial distribution of sampling units where faunal remains have been recorded during surveys of 2012, within Zone 2 (Past).

Ripley's *k* analysis on the distance between sampling units with fauna evidence suggests the possibility of few degree of spatial clustering at the scale of the total reference area (Figure 748).

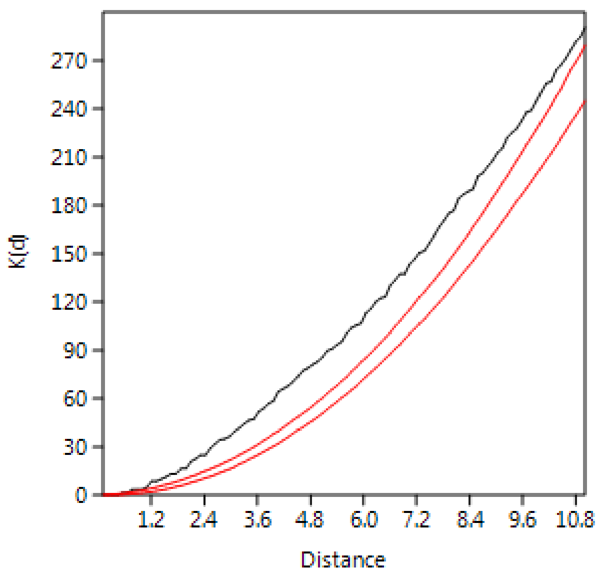


Figure 748 Ripley's k analysis on the distance between sampling units with faunal remains, recorded in surveys of 2012, within Zone 2 (Past).

Within the convex hull defined by the effectively surveyed sampling units, however, the null hypothesis of a random pattern (Poisson process) cannot be rejected at $p<0.05$. A Kernel Density Estimation shows the presence of two main concentrations located respectively between x=83-90 and y=85-90 and between x=75-83 and y=92-97 y and two additional low denser concentrations observed between x=85-90 and y=78-82 and between x=92-97 and y= 93-103 (Figure 749).

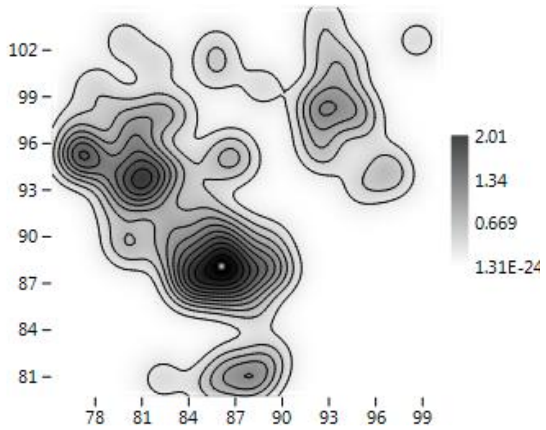


Figure 749 KDE of sampling units where faunal remains have been recovered during surveys of 2012, within Zone 2 (Past).

When considering the raw quantity of faunal remains at each cell, the probability density distribution of spatial frequencies clearly follows a J-shaped distribution. A majority of sampling units have raw counts of faunal remains of less than 2 elements (global mean=1.35 observations per sampling unit). Both histogram and box plot show the occurrence of a break point within the frequencies of fauna corresponding to the value of 3 items (Figure 750). Furthermore, one cell is distinguished from the majority (representing outlier), with 3 faunal remains.

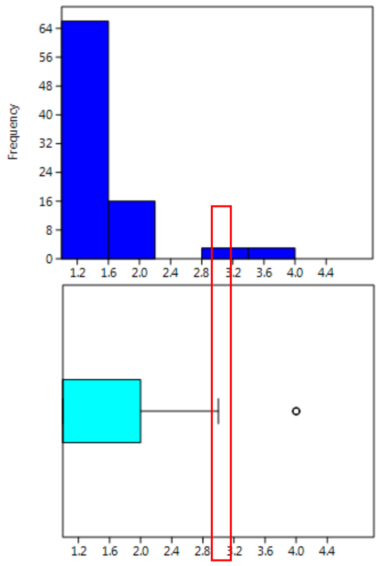


Figure 750 Histogram and box plot of frequencies observed for faunal remains (Past).

The Negative Binomial distribution (with k=0.321 and p=0.641) fits with the observed frequencies of fauna, according to the Kolmogorov Smirnov Test=1. This condition suggests a predominant randomness in the spatial distribution of the abundance of fauna per sampling unit (Figure 751).

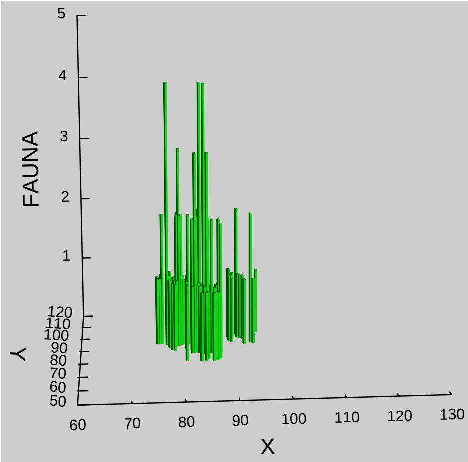


Figure 751 3D Histogram of faunal remains recovered during surveys of 2012, within Zone 2 (Systat 13).

The spatial centroid of the area with faunal remains, calculated using an abundance weighted mean spatial center is x=85.363445 and y=92.355042 with 5.07 m of standard deviation along the x axis and 5.55 m along the y axis. A standard deviation ellipse with a long axis of 15.80 m and a short one of 14.38 m delimits an area of 178.40 square meters, where most data count appears. It has been estimated an average density of 0.031 faunal remains per square meter.

The spatial distribution of the abundance of faunal remains per sampling unit gives a Global Moran's *I* result of -0.001444. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is -0-001515 and the standard error I is 0.001515. The test of significance using the normality assumption gave a highly non-significant z value of 0.46651. Consequently, we can accept that the spatial distribution of faunal remains is not different than the expected value under a random distribution. This is what would be expected in the case of the same frequency of faunal remains in every spatial location. These results are comparable with those of the Geary statistics (for this case C=1.001176) and Getis-Ord general G (G= 0.012181).

The Moran's *I* Correlogram (Figure 752) has been calculated for uniform class distance intervals of 1 meter, and taking into account a 10 meters active lag distance. At the starting point of the function *I* value is around 0. At 1 meter I value reaches 0.0653 and from this distance it drops off quite gently and above the expected value for randomness until 5 meters. Between 5 and 7 meter it is located on the line (corresponding to spatial randomness). Positive spatial autocorrelation is thus observed for 3 meters.

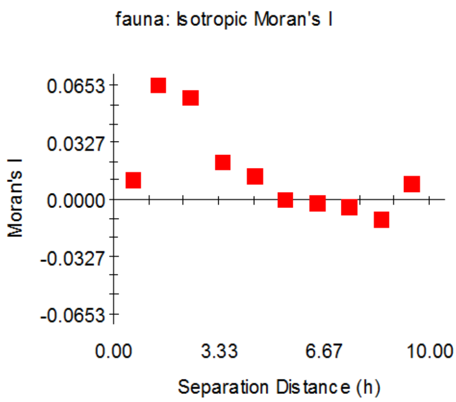


Figure 752 Moran's I Correlogram for faunal remains recovered during surveys of 2012, within Zone 2 (GS+).

This result gives the possibility of finding spatially dependent areas of 3 meters of radius, what is a suggestive working hypothesis for locating individual activity areas.

We have explored the possible presence of anisotropic variation fitting a theoretical variogram at different directions (Figure 753). Results show quite no homogeneous variation of semivariance at any degree.

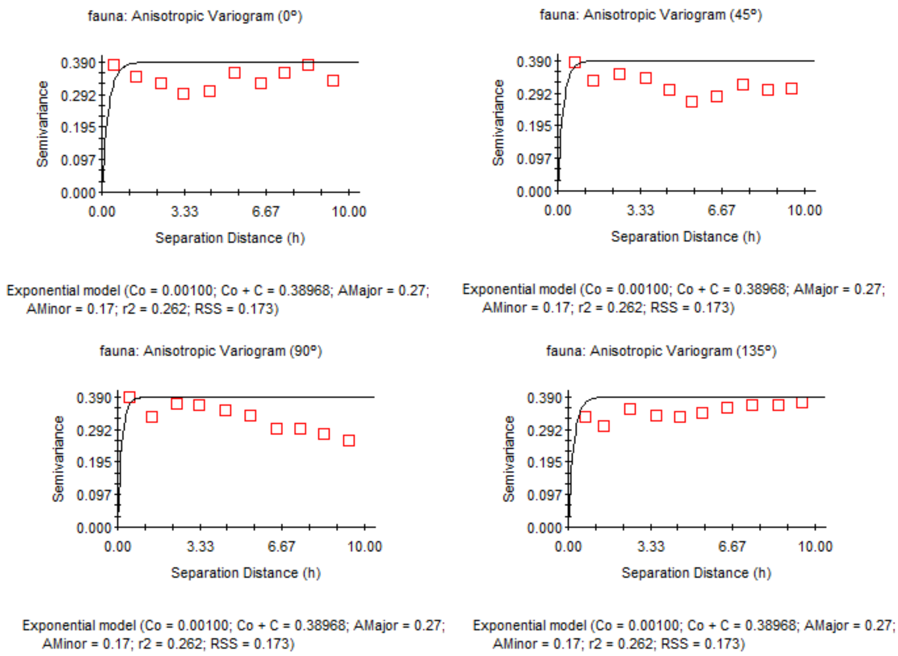


Figure 753 Anisotropic Variogram of faunal remains recovered during surveys of 2012, within Zone 2 (GS+).

The graph of anisotropic Semivariance Surface or Variogram Map (Figure 754) shows that anisotropy is particularly concentrated in the centre of the surveyed area and around the South-West and North-East corners.

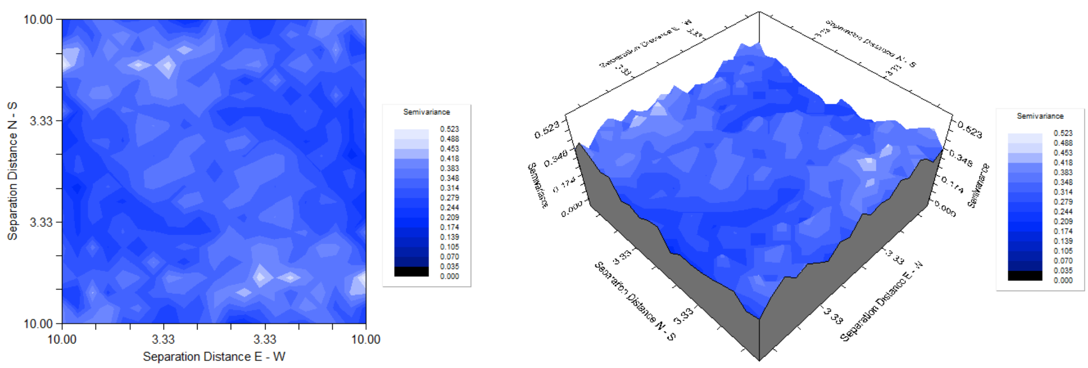
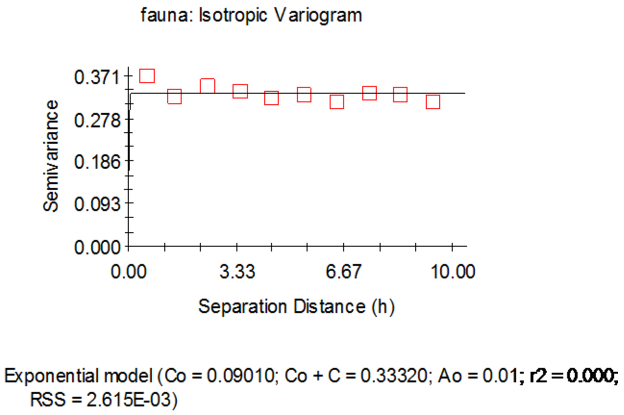


Figure 754 Variogram Map of faunal remains recovered during surveys of 2012, within Zone 2 (GS+).

The strong anisotropy makes misleading any effort to model spatial distribution using kriging or any other similar interpolation method. An isotropic variogram, with C_0 (nugget variance)

=0.0100, C_0+C (sill) = 4.510 and A_0 (Range) = 0.39 (Figure 755), does not explain the sample



variance

Figure 755 Exponential Isotropic Variogram for faunal remains recovered during surveys of 2012, within Zone 2 (GS+).

9.2.4 Pottery within Zone 2

1136 pottery fragments were identified and counted; 224 were the surveyed empty cells (that is, without any pottery) while the cell with more presence gave 21 items. The spatial distribution of sampling units where pottery has been identified is showed in Figure 756.

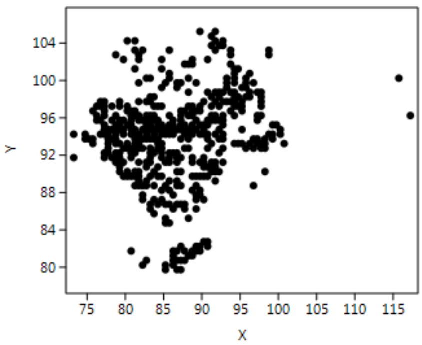


Figure 756 Spatial distribution of sampling units where pottery has been recorded in surveys of 2012, Zone 2 (Past).

Ripley's *k* analysis on the distance between sampling units with pottery evidence suggests the possibility of some degree of spatial clustering, at the scale of the reference area (Figure 757).

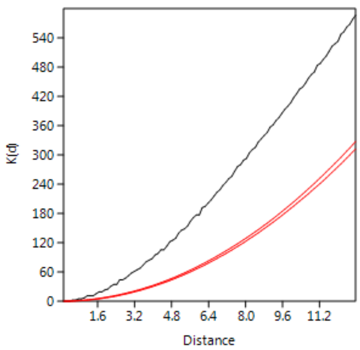


Figure 757 Ripley's K analysis on the distance between sampling units with pottery, recorded in surveys of 2012, Zone 2 (Past).

Within the convex hull configured by those sampling units with some potsherds, Clark and Evans test suggests clustering. KDE of such cells shows the presence of one main concentration, between x=73-100 and y=85-100 (Figure 756).

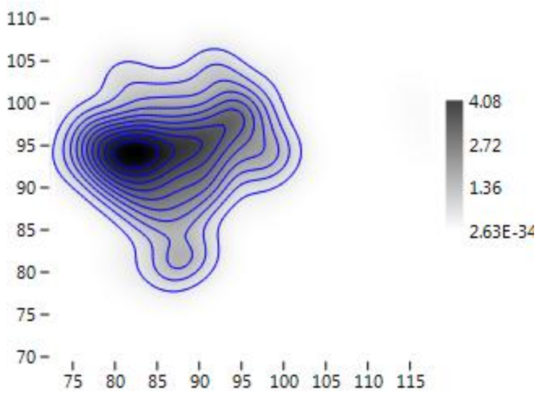


Figure 756 KDE of sampling units where pottery has been recovered during surveys of 2012, within Zone 2 (Past).

When considering the raw quantity of pottery at each cell, the probability density distribution of spatial frequencies clearly follows a J-shaped distribution. A majority of sampling units have raw counts of archaeological observations of less than 2 elements (global mean= 2.59 observations per sampling unit). Histogram as well as box plot identifies a break point in the distribution of frequencies corresponding to the value 6. One cell is distinguished from the majority, with 21 observations (interpretable as outlier) (Figure 757).

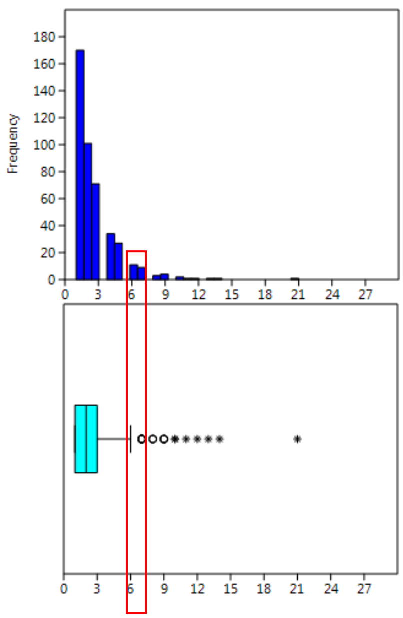


Figure 757 Histogram and box plot of frequencies observed for pottery (Past).

The spatial centroid of the area with pottery, calculated using an abundance weighted mean spatial center is x= 86.128521, y= 93.157130, with 5.98 m of standard deviation along the *x* axis, and 5.31 m along the *y* axis. A standard deviation ellipse with a long axis of 17.27 m and a short one of 14.66 m delimits an area of 198.80 square meters, where most count data appear. It has been estimated an average density of 0.29 objects per square meter.

The spatial distribution of the abundance of pottery per sampling unit gives a Global Moran's *I* result of -0.0001276. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is -0-001515 and the standard error is 0.001515. The test of significance using the normality assumption gave a z value of 0.157864, a highly non-significant value. Consequently, we can accept that the spatial distribution of pottery is not significantly different than the expected value under a random distribution. This is what would be expected in the case of the same frequency of pottery in quite every spatial location. These results are comparable with those of the Geary statistics (for this case C=1.000299) and Getis-Ord general G (G= 0.013507).

The Moran's *I* Correlogram (Figure 758) has been calculated for uniform class distance intervals of 1 meter, and taking into account a 10 meters active lag distance. *I* value at the starting point is about 0.243, above the expected value for randomness. As the distance between sampling units increases, *I* value drops off quite gently and continuously above the expected value for randomness until 6 meter. Between such distance and 10 meters I values are distributed on the line (corresponding to spatial randomness) or below the expected value for randomness. It is easy to see the presence of positive spatial autocorrelation for 5 meters.

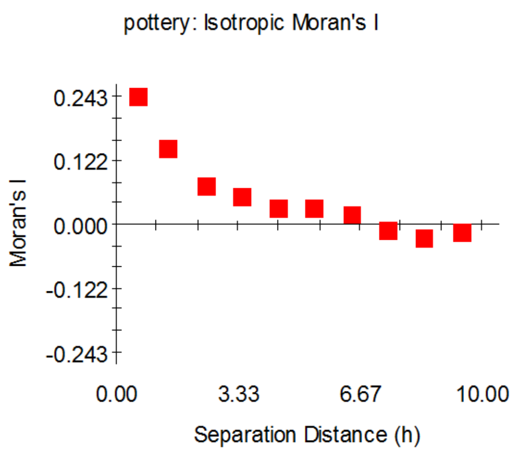


Figure 758 Moran's I Correlogram for pottery recovered during surveys of 2012, within Zone 2 (GS+).

This result gives the possibility of finding spatially dependent areas of 5 meters of radius, what is a suggestive working hypothesis for locating homogeneous activity areas.

Taking into account what is suggested both by box plot and histogram that is the occurrence of a breaki point in the frequencies pottery in correspondence with a value of 6 items, sampling units with respectively more than 6 frequencies of fragments are analysed separately. 81% of pottery are located in the 95% of the effectively surveyed area, in such a way that 19% of pottery show more than 6 items located in 5% of the effectively surveyed area. According to Clark and Evans test, for such cells the null hypothesis of a random pattern (Poisson process) cannot be rejected with $p<0.05$. However, it is interesting to observe their spatial distribution, different to the more usual North-West-South-East orientation (Figure 759A). Indeed, they seem to be predominantly allignead and concentrated in two main sub-areas (between x=80-88 and y=93-96 and between x=86-90 and y=80-83) as even proved by Kernel Density Estimation (Figure 759B).

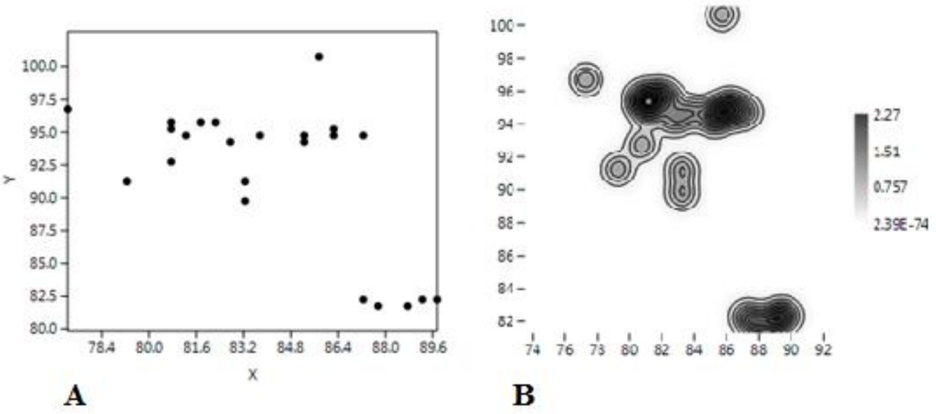


Figure 759 A)Spatial distribution of cells where more than 6 potsherds have been recovered; B)KDE of such cells.

We have explored the possible presence of anisotropic variation fitting a theoretical variogram at different directions (Figure 760). Results show limited similar variation of semivariance, only in the first meters and at 0º and 135º.

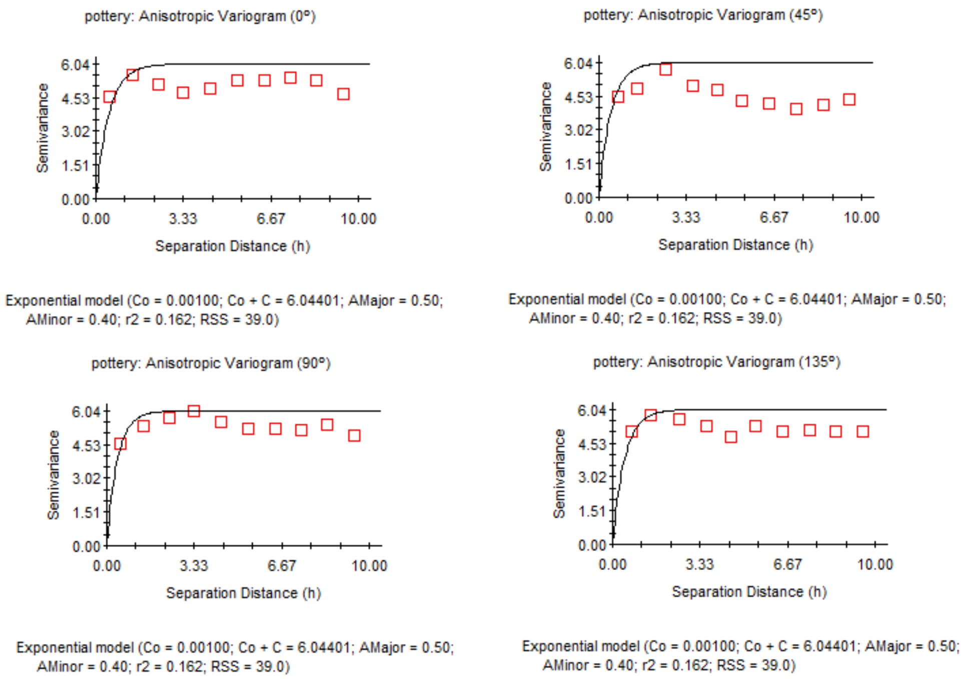


Figure 760 Variogram Map of pottery recovered during surveys of 2012, within Zone 2 (GS+).

The graph of anisotropic Semivariance Surface or Variogram Map (Figure 761) shows that anisotropy is particularly concentrated in the centre of the surveyed area, with peaks around the North-East and South-West corners.

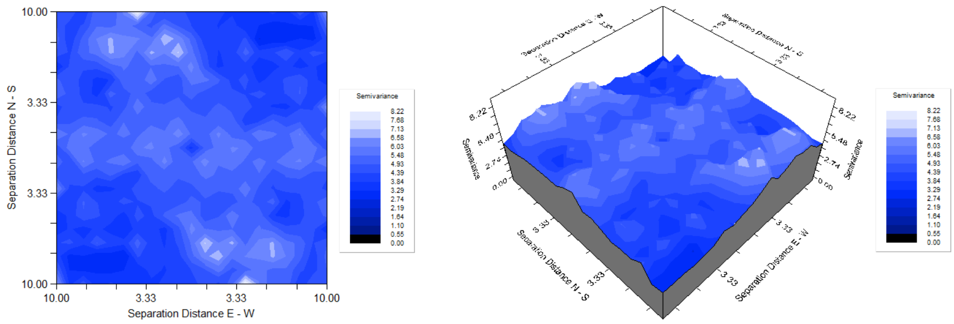


Figure 761 Variogram Map of pottery recovered during surveys of 2012, within Zone 2 (GS+).

An exponential variogram model has been fitted to the empirical variogram; in this case C_0 (nugget variance) =0.97000, C_0+C (sill) = 5.11200 and A_0 (Range) = 0.26 (Figure 762) showing a global fit of 23.9%. Such result for this zone does not allow interpolating data.

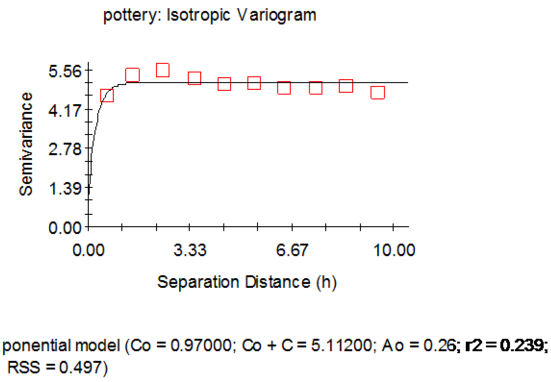


Figure 762 Exponential Isotropic Variogram for pottery recovered during surveys of 2012, Zone 2 (GS+).

9.2.5 Lithic industry within Zone 2

12 fragments of lithic industry were identified and counted. 649 were the surveyed empty cells, while all sampling units with lithic industry presence gave 1 item. Cells where lithic industry has been recorded are spatially distributed according to Figure 763.

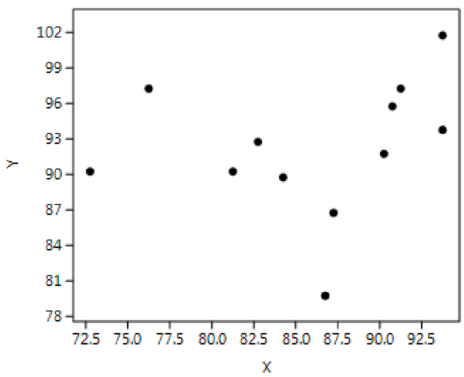


Figure 763 Spatial distribution of cells where lithic industry has been recovered during surveys 2012, within Zone 2.

Ripley's K analysis (Figure 764) on the distance between sampling units with lithic evidence, suggests the presence of a predominant random pattern.

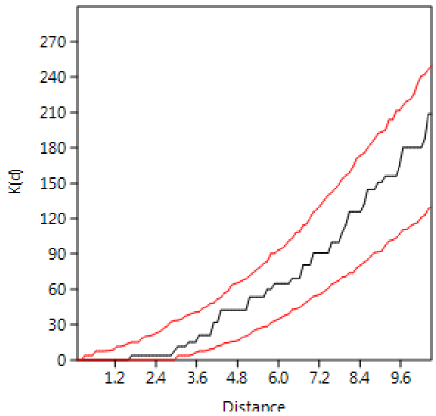


Figure 764 Ripley's K analysis on the distance between sampling units with lithic industry, recorded in surveys of 2012, Zone 2 (Past).

9.2.6 Wooden remains

As above mentioned in Chapter 5 this more general category includes two sub-classes (wood fragments and wood horizontal posts); however the scarce occurrence of such last category (wood horizontal posts) (4 remains within such area), the intra-site spatial analysis was performed only for wood fragments.

9.2.6.1 Wooden fragments

95 wood fragments were identified and counted. 609 were the surveyed empty cells, while the sampling unit with more presence gave 7 items. Sampling units where wood fragments have been recovered are spatially distributed as showed in Figure 765.

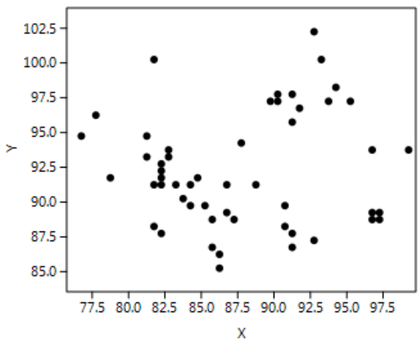


Figure 765 Spatial distribution of cells where wooden fragments have been recovered during surveys 2012, within Zone 2.

Ripley's *k* analysis (Figure 765) on the distance between sampling units with wood fragments evidence, suggests low possibility of clustering along all the function, since the curve seems to tend to the randomness and it is randomly distributed between 7 and 8 metres.

A Kernel density estimation (Figure 766) shows the presence of wood fragments in a main concentration (located between 80-86 x 87-95 y) and in some lower dense points (located between 90-92 x 86-87 y, between 96-97 x 87-89 y and between 87-92 x 95-98 y). The total amount of surveyed non-empty cells is 52 and, according to the Clark and Evans test, for them the null hypothesis of a random pattern (Poisson process) cannot be rejected at $p<0.05$. In the same way those cells where no evidence of wooden fragments was observed, are significatively overdispersed (p<1).

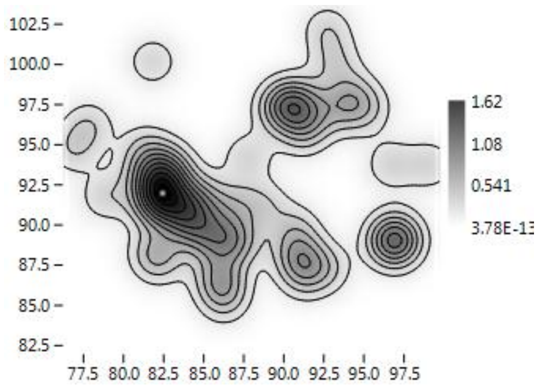


Figure 766 KDE of cells where wooden fragments have been recovered (Past).

A majority of sampling units have raw counts of wooden fragments of less than 2 elements (global mean=1.82 observations per sampling unit). A break point in the frequencies of wooden fragments is attested in correspondence with the value of 3 items; furthermore, three cells distinguish from the majority (representing outliers), with 4, 5 and 7 wooden remains.

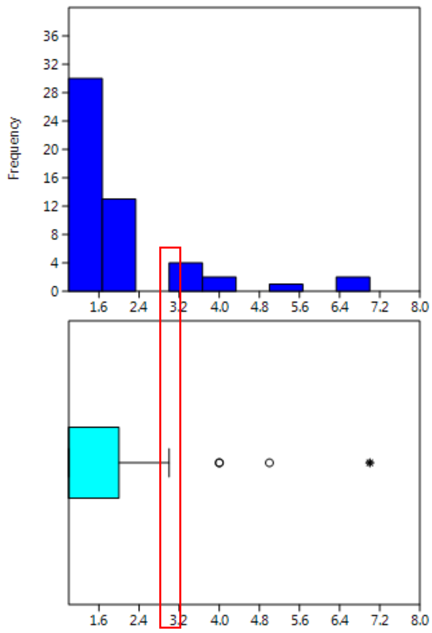


Figure 767 Histogram and box plot of frequencies (wooden fragments) (Past).

The Negative Binomial distribution (with k=0.082 and p=0.369) fits with the observed frequencies of wooden fragments, according to the K-S Test=1. This condition suggests randomness in the spatial distribution of the abundance of wood fragments per sampling unit (Figure 768).

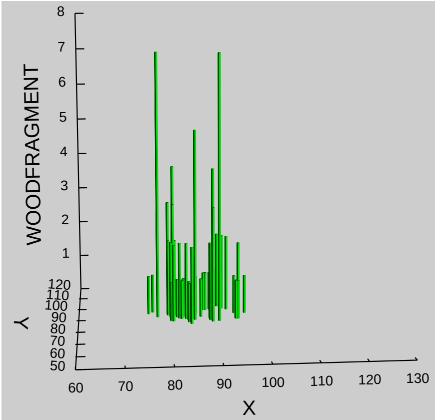


Figure 768 Distribution within the surveyed area of wooden fragments, with relative frequency (Systat 13).

The spatial centroid of the area with wooden remains, calculated using an abundance weighted mean spatial center is is x= 87.118421, y= 91.523684, with 5.65 m of standard deviation along the *x* axis, and 3.81 m along the *y* axis. A standard deviation ellipse with a long axis of 10.85 m and a short one of 16.09 m delimits an area of 137.17 square meters, where most count data appears. It has been estimated an average density of 0.024 items per square meter.

The spatial distribution of the abundance of wooden fragments per sampling unit gives a Global Moran's *I* result of -0.001492. The theoretical (expected) value assuming spatial autocorrelation (lack of spatial independence) is -0-001515 and the standard error is 0.001515. The test of significance using the normality assumption gave a z value of 0.015337, highly non-significant value. These results are comparable with those of the Geary statistics (C=1.001264) and Getis-Ord general G (G= 0.024223). Consequently, we can accept that the spatial distribution of wood fragments is not different than the expected value under a random distribution. This is what would be expected in the case of the same frequency of wood fragments in every spatial location.

The Moran's *I* Correlogram (Figure 769) has been calculated for uniform class distance intervals of 1 meter, and taking into account a 10 meters active lag distance. *I* value at the starting point of the function is 0.112, above the expected value for randomness. As the distance between sampling units increases, *I* value drops off quite gently and continuously above the expected value for randomness until 4 where I value is located on the line. For 3 meters is so attested some positive spatial autocorrelation as well as between 6 and 7 metres it is attested some negative spatial autocorrelation.

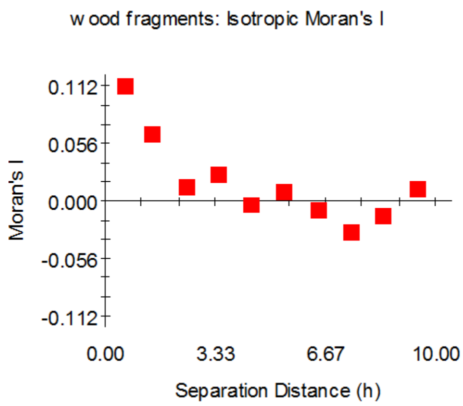


Figure 769 Moran's I Correlogram of cells with wooden fragments (GS+).

This result gives the possibility of finding spatially dependent areas of 3-4 meters of radius, what is a suggestive working hypothesis for locating homogeneous areas.

Taking into consideration what is suggested both by boxplot and histogram that is the occurrence of a breaking point in the frequencies of wood fragments in correspondence with a value of 3 items, sampling units with more than 3 frequencies of observations are analysed separately. However, 71% of wood fragments are located in 90% of the effectively surveyed area, in such a way that only 5 cells show more than 3 items.

We have explored the possible presence of anisotropic variation fitting a theoretical variogram at different directions (Figure 770). Results show no homogeneous variation of semivariance at any degree. The graph of anisotropic Semivariance Surface or Variogram Map (Figure 771) shows that anisotropy is quite widespread and some peaks are observed around the North-East and South-West corners.

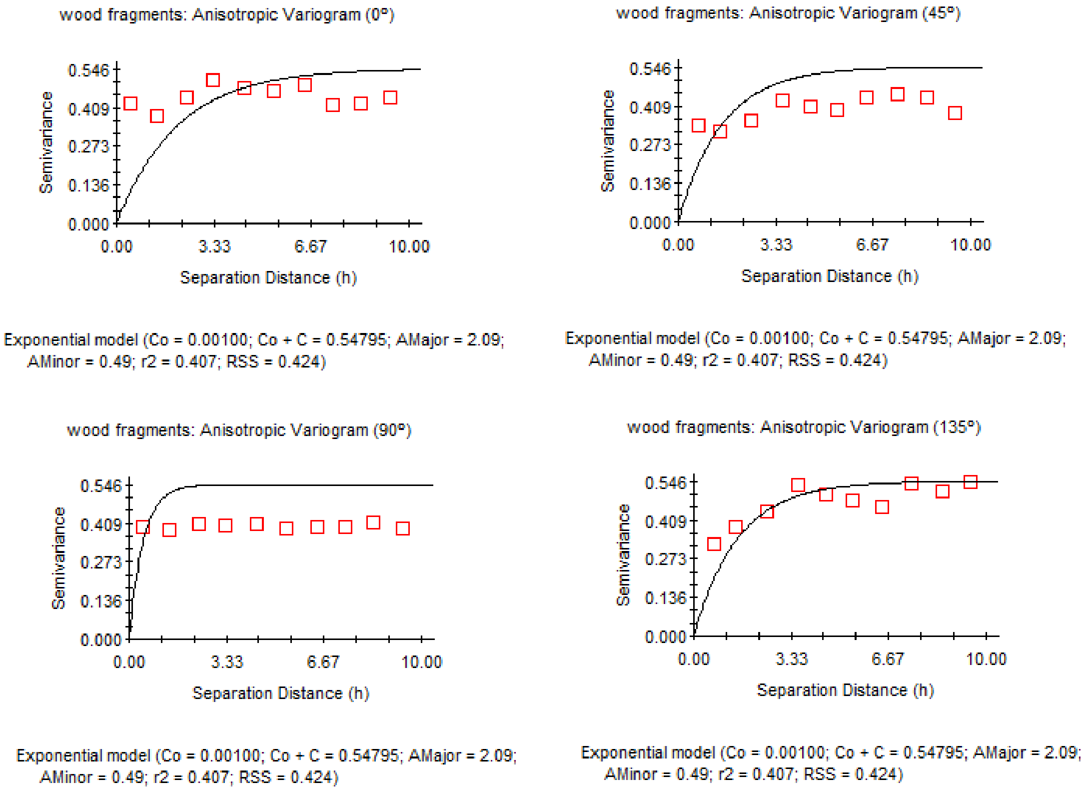


Figure 770 Anisotropic Variogram of wooden fragments recovered during surveys of 2012, Zone 2 (GS+).

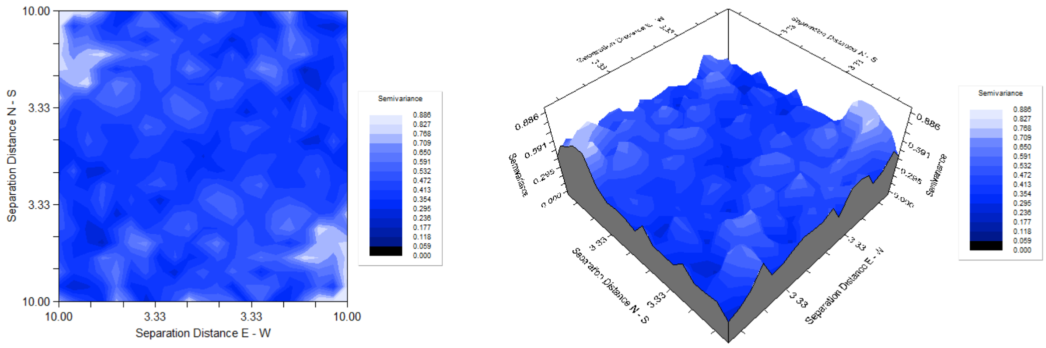


Figure 771 Variogram Map of wooden fragments recovered during surveys of 2012, within Zone 2 (GS+).

An Exponential variogram model has been fitted to the empirical variogram. In this case C_0 (nugget variance) =0.09600, C_0+C (sill) = 0.43900 and A_0 (Range) = 0.45 (Figure 772). This model explains 46.3% of sample variance explained by spatially structured variance.

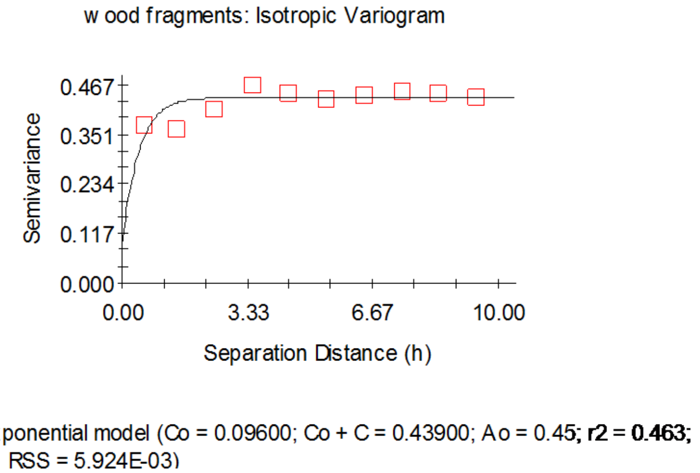


Figure 772 Exponential Isotropic Variogram for wooden fragments recovered during surveys of 2012, zone 2 (GS+).

With this particular variogram, we have estimated the global variation of wooden fragments, using a Kriging (Figure 773). A predominant concentration around the centre of the surveyed area is observed.

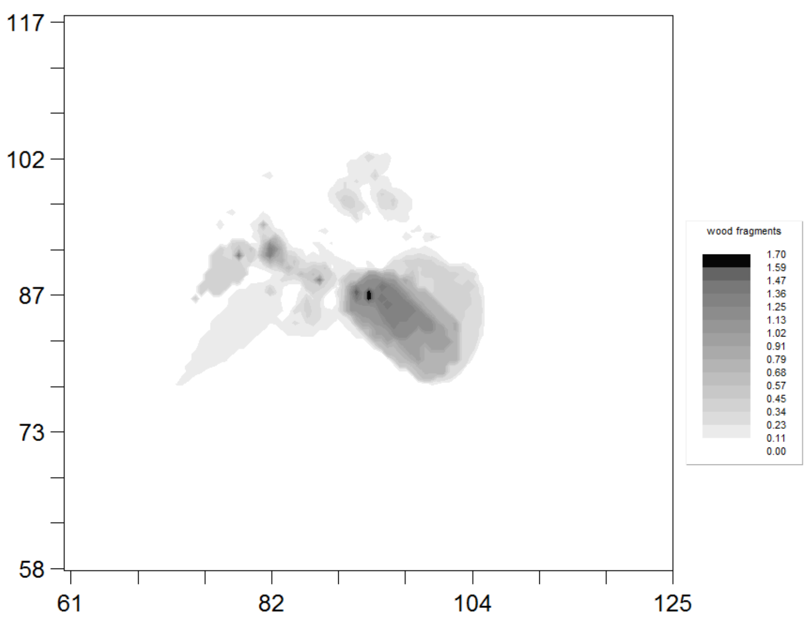


Figure 773 Graphic result of Kriging calculated for wooden fragments recovered during surveys of 2012, within Zone 2 (GS+).

9.2.7 Concotto remains

Among this general category are included both concotto remains as well as fragments of concotto slabs (for more details see Chapter 5). 34 fragments were identified and counted. 634 were the surveyed empty cells, while the sampling unit with more presence gave 6 items. Sampling units where concotto remains have been recovered are spatially distributed as showed in Figure 774.

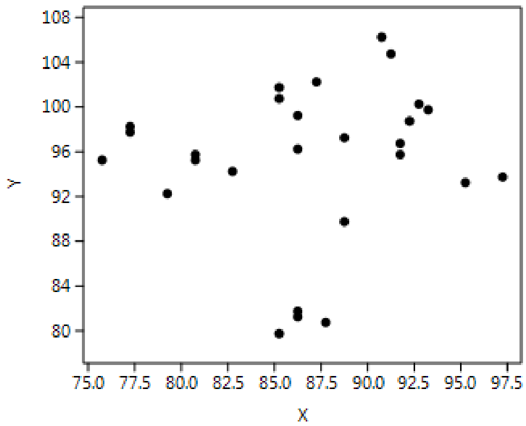


Figure 774 Spatial distribution of cells where concotto remains have been recovered during surveys of 2012, Zone 2 (Past).

Ripley's k analysis (Figure 775) on the distance between sampling units with concotto evidence, suggests the occurrence of a predominant random pattern.

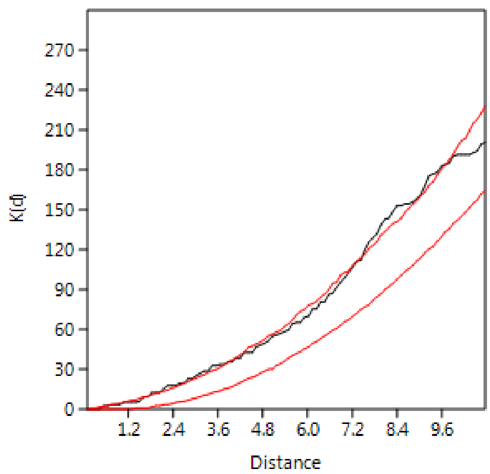


Figure 775 Ripley's *k* analysis on the distance between sampling units with concotto remains (surveys 2012, Zone 2) (Past).

Such condition is confirmed by Clark and Evans test that, for non-empty cells, cannot reject the null hypothesis of a random pattern.

9.3 MULTIDIMENSIONALITY OF SPATIAL RELATIONSHIPS

9.3.1 Introduction

The results of geostatistical intra-site analyses suggest the existence of two differentiated zones. To know better the spatial organization of these two sectors, the spatial correlation of main variables is analysed.

9.3.2 Selecting the most relevant areas (cells with the highest frequencies)

As it has been already mentioned in this chapter, the high amount of sampling units with very low counts of data may alter the correlation structure. Therefore, sampling units with the highest counts of each archaeological functional category have been selected. "Highest" means here what has been considered "outlier" in preceding analysis, that is, those sampling units clearly beyond the interquartile range. Local indicators of spatial association have also been taken into account to select locations with higher relevance. The following figures depict the localization of cells with higher measures of positive autocorrelation using Local Moran one dimensional analysis. The Local Moran statistic $I_{i,t}$ is positive when values at neighbouring locations are similar, and negative if they are dissimilar. Given a Null Hypothesis of no association between the value observed at a location and values observed at nearby sites, that is, where values of Moran I are close to zero, we have selected those cells for which this hypothesis was below the 0.05 threshold of statistical relevance. Monte Carlo randomizations, using conditional randomization, have been used for evaluating the significance of Local Moran statistic values (Jacquez et al. 2014).

9.3.3 Looking for correlations

9.3.3.1 Correlation between general categories within the entire dataset of Zone 1

The entire database (273 entries) has been used to calculate potential ordinal correlations between general categories (that is posts, saddle querns, faunal remains, pottery, concotto, wood fragments, horizontal posts remains and lithic industry). Spearman's Correlation Coefficient has significant positive as well as negative values in very few cases. Positive correlation relates faunal remains and wooden fragments, while posts are negatively correlated with both pottery and concotto remains (Table 22).

	posts	wooden fragments
concotto remains	1.15E-05	
pottery	3.87E-23	
fauna		0.0030364
	posts	wooden fragments
concotto remains	-0.26203	
pottery	-0.55164	
fauna		0.17876

Table 23 Spearman's Correlation Coefficient of the ranks for general categories within Zone 1 (values of p(uncorrect) (above) and p(uncorrect)-statistic (below).

9.3.3.2 Correlation between general categories within the entire dataset of Zone 2

The entire database (661 entries) has been used to calculate potential ordinal correlations between general categories (that is posts, saddle querns, faunal remains, pottery, concotto, wood fragments, horizontal posts remains and lithic industry). Spearman's Correlation Coefficient of ranks adopts negative values. For instance, posts are negatively correlated with pottery as well as with fauna; in the same way, negative correlation relates wooden fragments with both pottery and posts (Table 24).

	posts	wooden fragments
pottery	2.11E-20	0.046266
fauna	0.00013	
wooden fragments		0.004779
	posts	wooden fragments
pottery	-3.49E-01	0.046266
fauna	-0.07755	
wooden fragments		-0.10962

Table 24 Spearman's Correlation Coefficient of the ranks for general categories within Zone 2 (values of p(uncorrect) (above) and p(uncorrect)-statistic (below).

9.3.3.3 *Correlation between salient locations (Local Moran significant cells) within Zone 1*

Those cells that are beyond 0.05 level in the local Moran analysis have been selected. Rank order correlation between dependent variables has been recalculated for those 65 sampling units. Results are different from what obtained in the case of all surveyed sampling units, with a significant zero inflation. Negative correlation relates posts and concotto remains.

9.3.3.4 *Correlation between salient locations (Local Moran significant cells) within Zone 2*

Those cells that are beyond the 0.05 level in the local Moran analysis have been selected. Rank order correlation between dependent variables has been recalculated for those 58 sampling units. Results are different from what obtained in the case of all surveyed sampling units, with a significant zero inflation. Positive correlation relates faunal remains and pottery, as well as saddle querns and both pottery and concotto remains; in the same way, horizontal posts remains are positively correlated with pottery.

Negative correlation relates instead wooden fragments with both lithic industry and pottery (Table 25).

	fauna	lithic industr	saddle quern	concotto ren	pottery	posts
concotto ren	0.11922	0.15576	0.0097342		0.20341	0.27128
pottery	0.028006	0.11422	0.037659	0.20341		0.0022037
posts	0.10413	0.012974	0.72196	0.27128	0.0022037	
wood fragme	0.7326	0.48599	0.37098	0.26966	0.37901	0.055163
remains of h	0.17679	0.47111	0.13253	0.60235	0.020299	0.71631
	fauna	lithic industr	saddle quern	concotto ren	pottery	posts
concotto ren	0.20686	-0.18881	0.3368		0.20341	0.27128
pottery	0.28862	-0.20965	0.27365	0.16949		0.0022037
posts	-0.21557	-0.32441	-0.047737	-0.14686	-0.39414	
wood fragme	-0.045838	-0.093313	0.11965	-0.14736	-0.11767	-0.25318
remains of h	0.17982	-0.096509	0.19986	-0.069852	0.3041	0.048749

Table 25 Spearman’s Correlation Coefficient of the ranks for higher frequencies of general categories within Zone 2 (values of p(uncorrect) (above) and p(uncorrect)-statistic (below).

9.3.3.5 Correlation between sub-categories: domestic fauna versus ceramic open and closed forms within Zone 1

In some cases, global categories like “fauna” or “pottery” can be subdivided into more coherent functional categories, as open and closed ceramic forms. Using the results of the above Local indicators of spatial association, 53 cells have been selected, according to the frequency of those subcategories at those locations, higher than expected assuming the null hypothesis. Few negative correlations confirm what observed for highest frequencies, while subcategories are predominantly independent.

9.3.3.6 Correlation between sub-categories: wild and domestic fauna, ceramic open and closed forms versus concotto slabs and fragments within Zone 2

Subcategories of wild and domestic fauna on one hand, and open and closed ceramic forms have been considered; using the results of the above Local indicators of spatial association, 58 cells have been selected, according to the frequency of those subcategories at those locations, higher than expected assuming the null hypothesis. Rank order correlations are predominantly positive, relating subcategories of pottery within the same global category. Open forms are positively correlated with horizontal posts remains. Faunal subcategories are independent and a negative correlation relates posts and lithic industry.

9.4 *Correspondence Analysis between general categories within Zone 1*

Considering the scarce correlations observed between subcategories of pottery and faunal remains, Detrended Correspondence Analysis (Figure 776) is only performed for higher frequencies of general categories. First two axes explain a cumulative 72%. The first one explains the 44%, proving the negative correspondence between saddle querns and wooden fragments.

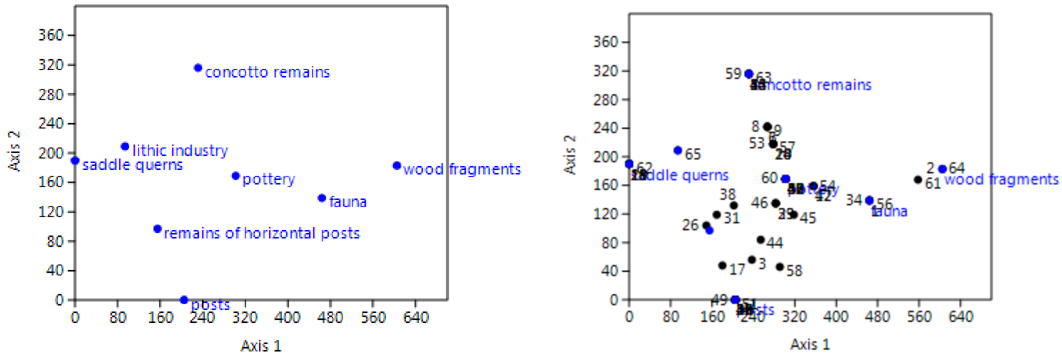


Figure 776 Correspondence Analysis between general categories within the entire dataset of Zone 1.

The graphic result of the inverse distance weighting for Axis 1 (Figure 777) shows the spatial distribution of cells with saddle querns (corresponding to clear values) negatively correlated to wooden fragments (corresponding to grey values). The former are predominantly distributed, in isolated points, in the middle of the area, while the latter in few isolated points are distributed in the South-West corner and around the North-East corner.

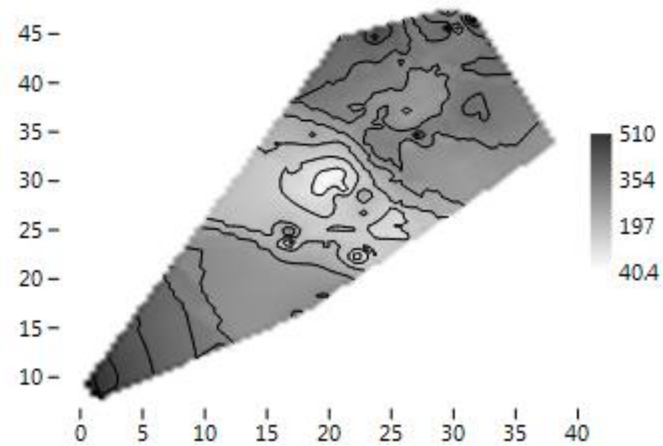


Figure 777 Inverse distance weighting for Axis 1 within Zone 1 (negative correspondence between wooden fragments and saddle querns)

Axis 2, which explains the 28% (Figure 778), shows the negative correspondence between posts and concotto remains. The graphic result of the inverse distance weighting shows a spatial distribution of cells with posts (corresponding to clear values) negatively correlated to concotto remains (corresponding to black values).

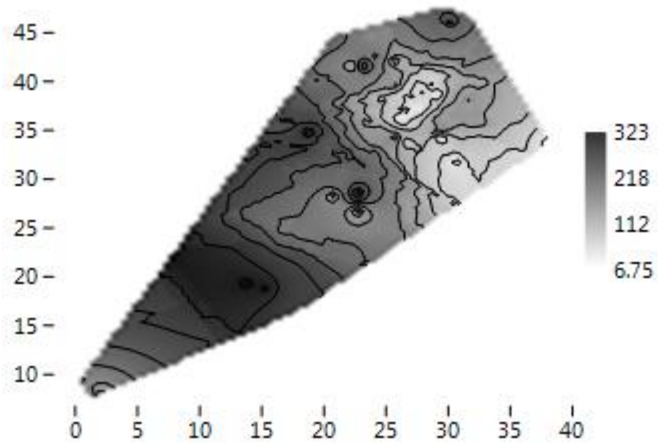


Figure 778 Inverse distance weighting for Axis 2 within Zone 1 (negative correspondence between posts and concotto remains).

Cells where concotto remains have been recorded are distributed in predominant isolated points between 10-20 x 16-18 y, in the middle of the area and around the North-East corner. Sampling units with posts are predominantly concentrated around the North-East and South-West corner, with some presences in the middle of the surveyed area.

9.4.1 Correspondence Analysis between general categories within Zone 2

Considering the scarce correlations observed between subcategories of pottery and faunal remains, Detrended Correspondence Analysis (Figure 4) is only performed for higher frequencies of general categories. Posts are excluded because of their frequency uniformity.
Correspondence Analysis between general categories within Zone 2 (Figure 779) shows that the first two axes explain a cumulative 83%. The first one in particular explains the 57%, proving the occurrence of negative correspondence between concotto remains and wooden fragments.

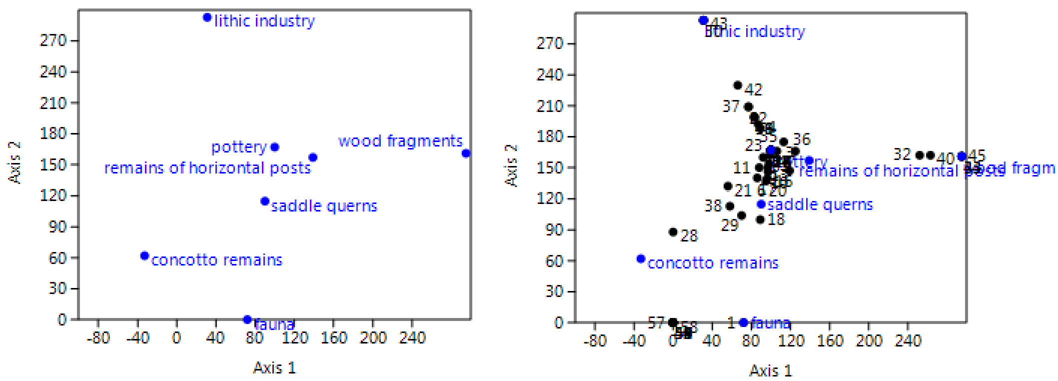


Figure 779 Correspondence Analysis between general categories within the entire dataset of Sector 2

The graphic result of the inverse distance weighting for Axis 1 is the spatial distribution of sampling unit with wooden fragments (corresponding to darkest grey and black values), negatively correlated with cells where concotto remains (corresponding to clear values) have been recovered. The former are distributed in three main higher density points located in the North-East corner and in the Eastern side of the surveyed area. The latter are instead predominantly concentrated in the Northern side (between 85-95 x 90-100 y) (Figure 780).

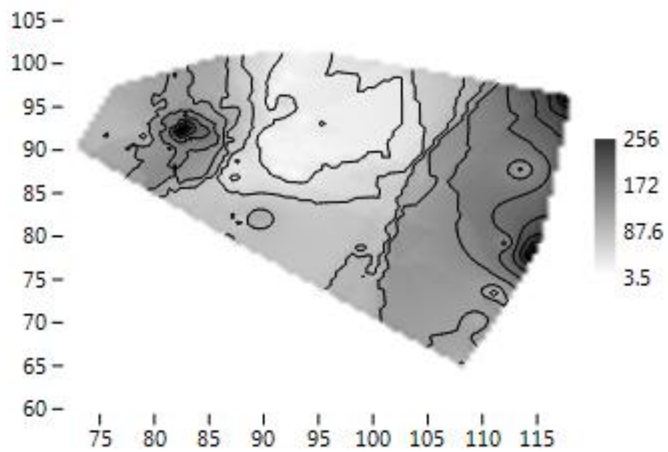


Figure 780 Inverse distance weighting for Axis 1 within Zone 2 (negative correspondence between wooden fragments and concotto remains)

Axis 2 (which explains 26%) shows the negative correspondence between lithic industry and faunal remains. The graphic result of the inverse distance weighting shows the spatial distribution of cells with lithic industry (corresponding to darkest grey and black values) negatively correlated to those where faunal remains (corresponding to clear values) have been recovered (Figure 781). The former are distributed in isolated points around the North-West corner and in the Southern-East portion of surveyed area, while the latter are predominantly concentrated in the middle.

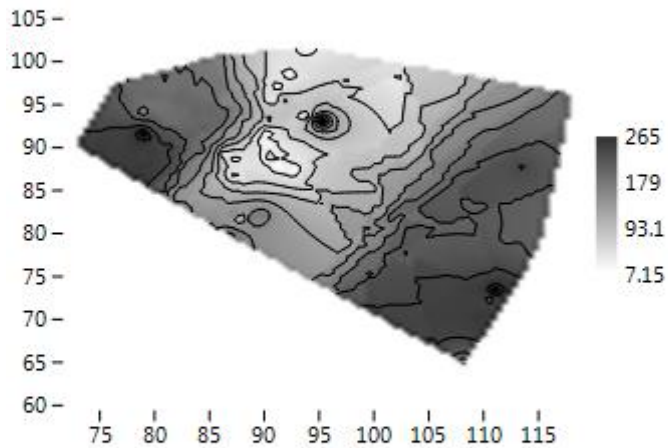


Figure 781 Inverse distance weighting for Axis 2 within Zone 2 (negative correspondence between lithic industry and faunal remains).

10. DISCUSSION

10.1 Introduction

Geostatistical analysis has allowed us to distinguish between random, uniform, and aggregated spatial distribution. In many cases, overdispersion makes it difficult to reach a clear understanding of spatial patterns, because it can be consequence of too many different unrelated mechanisms (more details in Chapter 4). Nevertheless, overdispersion and randomness are not synonymous with unpredictable and unintelligible. Rather, they are quantitative properties of observed distributions and, therefore, should be explained in terms of depositional events, post-depositional processes or survey biases. In this sense, it is indispensable to provide a “biographical” reconstruction of the processes that contributed to site formation and deformation. Similarly, any attempt to interpret accurately the observed spatial pattern, should take into consideration the “biography” of the material evidence that composes our archaeological record (see Chapters 2 and 3 for the general theory and Chapter 4 and 5 for the case study).

When explaining a spatial pattern, the survey bias (listed in details in Chapters 1 and 6) has to be considered, in order to avoid incorrect interpretation. Among them, it is important to remark the stratigraphic differences and the preservation issues associated to the three general sectors considered in this research (as below mentioned). The results obtained from a one-centimetre-compressed layer (surveys of 2009 and 2012) are not the same than those derived from the analysis of a selected portion of the entire archaeological “superficial package” (surveys of 2001, below mentioned).

Furthermore, the scale of analysis has to be taken into account. The use of 0.5 square metrers sampling units is very convenient when the proper coordinates of individual items are absent; however, such a method may introduce noise and indetermination (in the sample), in particular when the spatial dependence between single cells is analyzed. When a uniform lattice of equal sized cells is used, we expect to find, as general rule: (a) a predominant uniformity in the frequencies of each observable in nearby sampling units, and (b) random differences between neighbour frequencies. However, there are differences when such spatial pattern characterizes immovable material evidence (such as posts and saddle querns), rather than more portable objects (such as faunal remains and pottery). The interpretation of such pattern may indeed assume a different meaning for each distinct category of observation, in light of the “biographical reconstruction” that we need to attempt. For instance, each potsherd, fragmented bone or post had become part of the archaeological record through a specific “biographical itinerary”, which is strongly related to their use “in life” and potential re-use “after death”.

Furthermore (as summarized in Chapters 2, 3 and 5), several sources of disturbance (especially the water drop-off and wave action of the lake) have altered the initial spatial distribution of materials within this archaeological context. Such phenomena may have had stronger effects on light and small items (the so-called “portable objects” mentioned above), due to their intrinsic features (i.e. reduced weight and higher ratio of fragmentation observed; these items are also easy to move). This problem should be taken into consideration when interpreting the observed spatial patterns.

Therefore, overdispersion or uniformity as spatial rule for the immovable evidence, such as saddle querns and posts, is very likely to reflect the original spatial pattern that was intentionally chosen by the inhabitants of the settlement). This pattern is also related to the suitability of such artefacts – that were more difficult to move or be affected by post-depositional processes – to selected tasks that were performed in specific spatial locations. Support to this assumption is offered by archaeological evidence from previous mentioned lakeside settlement contexts: for example, posts, which represent the preserved remains of the interior of ancient buildings, have been driven up into the marl sediments of lakes for metres (between 2-3 and 4-5 metres), quickly and strongly stabilizing within such natural deposit (see Chapter 3). At the site considered here, where high frequencies of posts are counted, it is unlikely that the inhabitants had removed some of these items for re-use. This can also be suggested in view of the fact that posts were strongly embedded in the archaeological record, while also taking into consideration the energy expenditure required for their removal.

Other evidence supporting such reconstruction is the widespread cluster pattern (according to the Clark and Evans test) fitted by the sampling units where only one post has been recovered, despite the general overdispersion of cells with more items. Taking into account the scale of analysis, such condition suggests that these sampling units would have probably harboured additional posts. These posts might have been introduced in the ground surface following some building restoration/renovation, as archaeologically documented in other lakeside settlement contexts (for more details see Chapter 3). However, the lack of specific dendrochronological information does not allow us to prove such hypothesis. For saddle querns, a similar scenario is observed; they can be interpreted as immovable evidence according to their local provenience, because of their high weights and dimensions, and since they have been outcropped in the surrounding area. They are unlikely to have been moved *in antiquo* as well as nowadays, except for a few cases of modern reclamations that have been documented, particularly in relation to the smallest saddle querns (Chapter 5).

Concerning the portable objects, namely all the fragmented and light material evidence recovered at the site, different spatial models could be adequate to explain the patterns attested depending on the intentional or non-intentional behaviours that produced them (Chapter 4). For instance, an intentional accumulation of bone fragments, resulting from the repeated butchery of cattle and pigs in Zone 1 of sector A, should fit a geometric (exponential) model. Similarly, if accidental jar breakage was repeated within Zone 1, potsherds should be randomly distributed. In most cases, however, the spatial distribution of archaeological observables does not correspond to these models, because artefacts and ecofacts placement is influenced by various kinds of post-depositional processes. Such processes may have rendered the spatial pattern more amorphous, lower in elements density and more homogeneous in relation to their internal density. If all the material evidence ascribable to portable objects were uniformly or randomly distributed in the same way, this spatial pattern would suggest that the original distribution had been completely obscured by post-depositional processes. In contrast, accumulation of at least some categories of materials (such as wooden fragments and horizontal posts remains as well as pottery and faunal remains) appears to be overdispersed or uniformly distributed. Such pattern might be the consequence of changes to the archaeological record only partially affected by post-depositional disturbances. This is what we would expect for refuse, namely the discarded material evidence that was accumulated during the last phase of site occupation, and they may be largely located where the activity was performed. Conversely, the minority of sampling units, where the highest frequencies of observables have been recorded, reveal the partially preserved traces of the original spatial pattern. Despite the effects of post-depositional disturbances, these cells displaying the highest accumulation of items represent the foci of the relevant activities carried out in the settlement (Chapter 1 and 4). Thus, outliers (and potential multimodality) are decisive to reconstruct the differential use of space, especially for portable objects. Summarizing the obtained results, the interpolated scalar fields, which proved their statistical effectiveness, are introduced in the next sections.

10.1.1 Interpreting the results of geostatistic intra-site spatial analysis of the area surveyed in 2001

PALIMPSEST: the results provided by the analysis of all the archaeological observations summed up, confirm that non-empty sampling units are not distributed according to a random or uniform pattern. The null hypothesis of a post-depositional random or uniform dispersion of artefacts and other preserved material generated by the water drop-off of the lake can be rejected. Overdispersion is observed for non-empty sampling units and can be associated to multimodal patterns, with a heavy incidence of outlier cells (i.e. points of overabundance surrounded by cells with a lower frequency of artefacts). Global positive autocorrelation is absent; this is expected in a spatial pattern characterized by spatially differentiated accumulations. Local areas with high positive correlation confirm the existence of such differentiated zones, which are observed in the North-East and the South-West corners of the surveyed area. The interpolated scalar fields represent the spatial differentiation between individualized areas of accumulation vs. emptiness areas. An East-West pattern of anisotropy evidenced by the Variogram Map is compatible with differentiation in two areas.

VERTICAL POSTS: non-empty cells are uniformly distributed. Global positive autocorrelation is absent; this is expected in a spatial pattern characterized by uniformity in the spatial distribution of sampling units with posts. It is statistically attested the independence of the presence/absence of posts at any distances, with some hints of continuity in the medium sized areas (Variogram Map). The interpolated scalar field highlights the alignment of a majority of vertical posts along the estimated shoreline of the ancient lake (North-East-South-West orientation).

SADDLE QUERNS: non-empty cells are overdispersed. Global positive autocorrelation is absent, which is expected in the case of quite the same frequency of evidence in every spatial location. The interpolated model reveals some differences in the spatial distribution of posts; the general North-East-South-West alignment is maintained, while the differentiated areas in the South-West and North-East corners are more clearly remarked. The anisotropic deformation seems to affect (in higher degree) the North-East concentration, whereas the South-Western accumulation would have better maintained its original organization (Variogram Map). There are some very significant empty areas, more evident in the Center-Northern and Southern parts of the most relevant North-East concentration.

FAUNAL REMAINS: overdispersion is observed for non-empty sampling units and can be associated to a multimodal pattern, with a heavy incidence of outlier cells. Global positive autocorrelation is absent, which is expected in the case of a predominance of the same frequencies, in the quantity of faunal remains, in the majority of the spatial locations. It is possible to observe the existence of a major concentration of faunal remains (accumulation) in the South-West corner; it is also possible to note a deformation – probably due to post-depositional processes – parallel to the estimated shoreline of the ancient lake.

For both the categories of faunal remains and pottery, the analyzed sub-categories (functional types for pottery, and taxa as well as skeletal body portions for fauna) do not provide reliable results in relation to the specific spatial distribution of the cells where such remains have been recovered.

POTTERY: overdispersion is observed for non-empty sampling units and can be associated to a multimodal pattern, with a heavy incidence of outlier cells. Global positive autocorrelation is absent, which is expected in the case of a predominance of the same frequencies in the majority of the spatial locations. Pottery seems to be irregularly distributed, with very small continuity at medium distances. Points of maximum concentration are clustered and concentrated in the North-East corner of the surveyed area (accumulation). While the area with the least significant accumulation follows a South-West-North-East orientation, the sector of maximum concentration of pottery follows an East-West direction.

WOODEN FRAGMENTS: uniformity is observed for non-empty sampling units. Global positive autocorrelation is absent, which is expected in the case of a predominance of the same frequency of items in quite every spatial location. The Variogram Map suggests a higher impact of anisotropy, even at small distances, which can be interpreted in terms of statistical independence in the spatial difference of frequency. Sampling units where outlier has been recovered are distributed following the estimated shoreline of the ancient lake. The interpolated model suggests that the points of predicted higher concentration are equidistant from the South-West and North-East corners, where most of the observations from the other categories are recorded.

REMAINS OF HORIZONTAL POSTS: non-empty sampling units are clustered. Global positive autocorrelation is absent, which is expected in the case of a predominance of the same frequencies (of artefacts) in the majority of the spatial locations. The Variogram Map suggests a higher impact of anisotropy, even at small distances, which can be interpreted in terms of statistical independence in the spatial difference of frequency. Sampling units where remains of horizontal posts have been recovered are distributed along the estimated shoreline of the ancient lake.

As highlighted in Figure 782, positive correlation, suggested by the Spearman's Rank Correlation Coefficient, is observed between pottery and concotto remains. In particular, the former accumulated, in its highest frequency, in the North-East zone. In addition, wooden fragments and horizontal posts remains are positively correlated. This was predictable, since such artifacts could be predominantly associated with the remains of ancient buildings in this context. However, in most cases, they are not especially spatially related to posts. This differential distribution is a direct effect of post-depositional processes, which may have partially contributed to the displacement of such scarce and light evidence from their original location. In line with these correlations are the results of Correspondence Analysis, which positively correlates wooden fragments and the remains of horizontal posts; these are negatively correlated with concotto remains and pottery, which, in turn, are reciprocally positively correlated (first Axis). Therefore, when wooden fragments and horizontal posts remains are observed, both potsherds and concotto remains are absent, as confirmed by Figure 11. Moreover, the Spearman's Rank Correlation Coefficient proves the negative correlation between posts and saddle querns; such artefacts seem to be widespread within all the surveyed area, but, in some cases, they are observed in different spatial locations. This is for example the case of the North-East zones in the Eastern side of the surveyed area, where saddle querns are observed and posts are absent. Finally, Correspondence Analysis suggests an additional negative relationship between potsherds and faunal remains, which has already been mentioned for the spatially differentiated accumulations.

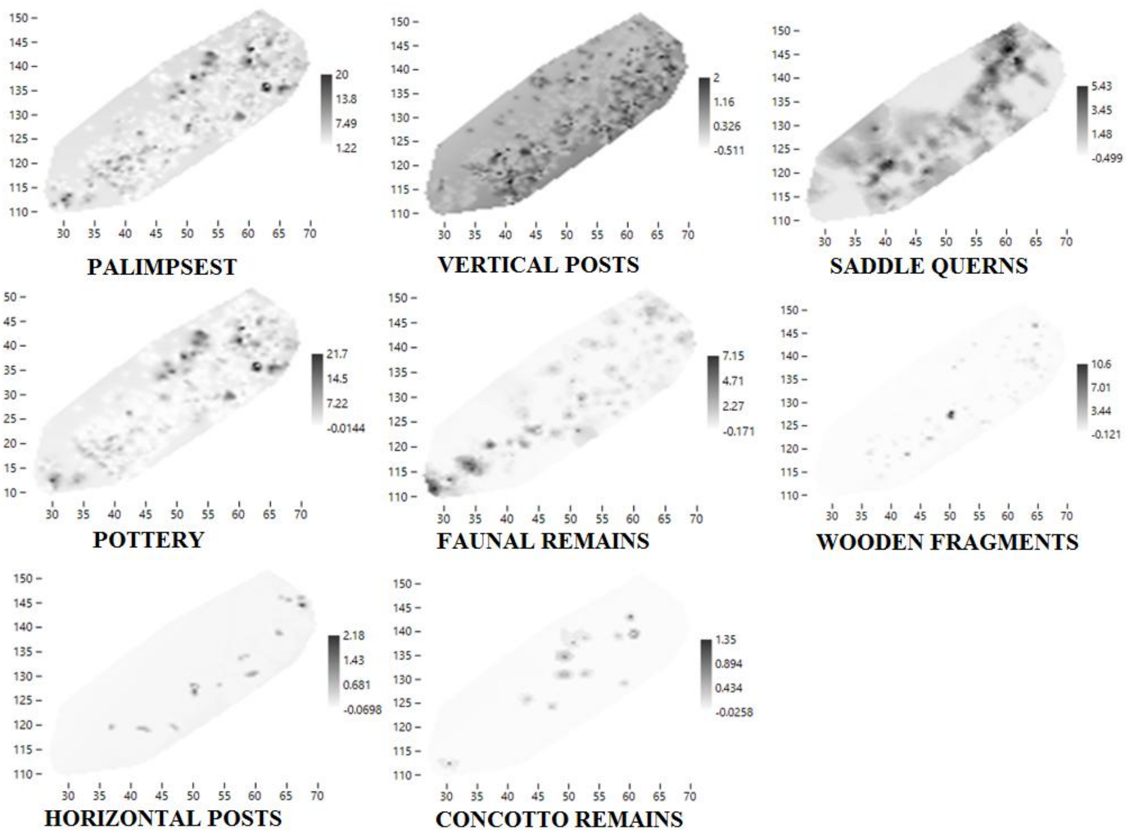


Figure 782 Graphic results of Inverse Distance Weighting for all categories of evidences (surveys 2001) (Past).

10.1.2 Interpreting the results of geostatistic intra-site spatial analysis of the area surveyed in 2009

PALIMPSEST: the results provided by the analysis of the absolute count of the archaeological observations confirm that non-empty sampling units are not distributed according to a random pattern. The Null Hypothesis of a post-depositional random or uniform dispersion of artefacts and other preserved materials generated by the water drop-off of the lake can be rejected. Overdispersion is observed for non-empty sampling units and can be associated to a multimodal pattern, with a heavy incidence of outlier cells. Empty sampling units are clustered, suggesting the existence of two zones. The first Zone is identified in the South-West corner, and extends from there into the central part of the surveyed area, while the second Zone has been recorded in the North-East corner. Global positive autocorrelation is absent, which is expected in a spatial pattern characterized by spatially differentiated accumulations. Local areas with high positive correlation confirm the existence of such differentiated zones. Material observations are continuously distributed, according to a predominant North-East-South-West orientation. A lack of spatial continuity and a predominant anisotropy are observed perpendicularly to the lakeshore line. The interpolated scalar fields reveal the spatial differentiation between individualized accumulation/emptiness areas.

VERTICAL POSTS: non-empty cells are clustered. Global positive autocorrelation is absent, proving that the probability of detecting posts in a specific sampling unit does not depend on their presence in the neighbourhood. It is statistically attested (the) independence of the presence/absence of posts at any distances, with some hints of continuity in the medium sized areas (Variogram Map). The interpolated scalar field stresses the alignment of a majority of vertical posts along the estimated shoreline of the ancient lake (North-East-South-West orientation). We can note the presence of two differentiated areas, separated by overdispersed empty cells.

SADDLE QUERNS: non-empty cells are clustered. Global positive autocorrelation is absent, which is expected in the case of quite the same frequency of evidence in every spatial location. The interpolated model reveals some differences in the spatial distribution of posts; the general North-East-South-West alignment is maintained, but the differentiated areas in the South-West and North-West corners are more clearly remarked. Saddle querns are absent in the North-West corner, whereas posts are very common there. Even the spatial continuity of saddle querns in the middle of the area is differently distributed compared to posts. Saddle querns seem to occupy the cells empty of posts and are predominantly located near the hypothetical shoreline of the ancient lake.

FAUNAL REMAINS: non-empty sampling units are clustered; a multimodal pattern and a heavy incidence of outlier cells is observed. Some kind of global positive autocorrelation is attested, which is expected when only some of the spatial locations have the same frequency of items. The existence of a main concentration of faunal remains (accumulation) in the South-West corner is observed alongisde a deformation parallel to the estimated ancient lakeshore line (Variogram Map); such deformation is probably determined by post-depositional processes.

For both the categories of faunal remains and pottery, the analyzed sub-categories (functional types for pottery, and taxa as well as skeletal body portions for fauna) do not provide reliable results in relation to the specific spatial distribution of the cells where such remains have been recovered.

POTTERY: overdispersion is observed for non-empty sampling units and can be associated to a multimodal pattern, with a heavy incidence of outlier cells. Some kind of global positive autocorrelation is attested, which is expected when not all the spatial locations have the same frequency of items. The points of maximum concentration are clustered and concentrated in the South-West corner, with a quite large "tail" in the middle of the surveyed area (Zone 1) and another small accumulation around the North-East corner (predominantly concentrated within Zone 2). Such "tail" could be an effect of anisotropy (determined by post-depositional processes), which is predominately concentrated around the Western and Eastern sides of the surveyed area; it is North-East-South-West oriented (i.e. parallel to the lakeshore line) and leaves only a narrow fringe of spatial continuity in the middle.

LITHIC INDUSTRY: non-empty cells are clustered. Global positive autocorrelation is absent, which is expected when the same frequency of items is observed in almost all spatial location. The Variogram Map suggests a higher impact of anisotropy, even at small distances, which can be interpreted in terms of statistical independence in the spatial difference of frequency. The interpolated model suggests that the points of predicted higher concentrations are predominantly accumulated in the South-West corner, where most of all observations of other "portable" categories are accumulated. The sub-categories of pebbles/choppers and debitage are accumulated in the same way.

WOODEN FRAGMENTS: non-empty cells are clustered. Global positive autocorrelation is absent, which is expected when the same frequency of wooden fragments is observed in quite every spatial location. The Variogram Map suggests a higher impact of anisotropy, even at small distances, which can be interpreted in terms of statistical independence in the spatial difference of frequency. The sampling units where outliers have been recovered are distributed along the estimated shoreline of the ancient lake. The interpolated model suggests the presence of higher frequencies in both sub-zones (with a predominant accumulation in the North-East corner).

REMAINS OF HORIZONTAL POSTS: non-empty sampling units are clustered. Global positive autocorrelation is absent, which is expected when the same frequency of items is observed in quite every spatial location. The Variogram Map suggests a higher impact of anisotropy, even at small distances, which can be interpreted in terms of statistical independence in the spatial difference of frequency. Sampling units where remains of horizontal posts have been recovered are distributed following the estimated shoreline of the ancient lake and are largely accumulated in the North-East corner.

CONCOTTO REMAINS: non-empty sampling units are uniformly distributed. Global positive autocorrelation is absent, which is expected when the same frequency of items is observed in every spatial location. The Variogram Map suggests a higher impact of anisotropy, even at small distances, which can be interpreted in terms of statistical independence in the spatial difference of frequency. The sampling units where remains of concotto have been recovered are distributed along the estimated shoreline of the ancient lake in both sub-zones (although a predominant accumulation is observed in the South-West corner).

As highlighted in Figure 783, positive correlation, suggested by the Spearman's Rank Correlation Coefficient, is observed between pottery, concotto fragments, lithic industry and faunal remains. These categories are all predominantly distributed, in higher frequencies, in the South-West corner. The same categories are negatively correlated with saddle querns (as also confirmed by Correspondence Analysis), proving that in most spatial locations where faunal remains or pottery are observed, saddle querns are largely absent. Furthermore, both the Spearman's Rank Correlation Coefficient and Correspondence Analysis prove the positive correlation between wooden fragments and horizontal posts remains; in turn, these are negatively correlated with faunal remains, pottery, lithic industry and concotto remains. In particular, while the former (i.e wooden fragments and horizontal posts remains) are predominantly distributed, in their higher frequencies, in the North-East corner, the latter are more often accumulated in the South-West corner. Correspondence Analysis, which predominantly associates faunal fragments with concotto remains, suggests the differentiated distribution of pottery, which is also accumulated in the North-East corner. Finally, some interesting observations regarding the sub-categories of pottery and faunal remains are provided by the Spearman's Rank Correlation Coefficient; in particular, positive correlation is observed between lithic industry and wild faunal remains, as well as between closed ceramic forms and concotto remains.

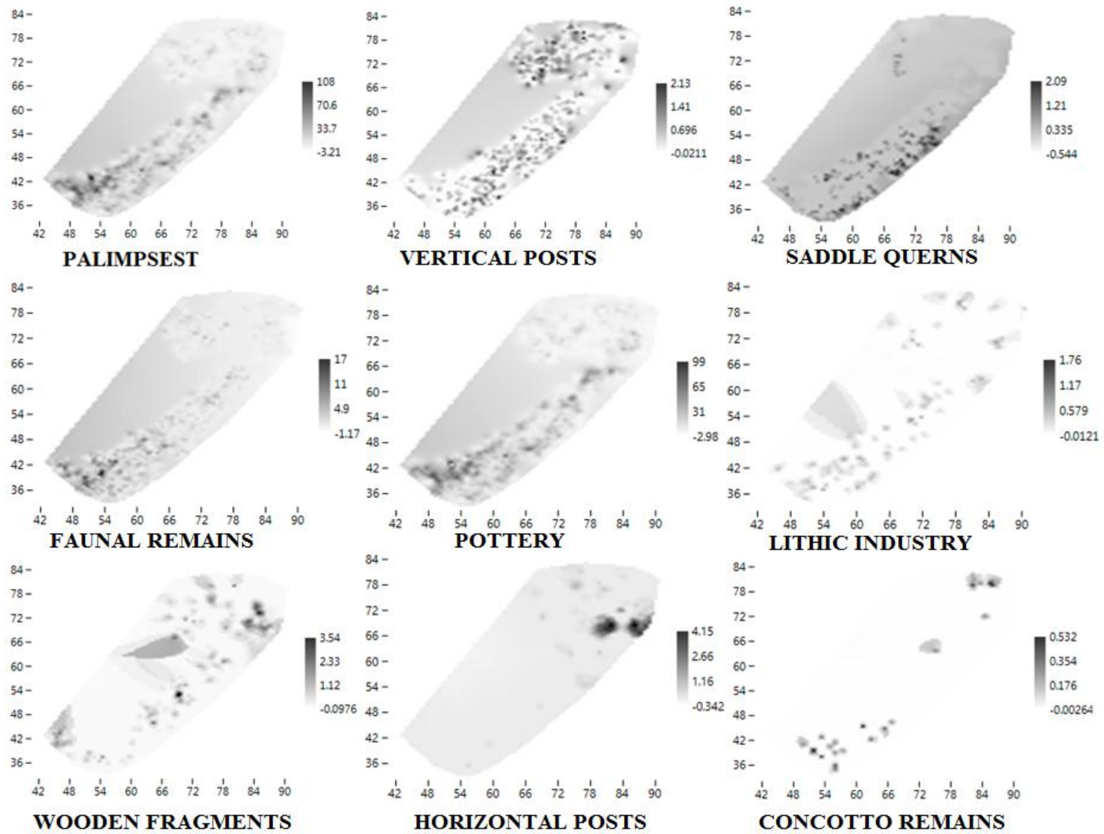


Figure 783 Graphic results of Inverse Distance Weighting for all categories of evidences (surveys 2009) (Past).

10.1.3Interpreting the result of geostatistic intra-site spatial analysis of Zone 1 surveyed in 2012

PALIMPSEST: the results provided by the analysis of all the archaeological observations confirm that non-empty sampling units are not distributed according to a random or uniform pattern. The Null Hypothesis of a post-depositional random or uniform dispersion of artefacts and other preserved material generated by the water drop-off of the lake can be rejected. Non-empty cells are clustered. Global positive autocorrelation is absent, which is expected in a spatial pattern characterized by spatially differentiated accumulations. A local area with positive correlation is observed in the North-East corner, where a major accumulation of observations is identified. By contrast, the presence of material evidence tends to decrease along the North-East-South-West alignment (i.e. the estimated shoreline of the ancient lake). The interpolated scalar field represents the spatial differentiation between individualized accumulation/emptiness areas. A widespread anisotropy evidenced by the Variogram Map is compatible with a deformation determined by post-depositional processes.

VERTICAL POSTS: non-empty cells are clustered. Some kind of global positive autocorrelation is observed, which is expected when not all the spatial locations have the same frequency of items. It is statistically attested independence of the presence/absence of posts at any distances, with few hints of continuity in the medium sized areas (Variogram Map). The interpolated scalar field stresses the alignment of a majority of vertical posts along the estimated shoreline of the ancient lake (North-East-South-West orientation), predominantly concentrated in the North-East corner.

SADDLE QUERNS: non-empty sampling units are randomly distributed. Saddle querns are scarcely observed within this zone; by contrast, they are predominantly accumulated, in separated points, around the central sector of the Western portion of the surveyed area; furthermore, they are distributed according to a North-East-South-West orientation (parallel to the ancient lake shoreline).

FAUNAL REMAINS: overdispersion is observed for non-empty sampling units. Faunal remains are scarcely observed within this zone; (by contrast,) they are predominantly accumulated in the North-East corner of the surveyed area (and in some additional, isolated points in the middle of the area, and in another point close to the South-West corner); they also display a North-East-South-West orientation (parallel to the lake shoreline).

POTTERY: non-empty sampling units are clustered. Global positive autocorrelation is absent, which is expected when a predominance of the same frequencies in the majority of the spatial locations is attested. Pottery seems to be irregularly distributed, with very small continuity at medium distances. Points of maximum concentration are noted in the North-East corner; an area of less significant accumulation is also observed in the middle of the surveyed area. Observations are predominantly distributed according to a South-West-North-East orientation, but some differentiated alignments are also observed in the zone of maximum concentration.

WOODEN FRAGMENTS as well as REMAINS OF HORIZONTAL POSTS are quite absent within the Zone 1.

CONCOTTO REMAINS (Figure 30): non-empty cells are randomly distributed. Concotto fragments are scarcely observed within this zone; they are predominantly accumulated in the middle of the surveyed area, with a North-East-South-West orientation (parallel to the lake shoreline).

Positive correlation, suggested by the Spearman's Rank Correlation Coefficient, is observed between faunal remains and wooden fragments for their shared distribution in the South-West and North-East corners. By contrast, posts and concotto remains are negatively correlated since when the former are observed, the latter are absent. This is also proved by Correspondence Analysis. According to the Spearman's Rank Correlation Coefficient, the sub-categories of both faunal remains and pottery are predominantly independent from each other.

10.1.4.Interpreting the results of geostatistic intra-site spatial analysis of Zone 2 surveyed in 2012

PALIMPSEST: The results provided by the analysis of all the archaeological observations summed up confirm that non-empty sampling units are not distributed according to a random or uniform pattern. The Null Hypothesis of a post-depositional random or uniform dispersion of artefacts and other preserved material generated by the water drop-off of the lake can be rejected. Clustering is observed for non-empty sampling units. Global positive autocorrelation is absent, which is expected in a spatial pattern characterized by spatially differentiated accumulations. Two predominant accumulations of observables are noted; the North-West corner is occupied by all categories of observations, while in the opposite corner quite only posts are present. The observed pattern of anisotropy evidenced by the Variogram Map is compatible with differentiation in the two Zones.

VERTICAL POSTS: non-empty cells are clustered. Global positive autocorrelation is absent, which is expected when the same frequency of posts is observed quite in every spatial location. It is statistically attested independence of the presence/absence of posts at any distances, with some hints of continuity in the medium sized areas (Variogram Map). The interpolated scalar field stresses the alignment of a majority of vertical posts along the estimated shoreline of the lake (North-East-South-West orientation), particularly in the North-West corner, while more differential alignments are observed in the opposite corner.

SADDLE QUERNS: non-empty cells are uniformly distributed. Global positive autocorrelation is absent, which is expected when the same frequency of evidence is observed in every spatial location. The interpolated model reveals some differences in the spatial distribution of posts within the same sub-zone; the general alignment North-East-South-West is maintained (together with a North-West-South-East arrangement). The anisotropic deformation is higher in the middle of the distribution (Variogram Map).

FAUNAL REMAINS: non-empty cells are uniformly distributed. Global positive autocorrelation is absent, which is expected when the same frequency of evidence is observed in every spatial location. A main concentration of faunal remains is observed in the North-East corner of the surveyed area and, as suggested by the Variogram Map, a strong post-depositional deformation, perpendicular to the estimated ancient lakeshore line, is attested.

POTTERY: non-empty cells are clustered. Global positive autocorrelation is absent, which is expected in the case of a predominance of the same frequencies in the majority of the spatial locations. Pottery seems to be irregularly distributed, with very small continuity at medium distances. Points of maximum concentration are uniformly distributed and concentrated in the middle of the North-East corner of the surveyed area. While the area with less significant accumulation follows a South-West-North-East orientation, higher concentrations are predominantly linearly distributed.

LITHIC INDUSTRY: overdispersion is observed for non-empty sampling units. Lithic industry is scarcely observed within this zone; the observations are predominantly distributed in isolated points in the Eastern side of the surveyed area, with a North-East-South-West orientation (parallel to the lake shoreline).

WOODEN FRAGMENTS: non-empty sampling units are uniformly distributed. Global positive autocorrelation is absent, which is expected in the case of a predominance of the same frequencies in every spatial location. Wooden fragments are accumulated in the middle of the surveyed area without continuity between frequencies at any distance (as suggested by the Variogram Map, due to the higher values of anisotropy in every direction).

CONCOTTO REMAINS: non-empty sampling units are uniformly distributed. Concotto fragments are rare within this zone; the observations are predominantly distributed in isolated points in the Eastern side of the surveyed area, with a North-East-South-West orientation (parallel to the lake shoreline).

Positive correlation, suggested by the Spearman's Rank Correlation Coefficient, is observed between faunal remains and pottery. Both are predominantly distributed, in their highest frequencies, in the middle, around the Western side, of the surveyed area. Saddle querns are also positively correlated with pottery and concotto remains. Conversely, negative correlation is attested between wooden fragments and the other categories of portable objects (such as, for instance, pottery and lithic industry). Such correlations, as well as the results of Correspondence Analysis, must be interpreted in terms of presence or absence in the same spatial locations. In this sense, concotto remains are negatively correlated with wooden fragments, as well as lithic industry with faunal remains.

10.1.5 Interpreting the superficial spatial patterns recognized at the site

The results of the analyses presented above offer some important answers to the research questions that inform this study. Crucially, this allows us to open windows into the past, by dissecting our palimpsest.

1) *POST-DEPOSITIONAL EFFECTS: was the spatial distribution of artefacts and ecofacts rearranged according to these deformation processes?*

In general, post-depositional effects have produced a more amorphous spatial pattern for most of the portable objects. The categories of fauna, pottery, concotto, wooden fragments and remains of horizontal posts are strongly affected by this disturbance; post-depositional processes have indeed changed their internal and external composition in such a way that, in most cases, their attribution to specific functional or taxonomic sub-categories was impossible. In all surveyed areas, however, such artefacts are not distributed according to a unique random or uniform pattern, as it would be expected if their spatial distribution had been produced by the same post-depositional processes. Conversely, they are characterized by differentiated spatial patterns, even within two zones of the same area (surveys 2001 and 2009). An accumulation of pottery, spatially differentiated from the accumulation of faunal remains, is observed in the area surveyed in 2001 and, partially, in the sector investigated in 2009. In contrast, both zones investigated in 2012 show a predominant uniform pattern, for quite all portable categories. Notably, these zones are the most threatened by post-depositional processes, probably due to their higher exposure to external phenomena (for instance, the operation of survey delayed to start).

Spatial differentiation is also observed for the wooden fragments and horizontal posts remains. Such artefacts, in particular as far as the area investigated 2001 is concerned, are spatially associated, but negatively correlated with the other categories that are more largely affected (by post-depositional phenomena). This situation confirms that their distribution is not only the effect of spatial re-arrangement.

The presence of a slope between the areas involved is also very unlikely to have determined the observed spatial patterns. Geo-archaeological analyses have disclosed a difference of ca. eighty centimetres in the absolute depth of the sectors surveyed in 2001 and 2009. A further difference of ca. 40 centimetres has been noted between the area located around the modern road and the sector surveyed in 2001. If the presence of such slope had produced the spatial distribution(s) we are currently exploring, we should have observed a differentiated spatial pattern for the same categories of material evidence in these two different areas. Then, (a) the original distribution of the observations should have been more preserved in the area surveyed in 2001, while (b) a predominant concentration of artefacts and ecofacts around the lake shoreline, with a main orientation corresponding to such slope (that is, perpendicular to the lake shoreline), should have characterized the sector surveyed in 2009. Some evidence, however, contributes to reject this reconstruction.

Firstly, in both sectors the observations are predominantly distributed according to a North-East-South-West orientation; such orientation is parallel (and not perpendicular) to the lake shoreline, where the majority of observables are accumulated. The immovable categories (saddle querns and posts) are spatially distributed according to such orientation, suggesting that this alignment had been intentionally chosen by the inhabitants of site. Furthermore, the spatial pattern identified within the area investigated in 2001 is only partially reproduced in the area investigated in 2009, in such a way that the original differential distributions are preserved. Therefore, it is not this slope but the distortion produced by post-depositional disturbances to have strongly affected the sector surveyed in 2009. As mentioned in Chapter 5, the mechanism of layers dehydration caused by the lake water drop, activated the onset of erosive phenomena that, in survey of 2009 have determined the total compression of sediment in a few-centimetre-deep layer near the shoreline (where the sector surveyed in 2009 is located). Thus, all the preserved archaeological observations have been compressed within such sediment, which has been investigated during the surveys. Carrying out the geostatistic intra-site analysis for separated categories of archaeological observations, when the 2009 surveys are concerned, has revealed a spatial predominant clustered pattern. This pattern has been observed for the posts, saddle querns, faunal remains, lithic industry, wooden fragments and horizontal posts remains. Within the category of the faunal remains, the same pattern has been noted for the cranial and appendicular fragments, as well as for the cervus elaphus species. Such pattern contrasts with the main spatial model of randomness or overdispersion observed for the area surveyed in 2001. Despite this predominant spatial pattern involving the non-empty sampling units investigated during 2001, the highest frequencies (outliers) are, as already noted above, our "narrative window into the past". They indeed represent, as the foci of past activities, the better-preserved evidence of the original spatial pattern. Therefore, *the spatial distribution of artefacts and ecofacts was not TOTALLY rearranged according to deformation processes.*

2) *THE LAST PHASE OF OCCUPATION AND THE ABANDONMENT: might these spatial distributions reflect the original location of material evidence left behind during the process of abandonment?*

The spatial pattern observed today is the result of two superimposed processes: the abandonment and final occupation of the site. The materials produced during both processes are summed up, thereby producing the accumulations analyzed in this research. In some cases, the material has been totally compressed into a unique layer (as observed for the sectors investigated in 2009 and 2012), in such a way that we are forced to study all the observations produced by both processes together, without any potential stratigraphic discrimination. On the other hand, for the area surveyed in 2001, a better preservation of the archaeological record allows us to analyse at least three layers separately, which have been produced as a consequence of both processes. This research has focused on the most superficial layer, namely layer 0, and has analysed the spatial distribution of the material evidence recovered and geo-referenced during the survey. This selection was operated in an attempt to compare the potentially differentiated effects of post-depositional processes in two sectors (2001 and 2009) that are characterized by a distinct preservation history and are located in two different spatial districts of the same settlement. In both cases, some traces of the original (spatial) pattern have been recognized, as suggested by the data presented above. Therefore, *these spatial distributions partially reflect the original location of material evidence left behind during the process of* *abandonment, summed up to the previous material consequences produced during the last occupation of the site.*

3) *THE INTRA-DEPOSITIONAL PHASE: Are different categories of refuse uniformly distributed across the settled/non settled area? Are particular spatial patterns recognizable for different categories of refuse? Has the rubbish been spatially distributed for particular purposes? Can the spatial distribution of refuse reflect the original location of activities? Can the spatial distribution of garbage and discarded material provide some information about how productive and residence activities occurred?*

The results summarised in this chapter allow identifying *spatially **differentiated** patterns for **different** categories of observations (and refuse)*. For all the surveyed areas, the two immovable categories of observables (i.e. posts and saddle querns) are differentially distributed. As a rule, where posts are observed, saddle querns are absent. This spatial pattern is particularly evident for the 2009 survey, since saddle querns are observed only in the South-West sector of the surveyed area. On the contrary, for both the zones surveyed in 2012 saddle querns are predominantly distributed in the middle of the area, but are always spatially differentiated in respect to posts. While saddle querns are predominantly located in the middle of the area surveyed in 2001, in the 2009 survey they are especially concentrated near the estimated shoreline of the ancient lake. Notable is also the highest concentration of faunal remains in this South-West sector (Zone 1), where faunal remains are also associated to pottery, lithic industry and some concotto remains. Both patterns are crucial to put forward some hypotheses concerning the use of space within this zone. In particular, we can note that productive activities seem to have been performed exactly in this area, as proved by the predominance of debitage, pebbles and bone fragments as well as by the presence of some rare spindle-whorls and clay-fishing. In addition, this accumulation is characterized by an internal predominantly undifferentiated distribution of faunal skeletal body parts and fragments ascribable to both wild and domestic species. Furthermore, broken bone fragments are predominantly burnt and in some cases even calcinated, showing evident traces of a repeated contact with fire; additionally, cut marks are often observed. All these data allow interpreting such accumulation as a dump area, with the presence of refuse accumulated near the original location of productive activities. Indeed, for hygienic issues (and as a quite widespread practice, as suggested by the ethnoarchaeological studies presented in Chapter 2) bone fragments are predominantly accumulated in small dump and, in some cases, they could also be burnt. As mentioned in Chapter 3, in lakeside settlement contexts such remains could be located at the back or in front of the houses, where they were often discarded in relation to everyday maintenance practices. However, the cleaning up of refuse, which is periodically documented in such contexts, involved the spatial relocation of such garbage elsewhere. As observed in this case study, such remains could be accumulated not far from their original spatial location. Conversely, material refuse associated with activities that do not involve hygienic issues, have predominantly been left *in situ*. These remains represent the discard evidence of the activity itself, as observed, for instance, for the lithic industry.

For the 2001 survey, a similar dump area is observed in the South-West corner (Zone 1), where the highest frequencies of faunal remains are concentrated. Such remains largely show the same features documented in the sector described above (i.e. they are predominantly burnt and traces of cut marks are often identified). It is remarkable that areas with a similar function are located in two distinct sectors of the settlement, roughly in the same spatial location. Currently, the chrono-typological information available for the three surveyed areas (for more details about the specific chronology of site see Chapter 5) places all the sectors in a same time-span that covers some generations. However, as their specific temporal relations cannot be explored in detail, a more sophisticated contextualization of the finds is presently impossible.

In the North-East corner (Zone 2, for both the 2001 and 2009 surveys), an accumulation of pottery (highest frequencies) is observed; this can be associated with a differential use of space, more residentially oriented. For the 2009 survey, this consideration is also confirmed by the presence of wooden fragments (attested in their highest frequencies), and by all the preserved remains of horizontal posts found there. Conversely, if we consider the 2001 survey, these categories of archaeological remains are more scattered within the entire area. Moreover, the Spearman's Rank Correlation Coefficient suggests that quite all remains of concotto slabs are distributed in this North-East corner (4 out of 6), where they are associated with closed ceramic forms. Notably, closed ceramic forms are predominantly related to the conservation of food and – concretely, in some cases at least, - off seeds; some of these slabs have also revealed negative traces of seeds, which confirmed their involvement in roasting practices (Chapters 5 and 6). This evidence, therefore, suggests that this area can be interpreted as the original spatial location of this activity. For the area surveyed in 2001, this interesting association is confirmed by data from the North-East zone, where all the remains of concotto slabs are observed, together with the majority of closed ceramic forms. In Zone 2, surveyed in 2012, these categories of evidence are also positively correlated and distributed in a spatial location (that corresponds to the one noted in the 2001 survey). However, in these more residentially oriented zones, two different alignments in the distribution of the observations are attested (that is not only the predominant North-East-South-West), as well a more irregular spatial distribution.

This data suggests that post-depositional processes might have affected these zones more than the others, determining the creation of a more amorphous spatial pattern. However, this hypothesis cannot be proved beyond any doubt. In particular, we have to consider that the area subject to investigation is not the entire site surface; rather we are only analysing four distinct sectors, which are separated by an unexplored area. Notably, the centre of the accumulation discussed here, in some cases could have been located around one metre far from our sampling unit. Thus, the results obtained in this research must be interpreted as strictly related to the areas under study, while the continuation of surveys and excavation campaigns will make further data available in the future.

Both zones investigated in 2012 are among the areas more significantly affected by the survey bias. In this case, our bias relates to the spatial discontinuity imposed by the natural limits of the site investigated. The analysis of such zones is predominantly intended to fill the spatial gap relating to the archaeological data at the two limits of the area surveyed in 2009. The results of this study unveil some interesting scenarios. In both zones, the material observations are particularly concentrated in the Northern side of the surveyed areas where they are attested with different frequencies. For instance, Zone 1 (survey 2012), located in the South-Eastern side of the Zone 1 (survey 2009) shows a quite low frequency of material evidence. Moreover, an interesting decrease in the number of observations is noted outside the main accumulation previously mentioned, along the predominant North-East-South-West alignment, which is parallel to the lake shoreline. Both portable and immovable objects are absent, suggesting that this pattern is not the result of post-depositional processes, but, rather, the effect of intentional behaviour only partially affected by subsequent disturbances. Thus, the material items seem to belong to a wider accumulation and are distributed in a way that resembles the "tail effect" observed in the middle of Zone 1 in the 2009 survey. In light of their spatial vicinity and spatial location, it is reasonable to imagine that this Zone 1 (preserved and noted in the 2012 survey) might have originally been part of the wider accumulation observed in Zone 1 (2009) (Figure 784).

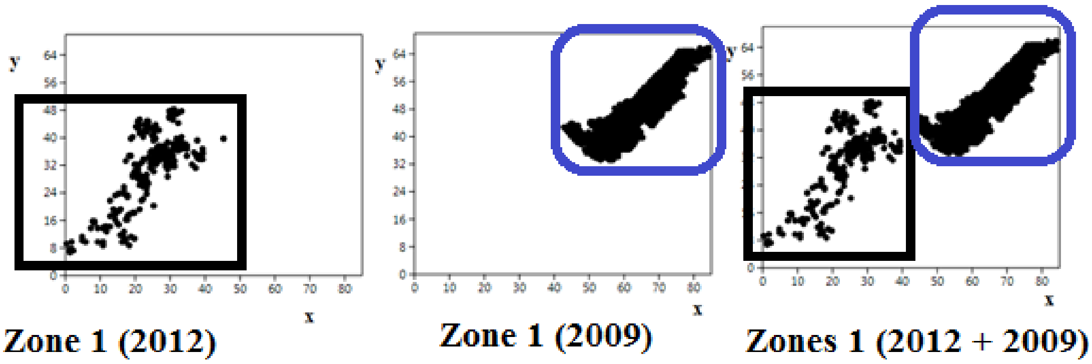


Figure 784 Spatial distribution of surveys carried out during 2009 and 2012 (both Zones 1).

For Zone 2 (2012) higher frequencies of material evidence are observed. These mirror the spatial patterns recognized for Zone 2 (2009), in such a way that the observations related to residence practices are predominant (Figure 785).

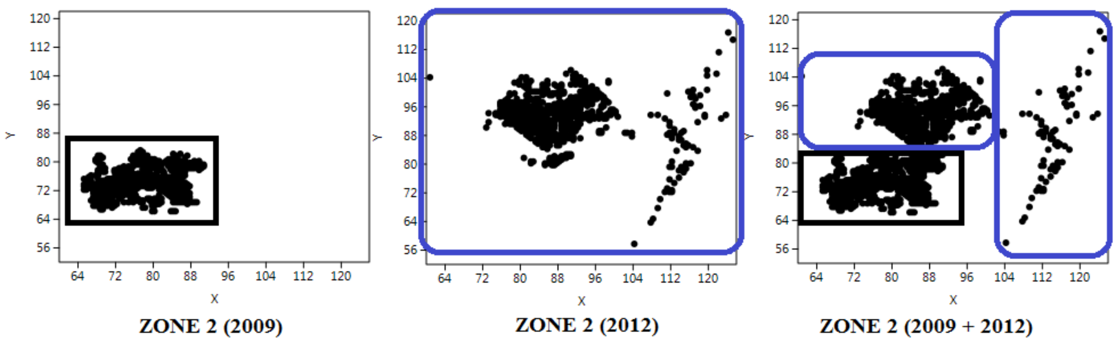


Figure 785 Spatial distribution of surveys carried out during 2009 and 2012 (both Zones 2).

Currently, however, this hypothesis cannot be confirmed through an interpolated model, which does not produce reliable results because of the scarceness of the material evidence found in Zone 1 (2012).

10.1.6 Final remarks

The multi-stage strategy used in this research has proved to be successful in its application to the case study presented here. In particular, we have highlighted and discussed the theoretical preconceptions that, in some cases, consider archaeological context affected by post-depositional processes, as unpredictable and inexplicable. It is however imperative that the effects of such processes are evaluated before interpretation, about the use of space by humans living at the site, are made; in light of this consciousness, a biographical approach drives this research, since it proved (in this archaeological context as well as in several others, quoted along all these chapters) to be an essential tool to reconstruct each stage of the formation (and deformation) of the archaeological record. A deeper understanding of such processes assures that our reconstructions are based on a solid knowledge of depositional contexts, which allows carrying on a geostatic intra-site spatial analysis. It was oriented to define the potential differentiated use of space within the settlement, associated to several categories of observables, and this aim is accomplished along this research, as above summarized. Among the most interesting causes of reflection that have been stressed within this work, the importance of emptiness as deliberate choice can be listed. As proved by this case study, the general organization of space within the settlement includes the management of empty areas, intentionally selected by inhabitants in an attempt to spatially separate independent sectors where different activities were performed. Then, they assume an interesting role preserving the internal equilibrium as well as the livable and healthy condition. In the same way, the analysis of anisotropy in this research has proved its usefulness, suggesting, even in a spatial dimension, how the disturbance processes could have influenced (and according to what directory) the spatial pattern nowadays preserved, and observed in the archaeological record, associated to specific categories of observations. Finally, the focus of this research on a surface context, analyzed whereby surveys, allows to stress some bias and issues related to such techniques, which have to be considered, in order to live and work outside a “Garden of Eden”, and to provide more strength to our reconstruction. This work, as a first operative proposal of an innovative approach, which combines a biographical approach and a geostatic intra-site analysis, is a first attempt for solving archaeological problems and certainty refinements are required, particularly in order to better control the temporal scale (which in this case is limited to a chrono-typological definition). However, as quoted by Simek (1984: 419) “*if the research discussed here stimulated further work on contextual integration in spatial archaeology, then it will have achieved its ultimate goal*”.

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