

# Describing the Geographical Background of the Archaeological Sites Presented as Point Features An Analysis of the Effect of Different Spatial Resolutions and Different Software on Interpretations

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**Abstract.** This case study was done as part of critical discussion of sources in my PhD. The aim was to enquire, if the use of different software and DEMs with different spatial resolutions has an effect on the resulting conclusions. For this purpose an area of 10 x 10 km<sup>2</sup> was chosen; the area corresponds roughly to the Calcata map sheet of the I.G.M. (*Istituto Geografico Militare*) map series at a scale of 1:25,000. Elevation, slope and aspect values were extracted for a set of pre-Roman settlement points. Idrisi for Windows and Arc/Info, which use different algorithms to calculate slope and aspect, were compared while using two different DEMs with the resolutions of 20 m and 100 m. The differences could be visually shown, but they had no significant effect on the results of chi-squared tests. However, errors were noticed in the I.G.M. elevation raster data.

**Keywords:** GIS, resolution, elevation, aspect, slope, algorithms, software, interpretation.

## 1 Introduction

For a long time, it has been acknowledged that different GIS programs use different algorithms to calculate the same variables. It is a well-known fact that these algorithms give different results with the same set of data depending on the programme used (e.g. Kvamme 1990; Zubrow 1990). This paper grew out of a curiosity to know to what extent the use of different programmes and algorithms affect the results and interpretations obtained. Furthermore, I wanted to know if the results do differ when one uses DEMs with different resolutions.

This case study was done as a source critical enquiry for my PhD although it also evaluated previous work I did for my MA dissertation. I also tested the accuracy of the elevation data purchased from the I.G.M. (*Istituto Geografico Militaro*) for my PhD as the work advanced. In addition, I review methodological effects of using different software.

## 2 Archaeological Sites and Geomorphology

All GIS work is based on grid reference. The natural way to describe the location of an archaeological site is to give its x and y coordinates. With this information, the logical representation of a site is a point. One has to acknowledge that while presenting these point distribution maps, one continues the positivist traditions of spatial mapping. But in this way, the site distribution can be used in point pattern analyses. Very often this is also the only way to present the data available, because in older publications, the grid reference of a point is the only information, which can be obtained to connect a site to its geographical location. When size information is lacking, point format is the only one, which can be effectively used in GIS studies. However, this format

gives limited possibilities to describe the geographical background of a site.

The digital representation of real landscapes is based on raster format and Digital Elevation Models (DEMs). The geomorphological attributes easily obtainable from a DEM are elevation, a feature of the DEM itself, slope and aspect. As already noted, slope and aspect values are directly dependent on the algorithms, which differ from one programme to another (cf. Skidmore 1989; Wise 1998). Therefore, of the three basic surface attributes connected to a point feature, two are likely to differ depending on the GIS programme used. Furthermore, the extraction of geomorphological data for a point feature can also be seen as problematic since one has to use a pixel to present a point. Since the size of a pixel depends on the resolution of the model used, the coarser the DEM the farther the values are from the exact values of the site. Logically, when a more detailed model is used, the elevation values are nearer the real ones.

One has to discuss the character of these simple attributes. The elevation model itself is an approximation, which has been modelled using interpolations (e.g. Wise 1998). On the other hand, slope values, as well as aspect values, are maximum values in a neighbourhood. Thus, programmes give just one value, which does not present a typical value, but the upper limit of all values given by a model. This liminal value can, however, give us a hint, if the overall values show similar variability across the area.

## 3 The Case Study

The textbook case study in archaeological GIS literature is based on the research strategy modelled by Gaffney and Stančić (1991). In this study, a series of different attributes were measured for archaeological locations and the distribution of the values were compared against

the background values using chi-square test in order to find the key attributes which have contributed to the selection of the site.

To study the effect that different programmes and resolutions have on results, a 10 km x 10 km area was chosen from my study area in central Italy (Fig. 1). The area which is more or less equivalent to the Calcata map sheet of the I.G.M. (*Istituto Geografico Militare*) map series. This area is dominated by deep ravines of the Treia river system; between canyon-like river valleys, there are plateaux of slightly hilly land. However, the differences in altitude can be steep locally. To review the basic research strategy, a sample of 84 pre-Roman sites was presented in point format. For the points, the values for elevation, slope and aspect were extracted. A DEM with a resolution of 100 metres, which was used in my MA dissertation, was originally provided by the Enhancement of South Etruria Survey Project. It was interpolated by Dr Andrew Harrison from the original delivered by the US Geological Service. In addition, a DEM provided by the I.G.M. (reproduction authorisation no. 4706) was used. This DEM came as a raster file with a resolution of 20 metres. The first aim of the case study was to see if the use of different resolutions changes the result of the analysis of the selection of a suitable site.



Fig. 1. The research area in central Italy

To extract the values for geomorphological variables, Arc/Info and Idrisi for Windows programmes were used. ArcView was not used, because it uses the same algorithms as Arc/Info. Both Esri programs use an estimator, which uses all eight outer points of a 3 x 3 window to determine slope and aspect. This estimator is the third-order definite given by Horn (1981). The Idrisi programme, designed by Clark University, uses a simple second order finite difference algorithm fitted to the four closest neighbours (cf. Burrough and McDonnell 1998:190). The second aim of the case study was to see if there are significant differences in results between these two algorithms.

## 4 Results

Naturally, the elevation itself does not change from one programme to another, but the distribution does change from one DEM to another (Table 1). Normally in the area, the elevations are between 200 and 300 metres. The proportion of this category is notably larger in the finer DEM and a larger proportion of sites is located at those heights. The coarser DEM gives a larger proportion of less typical elevations. The difference is due to DEMs. Furthermore, many sites are located near major changes in the landscape (Rajala 1999). But the final interpretation – whichever the DEM – is the same: elevation is not a significant locational attribute. In both cases, the sum of chi-squares is lower than the  $\alpha$ -value for any significant probability.

Table 1. The proportions of different elevation classes in different DEMs

Elevation	Resolution 100 m	Resolution 20 m
0 – 100	-	0.38 %
100 – 200	34.11 %	27.49 %
200 – 300	65.65 %	71.89 %
300+	0.24 %	0.24 %

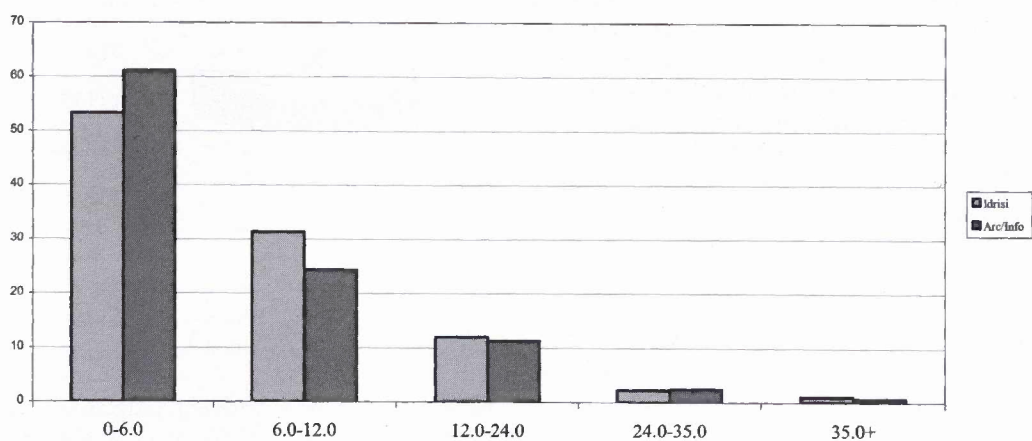
In the case of slope values, the distribution is totally different depending on the resolution of the DEM (Fig. 2). Because the slope is also a function of distance between points – i.e. of resolution – the maximum values of the coarser DEM stay near 20 degrees. Only with the finer resolution is it possible to have a more normal slope distribution, which contains values for gradients over 35 degrees. In further GIS modelling, if the slope values of the coarser model are used, one has to test suitable boundary values in order to reclass values for agricultural modelling.

Like elevation, slope seems to belong to the less important attributes of a site. This interpretation can be drawn despite of the resolution or the programme. However, the distribution calculated by Idrisi gives higher sums for chi-squares with both DEMs. Furthermore, there are more higher values than with Arc/Info. When all slope values are looked at, it becomes clear that Arc/Info calculates on average lower slope values than Idrisi. Arc/Info gives the highest slope value of 62.624 degrees with the finer resolution and that of 18.255 degrees with the coarser resolution, while Idrisi gives the highest values of 65.2969 and 20.3113 degrees with the respective resolutions. Furthermore, Idrisi gives higher means (6.6922 degrees with the finer resolution and 3.4352 with the coarser), although the differences are minor (with Arc/Info the means are 6.474 and 3.320 degrees respectively).

Unlike elevation and slope, aspect, i.e. the direction a site faces, is a significant attribute. No matter which resolution or programme is used, this result does not change. The distributions are very similar (Fig. 3), although the values given by Arc/Info give more importance to the eastern facing than those calculated



Slope, resolution 20 m



Slope, resolution 100 m

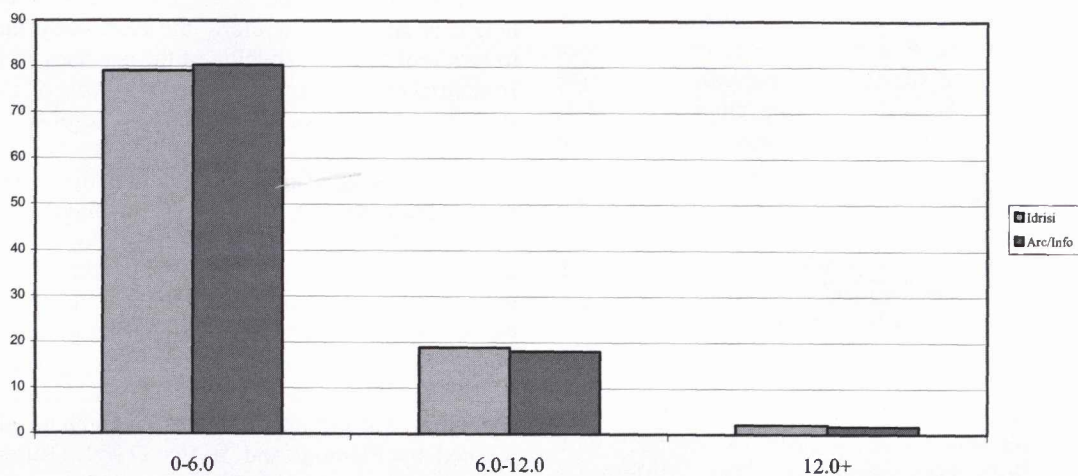


Fig. 2. The difference in the proportions of slope classes between the programmes

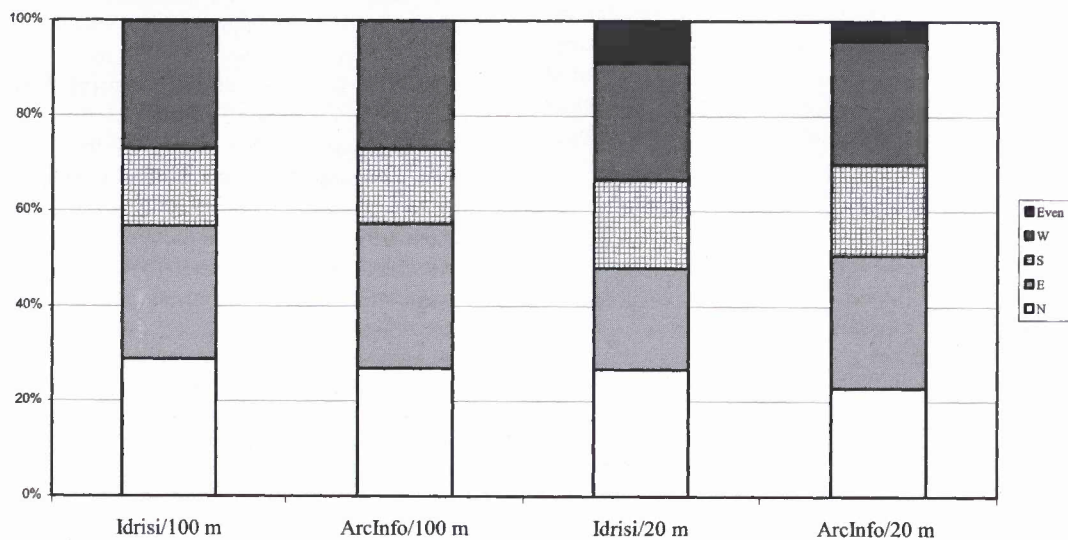


Fig. 3. The difference in the proportions of aspect classes between the programmes

by Idrisi. The mean slope values calculated with Arc/Info are higher (168.855 with the finer resolution and 182.032 with the coarser) than those calculated with Idrisi (152.0559 and 177.0556 respectively). However, the distribution of site locations extracted by Idrisi differs more from the background distribution than the one given by Arc/Info. While the sums of chi-squares are with both resolutions with Arc/Info, the difference is larger with Idrisi. The sum of chi-squares with the finer resolution is higher than the  $\alpha$ -value at the level of confidence of 99.9 %, while when using Arc/Info the sum does not exceed  $\alpha$ -value at the 98 % level. With the coarser resolution, the sum of chi-squares for the distribution of slope values calculated by Idrisi exceeds the  $\alpha$ -value at the 99 % level, while with Arc/Info the sum exceeds only the  $\alpha$ -value at the 98 % level.

## 5 Discussion and Conclusions

The most important conclusion is that the interpretations seem not to differ or change whatever programme is used, though the level of confidence changes. Part of the variability is naturally due to the characteristics of the test itself: the chi-square test is known to be sensitive to minor changes in numbers in distributions. It is reassuring that there are no major differences in the final outcomes. However, the result might be different if the number of sites were smaller and if one was near the boundary between relative significance and insignificance.

Although differences between values calculated for site locations with different programmes seem to be small, typically, the values are not exactly the same. The slope values seem to coincide more often (cf. Figs 4 and 5) and this tendency becomes stronger with refinement of the resolution. The differences concentrate on the main ravines whereas in the flatter areas the values are very similar with both programmes (cf. Figs 6 and 7). The different algorithms seem to handle differently areas with steep changes in elevations. In the case of aspect, different results are common though small. In a normal case, only large differences, especially near the boundary values, would actually affect the results to a greater extent. The same patterns are visible with both resolutions and with both programmes.

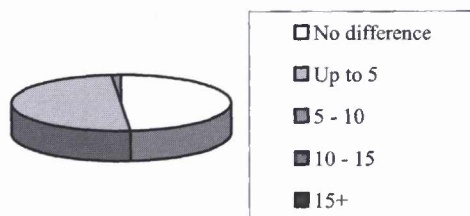


Fig. 4. The difference between slope values calculated with Idrisi and Arc/Info, resolution 20 m

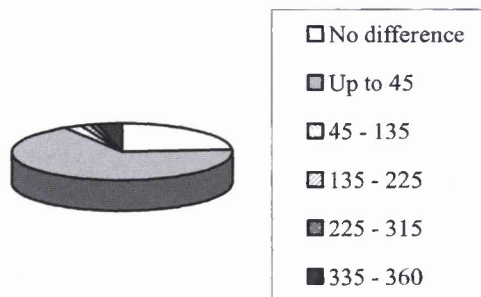


Fig. 5. The difference between aspect values calculated with Idrisi and Arc/Info, resolution 20 m

Before considering different programmes, one has to return to the notable differences in the proportions of different elevation classes between coarser and finer DEMs. When the raster data was compared with the maps it originated from, it became apparent that the purchased data lacked some underlying contour and height point data. Therefore, the case study turned out to be a tool of the evaluation of the accuracy of the data. In normal cases, the proportions of classes of elevations should be comparatively close despite differing resolutions.

Lastly, it is crucial to try to evaluate the suitability of the programmes. In the case of coverages at the 20-metre resolution, the differences in slope calculations are very difficult to catch instantly. The aspect coverages, on the contrary, differ more clearly. One of the problems in evaluating programs is that the makers do not state unambiguously enough the algorithms used. It is clear that in Arc/Info one is using Horn's algorithm, but the use of the four-neighbour algorithm defined by Fleming and Hoffer (1979), Ritter (1987) and Zevenbergen and Thorne (1987) can only be assumed. One can use Skidmore's (1989) study where he compared different techniques to calculate slope and aspect as a guide. In his case, Arc/Info was among the programmes, which gave the best match between calculated and real values. The second-order finite difference method was inferior to the third-order algorithm. Furthermore, Jones' tests (cf. Burrough and McDonnell 1998: 191-192) suggest that Arc/Info can model the characteristics better in my research area, though he valued the four-neighbour analysis the best. The assumed superiority of Arc/Info is due to the nature of the surface in the Calcata area where sudden changes in local elevations are common. Since the differences in slope coverages are concentrated in the areas of the ravines, roughness must be the key element. The four-neighbour second-order algorithm performs better with smoother surfaces. Therefore, one can assume that Idrisi would give more reliable values near the Tyrrhenian coastline. In a dissected inland area, one can rely on Arc/Info.



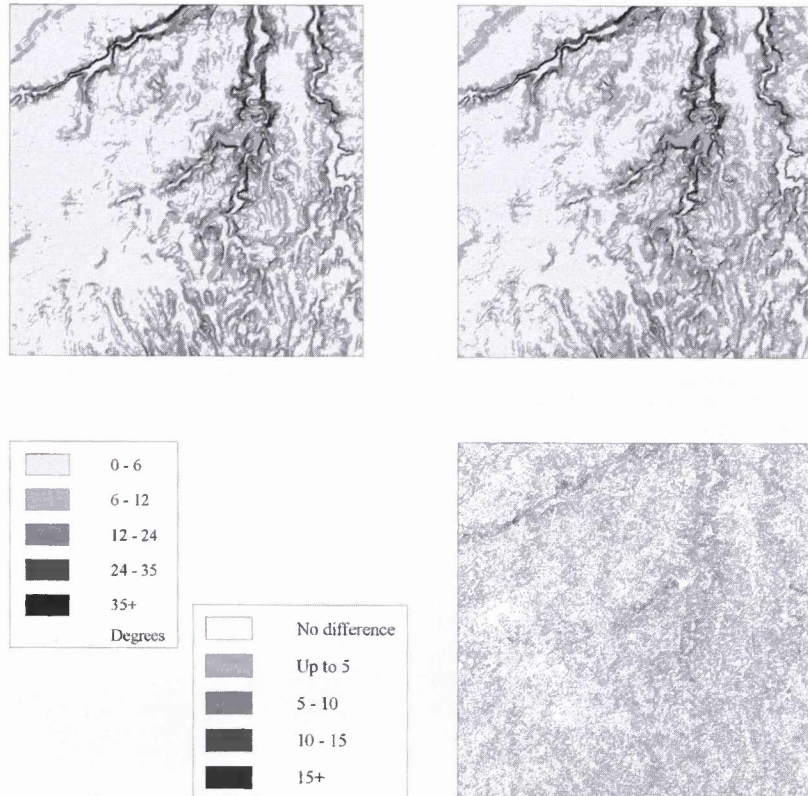


Fig. 6. The difference in slope between Arc/Info (upper left) and Idrisi (upper right)

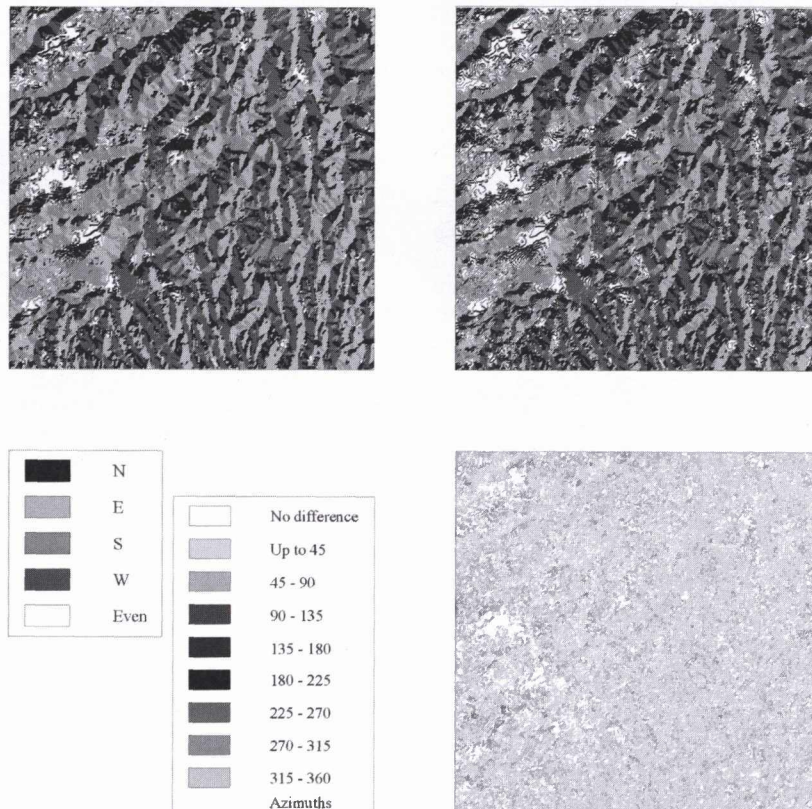


Fig. 7. The difference in slope between Arc/Info (upper left) and Idrisi (upper right)

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