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A GIS study of potential traces of a Roman cadastre and soil types in Romney Marsh

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22.1. Introduction

In this paper we describe the application of Geographical Information System (GIS) software to the study of the possible traces of a Roman land information system, or cadastre. Roman cadastres have been the subject of recent research using a variety of techniques (Clavel-Lévêque 1983; Chouquer *et al.* 1987; Peterson 1992a). This has resulted in the extension of the area where these systems of land division and administration are thought to exist, from the Mediterranean to eastern France (Chouquer and de Klijn 1989) and even perhaps to Britain. One such British system, Kent A, was proposed by one of the authors (Peterson 1992b) following observation of a trigonometrical relationship between Roman roads in east Kent which is typical of those occurring in centuriation grids.

Potential traces of this cadastre appear in Romney Marsh, and their density seems to vary according to the area of soil type within which they occur. GIS software, in this case the IDRISI system (Eastman 1990), allows this information to be stored and displayed. More importantly, it allows the variation to be measured.

In this case, these measurements were further processed with a spreadsheet in order to reduce the complex geographical information to simple graphs, showing marked changes in trace density across the boundary between the two main soil types. This result could be satisfactorily explained by the cadastral hypothesis, thus lending it some support.

22.2. Capture and display of possible cadastral traces and environmental data

Potential elements of the cadastral grid in Romney Marsh were traced from Ordnance Survey Landranger 1:50,000 map 189, using a computer-plotted transparent overlay grid. Its position was determined by coordinates calculated from the cadastral grid parameters. These parameters had originally been generated in order to explain the parallel and 1:1 relationships of roads in the Canterbury, Dover and Deal area (Fig. 22.1).

The overlay used corresponded to a grid of 710m, the "standard" centuriation, but it could be seen that there were intermediate roads and ditches forming a fragmentary, but recognisable, grid pattern with a module of 355m. This could be due to a quartering of the centuries, as occurs in some centuriations in areas of poor drainage, such as the Po valley (Romano and Vivanti 1976: Figs. 66–70).

As far as the soils are concerned, there is a distinction, first made by Green (1968), which Nicholas Brooks (1988)

regards as "fundamental to any understanding of Romney Marsh in the early Middle Ages". As he says, this is between the "Calcareous" or New Marshland, which has been subjected to inundation by the sea within historic times (i.e. since the early middle ages), and the "Decalcified" or Old Marshland from which the calcium has largely leached away.

The grid traces seemed to be generally less visible in the New Marsh, as one might expect if they genuinely date back to Roman times. However, they were not completely absent in these areas, nor would one expect them to be because of possible coincidence of topographic traces by pure chance. It is also possible that the *limites* might be preserved physically or conceptually despite temporary flooding, or that new land divisions might be constructed in reclaimed land along the same lines as the divisions on the neighbouring dry land.

Given this uncertainty, we decided to quantify the traces in relation to the two types of soil in order to see if the detailed variation in density might suggest any model for the process of formation of the present landscape.

A simplified soil map, based on those of Green (1968: Figs. 14 and 16) was digitised using a Summagraphics Microgrid III digitiser linked to a Viglen 386 personal computer running DIGIT II software. In order to check the completeness of the digitisation, the individual areas of soil type were digitised as polygons. The data for these arcs was unsuitable for direct input to IDRISI and no conversion soft-
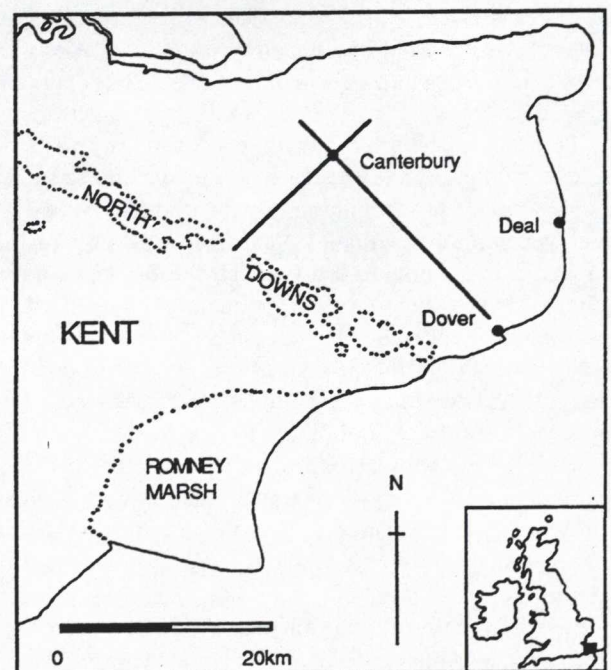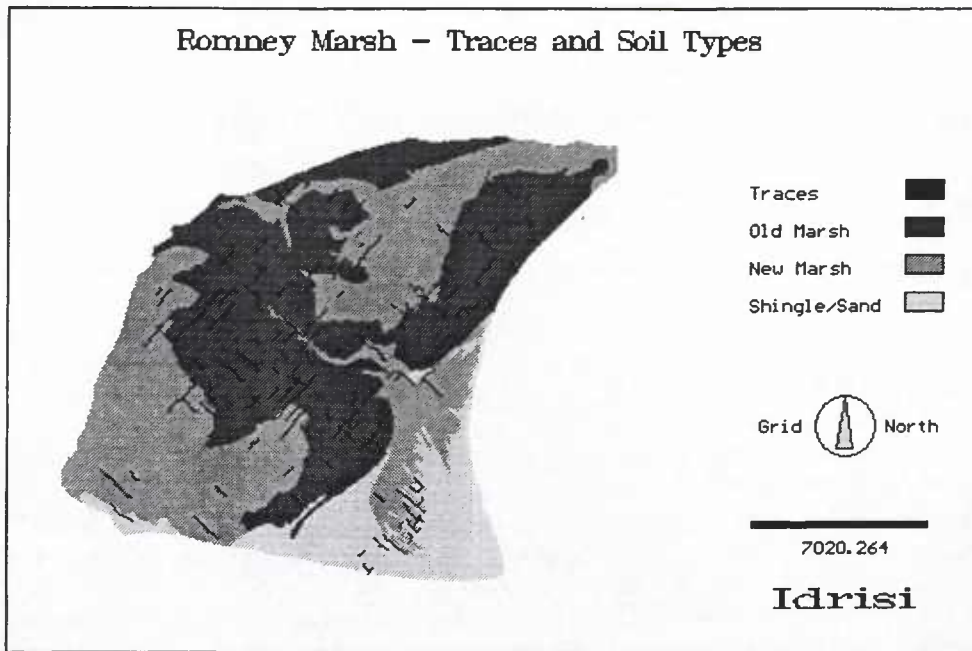

Figure 22.1: Location of Romney Marsh

Figure 22.2: Display of possible cadastral traces and generalised soil types in Romney Marsh.

ware was available so the DIGIT II output was converted to ARC/INFO format using the TOARC software. This produced a list of pairs of coordinates for each arc as ASCII text, a format close to that used by IDRISI. The sequences of coordinates were transferred to a Microsoft Works spreadsheet. The sequences of coordinates could then be copied, reversed if necessary and joined together to make IDRISI polygons, with IDRISI headers and trailers added. Given that the simplified soil map contained only 8 polygons, this semi-manual method probably took less time than would have been required to write a conversion program. The features corresponding to a grid of 355 metres were also digitised and converted by TOARC to ARC/INFO format. This could be read directly by the IDRISI "arcidris" function into a line vector file.

These vector files were converted into raster images with a cell size of 75m x 75m. The individual polygons were reclassified according to soil type and the traces were overlaid to produce a composite image (Fig. 22.2) of the two sets of data.

This image is similar to that seen in hand-drawn maps, but less detailed. This was the result of the choice of cell size suitable for processing on an Amstrad PC1640 HD20 which was initially available. Nevertheless, even with this grid size it is possible to see the distribution of the traces and it is also possible to treat them quantitatively. Looking at the image it appears that the density of traces is low in the New Marsh but that it increases towards its boundary with both the Old Marsh and shingle/sand areas. It can also be observed that in several places a trace forms part of this boundary. This subjective impression can be tested by measuring how the density of traces changes with distance relative to the New Marsh edge, from the extreme point within the New Marsh, across the boundary and up to the opposite extreme point.

Reclassification and the "distance" function were used to produce an image of distances from the New Marsh boundary, in the Old Marsh and elsewhere. The equivalent image of distances from these areas within the New Marsh

was also produced. The range of distance values in the New Marsh cells was then found by using the IDRISI histogram function. This showed that the lowest non-zero value was 75m. This is the cell size, and we note that, as far as IDRISI raster processing is concerned, it is impossible for a point defined as a raster cell to be at zero distance from a boundary. We also note that this may affect the display of some results, as for example in Kvamme's plot of the cumulative distance values from a set of lines representing Roman roads (1992: Fig.10.2d). Here he used 1km square cells, and indeed the number of background cells in the range 0–1km looks low.

In the new soils the greatest distance from the old soils was 3624.9m. So, in order to produce an image with a lowest value at the greatest distance from the boundary, the distance values in the New Marsh were subtracted from 3626. Distances from the boundary in the Old Marsh were calculated similarly and increased by 3551. These two sets of distances were joined to produce an image with non-zero values only in the Marsh area, increasing from a rounded value of 1, in cells furthest from the boundary within the New Marsh, to 3551 and 3626 on each side of the New/Old Marsh boundary, and then increasing further with greater distance from the boundary within the Old Marsh. If the traces are overlaid on this image from the vector file (Fig. 22.3) we can observe the relationship between them and the band containing the edge

This relationship can also be quantified using the histogram function to compute numbers of cells in bands of width 100m from the New and Old Marsh boundary. For the purposes of comparison this was done for the whole image and for an image which had non-zero distance values only for cells corresponding to the possible cadastral traces.

22.3. Spreadsheet procedures

Given the two histograms produced by IDRISI, we compute the ratio of numbers of trace cells to total cells in each 100 metre band, thus giving us a measure of the density of traces
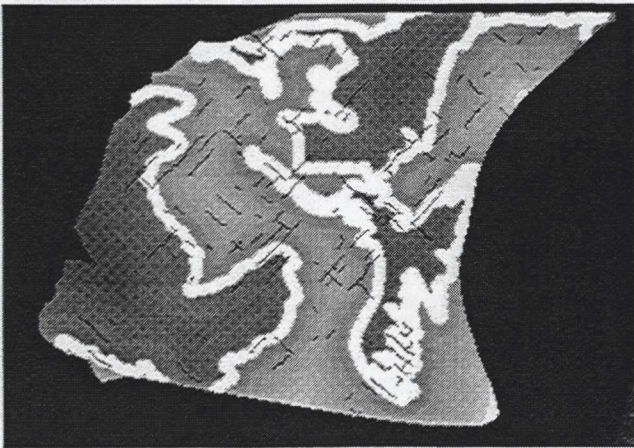
Figure 22.3. Display of bands equidistant from New/Old Marsh with possible cadastral traces.

Figure 22.4: Variation of density of cadastral traces with distance from New/Old Marsh boundary in bands of equal area.

Figure 22.5: Distribution of cadastral and sample traces, both in bands of 2% of total area covered in each case.

in relation to distance from the New Marsh boundary. The two sets of histogram values were processed in an MS Works spreadsheet on a Macintosh plus. Trace densities in each 100m band were noticeably lower in the New Marsh, compared to the Old, and high on the boundary. However, figures expressed in this way are difficult to interpret because of the wide range of areas in each 100m band. When the area in each band becomes relatively small, as in the case of the extreme values, the density figures are unreliable. For this reason the data were examined on the basis of bands of equal area, rather than equal distance from the new marsh edge. A band area of 800 cells (of 75m x 75m) was chosen as a convenient round number which would produce a number of bands approaching the maximum number of 80 points allowed in an MS Works series chart.

Columns for corresponding cumulative marsh area and trace area were created from the original histogram values, and from these, by linear interpolation, cumulative trace area figures were calculated at intervals of 800 units of Marsh area (Fig. 22.4).

This chart shows the density of traces is low in the New Marsh, higher in the Old Marsh and very high on the boundary between the two. However, these results are uncalibrated. Perhaps this distribution of possible cadastral traces merely reflects a general distribution of topographic features. Possibly all traces have a highest density near the edge of the New Marsh, with lower values elsewhere, particularly in New Marsh areas. It was therefore necessary to obtain a measure of the density of all topographic traces with respect to the Old/New Marsh boundary.

It would have taken about two working days to digitise all the features in the Marsh from the 1:50,000 map, so a sampling strategy was adopted. Squares were selected at random, using a speadsheet to generate their national grid coordinates, until the set of squares selected included 10 which were completely in the Marsh. All the map traces lying within these squares and within the Marsh area were digitised as if they might have been cadastral traces. The outlines of the sample squares were also digitised.

The sample squares and the digitised traces were processed as before to produce two images of distance values:
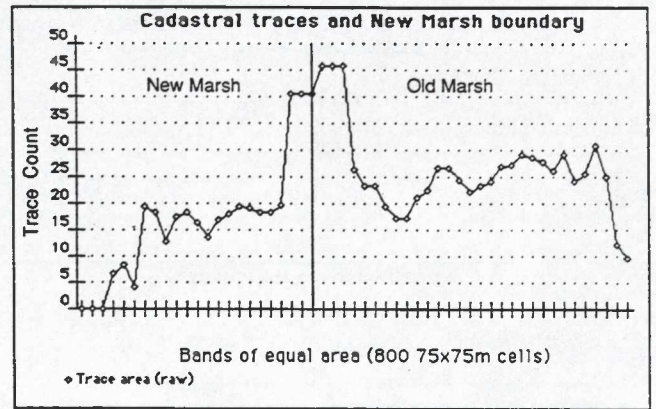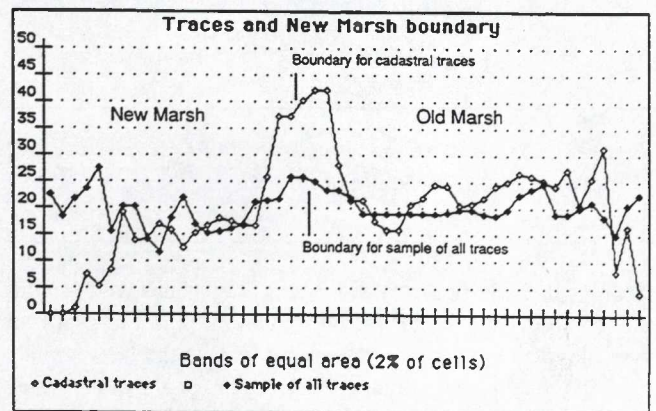
one for a sample of the Marsh area and the other for all the topographic features within that sample (railways and power lines excluded). Histograms were produced for these images using the same intervals and limits as previously.

We thus had two sets of data giving trace density values: the original set of potential cadastral traces compared to the whole marsh area and the new sample set of all topographic traces compared to sample area. The next step was to compare them in bands of equal area at a given distance from the New Marsh edge. Because the sets of data cover different areas, a band area of 2% of the total Marsh area in each case, giving 50 bands for both sets of data. As before, linear interpolation from the count of traces per 100m band gave us cumulative trace values for these intervals and hence trace values per band.

The spreadsheet was run for both sets of data and the two results plotted on one chart (Fig. 22.5). The values for trace cells in each 2% band were scaled so that they would total 1000 in both cases, thus giving a mean value per band of 20. It can be seen that the cadastral traces depart grossly from this mean, with 100% variation both ways. The count of trace cells is more than twice as high just inside the Old Marsh and zero or very low for the furthest fifth of the New Marsh. On the other hand, with the exception of five values, the sample traces do not vary from the mean by more than

	New Marsh	Old Marsh
Cadastral Traces	15.4	23.4
Sample Traces	19.8	20.1

Table 22.1: Mean trace densities in New and Old Marsh.
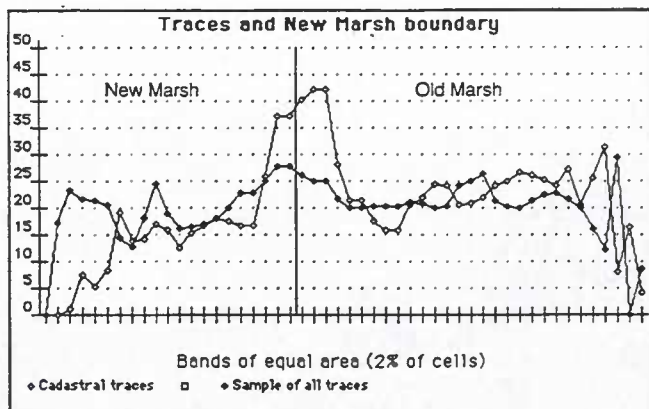

Figure 22.6: Comparison of distribution of cadastral traces and adjusted sample of all traces.
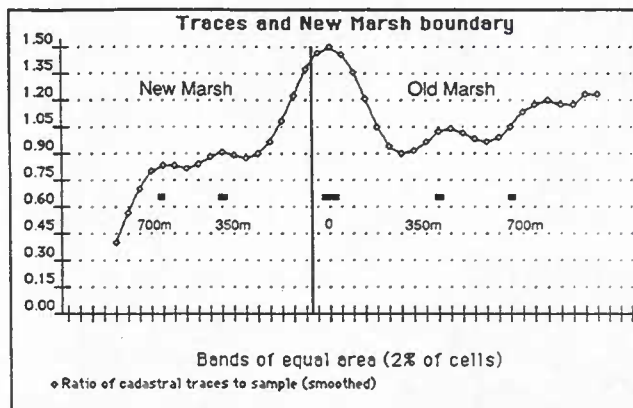

Figure 22.7: Cadastral trace density compared to background density of all traces.

Upper Limit of Distance	-656	-29	55	415	748
Band Number	9	14	23	32	38

Table 22.2: Equal area band numbers corresponding to distances of approximately 350m and 700m from the New/Old Marsh boundary

25%. The only possibly significant departure from a constant value with random fluctuations may be the group of five elevated values which peak just inside the New Marsh.

We may also compare the figures for the mean trace count in New and Old Marsh (Table 22.1). Here again there is a contrast between the values for the sample, which differ by no more than 1% from the mean, and the cadastral trace values, which differ by as much as 27%.

However, before attempting further comparison of these two sets of data, we note that their boundary points are not between the same intervals. The reason for this is that the sample represents only 5.3% of the total Marsh area so there is no guarantee that the proportions of old to new soils in the sample will be the same as that for the Marsh as a whole. Hence, if we are to compare the distributions of traces on the basis of the same bands of area it is necessary to scale the figures in the sample. We need a figure for the number of trace cells which would have been in any particular 100m band, if the sample densities applied to the whole Marsh. The calculation is:

Sample Trace Area for band x Total Marsh Area for band
Sample Marsh Area for band

These values could then be interpolated as before and charted with the cadastral trace values (Fig. 22.6).

In order to improve the presentation of the data and prevent division by zero, the leftmost and the two rightmost pairs of figures were discarded. Both sets of data were then smoothed by a 5 point moving average, the ratio of each pair of corresponding values was calculated and smoothed by a three point moving average to produce a simplified form of the original data (Fig 22.7) which represents, in all probability, the most outstanding features of

the distribution of cadastral traces when compared to the background of all topographic traces in the Marsh.

This idealised density distribution shows a sharp rise from very low values at the points furthest from the boundary in the New Marsh, followed by a steady rise (with fluctuations) from about 80% to 120% of the mean value on going from the New Marsh into the Old Marsh. This is interrupted by a peak of 150% of the mean value just inside the boundary.

22.4. Interpretation of results

The result of this analysis seems to show a number of features which can be explained according to the following hypothesis: that the partial inundation, possibly on more than one occasion, of a centuriated cadastre has led to the selective preservation of its major features, which are *limites* at 355m. The most striking feature of the distribution is the high density of possible cadastral traces corresponding to the well-documented division between Old and New Marsh. The position of this peak is at about 50m–60m on the Old Marsh side of the Old/New Marsh Boundary. This small shift in the peak position from that shown in the previous figure, where it is on the boundary, is the result of smoothing an asymmetrical peak. In any case, the association with the boundary seems clear.

There also appear to be subsidiary peaks whose approximate distances can be judged. Bars about 50m wide are shown in Fig. 22.7 for area bands at distances of approximately 350m and 700m, obtained by using spreadsheet data for the band distance limits (Table 22.2). The suggested explanation for these subsidiary peaks is that they represent those traces of *limites* spaced at 355m which are parallel to sections of the boundary defined by a *limes*.
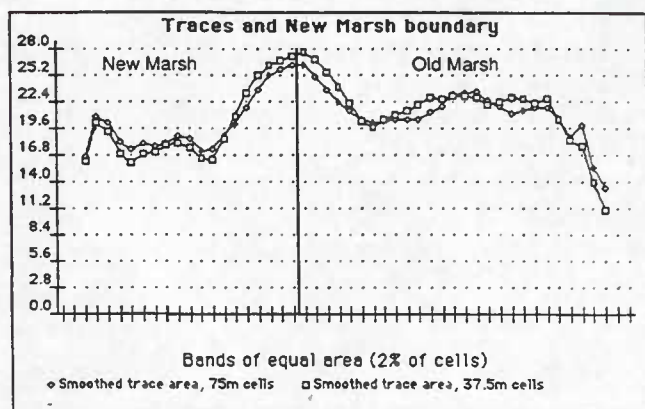
Figure 22.8: Comparison of distribution of raster cells in sample of traces for different raster cell sizes.

Figure 22.9: Ratio of cadastral traces to a sample of all traces for a raster grid size of 37.5m.

Considering the general trend of the distribution, we can suggest that there is very little possible trace of the cadastre at a distance within the New Marsh greater than 1km from its boundary. This would represent areas inundated totally since the Roman period, in which all organisation has been lost. Nearer the boundary, however, traces are apparent at about 85% of their mean value; this would represent areas in which the inundation was neither total nor constant, so cadastral structures were preserved physically or in human memory and could be reconstituted when possible. Finally, the higher level of traces in the Old Marsh, at about 105% of the mean value, is a result of the better preservation of cadastral structure on land that was flooded only a little, if at all.

Thus the numerical treatment of these data confirms the subjective impression of a major difference in density of traces between the Old and New soils, even when any possible variation in the density of all traces is taken into account. It also suggests that there is a real association between their boundary and the boundaries which would have been established by the Kent A cadastre.

However we must conclude on a cautionary note. It is possible that in the sample of all traces the density of traces in a kilometre square is underestimated for those kilometre squares which include a large number of traces. They were originally digitised as vectors, but are represented as lines of raster cells. Thus there is an upper bound on the apparent trace density, when all raster cells in a sample are trace cells. This would occur when no point on a trace is further than the raster grid distance from another trace. In other words, only for low trace densities will the ratio between trace density, expressed in two ways, as a vector length and as cell count, be approximately constant. At higher densities, approaching the upper bound of cell count, the relationship is non linear, and this non-linearity is a function of the grid size.

In this example, visual inspection of the raster representation of the traces in the most dense sample kilometre square does not show it to have approached the upper bound. Also, if we halve the side of the raster cell, convert the vector sample traces to an image at this new cell size and produce a chart which compares the distribution of sample traces in bands of equal area for the two different raster grids, we find
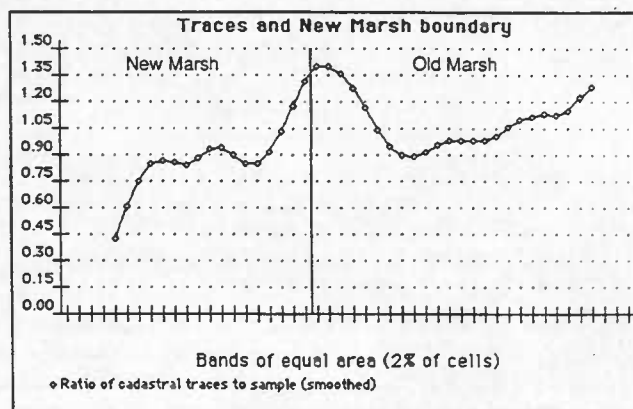
that there is not a large difference between the two (Fig. 22.8). As expected, the peak heights for the distribution using 37.5m cells are slightly higher, but this has little effect on the graph which compares the density of potential cadastral traces to the background of traces as a whole (Fig. 22.9). It is clear that this conveys much the same information as the graph produced from a 75m raster cell image.

Thus, for our case, the conclusions remain unchanged. The distribution of potential cadastral traces is not typical of the distribution of traces in the Marsh as a whole, and has anomalously high values apparently associated with the boundary between Old and New Marsh. One possible explanation for this association is that it was these parts of the cadastral structure which became fossilised most rigidly by the construction of sea defences at a time when the New Marsh was under water, but the Old Marsh was not.

More generally we find that spreadsheet processing is a straightforward way of handling measurements produced by a GIS such as IDRISI and we suggest that these techniques could be used in other cases to study the variation in cultural aspects of landscape across environmentally defined boundaries.

Bibliography

Brooks, N. P. 1988. "Romney Marsh in the Early Middle Ages", in Eddison, J. & C. P. Green (eds), *Romney Marsh — Evolution, Occupation, Reclamation*. Oxbow Books, Oxford.

Chouquer, G., M. Clavel-Lévêque, F. Favory & J. P. Vallat 1987. *Structures agraires en Italie centro-méridionale*. L'École Francaise de Rome, Rome.

Chouquer, G. & H. De Klijn 1989. "Le Finage antique et médiéval", *Gallia* 46: 261–299.

Clavel-Lévêque, M. (ed.) 1983. *Cadastres et Espace Rural. Approches et réalités antiques (table ronde de Besançon mai 1980)*. CNRS, Paris.

Eastman, J. R. 1990. *IDRISI, A Grid-Based Geographic Analysis System*. Graduate School of Geography, Clarke University, Worcester, Massachusetts, USA.

Green, R. D. 1968. *Soils of Romney Marsh*. Soil Survey of Great Britain Bulletin No. 4, Agricultural Research Council, Harpenden.

KVAMME, K. L. 1992 "Geographic Information Systems and archaeology", *in* Lock, G. & J. Moffett (eds), *Computer Applications and Quantitative Methods in Archaeology 1991,* pp 77–84. British Archaeological Reports, International Series S577, Tempus Reparatum, Oxford.

PETERSON, J. W. M. 1992a. "Fourier analysis of field boundaries", *in* Lock, G. & J. Moffett (eds), *Computer Applications and Quantitative Methods in Archaeology 1991,* pp. 149–156. British Archaeological Reports, International Series S577, Tempus Reparatum, Oxford.

PETERSON, J. W. M. 1992b. "Trigonometry in Roman cadastres", *in* Guillaumin, J.-Y. (ed.), *Mathématiques dans l'Antiquité, Centre Jean-Palerne: Mémoires* 11, pp. 185–203. Université de St-Étienne, St-Étienne.

ROMANO, R. & C. VIVANTI (eds) 1976. *Storia d'Italia,* Vol. 6 *Atlante.* Einaudi, Turin.

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