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Recognising and controlling for cultivation-induced patterning in surface artefact distributions

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15.1 Introduction

It has long been recognised by archaeologists that cultivation destroys or alters surface and subsurface features. Until recently, however, very little information was available concerning the effects of cultivation on the form and content of artefact distributions in the plough zone. The results of experimental studies designed to investigate the effects of cultivation on artefact distributions have often been inconclusive, sometimes conflicting and seem to have 'raised as many questions as they have answered' (Odell & Cowan 1987, p. 457). All have, however, indicated that cultivation produces a number of horizontal and vertical changes in the form and content of artefact distributions.

The major pattern-recognition problems posed by these changes are concerned with the extent to which surface artefact distributions reflect not only cultivation-induced patterning but also their original behavioural patterning, and whether both of these forms of patterning can be analytically distinguished. This paper presents the results of an initial pattern-recognition study undertaken at a small Mesolithic lithic scatter to determine if cultivation-induced patterning can be recognised and controlled for in an archaeological situation. A series of t-tests, line plots and least squares regressions are used as exploratory procedures to detect the presence of cultivation-induced vertical and horizontal patterning in the artefact distributions from the scatter. The data are then regrouped into larger units and the same series of line plots and regression analyses carried out to see if the regrouped data have any effect on minimising the presence of cultivation-induced patterning. Least squares regression is used throughout the paper as an initial exploratory procedure to search for patterning that may be accounted for by linear relationships and to determine where patterning departs from the assumptions of the regression model.

15.2 The data set

A small Later Mesolithic lithic scatter located within the suburban fringes of Fair Oak in south-central Hampshire was selected as a test case. The scatter was discovered in January 1985 (Boismier 1989) and covers an area of 0.70 hectares situated along the lower portion of a gently sloping hill. In December of the same year a gridded surface collection was undertaken which provides the data used in this paper. An area 40 × 64 metres through its centre was selected and subdivided into 160 four-metre-square units. All observable pieces of chipped stone and burnt flint were then collected from the surface of each unit.

For the analyses presented in this paper the individual collection units across the slope were pooled into sixteen rows. While the pooling of individual collection units may have obscured some distributional information, the need to reduce the amount of variation masking major trends in the data far outweighed the loss of some

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information. This pooling was carried out on the basis of the direction of cultivation and slope profile. Cultivation operations are carried out by equipment moving predominately up and down the slope and indicate that the major displacement patterns will be orientated along this axis. As one moves uphill, the slope across the grid remains constant and suggests that very similar, if not identical, downslope movement conditions occur along a row of collection units.

The ten variables listed in Table 15.1 were selected for analysis. Nine of these variables have been indicated by the archaeological and agricultural engineering literature (cf. Lewarch 1979) as being the ones most affected by cultivation and those most likely to reflect any indications of cultivation-induced patterning.

15.3 Changes in artefact frequency

Experimental results (Lewarch 1979, Lewarch & O'Brien 1981, Reynolds 1982, Ammerman 1985, Odell & Cowan 1987) have indicated that surface materials represent a sample of less than 10% of the plough zone population and that certain artefact classes are either under or over represented on the surface relative to their frequencies in the population as a whole. Changes in artefact class frequency after cultivation are a product of vertical displacement. Research in agricultural engineering summarised by Lewarch (Lewarch 1979, p. 112–116) has indicated that tillage implements tend to move and segregate objects within the plough zone profile. Large objects such as stones and artefacts are displaced to higher levels and small objects into lower levels. The result of vertical segregation on large artefacts is that they tend to be over represented on the surface relative to their total population in the plough zone. Segregation effects on small artefacts result in their being either more evenly distributed throughout the plough zone or sorted to lower levels within it. Both result in lower frequencies of small artefact classes on the surface relative to the total plough zone population.

Changes in size class frequencies at Fair Oak were initially evaluated by inspection of Table 15.2. For both chipped stone and burnt flint, pieces larger than 1.5 cms were recovered at higher rates than pieces smaller than 1.5 cms. Chipped stone, for example, shows recovery rates of 11.4%, 40.8% and 47.8% for the three size classes. A similar pattern can be observed for burnt flint. Table 15.2 also reveals a similar proportional relationship between size and recovery rates when the frequencies of chipped stone and burnt flint are combined by size class. These relationships would appear to indicate that the recovery processes operating on small pieces are different from those affecting larger pieces.

The significance of these relationships was then examined through the use of a series of t-tests for the difference between proportions (Blalock 1979, p. 232–234). Tables 15.3 to 15.5 present the results of these tests. For chipped stone and burnt flint seperately and in combination, a significant difference at the 95% level occurs between the smallest size class and the two larger classes. This pattern of seems to substantiate the conclusion that different recovery processes appear to operate on small pieces when compared to larger pieces. Such patterns are consistent with those reported by experimental studies (Lewarch 1979, Lewarch & O'Brien 1981, Odell & Cowan 1987) for cultivation-induced changes in size class frequencies produced by the sorting action of implements.

A series of t-tests was also carried out between chipped stone and burnt flint to determine whether there were any differences between the two populations that might reflect differences in recovery processes (Table 15.6). The lack of any significant differences between chipped stone and burnt flint indicates that the recovery processes affecting the two populations are of the same order and supports the interpretation of cultivation-induced changes in the frequencies of size classes.

Variable	*Description*
Sc01	Pieces less than 1.5 cms in size
Sc02	Pieces between 1.5 and 3 cms in size
Sc03	Pieces greater than 3 cms in size
TF	Total frequency of all items recovered
FCS	Frequency of chipped stone
FBF	Frequency of burnt flint
AS	Average size of all items recovered
ASCS	Average size of chipped stone
ASBF	Average size of burnt flint
SLOPE	Slope angle

Table 15.1: Variables used in analyses

	Sc01		*Sc02*		*Sc03*		n
chipped stone	21	0.114	75	0.408	88	0.478	184
burnt flint	21	0.068	131	0.425	156	0.506	308
n	42	0.085	206	0.42	244	0.496	492

Table 15.2: Frequencies and proportions of size classes recovered

	ScO1	ScO2	ScO3
Sc01	—	2.51*	3.06*
df		94	107
Sc02			0.90
df			161
Sc03			—
df			

Table 15.3: Results of the difference-of-proportions test for chipped stone

	ScO1	ScO2	ScO3
Sc01	—	3.13*	3.81*
df		150	175
Sc03			1.37
df			161
Sc03			—
df			

Table 15.4: Results of the difference-of-proportions test for burnt flint

	ScO1	ScO2	ScO3
Sc01	—	4.12*	4.04*
df		246	284
Sc02		—	1.62
df			448
Sc03			
df			

Table 15.5: Results of the difference-of-proportions test for the combined populations

	ScO1	ScO2	ScO3
Sc01	0.517		
df	40		
Sc02		0.239	
df		204	
Sc03			0.418
df			242

Table 15.6: Results of the difference-of-proportions test between the the size classes for the two populations

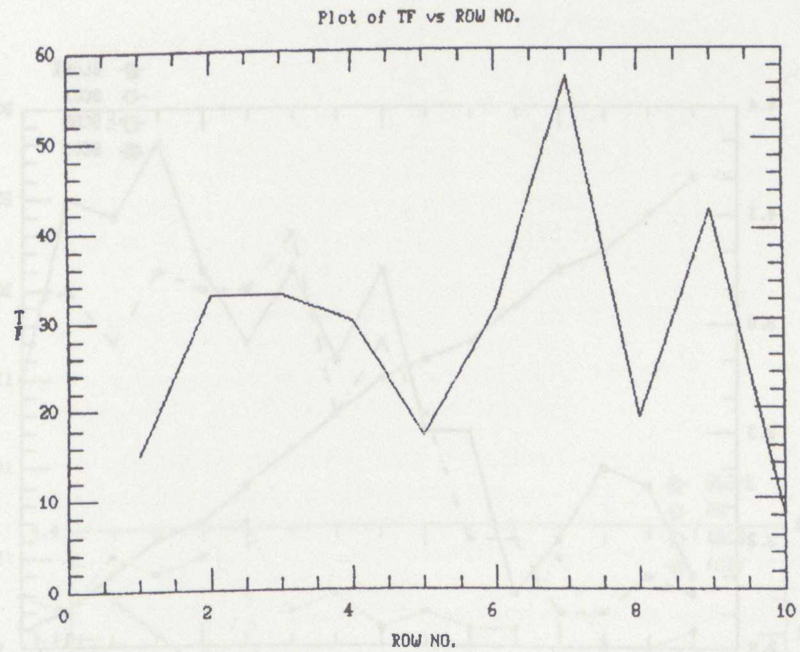

Figure 15.1: Line plot for the total frequency of one of Lewarch and O'Brien's (1981) experimental patterns

15.4 Horizontal displacement

The horizontal displacement of artefacts has received considerable attention in experimental studies. Results of these studies have indicated that the horizontal displacement of an artefact is largely related to its size, equipment type, the number and direction of equipment passes, and slope. Larger blocky or irregular objects apparently do not flow as easily through the soil as do smaller objects and tend to be dragged further along in the direction of equipment movement. Fig. 15.1 has been derived from experimental data presented in Lewarch & O'Brien 1981, Figures 1.2 to 1.5 for one of their experimental patterns and provdes some indication as to what the horizontal patterning produced by cultivation may look like. This line plot and a number of others not shown here were produced by pooling individual collection units within rows along the axis of equipment direction. The plots all revealed a recurring pattern of extreme fluctuations in frequency or average size reflecting the dispersal of objects along the axis of cultivation.

As an initial procedure for the Fair Oak data the nine variables were plotted against slope in a series of line plots (Figs. 15.2 to 15.4). These line plots indicated two general patterns for the data. First, the size class and frequency variables show a negative relationship with slope angle and a positive relationship among themselves. The only exception to this patterning is the smallest size class which appears to be unrelated to the other classes and slope. This pattern also supports the idea of different recovery processes for small pieces. Secondly, the average size variables when plotted against slope angle show no relationship with slope and very little between themselves.

The line plots for the size class and frequency variables show that the general downslope trend of increasing numbers is broken by a series of relatively abrupt changes. When compared to the experimental data such patterning appears to be

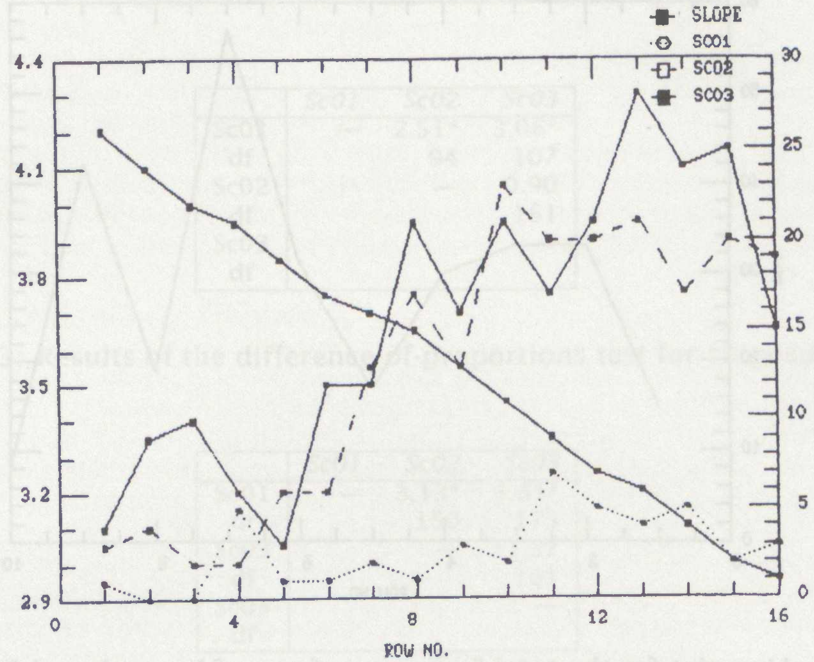

Figure 15.2: Line plot for the size class variables

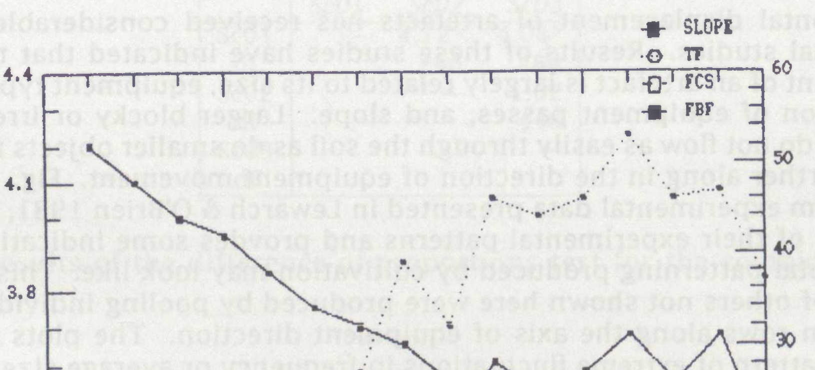

Figure 5.3: Line plot for the frequency variables

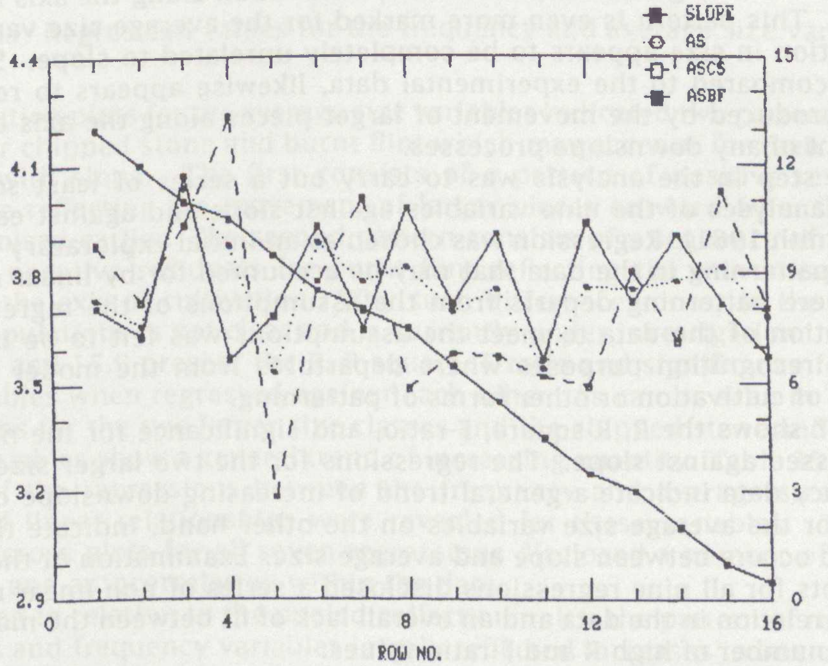

Figure 15.4: Line plot for the average size variables

variable	R	R-square	F-ratio	Significance
Sc01	−0.413	0.171	2.47	0.142
Sc02	−0.878	0.771	47.09	0.00001
Sc03	−0.821	0.674	28.89	0.0001
TF	−0.892	0.796	54.67	0.0000
FCS	−0.912	0.832	69.27	0.0000
FBF	−0.829	0.687	30.76	0.00007
AS	0.182	0.033	0.48	0.499
ASCS	0.224	0.05	0.74	0.405
ASBF	0.02	0.0004	0.006	0.939

Table 15.7: Regression values for the variables against slope

indicative of density gradients produced by cultivation along the axis of equipment movement. This pattern is even more marked for the average size variables where the fluctuation in size appears to be completely unrelated to slope. Such patterning, when compared to the experimental data, likewise appears to reflect density gradients produced by the movement of larger pieces along the axis of cultivation independent of any downslope processes.

The next step in the analysis was to carry out a series of least squares linear regression analyses of the nine variables against slope and against each other (cf. Draper & Smith 1981). Regression was chosen as an initial exploratory procedure to search for patterning in the data that may be accounted for by linear relationships and for where patterning departs from the assumptions of the regression model. Transformation of the data to meet the assumptions was felt to be inappropriate for pattern recognition purposes where departures from the model may provide indications of cultivation or other forms of patterning.

Table 15.7 shows the R, R-square, F-ratio, and significance for the nine variables when regressed against slope. The regressions for the two larger size classes and the frequency data indicate a general trend of increasing downslope quantity. Regressions for the average size variables on the other hand, indicate that no linear relationship occurs between slope and average size. Examination of the scatter and residual plots for all nine regressions disclosed a series of non-linear relationships and autocorrelation in the data and an overall lack of fit between the model and data despite the number of high R and F-ratio values.

When plotted on a map of the pooled collection units the pattern of residuals for the nine variables closely mirrored that revealed for the line plots. It is reasonable to hypothesize on the basis of this close similarity that the patterning in the residuals largely reflects cultivation-induced density gradients along the axis of equipment movement.

Two patterns were also indicated by the distribution plots for the size class and frequency variables which may account for the high negative R-values produced by the regression analyses. The first consists of a recurrent pattern of positive residuals for the frequency and size class variables within one area of the grid and suggest the presence of a major concentration of artefacts. The second pattern consists of a trend in the residuals reflecting decreasing frequencies both uphill and, to a lesser extent, downhill from the area containing the concentration of artefacts. This pattern is also reflected in the line plots (Figs. 15.2 and 15.3) and suggests the outward movement of objects by cultivation. Both patterns suggest that the high R-values produced by the regressions may be more indicative of the scatter's location on the slope as opposed to any major downslope movement of the artefact distributions.

variables	*R*	*R-square*	*F-ratio*	*Significance*
Sc01,Sc02	0.494	0.244	4.51	0.052
Sc01,Sc03	0.397	0.158	2.62	0.127
Sc02,Sc03	0.866	0.75	41.93	0.00001
FCS,FBF	0.883	0.779	49.42	0.00001

Table 15.8: Regression values for the size class and frequency variables

variables	*R*	*R-square*	*F-ratio*	*Significance*
TF,AS	−0.112	0.013	0.179	0.679
FCS,ASCS	−0.235	0.055	0.821	0.38
FBF,ASBF	0.166	0.028	0.398	0.538

Table 15.9: Regression values for the frequency and average size variables

The distribution plots for the average size variables indicated two patterns of object movement for chipped stone and burnt flint which may account for their non-linear relationship with slope. The first consists of a pattern of positive residuals for chipped stone reflecting the movement of larger pieces outward from the concentration recognised earlier. The second pattern consists of a sequence of alternating positive and negative residuals for burnt flint reflecting the movement of larger pieces along the axis of cultivation. Why such differences occur in the patterning of the two populations is not clear and is currently under investigation.

Tables 15.8 and 15.9 present the R, R-square, F-ratio and significance for selected pairs of variables when regressed against each other. As can be seen in Table 15.8, the regressions for the two larger size classes and the chipped stone and burnt flint frequency variables show a general trend of increasing quantity. Table 15.9 presents the results of the regressions between the frequency and average size variables. No pattern of linear relationships were revealed for these variables. The scatter and residual cross plots for all seven regressions disclosed a number of non-linear relationships and autocorrelation within the data.

When plotted in relation to the pooled collection units, the pattern of residuals for the size class and frequency variables largely reflected increases in one or the other of the two variables rather than any more meaningful patterning. Two patterns were, however, revealed for the frequency and average size variables when their residuals were plotted. The first consists of a pattern of positive and negative residuals for chipped stone indicating the dispersal of larger pieces from the recognised concentration. The positive residuals reflect large average size and low frequencies, and the negative residuals smaller average size and higher frequencies. The second residual pattern consists of a series of alternating positive and negative residuals for burnt flint reflecting the movement of larger pieces along the axis of cultivation. The positive residuals here reflecting large average size and high frequencies with the negative residuals indicating smaller average size and lower frequencies. Both patterns support the conclusions made earlier concerning the movement of objects for the two populations. Fig. 15.5 shows the patterning of the residuals for the two populations.

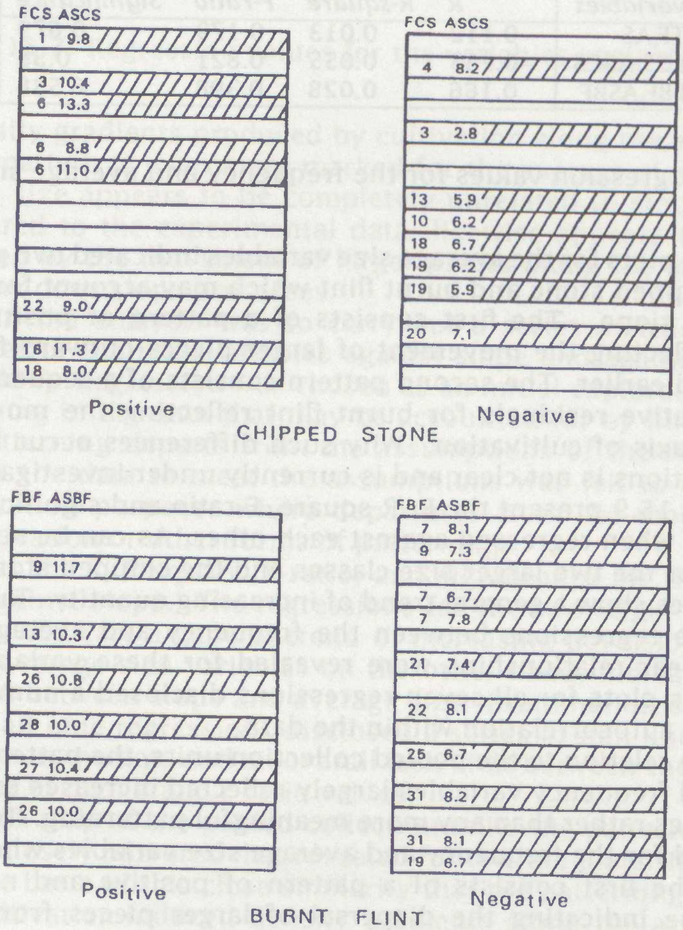

Figure 15.5: Residual patterning from the regressions between frequency and average size

15.5 Minimising horizontal displacement patterns

Having recognised a number of apparent cultivation-induced horizontal patterns in the artefact distributions at Fair Oak, the next problem to be addressed is to what extent the effects of these patterns on any subsequent intra-site analyses can be reduced or controlled for. As an initial attempt to minimise this patterning, pairs of adjacent rows were grouped together and the data from each tabulated and used in the same series of exploratory analyses involving line plots and least squares regression. The adding of two rows together was chosen as the simplest option and the one most likely to be applied by other archaeologists when faced with similar forms of patterning. Its underlying purpose was to see if the wider rows would reduce the patterning to a reasonable scale and indicate the optimal quadrat size when the rows were broken back down into individual units for intra-site analyses.

The line plots for the nine variables against slope all indicated that increasing row width had generally removed the trend of cultivation-induced density gradients from the artefact distributions but had much less effect on minimising the larger patterns of object movement implied by the data. Regrouping the rows for the size class and frequency variables removed the trend of fluctuating values reflecting cultivation-induced density gradients and revealed the pattern of object dispersal more clearly. The line plots for the average size variables produced somewhat more mixed results. Like the size class and frequency variables, the plots indicated that the regrouped rows had largely removed the trend of cultivation-induced density gradients and more clearly revealed the pattern of object dispersal. For burnt flint the regrouping also appeared to have minimised the pattern of object dispersal along the axis of cultivation indicated by the results of the first set of analyses.

Table 15.10 shows the R, R-square, F-ratio and significance obtained for the nine variables when regressed against slope using the regrouped rows. These results reflect the same patterns as that found by the first set of regressions and indicate that no real improvement in the fit of the data to the model was made by increasing row width. This lack of improvement was also reflected in the scatter and residual cross plots where the same patterns of non-linear relationships and autocorrelation were revealed. Reductions in cultivation-induced patterning were only observed when the residuals were plotted onto maps of the regrouped rows. As with the line plots, the residuals indicated that the regrouping of rows had largely removed the pattern of density gradients from the data. The recurring pattern of residuals indicating the presence of the artefact concentration and the outward trend of frequencies and average size became much more apparent and clearly defined by the regrouped rows. Only for the burnt flint average size data did the residuals indicate that the regrouping of rows had minimised displacement patterns.

The regressions between selected pairs of variables also revealed that no real improvement had been made by increasing row width. Tables 15.11 and 15.12 present the results of these analyses. As with the regressions against slope, reductions in cultivation-induced patterning were revealed when the residuals were plotted onto maps of the regrouped rows. For all variables the patterning of the residuals indicated that the wider rows had largely removed the trend of density gradients from the data.

The residual patterning of the regressions between the frequency and average size variables also indicated that the regrouping of rows had reduced the larger patterns of object displacement for chipped stone and burnt flint. For both artefact populations negative residuals, reflecting lower frequencies and larger average sizes, occurred in the first three or four uphill rows followed by a sequence of positive residuals reflecting higher frequencies and smaller average size. The two patterns of

variable	*R*	*R-square*	*F-ratio*	*Significance*
Sc01	−0.662	0.562	4.68	0.074
Sc02	−0.881	0.776	20.85	0.004
Sc03	−0.874	0.774	19.47	0.005
TF	0.896	0.803	24.53	0.003
FCS	−0.906	0.821	27.53	0.002
FBF	−0.862	0.743	17.32	0.006
AS	0.15	0.022	0.14	0.723
ASCS	0.244	0.059	0.38	0.559
ASBF	−0.013	0.0002	0.001	0.976

Table 15.10: Regression values for the variables against slope using the regrouped rows

variables	*R*	*R-square*	*F-ratio*	*Significance*
Sc01,Sc02	0.65	0.422	4.39	0.074
Sc01,Sc03	0.687	0.473	5.38	0.059
Sc02,Sc03	0.932	0.868	39.56	0.0007
FCS,FBF	0.934	0.873	41.28	0.0007

Table 15.11: Regression of size class and frequency variables using the regrouped rows

variables	*R*	*R-square*	*F-ratio*	*Significance*
TF,AS	−0.30	0.09	0.59	0.469
FCS,ASCS	−0.286	0.082	0.53	0.493
FBF,ASBF	0.042	0.002	0.01	0.922

Table 15.12: Regression of frequency and average size variables using the regrouped rows

object movement revealed by the residuals from the initial regressions were reduced, although not all together removed, by the regrouping of rows.

The line plots and the residual maps of this second set of analyses indicate that the relatively simple procedure of adding two rows together had largely removed the occurrence of cultivation-induced density gradients and substantially reduced the displacement patterns observed for the two artefact populations. These results suggest that for any subsequent intra-site analyses, the optimal quadrat size is an 8m × 8m unit. This unit size is optimal for the investigation of intra-site structure in the sense that while it is large enough to encompass most displacement patterns, it is also still small enough to retain some of the detail of the artefact associations.

15.6 Conclusion

As increasing emphasis is being placed on the use of surface remains for both research and management purposes it is becomming increasingly essential to be able to distinguish between post-depositional patterning, such as that produced by cultivation, and any surviving indications of behavioural patterning. The results of this study, although only preliminary, are encouraging in that while cultivation produces a number of changes in the form and content of artefact distributions, it does appear possible to recognise this patterning and miminise its effects on any subsequent investigation of behavioural patterning.

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