

PATTERN ANALYSIS: A REVIEW AND SOME PROPERTIES OF A METHOD

L. KÖRMÖCZI

*Department of Botany,
Attila József University, H—6701 Szeged, P.O.B. 657. Hungary*

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Abstract

A wide variety of information can be gained on the spatial pattern of the individuals within a population with the help of the grid analysis developed by GREIG-SMITH. Though the statistical testability of the method is rather weak owing to the dependence of the samples, it is less time consuming than other methods, which is an advantage.

Following the detailed description of the method, a demonstration is given in respect to a few characteristics of the pattern analysis, using a computer program. Following the questions related to aggregation square size and the detectability of the intensity of group formation, the problems pertaining to aggregate orientation are discussed. Based on the one-way complete reduction of the fundamental units of the quadrat grid, the specific spatial orientation of the aggregates is demonstrable.

At the end of the paper, a concrete example is given for the course of the calculation and the mode of evaluation of the analysis.

Key words: pattern analysis, spatial orientation

Introduction

In real space the individuals of a population may show rather varied arrangement, spatial pattern depending on the heteromorphy of the topography, the space-gaining strategy of the population, as well as on the group characteristics of the coexisting populations. Further combinations are possible apart from the familiar three basic types of this pattern (random, clumping, and uniform arrangements), and these frequently complicate the recognition of the real pattern.

Several methods have been elaborated for the detection of the spatial distribution of a population (e.g. mathematic distribution functions, distance methods, variance/mean value indices; for details see GREIG-SMITH, 1983). These methods provide authentic information as to the quality of the distribution, but the result is greatly influenced by the unit size of the sample. Furthermore, the scale of the pattern is also left unrevealed. Nevertheless, these methods have good statistical probes. The methods showing pattern scale as well, however, cannot be tested so reliably due to the dependence of the samples.

One of the methods based on the variance of the samples is the grid-analysis developed by GREIG-SMITH (1952), with the help of which the scale and intensity of

the spatial pattern of the populations can also be obtained. (Using the expression "pattern" in the sense given by PRÉCSÉNYI et al. 1967: "by pattern a significant non-randomness is expressed"). Naturally several patterns can be discovered simultaneously in a biocenosis. Characteristic pattern is shown by the vertical and horizontal structure of the communities, by the regulation of the dynamics of the populations living together, etc. (PRÉCSÉNYI, 1981). The present paper only deals with the spatial distribution pattern of the individuals belonging to one single population.

The significance test of the method was elaborated by THOMPSON (1958), the confidence limits were also given. This author also pointed out that contrary to chance pattern arrangement, the orientation of the pattern is also given by the grid-analysis. This property of the analysis was emphasized by PRÉCSÉNYI et al. (1967), too.

Summary of the effectuation of the grid-analysis

Such quadrat grid is to be used for pattern analysis performed with contiguous quadrat grid where the number of basic quadrats, K , is:

$$K = 2^n \quad (n = 1, 2, 3, \dots) \quad (1)$$

The grid may be square, rectangle, or a so-called transection.

The elemental squares of the grid containing 2^n squares are regarded as functional unit. The individual number of the studied population (or the presence if the elemental square is small enough to be commensurate with the individuals of the studied species) is recorded in every elemental square during the course of the topometry. This kind of sampling is less time consuming than e.g. the distance

Table 1. 98%, 95% and 90% confidence limits for distribution
(DF = degree of freedom; U = upper limit; L = lower limit)

DF	U _{98%}	L _{98%}	U _{95%}	L _{95%}	U _{90%}	L _{90%}
1	6.62	0.00	5.02	0.00	3.84	0.00
2	4.61	0.01	3.69	0.02	2.99	0.05
4	3.33	0.07	2.78	0.12	2.37	0.18
8	2.15	0.21	2.19	0.27	1.94	0.34
16	2.00	0.36	1.80	0.43	1.64	0.49
32	1.67	0.52	1.55	0.57	1.44	0.63
64	1.46	0.64	1.37	0.68	1.31	0.73
128	1.32	0.75	1.26	0.77	1.22	0.79
256	1.21	0.81	1.18	0.83	1.16	0.85
512	1.16	0.86	1.13	0.88	1.11	0.90
1024	1.11	0.89	1.09	0.91	1.07	0.93
2048	1.08	0.91	1.06	0.93	1.05	0.95

measurements, at the same time the amount of information gained by the latter is not greater either. The accurate mapping of the individuals — the sort of sampling analysable from the most sides (SZŐCS, 1977) — is also rather labourconsuming, even with the use of photograph.

The variance analysis is performed with the individual numbers of the successively increased quadrats. In the course of the analysis the quadrat areas duplicate in every case with fusion of the blocks, in such manner that first the quadrats take up oblong shape, then become square again. The individual numbers become summed in the joined quadrats.

The variance between the units of the sample consisting of K quadrats is studied by a nested analysis of variance. The sum of squares belonging to the blocks consisting of r basic unit can be given by the following formula:

$$SSQ_r = \frac{1}{r} \sum_{i=1}^{\frac{K}{r}} X_{i(r)}^2 - \frac{1}{2r} \sum_{i=1}^{\frac{K}{2r}} X_{i(2r)}^2 \quad (2)$$

$$(K = 2^n ; r = 2^k ; k = 1, 2, 3, \dots, n)$$

where $x_{i(r)}$ and $x_{i(2r)}$ are the individual numbers measured in the i^{th} block containing r and $2r$ units, resp. The pertaining mean square, MS_r , is as follows:

$$MS_r = 2r SSQ_r / K \quad (3)$$

Assuming the random distribution of the individuals, each mean square is the estimation of the variance of the Poisson distribution, related to the values measured in the quadrat grid units. In this case the mean square/overall mean is approximately 1 in respect to every block size (PODANI, 1983).

The deviation of the mean square/overall mean value from that of random distribution can be tested by the critical values of the χ^2 probe. The upper (and lower) critical limit can be given by the ratio of the critical χ^2 value belonging to the required error-probability level, as well as by the ratio of the appropriate degree of freedom (THOMPSON, 1958, GREIG-SMITH, 1961):

$$U_{P\%} = \chi^2_{U, P\%} / DF \quad (4)$$

(The values of the critical limits are summarized in Table 1.).

The following relationships is valid for the confidence limits. If the mean square/overall mean value falls into the critical limits, there is no significant deviation from random distribution. If this value surpasses the upper critical limit, the trend of the deviation is contagious distribution, showing group-formation; while being uniform distribution in case the value is below the lower limit.

The mean square — block size graph usually takes up a serrated curve shape. In case of random distribution the mean square/overall mean value ranges between the two limits, close to 1. If the value shows an elevating peak over the upper limit, this indicates aggregation at the given square size. In such case the MS/\bar{x} increases till the pertaining block size reaches the mean size of the aggregates, groups. If the aggregates themselves also show grouped localization, the MS/\bar{x} remains at almost identical level (PRÉCSÉNYI, 1964, GREIG-SMITH, 1983). In case of aggregates showing random distribution, however, it falls below the critical value again, as also proved by computer-simulations (see Fig. 1).

A computer programme was prepared for performing the analysis, in BASIC programming language for use in Commodore—64 microcomputer. This programme provided to study several properties of the analysis on the computer-generated point-mass of random distribution and on populations of know pattern, and also to compare the distribution of natural populations with "populations" of random distribution.

Orientation of the aggregates

In the course of the analysis the direction of the oblong block can be chosen in two ways. The graphs obtained as a result of the two different analyses will show divergent courses, the peaks will arise at different square sizes (see Fig. 1), except if the distribution is symmetrical to one of the diagonals. Often the size of the peaks (which also indicates the pattern intensity) is not uniform either, which might mean the specific orientation of the aggregates. As also expounded by GREIG-SMITH

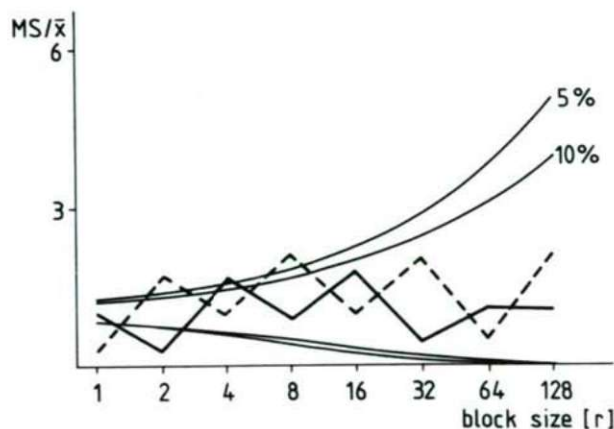


Fig. 1. Graph of MS/\bar{x} against block size for a simulated population, with 95 % and 90 % confidence limits. Solide line and broken line show different orientations of rectangular blocks during processes (see text).

(1961), in such cases it is more effective to affiliate the units in one direction (along a transection), than to alternating oblongs and quadrats. In this case the peaks are in correlation with the mean linear size of the patches.

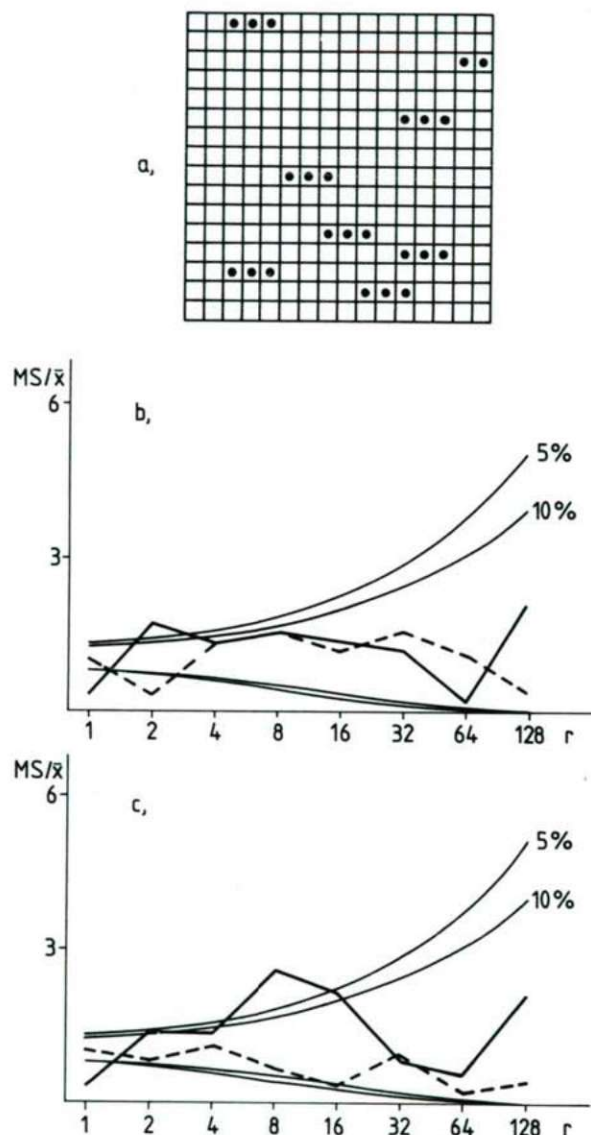


Fig. 2. Graphs of MS/\bar{x} against block size for simulated population (a). Part (b), shows alternating, while part (c) shows non-alternating grouping. Orientation of rectangles is → (solid line) and ↑ (broken line)

The complete fusion of the quadrat grid units, first in one direction then in perpendicular direction, gives the following results. If the aggregates have specific orientation, significant differences will arise between the results of the two analyses

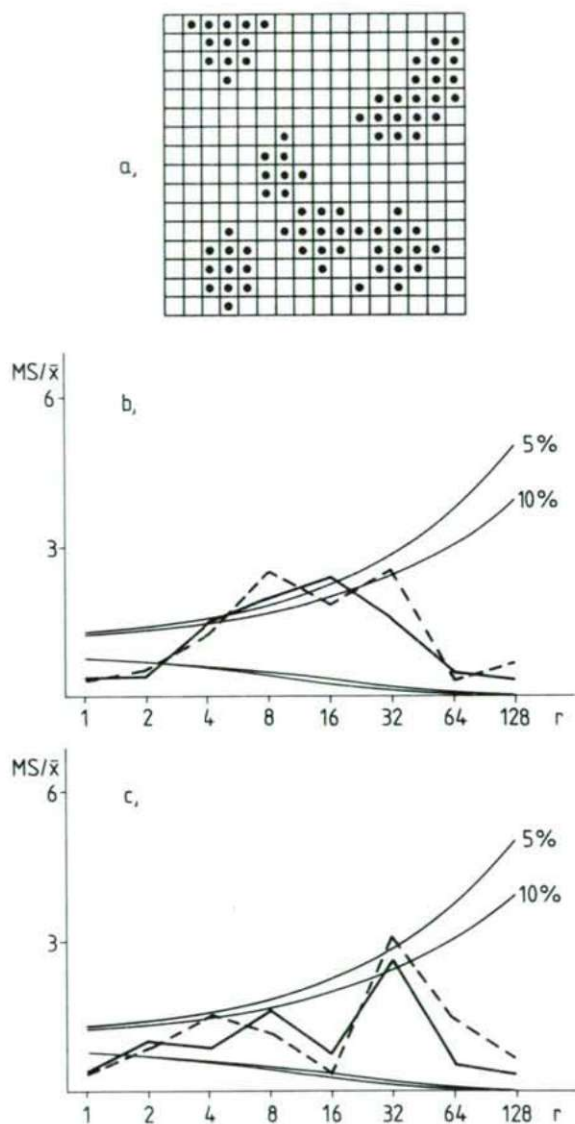


Fig. 3. Graphs of MS/\bar{x} against block size for simulated population (a).
(See labellings for Fig. 2.)

started in different directions (see Fig. 2), while in lack of specific orientation the differences can be neglected. In case the direction of the first fusion corresponds to the orientation of the groups, the peaks may be multiples of the results of the analysis started in perpendicular direction. Fig. 2/a shows such an arrangement where groups of random distribution and identical orientation are present. Fig. 2/b demonstrates the results of the alternate fusion. Only slight differences are between the graphs of the two analyses. A peak indicating aggregation is only observable on one of the curves, while the other runs between the confidence limits.

In case of complete fusion in one direction (Fig. 2/c), two outstanding peaks were the results of the fusion corresponding to the orientation of the aggregates, while again the other curve remained between the confidence limits.

Fig. 3. sets an example for non-elongated patches, where the two parts of both the alternate (Fig. 3/b) and one-way fusion (Fig. 3/c) result close to similar curves.

The centre of the aggregates is of random distribution in both examples. The intensity of the pattern was low in both cases, owing to the low individual numbers.

AN EXAMPLE

In the followings the calculation course of the analysis and the explanation of the results are shown in a concrete example.

The individual numbers set in the basic units of the quadrat grid made up of $16 \times 16 (= 256)$ squares seen in Fig. 4. serve as the starting-point of the analysis. The units of the quadrat grid were 10×10 cm in size. (The recording was made in 1984 at Bugacpuszta from the *Achilleo-Festucetum pseudovinae* association. The studied species was the *Plantago maritima*).

The course of the calculations is observable in Table 2.

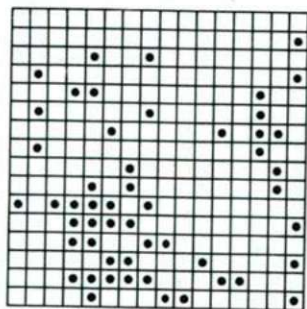
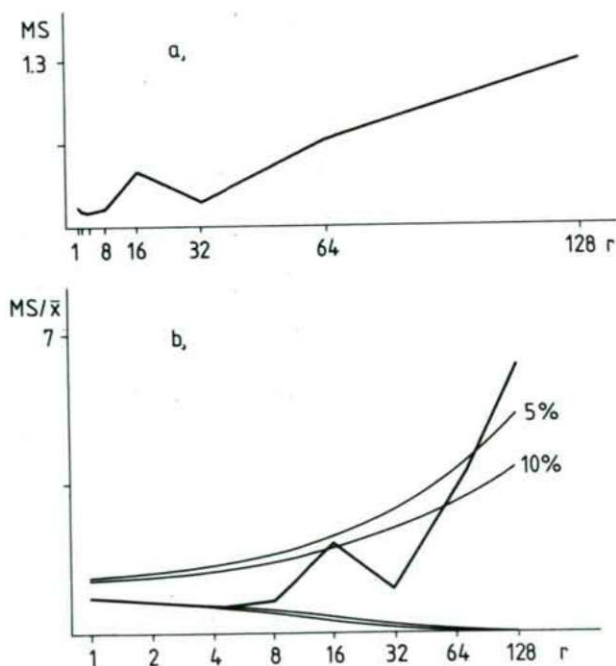


Fig. 4. Map of distribution of *Plantago maritima*

Table 2. Partial results of the calculation

r	S	SSQ	DF	MS	MS/ \bar{x}	$U_{95\%}$	$U_{90\%}$
1	52.0	20.0	128	0.1563	0.7695	1.26	1.22
2	32.0	8.5	64	0.1328	0.6538	1.37	1.31
4	23.5	3.75	32	0.1172	0.5770	1.55	1.44
8	19.75	2.375	16	0.1484	0.7306	1.80	1.64
16	17.375	3.375	8	0.4219	2.0770	2.19	1.94
32	14.0	0.8438	4	0.2109	1.0383	2.78	2.37
64	13.1563	1.3282	2	0.6641	3.2694	3.69	2.99
128	11.8281	1.2656	1	1.2656	6.2306	5.02	3.84
256	10.5625	—	—	—	—	—	—

Fig. 5. Graphs of MS against block size (a) and of MS/ \bar{x} against block size (b) for *Plantago maritima*

The first column of Table 2 indicates the number of the combined elemental blocks. The second column comprises the series of sums of squares. The differences according to pairs of the sums of squares are observable in the third column (the

second is deducted from the first, the third from the second, etc.). These are actually the values deriving on the basis of the (2) equation.

The values of the fourth column are the degrees of freedom of the successive sums of squares. The value of the degrees of freedom is obtained by taking the difference of the elemental numbers of the consecutive samples. Here, the initial elemental number is 256, and 128 for the sample of 2 block numbers. The difference of the two will be the degree of freedom = 128.

The fifth column shows the ratios of the SSQ values and the degrees of freedom, the variances. The ratio of the variances and the mean individual number is demonstrated in the sixth column. There are 52 individuals in our example, thus the overall mean is 0.203. The last two columns show the upper critical limits of the MS/overall mean, which belong to 5% and 10% error probability level.

The results can be illustrated as the function of the mean square or the mean square/overall mean and the block number, as observable in Fig. 5, with the block size demonstrated on linear or logarithmic scale.

The Figure shows that the variance of the individual numbers increases with the increase in block size. At block size 16 (1600 cm²) an outstanding peak is observable, then the curve falls back to the following square size. This peak appearing at block size 16 indicates weak aggregation, its deviation from chance distribution is only significant at 10% level.

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