STATISTICAL MEASURES

OF

FIELD PLOT UNIFORMITY[1]

BY

Eugene R. Perrier, Larry P. Wilding and Bruce Gilliver[2]

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[1]*Farm Development Committee of the ICRISAT Sahelian Centre (ISC), ICRISAT, P. O., Patancheru 502 324, Andhra Pradesh, India.*

[2]*Soil Physicist, ICRISAT/SAFGRAD, Ouagadougou, Upper Volta, West Africa; Pedologist, Soil and Crop Sciences Dept., Texas A & M Univerisity, College Station, Texas; and Principal Statistician, ICRISAT, Hyderabad, India.*

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E. R. Perrier, L. P. Wilding and B. Gilliver[1]

INTRODUCTION

Soil variability is a familiar problem to agricultural scientists who must constantly deal with the cumulative effects of micro-variation which can easily mask treatment differences. Spatial variation of soil parameters is a problem when applying results from analysis of localized soil and yield data from experimental plots to farmer's fields. In many experimental situations, conventional methods to control inherent soil variation from treatment comparisons through randomization and replication are difficult if not inadequate to determine appropriate management practices.

An experimental field plot is a land area prepared for a physical or chemical measurement or a specific crop where the optimal plot size and replication enables evaluation of treatment effects to a desired precision (Nelson, 1981). To establish experimental field plots, the scientist must estimate soil variability. Results from experimental field plots may reflect not only the specified treatment effect but also the effects of other factors such as rainfall, surface irregularities, infiltration, fertility, cultivation, plants, management, etc. As the Sahel Region of West Africa is comprised of heterogeneous soils and sporadic rainfall (Virmani, et al, 1980), the variability of experimental yields may be caused by these uncontrolled factors on the imposed treatments (Angus, 1981).

Discussions by scientists have concluded that if the "natural" condition of the soil could be preserved then fields would be sufficiently "homogeneous" so that no soil surface or profile modification is needed (Niamey, 1982 and Hyderabad, 1983). However, the question can be debated about how one could possibly manage research plots under these conditions; and if everything is "homogeneous," should statistical measures be used to estimate or test their uniformity? The purpose of this report is to review the literature on statistical methods available to measure field plot uniformity. Methods are described in detail in the following sections with recommendations for application of these techniques.

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1. Soil physicist, ICRISAT/SAFGRAD, Ouagadougou, Upper Volta; Pedologist, Soil and Crop Sciences Dept., Texas Agric. Exp. Stn., College Station, Texas; Statistician, ICRISAT, Hyderabad, India

The following statistical methods used to estimate the uniformity of field plots were examined:

1. Yield variablity trials,

2. Auto and spatial correlation with spectral analysis, and

3. Semivariograms and Kriging analysis.

To illustrate the analyses of the various methods, cotton seed yield data taken in 1926 and presented by Panse and Sukhatme (1978) were evaluated. Yields were taken from 1280 plots which measured 1.42m by 1.42m each within a field measuring 45.5m by 56.9m or 2590 square meters (>0.25 hectare). The data set is presented in Appendix A together with examples of computer program output. All computer programs used to analyze the data are presented in Appendix B. Computer program number 1, ENTDAT.BAS, was used to enter the cotton seed yield data set on file for further use. The conclusions present recommendations and priorities to be used when developing new field plots or quantifying the uniformity of existing field plots[2].

An objective of this report is to present methods in a form suitable for field application. Although many of the methods appear to be mathematically sophisticated, the intention is that only the "nuts and bolts" are presented for each method; albeit, some of the "nuts and bolts" may appear to be chrome plated. The computer programs in Appendix B are adapted to a portable computer and written in the universal language of Microsoft BASIC.

YIELD VARIABILITY TRIALS

The choice of plot size has been recognized as important for efficient and economic experimentation (Binns, 1982). Plot sizes that reduce variance to acceptable levels are influenced by available equipment, crop competition, crop and soil variability, required precision, and many other factors. Proper interpretation of experimental field plot data largely depends on the 'best' estimation of the experimental error. Enough data points can be obtained to estimate the variance of a specified parameter by measuring that parameter at the finest grid possible (Vieira, et al, 1981). Although this may be the best criteria for determining shape and size of field plots, it is usually not feasible in practice because of excessive costs and the need for many samples. If the soil variation is known, long and narrow

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2. These remarks do not infer criticism on or of the analysis as presented by Panse and Sukhatme (1978).

plots with the longer dimension in the direction of greatest soil variation are the best arrangements to overcome the effects of soil heterogeneity (Li and Keller, 1951).

Plot size within a given range usually is regarded as a matter of convenience, i.e., use of farm machinery demands larger plots than hand tools (leClerg, et al, 1962). Also, plots must be small when a breeding program has only a limited amount of seed. For a fixed land area, the plot size varies inversely with the number of treatments to be included in the test. For example, if a researcher has 1/4 hectare and wishes to study 5 varieties of sorghum at 2 planting dates and with 5 replications, his plots could be 5m by 10m in size ($50m^2$ per plot). The longer length (10m) then, should be directed towards the region of the greatest soil variability (assumed or measured). Although randomization and replication are considered essential in modern field experimentation, it is still not unusual to find trained scientists using an inadequate number of replications without randomization[3]. But ways to increase precision of field experiments and reduce effects of soil variability on treatments is by increasing the number of replications, by randomization, and by using concomitant information[4].

Pedologists (Wilding and Drees, 1978, 1983) have categorized field variability into two broad groups:

1. Systematic variation

2. Random variation

In general, investigators prefer to deal with random variation and assume that systematic variation is non-existent. "Systematic variability is a gradual or marked change in soil properties (or a sign of trend effects) as a function of landform, geomorphic elements and soil-forming factors, and/or soil management by man." The systematic variation is usually considered deterministic and resolved by effective soil surveys and pedological investigations. Wilding and Drees have grouped systematic variability as a function of the following factors:

1. Land forms: mountains, plateaus, basins, plains, terraces, fans, valleys, moraines, etc.

2. Geomorphic elements: summit, shoulder, backslope (sideslope), and toeslope (footslope).

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3. It is accepted that systematic designs still have a role in agricultural research.

4. (Statistics), then, is not everlasting, revealed truth. It is a living body of ideas that changes with time. There are many methods, and what is right and valid today may be wrong and invalid tomorrow (Hirschi and Selvin, 1973)."

3. Soil-forming factors:

   a. Chronosequences: a function of geomorphic age and landscape stability;

   b. Lithosequences: a function of parent material or bedrock types;

   c. Toposequences (Stoop, 1982): a function of topographic relief on similar parent materials; and,

   d. Biosequences: a function of biology, i.e., forest vs grassland or organic vs mineral sequences.

4. Interactions of the above three factors.

Random variation cannot be determined by exact measurement but can be managed by randomization and replication. For general approaches to the study of field plot uniformity, statistical probability analysis and spatial correlation techniques are usually employed to assess the effects of random variation; whereas, autocorrelation, spectral analysis, and kriging analysis are used to evaluate the effects of both systematic and random variation. However, all these techniques can be used to estimate field plot uniformity.

Probability Analysis

When attempting to apply various methods available to estimate field plot uniformity, it is essential to know if the data fits a normal, logarithmic, or other skewed distributions. The shape of the frequency distribution determines the method selected for analysis. Statistical methods require that the probability or frequency distribution be known before estimating the statistics of a spatial or temporal variable. Nielsen, et al (1973) and Vachaud (1982) suggest that fixed terms such as soil moisture retention are normally distributed whereas terms dealing with time or transport such as hydraulic conductivity follow a log-normal distribution. As different measurements of soil and plant properties can have different scales of spatial dependence, it is important to evaluate their probability distribution before the start of large scale sampling (Russo and Bresler, 1981). Normal and log Pearson type III curves will be presented as examples for estimating the design probability for field plot uniformity trials.

The mean yield is usually obtained by taking samples from many (random) locations in the field. Probabilities associated with individual plot data, y, (if values are distributed normally) are given by:

$$y = Y + Ks \qquad \text{(EQ. 1)}$$

where

Y = mean $= \sum y_i / n$,

n = number of samples

s = standard deviation = $[\sum (y_i - Y)^2/n-1]^{1/2}$

K = numerical value of the frequency integral (taken from statistical tables).

The cotton seed data was analyzed by computer program number 2, FREQ.BAS, and shown in Appendix B. Mean, standard deviation, skewness, and kurtosis with significance levels were determined (Snedecor and Cochran, 1980).

Table 1 shows the mean, standard deviation, coefficient of variation percentage, and the coefficients of skewness and kurtosis with the 5% significance level indicated for the analysis of both columns and rows of the cotton seed data. The coefficient of variation of the row data appears less variable than the column data. However, the rows and columns which are significantly different from the normal distribution are proportional, i.e., 28% of each data set are not normally distributed.

Skewness and kurtosis are terms that need clarification. Skewness is a term which describes the degree of distortion from symmetry or normality exhibited by a frequency distribution (Arkin and Colton, 1950). For skewed distributions, the mean lies on the same side as the longer tail and for a negative skewness the mean lies to the right of the mode. The mode is the value which occurs with the greatest frequency and is not affected by extreme values; whereas, the mean is greatly affected by extreme values. Therefore, as the degree of skewness increases, the distance (the measure of skewness) between the mean and the mode increases (Spiegel, 1961).

Kurtosis is the degree of 'peakedness' of the frequency distribution of a data set. A frequency distribution with a sharp or high peak is called leptokurtic although a flattopped or squatty curve is called platykurtic. When the skewness = 0 and the kurtosis = 3, then the data set is said to be normally distributed. Although the coefficients of skewness and kurtosis are easy to calculate, they have a drawback when determining the significance level of a frequency distribution. The assumption that the skewness coefficient is normally distributed is an accurate estimate only if the number of samples is large (a minimum calculation requires that n exceeds 25). For the kurtosis coefficient, the sample size must be even larger than for the skewness coefficient, i.e., n must be greater than 50 (Snedecor and Cochran, 1980). For the small cotton seed data set the values for skewness and, especially kurtosis, may only be indicative of the test for normality and a plot of the data set using probability paper is necessary.

Table 1 shows that column averages vary from 65.9 to 95.2 gm/plot with standard deviations and coefficients of variation percentages increasing slightly from left to right (Figure 1). However, the non-normal data indicated by the skewness and kurtosis coefficients tend to group in the left portion of the field between columns 3 and 16. Yield averages of the row data (Figure 2) range from 52.1 to 98.2 gm/plot with the yield decreasing from top to bottom and the standard deviation and coefficient of variation percentage increasing from the top of the field to the bottom. The non-normal data sets tend to group in the bottom half of the field between rows 20 and 40.

Therefore, the lower righthand corner of the field between rows 20 and 40 and columns 16 and 32 has the greatest variability. The greater number of plots with non-normal distributions are in the lower lefthand corner of the field between rows 20 and 40 and columns 1 and 16. The highest average yields are in the upper righthand corner of the field between rows 1 to 20 and columns 16 to 32. Figures 1 and 2 point out an important relation (to be discussed later) in that there are trends in the data set from top to bottom (decreasing trend) and from left to right (increasing trend).

For row = 19 of the cotton seed data (Table 1), the above equation (1) would have the following parameters:

$$\text{Mean} = \bar{Y} = 73.8 \text{ gm/plot}$$

$$\text{Standard deviation} = s = 17.1 \text{ gm/plot}$$

for n = 32 values. The skewness (S = 0.01) and the kurtosis (k= 2.20) show that the yield data of row = 19 fits a normal distribution. Several points at given probabilities are calculated (0.99, 0.9, 0.7, 0.5, 0.3, 0.1, 0.025 and 0.01) so that the data can be displayed graphically. For example, the particular yield that will be exceeded or equalled at 10% probability can be computed as follows:

$K = 1.282$ at 0.10 probability, then

$Y_{10} = \bar{Y} + Ks = 73.8 + 1.282(17.1)$

$Y_{10} = 95.8$ gm/plot

Figure 3 displays these data showing that row = 19 for the data set is normally distributed; whereas, row = 23 is not. Also, for the column data set shown in Figure 4, column = 7 is normally distributed but column = 14 is not. Figures 5, 6, 7, and 8 show the histograms for these four examples and although row = 19 and column = 7 were shown to be normally distributed by graphical presentation (Figures 3 and 4), their shapes are not well defined in the bell-shaped manner. And, it can be pointed out in Figures 6 and 8, that row = 23 and column = 14 do not conform to a normal distribution.

TABLE 1. The mean (Y), standard deviation (s), percent coefficient of variation (CV), skewness coefficient (S), and kurtosis coefficient (k), with 5 percent level of significance (*) for both the row and column effects of the cotton seed yield data (gm/plot).

POSITION		Y	s	CV	S	Sign.	k	Sign.
COLUMN	1	65.9	18.5	28.0	-0.17		2.23	
	2	69.3	18.4	26.6	-0.14		2.28	
	3	78.3	23.8	30.4	0.21		1.96	*
	4	82.4	17.7	21.5	0.95	*	3.93	
	5	78.5	18.4	23.5	0.36		2.80	
	6	78.9	18.8	23.8	0.44		4.54	*
	7	77.9	17.0	21.9	0.23		2.54	
	8	83.0	19.3	23.3	0.42		2.51	
	9	79.1	17.4	22.0	0.59	*	4.07	*
	10	76.5	19.2	25.1	-0.14		3.01	
	11	75.9	19.9	26.3	0.77	*	4.34	*
	12	72.4	19.4	26.8	-0.27		2.62	
	13	72.5	19.2	26.5	-0.42		3.28	
	14	76.5	23.3	30.4	1.14	*	4.38	*
	15	79.4	24.3	30.7	0.61	*	2.21	
	16	72.5	25.1	34.6	-0.10		1.84	*
	17	95.2	29.8	31.3	0.17		2.83	
	18	76.7	31.2	40.7	0.37		2.47	
	19	75.1	28.4	37.9	0.31		2.53	
	20	81.8	29.8	36.5	-0.41		2.16	
	21	79.0	30.7	38.9	0.18		2.50	
	22	81.0	29.5	36.4	-0.10		3.04	
	23	74.1	25.9	34.9	-0.05		2.31	
	24	78.2	29.3	37.2	0.39		3.07	
	25	72.6	29.4	40.5	-0.28		2.70	
	26	78.5	30.2	38.5	0.27		2.85	
	27	78.1	25.9	33.1	0.19		2.29	
	28	78.7	26.1	33.3	-0.05		3.49	
	29	86.5	28.5	32.9	0.49		2.88	
	30	77.4	24.6	31.8	-0.10		3.31	
	31	84.7	25.3	29.9	0.26		2.54	
	32	85.9	24.6	28.6	0.64	*	3.43	

TABLE 1. cont.

POSITION		Y	s	CV	S	Sign.	k	Sign.
ROW	1	97.0	20.4	21.1	-0.10		2.26	
	2	71.4	19.8	27.7	0.51		2.67	
	3	87.5	27.8	31.8	0.19		2.39	
	4	78.8	16.8	21.3	0.37		2.23	
	5	93.9	18.0	19.2	-0.29		2.19	
	6	87.8	22.2	25.3	-0.30		3.07	
	7	88.8	17.0	19.1	-0.18		2.25	
	8	98.2	25.6	26.1	0.79	*	2.88	
	9	85.0	24.9	29.3	0.32		2.20	
	10	83.2	24.3	29.2	0.87	*	3.78	
	11	90.1	22.5	25.0	-0.09		2.23	
	12	78.3	14.5	18.5	0.65		3.11	
	13	86.1	14.1	16.3	-0.24		2.77	
	14	77.3	13.4	17.3	0.23		2.21	
	15	77.1	16.5	21.4	0.42		3.07	
	16	83.1	14.3	17.2	0.29		3.12	
	17	67.9	17.7	26.1	0.01		2.53	
	18	85.0	24.6	28.9	0.17		2.52	
	19	73.8	17.2	23.3	0.01		2.19	
	20	76.2	20.1	26.4	0.26		2.08	*
	21	70.0	15.6	22.3	0.09		2.21	
	22	82.5	21.6	26.1	0.19		1.89	*
	23	79.8	25.2	31.6	1.02	*	4.09	*
	24	92.3	28.1	30.5	0.50		2.40	
	25	91.8	24.7	27.0	-0.51		3.47	
	26	85.5	18.2	21.3	-0.75	*	3.22	
	27	90.9	28.0	30.8	0.14		2.75	
	28	93.4	33.6	35.9	0.43		2.01	*
	29	82.1	24.7	30.1	0.19		3.33	
	30	72.4	24.9	34.9	1.36	*	5.38	*
	31	69.0	17.2	25.0	-0.37		2.30	
	32	63.5	26.6	41.8	0.79	*	3.74	
	33	57.4	20.9	36.4	0.58		3.64	
	34	64.7	23.8	36.9	-0.32		2.37	
	35	52.1	23.2	44.6	-0.19		1.71	*
	36	66.0	28.9	43.8	0.65		3.18	
	37	54.7	23.5	43.0	0.57		3.57	
	38	61.4	18.6	30.2	-0.08		2.62	
	39	70.8	22.4	31.6	0.49		2.15	*
	40	62.5	20.9	33.5	-0.23		2.48	

FIGURE 1. Mean yield (gm/plot) for columns

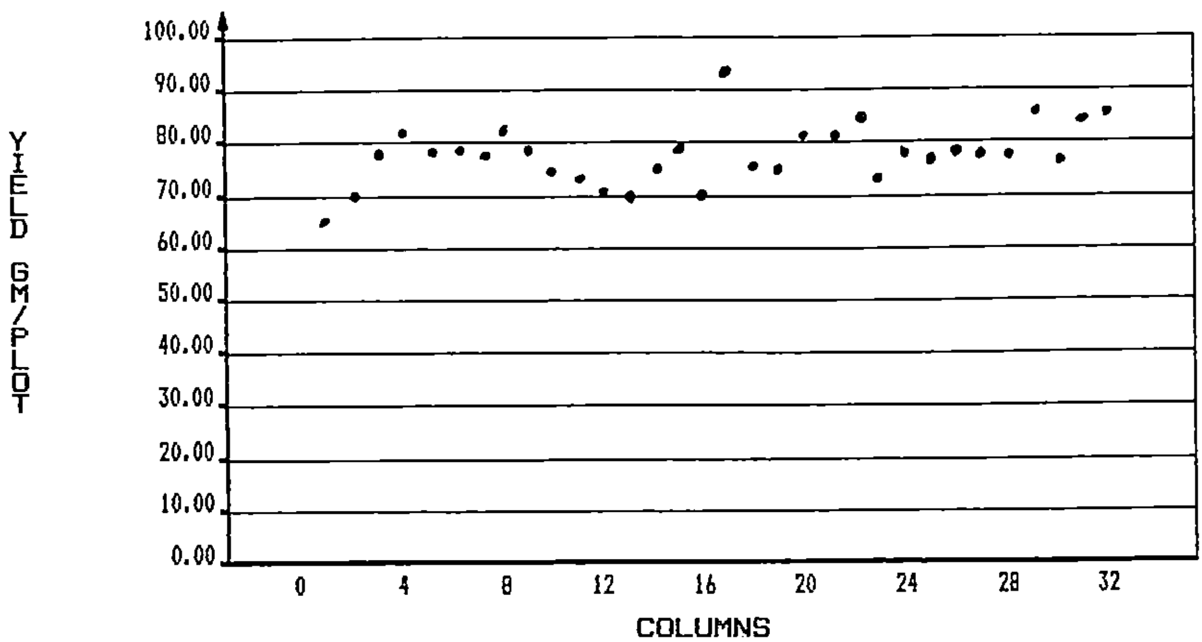


FIGURE 2. Mean yield (gm/plot) for rows

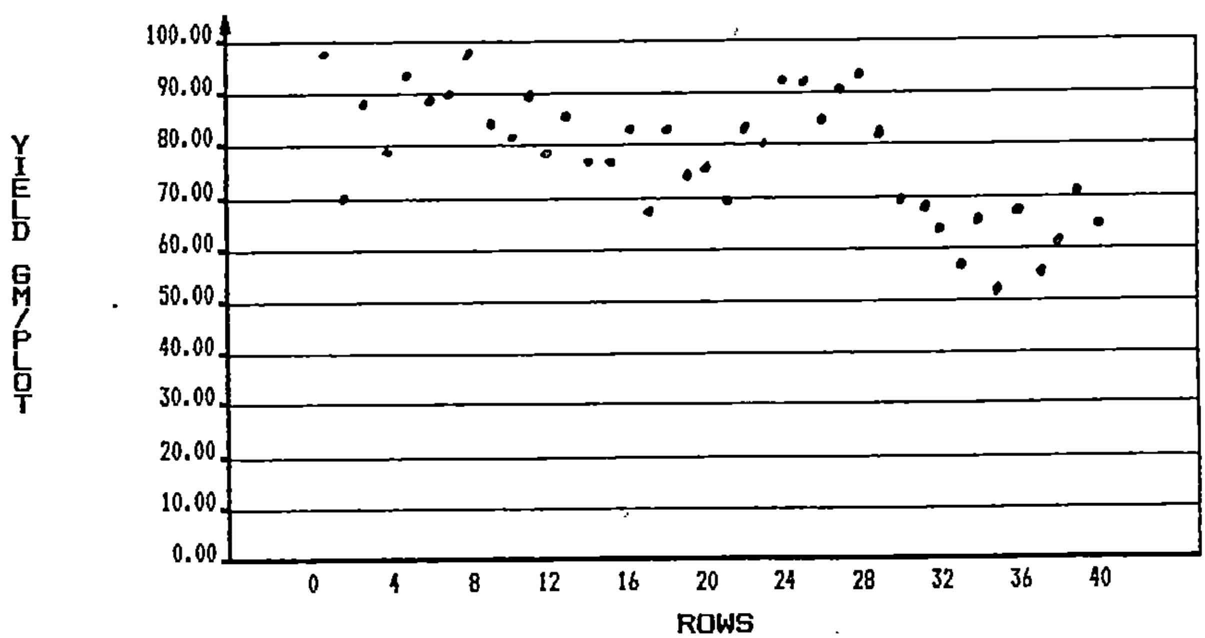


FIGURE 3. Probability curves for skewed and normal distributions.

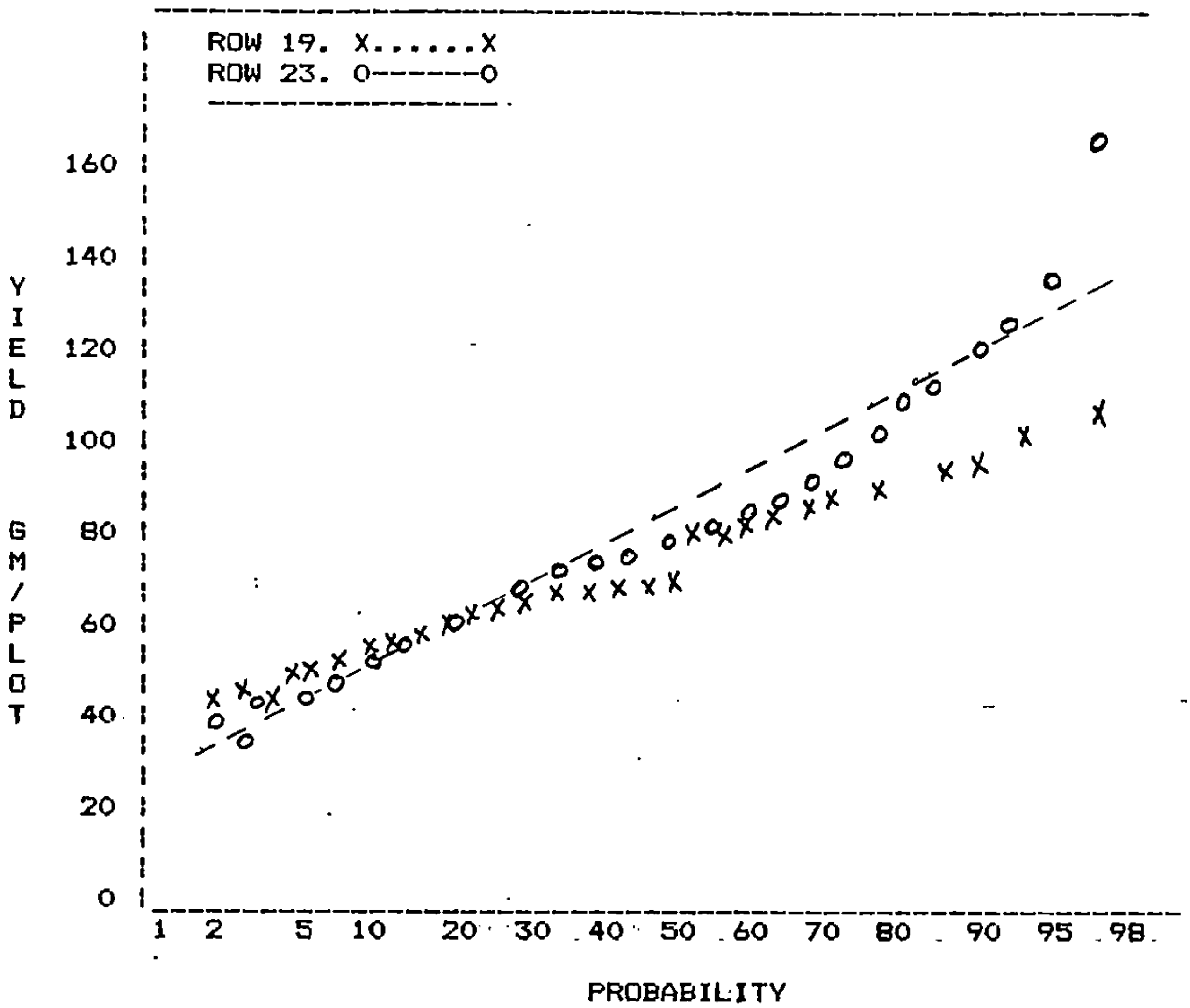


FIGURE 4. Probability curves for column data.

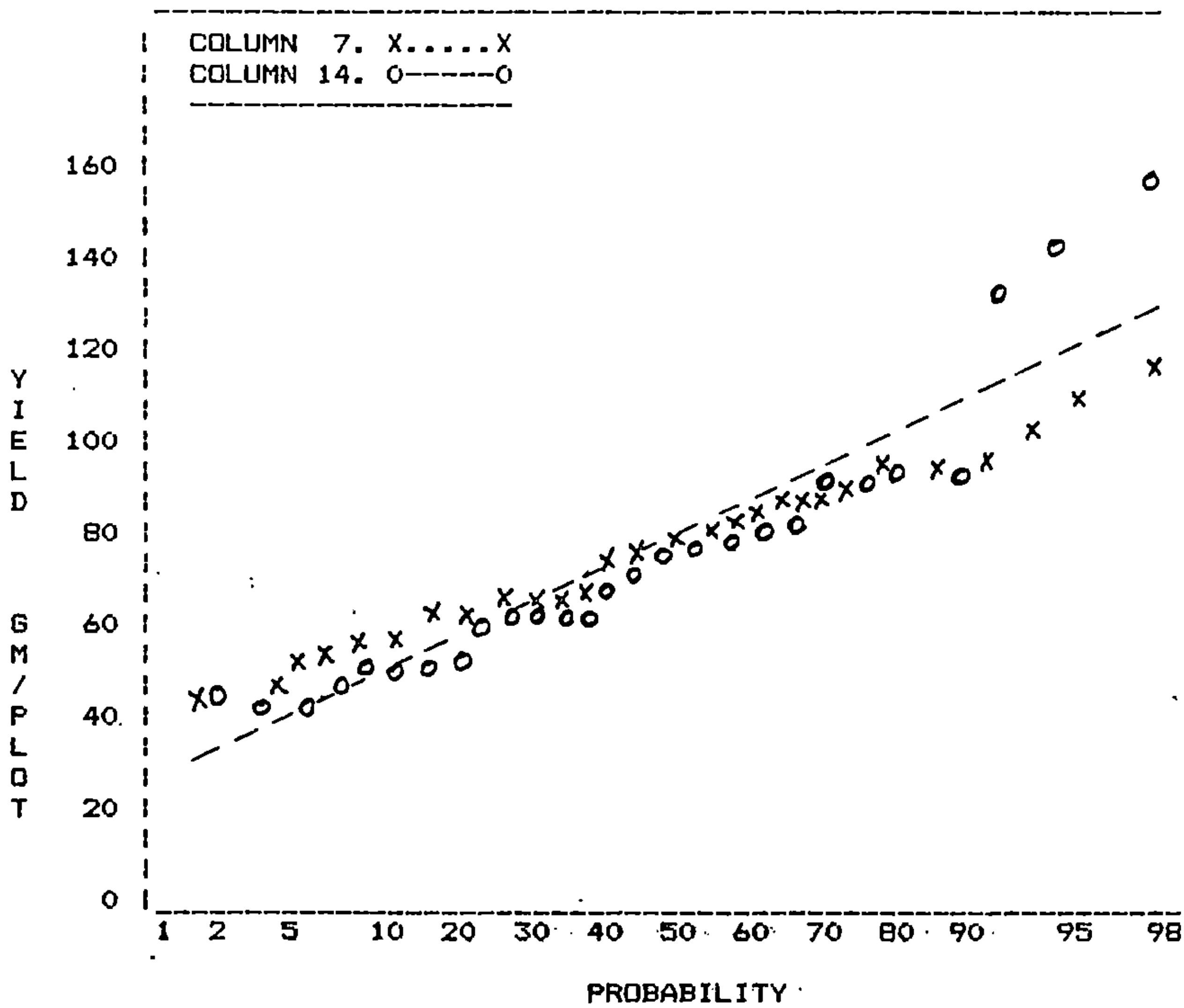


FIGURE 5. Frequency data for row 19.

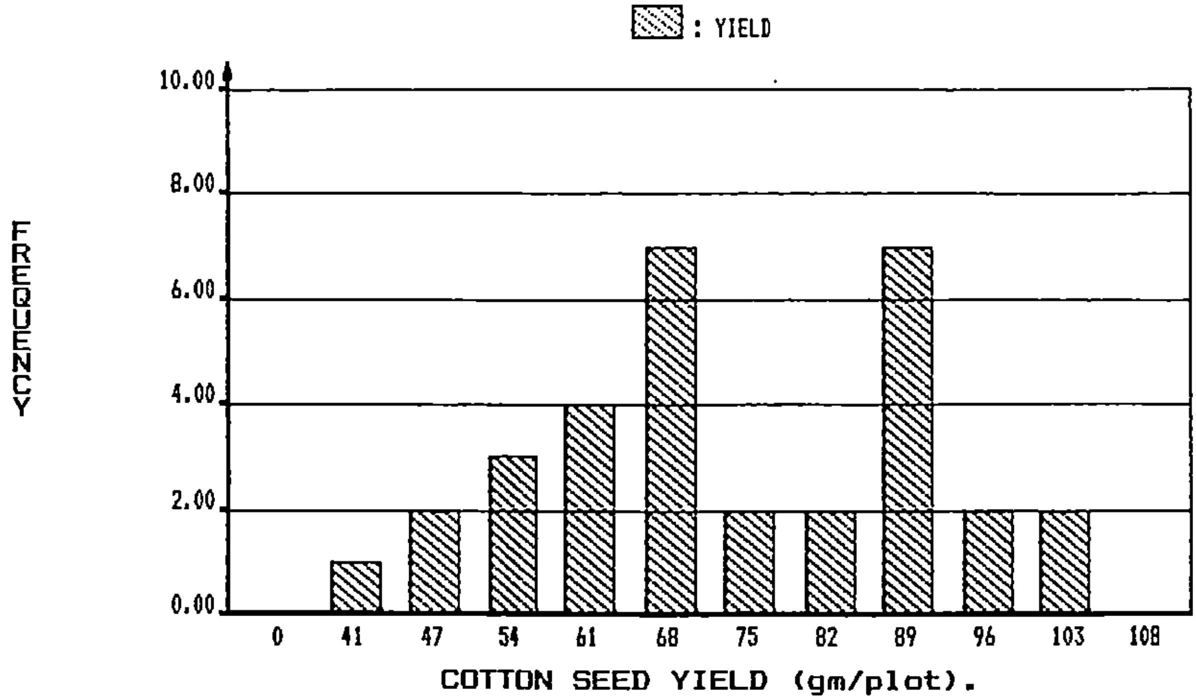


FIGURE 6. Frequency data for row 23.

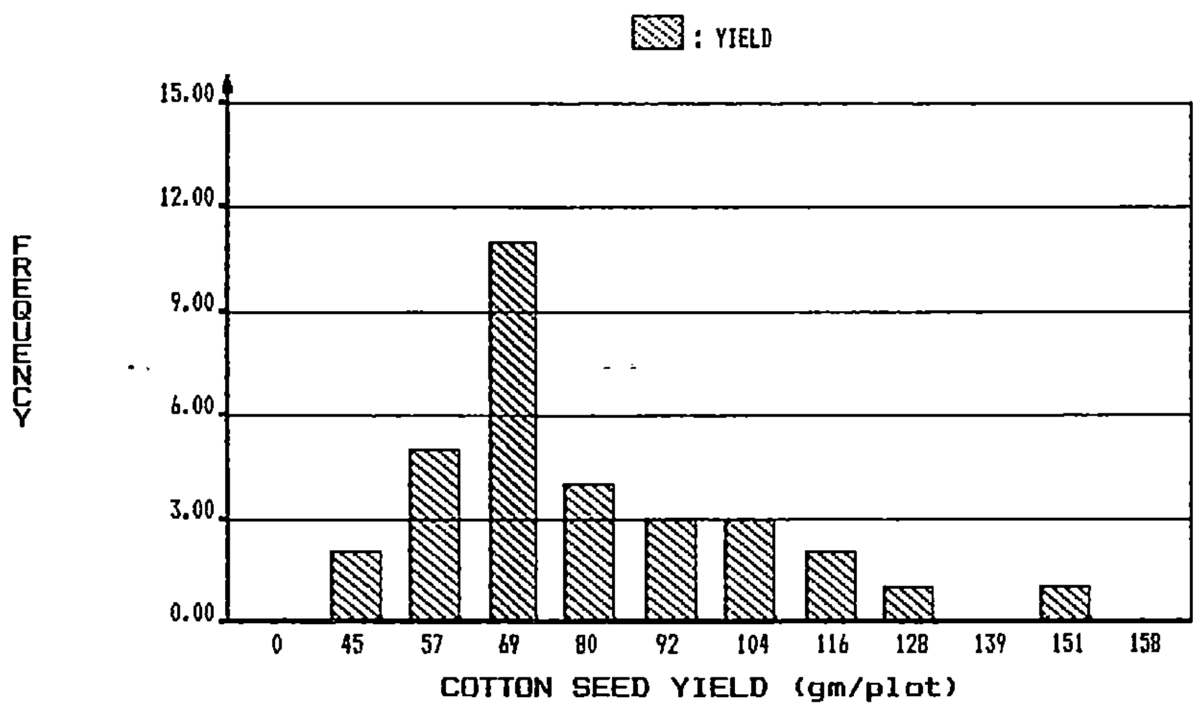


FIGURE 7. Frequency data for column 7.

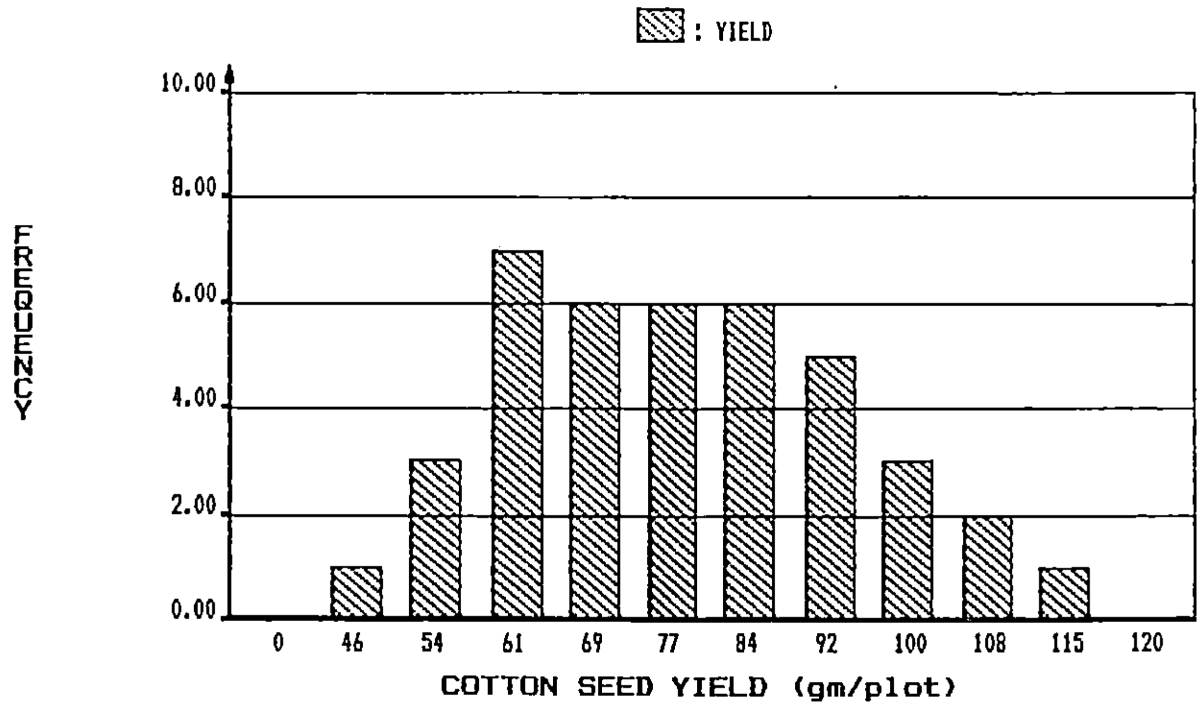
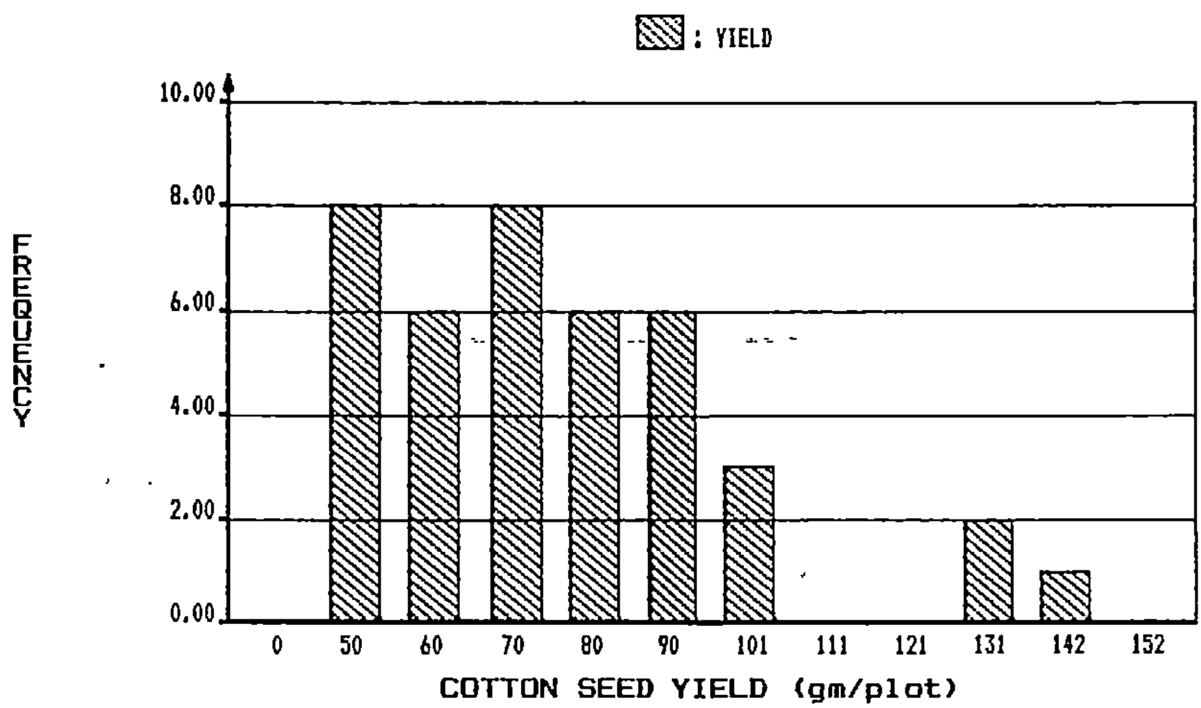


FIGURE 8. Frequency data for column 14.



For the total data set, the mean yield = 78.2 gm/plot with a standard deviation of 25.1 gm/plot, a coefficient of variation of 32.1%, a coefficient of skewness of 0.26 and a kurtosis coefficient of 3.26. These values show that the total data set is normally distributed; however, there are certain rows and columns with skewed frequency distributions.

For those cases that fit the log-normal distribution, the log Pearson type III curves can be used. To establish the normal distribution of precipitation, streamflows or, in our example, the yield of cotton seed, the logarithms of yield will be assumed to fit a particular family of curves (Hjelmfelt and Cassidy, 1975). The sequential equations are as follows:

1. Transform the yield, y, to logarithms.

   $$X = \log y$$

2. Compute the mean of the logarithms.

   $$M = (\sum X)/n$$

3. Compute the standard deviation, s, of the logarithms.

   $$s = [\sum (X_i - M)^2/n-1]^{1/2}$$

4. Compute the skewness, g, of the logarithms.

   $$g = \frac{n^2(\sum X^3) - 3n(\sum X)(\sum X^2) + 2(\sum X)^3}{n(n-1)(n-2)\ s^3}$$

5. Compute the curve from the relationship where:

   $$\log y = M + K'\ s$$

where K' is selected from engineering handbook tables for the Pearson type III distribution. For the K' values, they are dependent both upon the probability, p, and the skewness coefficient, g. Computer program number 2, FREQ.BAS, in Appendix B contains a complete table of K' values.

The exceedence probability, p, is the probability that a value, X, will not exceed a given p. The exceedence probability and the cotton seed yield, y, are usually displayed graphically on logarithmic probability paper. When the skewness coefficient, g, is zero the log Pearson type III distribution reduces to the log-normal type of distribution. To graphically display the measured data the following procedure can be followed:

1. The cotton seed yield, y, is sorted by magnitude. The largest y is given the order number m = 1, and the smallest order number m = n, where n is the number of plots of record.

2. Plotting positions for the probability, p-axis, on the graph are assigned to each yield value. The plotting position is determined by the order number, m, and the number of plots on record, n, by use of the formula:

$$p = m/(n + 1)$$

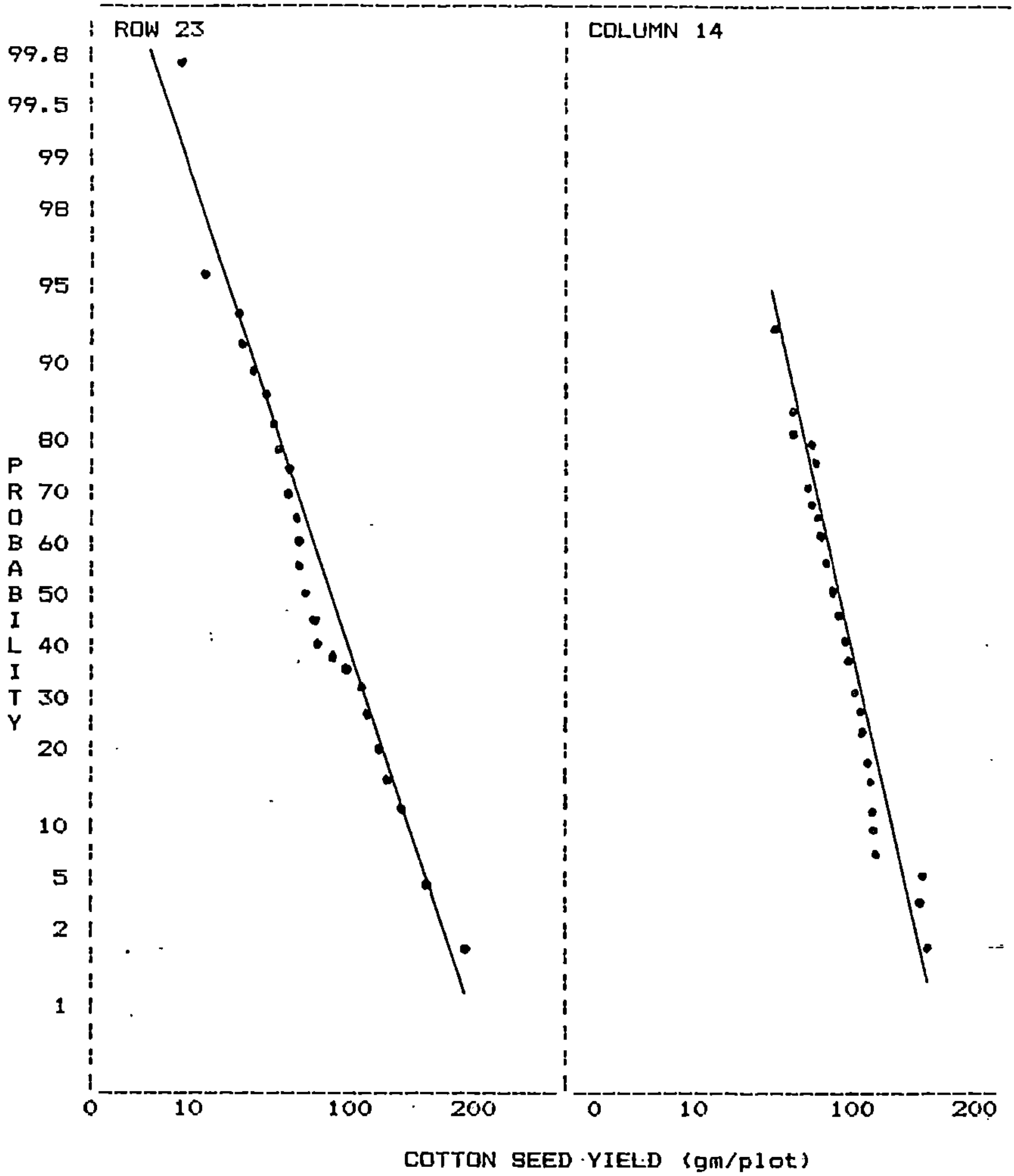
3. To estimate the return yield, I, the reciprocal of the probability, p, is used. The recurrence or return interval, I, is computed by

$$I = 1/p$$

A yield that has been exceeded, on an average once in 20 plots, has an exceedence probability of 0.05 or 5%. But, a yield having a recurrence at 50 plots does not mean that for every 50 plots a yield of that magnitude will occur.

Figure 9 shows the logarithmic probability distribution for row = 23 and for column = 14 which appear to fit the log-normal distribution. For further explanation, for a probability of 20% or a recurrence interval of 5 years, Figure 9 for row = 23 would have a yield of 110 gm/plot; whereas, for a recurrence interval of 100 years or 1% probability, row = 23 would have a yield of 200 gm/plot. Every 2 years or 50% probability for row = 23 would have a yield of about 80 gm/plot. Therefore, with further analysis of these data sets where the assumption of a normal distribution is used, these particular rows and columns should be transformed to logarithms.

FIGURE 9. Comparisons of probability distributions.



Plot Size

A simple technique to follow when considering plot size is the method proposed by Smith (1938) and expanded on by many others, for example, Hatheway and Williams (1958), Wiedemann and Leininger (1962), Freeman (1963), Pearce (1976), Binns (1982), Reddy and Chetty (1982), and Pearce (1983). In this method, the question of "optimal" plot size is related to costs and the parameters of soil and site variability. To calculate the effect of changing experimental plot size the variance is calculated over the entire area for each of several plot sizes. Smith determined an empirical relationship between plot size and plot variance as:

$$V_x = V/x^b$$

where,

V_x = among plot variance on a per unit basis of x units/plot

V = variance of single-unit plots

x = number of units/plot

b = index of soil variability

The values for the above equation are determined using computer program number 3, MEVAST.BAS. The values are then transformed to a logarithmic scale and computer program number 10, REGM.BAS, obtains the relation where:

$$\log V_x = \log V - b \log x$$

The variances of plots of several sizes and shapes are given in Table 2. To determine the variance per unit area, the plot variance, Var, is divided by the square of the size of plots, x. The plot shape and size has been arranged in descending order for convenience.

Figure 10 shows the regression of the logarithm of variance per unit area on the logarithm of the size of plot. The regression equation is:

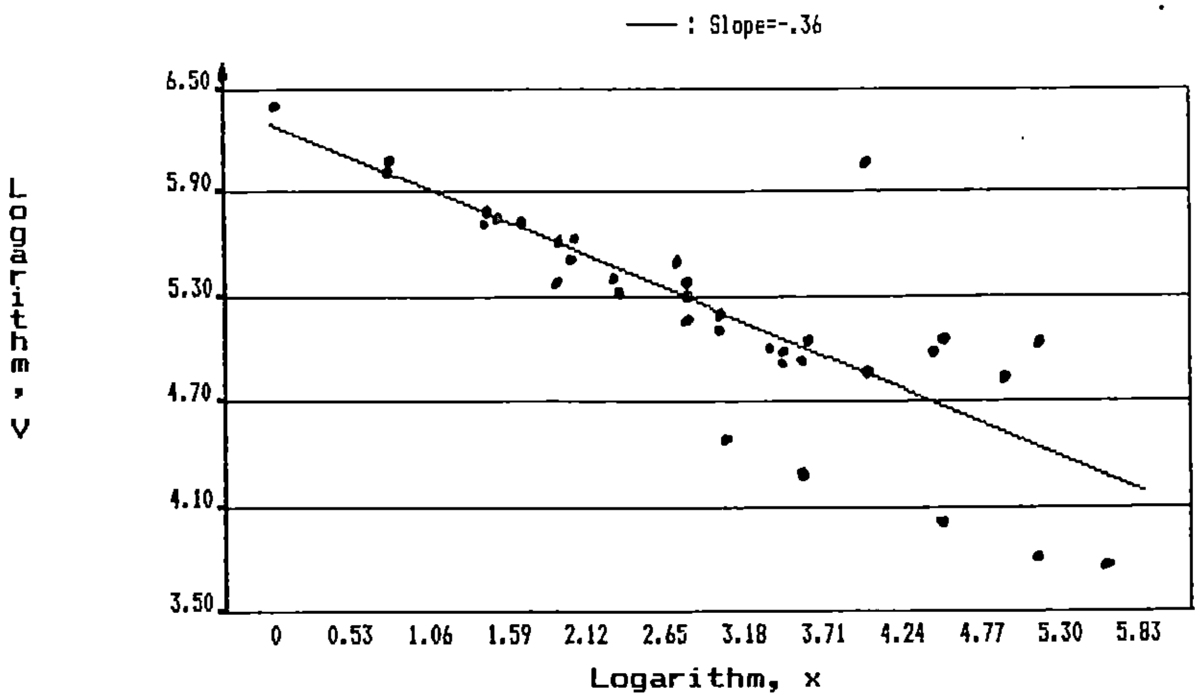
$$\text{Log } V_x = 6.2832 - 0.3553 \text{ Log } x$$

This figure shows a separation of the data into 2 groups, the lower group being the plots for columns of 20 x 1, 2, 4, 8, 16 rows wide. This exemplifies that the variability in the lower half (rows 21 through 40) of the field is greater than the upper half (rows 1 through 20).

TABLE 2. Number of basic units, x, shape and size of plots as column by row, total variance of plots, Var, and variance per unit area, V_x.

x	Column By Row	Var	V_x
1	1 x 1	629.0	629.0
2	1 x 2	1708.0	427.0
2	2 x 1	1714.3	428.6
4	1 x 4	5360.3	335.0
4	4 x 1	4928.5	308.0
4	2 x 2	5094.8	318.4
5	5 x 1	7024.3	281.0
8	1 x 8	16697.9	260.9
8	2 x 4	17034.1	266.2
8	4 x 2	15707.0	245.4
8	8 x 1	13737.3	206.8
10	5 x 2	22152.2	221.5
10	10 x 1	21785.9	217.9
16	1 x 16	58697.5	229.3
16	2 x 8	54381.8	212.4
16	4 x 4	54746.5	213.9
16	8 x 2	44560.9	174.1
20	5 x 4	78023.2	195.1
20	10 x 2	76844.0	192.1
20	20 x 1	34663.2	86.7
32	2 x 16	195651.0	191.1
32	4 x 8	184677.0	180.3
32	8 x 4	156428.0	152.8
40	5 x 8	258485.0	161.6
40	10 x 4	280960.0	175.6
40	20 x 2	110620.0	69.1
64	4 x 16	686721.0	167.7
64	8 x 8	530822.0	129.6
80	5 x 16	966240.0	151.0
80	10 x 8	995043.0	155.5
80	20 x 4	363305.0	56.8
128	8 x 16	2064100.0	126.0
160	10 x 16	3905860.0	152.6
160	20 x 8	1084830.0	42.4
320	20 x 16	4287210.0	41.9

FIGURE 10. Variance/unit area to size of plot



The data shows that there is a bend or upward curve of the data set starting after a distance unit of 10 and this would indicate a decrease in information if plots above this size were used and although the variance would reduce still further the amount of land required would become too costly.

This effect of field heterogeneity is made clearer in Figure 11 where the rows and columns are plotted separately for each direction. The regression equations for these curves are:

for 2 x 1, 2, 4, 5, 8, 10, and 20

$$\text{Log } V_x = 6.5519 - 0.5331 \text{ Log } x$$

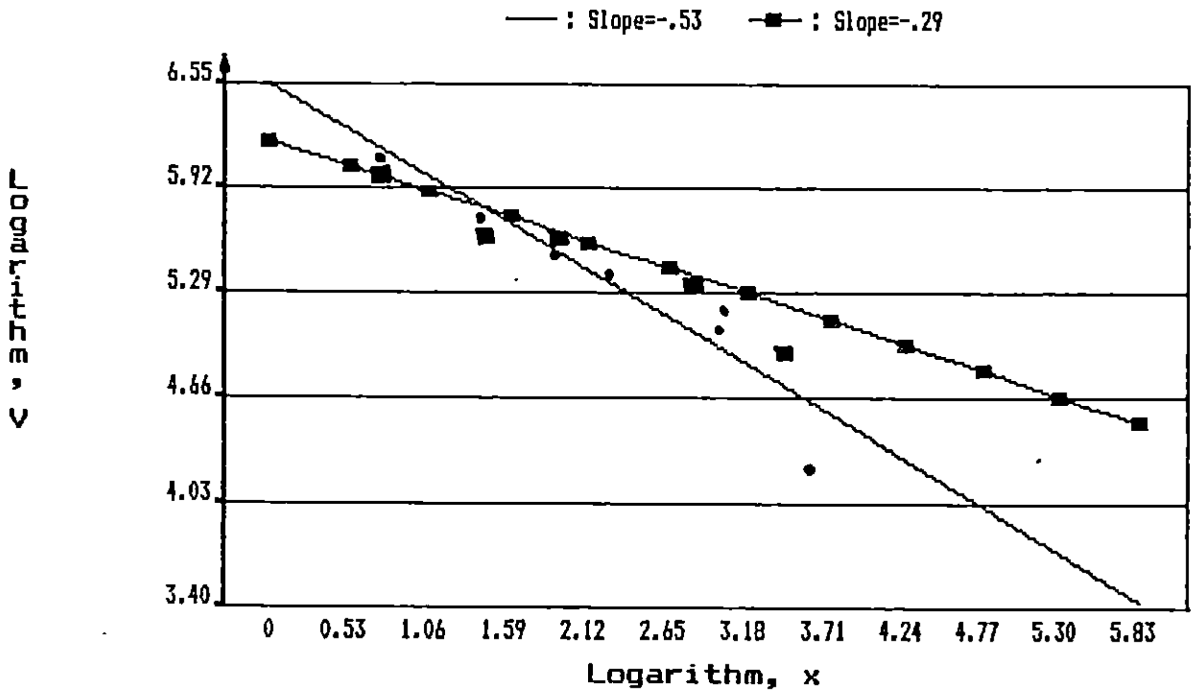
for 1, 2, 4, 8, 16 x 2

$$\text{Log } V_x = 6.2100 - 0.2915 \text{ Log } x$$

The greatest variance is shown down the columns and not across the rows.

In Table 3, the mean yield, standard deviation, and coefficient of variation percentage as a function of plot size shows the type of variability to expect when observing yield data following the method of analysis as outlined by Panse and Sukhatme (1978).

FIGURE 11. Variances for blocks of 2.



The results in Table 3 show the amount of variability in the field when the cotton seed data was used as a measure of field uniformity. These data were analyzed using computer program number 3, MEVAST.BAS (Appendix B). The variability of the plots (1.42m x 1.42m) reduced at a greater rate in the column direction, i.e., the coefficient of variation reduced at a greater rate from the top of the field to bottom than from left to right. The number of replications, r, needed when the coefficient of variation, CV, and the percentage difference from the mean yield, D, is known can be calculated from the expression as given by Panse and Sukhatme (1978):

$$t_{0.05} = D/CV \quad (2/r)^{1/2}$$

For example, if the smallest plot size were used, there would be 1280 plots available for experimentation. If the data set is normally distributed, than for $t_{0.05}$ = 1.96, a percentage difference from the mean yield that can be tolerated is D = 10%, and the coefficient of variation is CV = 32.1% (Table 1), then the number of replications, r, needed is 75. For the 1280 plots, there would be 17 treatments or combinations of treatments available for experimentation with 75 replications. For another example, if a plot size of 2.84m by 5.96m was aligned in the column direction with a coefficient of variation, CV = 19%, the number of replications would be r = 27 which leaves a possibility of 6 treatments available for the 160 plots. However, if a plot size of 1.42m by 28.4m was aligned in the column direction where

TABLE 3. Plot yields, Y, (gm/plot) to various plot areas, m^2, and shapes with the standard deviation, s, and percent coefficient of variation, CV.

STATISTIC	NUMBER OF PLOTS (VERTICAL)	NUMBER OF PLOTS (HORIZONTAL) 1	2	4	8	16
Y	1	78	156	313	626	1251
s		25	41	73	129	242
CV		32	26	23	20	19
area		2	4	8	16	32
Y	2	156	313	626	1251	2503
s		41	71	131	233	442
CV		26	23	21	19	18
area		4	8	16	32	65
Y	4	313	626	1251	2503	5005
s		70	125	234	429	829
CV		22	20	19	17	17
area		8	16	32	65	138
Y	5	391	782	1564	3128	6256
s		84	149	279	508	983
CV		21	19	18	16	16
area		10	20	40	81	162
Y	8	626	1251	2503	5005	10010
s		115	211	396	729	1437
CV		17	17	16	15	14
area		18	32	65	130	259
Y	10	782	1564	3128	6256	12513
s		147	277	530	998	1976
CV		19	18	17	16	16
area		20	40	81	162	324
Y	20	1564	3128	6256	12513	25025
s		186	333	603	1042	2071
CV		12	11	10	8	8
area		40	81	162	324	648

the coefficient of variation was 10% then only 7 replications are needed. This would allow 64 plots with 9 treatments available for study. The entire field of study is about 0.25 hectares and randomization of the treatments within any particular replication is implied to ensure equal influence of the field plot uniformity.

When reasonable plot sizes are considered, i.e., excluding long narrow plots, there is a cutoff or limit at a plot size of a $100m^2$. Increasing the plot size would only reduce the coefficient of variation slightly. The optimal plot size could be 10m x 10m, and would have a coefficient of variation of about 16%. Therefore, 20 plots would be needed for replication but only 26 plots of $100m^2$ are available in the field. The investigator could study only one treatment effect in the 1/4 hectare field.

AUTO AND SPATIAL CORRELATION WITH SPECTRAL ANALYSIS

The importance of soil heterogeneity as a source of experimental error has been extensively studied during the first 30 years of the 20th century (leClerg et al, 1962). Within this early period, many correlation studies between contiguous plots and with distances of up to 10 plots away were made which showed an estimate of the statistical measure of uniformity between plot size and yield. These were the first studies in which a form of the autocorrelation technique[5] was used to measure field plot uniformity. The evidence for small plots, randomization, and support for increasing the number of replications have come from these early trials. Now, field plots are generally randomized and vary in size from 1/25-hectare to 1/2500-hectare with replications ranging from 4 to 10 plots per treatment. Li and Keller (1951) have suggested that during this early period and up to 1950, the use of the autocorrelation technique for testing the randomness of a data set was being examined for comparing the efficiency of various sizes and shapes of plots.

When a sequence of data values repeat themselves in space or time, it is possible to analyze these inexact cycles or periodic data sets to determine the maximum correspondence and measure the similarity between sequences. The techniques available are called autocorrelation and spatial correlation. If the cyclic or periodic nature of the data persists or is known to exist then another technique, spectral analysis, can be used to examine successive observations. The application of these techniques to the cotton seed data will be followed in order.

Detrending

For the cotton seed yield, 28% of the data should be transformed before all frequency distributions are normal (see Table 1). In addition, Figures 1 and 2 show that the data for columns and rows should be detrended. In the straight line model where yield, y, can be expressed as a first-order function of distance, x, it is assumed that x is "fixed" and does not have a probability distribution, i.e., y is assumed to be the random variable which has a probability distribution with mean = a + bx and variance, / s^2. If the correlation coefficient, r = 0, then x and y are not correlated with each other and they have no trend. This does <u>not</u> imply that x and y are statistically independent. The value of r only shows to what extent a linear association exists between x and y but it does not imply any causal relation between the two (Draper and Smith, 1981).

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5. Sometimes the auto correlation has been incorrectly called serial correlation.

Table 4 shows that most of the column data has a negative slope, -b, which reconfirms the findings shown in Figure 1 where yields decreased from top to bottom. These data were analyzed using computer program number 2, FREQ.BAS, in Appendix B. Also, the standard error of estimate, SE, increases from top to bottom as expected. For the row data set, the findings are similar to those presented in Figure 2 where 60% of the data had a positive slope where yields increased from left to right. Again, the standard error of estimate increases from left to right. Table 4 shows the analysis of linear regression and reconfirms the previous conclusions shown in Figures 1 and 2, i.e., the data set has linear trends.

The total data set showed that linear detrending was given by $y = 74.81 + 0.1445\ x$ (distance) with a value for the test of linearity of $t = 5.18$ which was statistically significant at the 5% level. The data has a positive trend even though it was found earlier to be normally distributed. Any further evaluation of the data for correlatable and kriging relationships requires detrending.

A trend is a systematic, smooth component of a function, e.g., a linear function of distance is a linear trend. The linear regression equations in Table 4 were used for detrending the data set before analysis of the autocorrelation, spatial correlation and spectral analysis. In addition, the data sets of rows 8, 10, 23, 26, 30 and 32 and columns 4, 9, 11, 14, 15 and 32 are only normally distributed when they are transformed to the logarithm. These particular data sets were transformed to their logarithm for calculating the autocorrelation coefficient.

Student t-test provides a test of the hypothesis that slope $b = 0$, i.e., no trend exists in the data set. It should be noted that as b approaches zero, the coefficient of determination, r^2, approaches zero, and the t-test is not significant at the 5% level. Table 4 shows that 57% of the row data and 75% of the column data have significant trends.

For a further example of trending, Figure 12 shows two rows of nonstationary data, rows = 28 and 37. Row = 19 would be an excellent example of a stationary data set. Nonstationary data sets show that the data may not be a continuous record but may be cyclic in nature. For autocorrelation analysis, it is assumed that the data set is a continuous record of finite length.

If the data is transformed to be normally distributed, the random variable, y, for rows and columns has the same probability distribution and the data has no trends then it is called stationary. Little is known about the behavior of the spatial and autocorrelation functions and the spectral analysis technique when the generating stochastic process is nonstationary. In stationary models, e.g., autocorrelation, the variance of measurements converges to a constant value when the size of the sampled block or interval is increased (Agterberg, 1974).

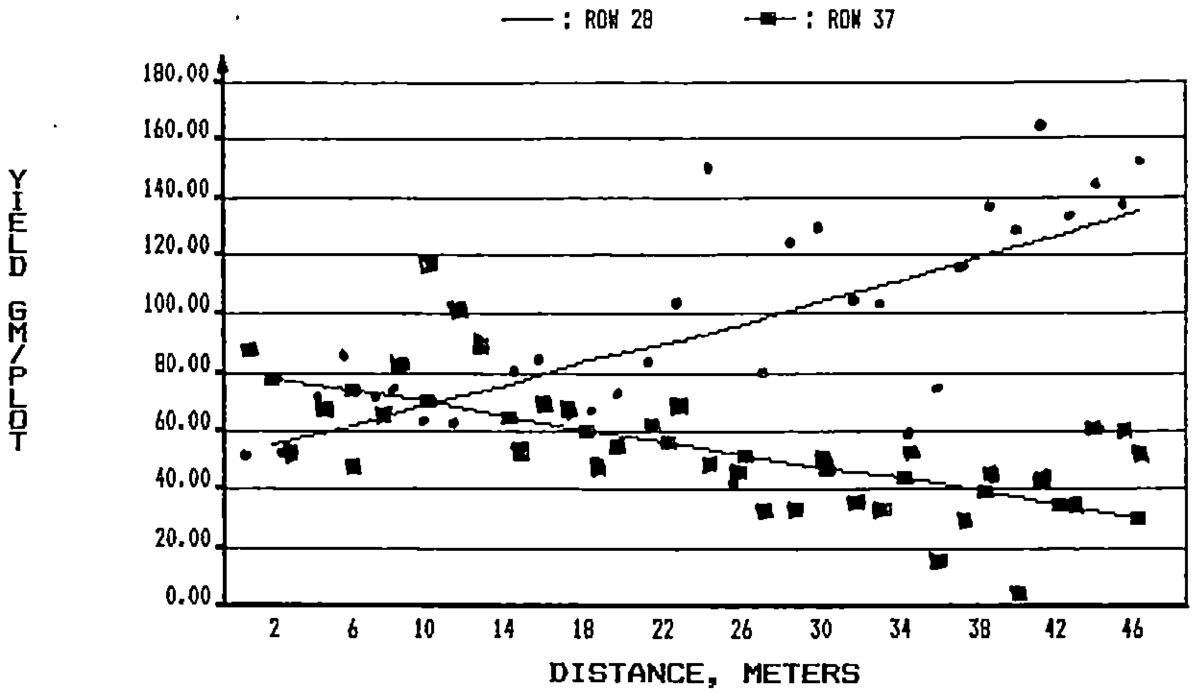
TABLE 4. The linear regression equations for trending analysis [yield = a + b x (distance)], coefficients of determination, r^2, standard errors of estimates, SE, and test of hypothesis that b = 0 (t-test at 5% level of significance = *) for the cotton seed yield data set [by rows (40) and columns (32)].

COLUMN	a	b	r^2	SE	t-test
1	75.16	-0.3185	0.080	18.2	-2.05 *
2	81.28	-0.4126	0.136	17.6	-2.74 *
3	101.50	-0.7964	0.303	20.4	-5.88 *
4	100.97	-0.6385	0.350	14.7	-4.88 *
5	99.29	-0.7148	0.406	14.6	-5.72 *
6	87.92	-0.3103	0.734	18.6	-1.99 *
7	75.88	0.0684	0.004	17.4	0.42
8	88.20	-0.1802	0.023	19.6	-1.12
9	72.13	0.2400	0.051	17.4	1.52
10	82.25	-0.1982	0.029	19.4	-1.24
11	65.77	0.3464	0.081	19.6	2.23 *
12	88.58	-0.5542	0.219	17.6	-3.87 *
13	77.50	-0.1713	0.021	19.5	-1.07
14	86.49	-0.3434	0.059	23.2	-2.18 *
15	102.13	-0.7786	0.276	21.3	-5.64 *
16	97.05	-0.8429	0.305	21.4	-6.23 *
17	99.69	-0.1529	0.007	30.5	-0.95
18	102.66	-0.8911	0.220	28.3	-6.22 *
19	92.22	-0.5871	0.115	27.4	-3.85 *
20	103.50	-0.7451	0.168	27.9	-5.04 *
21	96.94	-0.6153	0.108	29.8	-4.02 *
22	101.47	-0.7010	0.152	27.9	-4.69 *
23	99.09	-0.8561	0.295	22.3	-6.28 *
24	104.62	-0.8879	0.247	26.1	-6.31 *
25	102.24	-1.0183	0.323	24.8	-7.63 *
26	97.83	-0.6645	0.130	28.9	-4.39 *
27	95.08	-0.5822	0.137	24.7	-3.86 *
28	99.05	-0.6996	0.193	24.1	-4.80 *
29	86.76	-0.0107	0.000	29.1	-0.07
30	89.65	-0.4201	0.079	24.2	-2.70 *
31	96.77	-0.4148	0.072	25.0	-2.65 *
32	90.56	-0.1599	0.011	25.1	-0.99

TABLE 4. cont.

ROW	a	b	r^2	SE	t-test
1	104.10	-0.3026	0.038	20.7	-1.69
2	70.34	0.0441	0.001	20.4	0.24
3	106.06	-0.7921	0.140	26.7	-4.68 *
4	83.85	-0.2133	0.028	17.1	-1.18
5	82.83	0.4717	0.118	17.5	2.75 *
6	86.22	0.0692	0.002	22.9	0.38
7	83.31	0.2317	0.032	17.3	1.29
8	85.91	0.5243	0.072	25.5	2.98 *
9	88.16	-0.1359	0.005	25.7	-0.75
10	63.32	0.8477	0.210	22.3	5.23 *
11	80.28	0.4196	0.060	22.5	2.37 *
12	74.88	0.1435	0.017	14.9	0.79
13	81.55	0.1934	0.326	14.3	1.08
14	81.11	-0.1630	0.256	13.6	-0.90
15	76.02	0.0446	0.001	17.0	0.24
16	75.98	0.3046	0.079	14.1	1.74 *
17	56.01	0.5068	0.141	17.0	3.00 *
18	71.28	0.5859	0.098	24.1	3.38 *
19	72.98	0.0356	0.001	17.7	0.19
20	82.31	-0.2608	0.029	20.4	-1.45
21	68.49	0.0644	0.003	16.1	0.35
22	69.68	0.5475	0.111	21.0	3.18 *
23	54.32	1.0863	0.320	21.5	7.22 *
24	57.67	1.4733	0.473	21.1	11.12 *
25	67.87	1.0200	0.293	21.5	6.65 *
26	72.56	0.5515	0.158	17.3	3.29 *
27	61.76	1.2404	0.340	23.5	8.36 *
28	51.26	1.7973	0.494	24.7	13.84 *
29	69.73	0.5266	0.078	24.5	3.01 *
30	69.49	0.0816	0.001	25.8	0.45
31	77.34	-0.3568	0.074	17.1	-2.03 *
32	81.93	-0.7864	0.151	25.3	-4.68 *
33	69.95	-0.5344	0.113	20.3	-3.11 *
34	73.95	-0.3946	0.047	24.0	-2.21 *
35	70.97	-0.8030	0.206	21.4	-4.94 *
36	86.07	-0.8565	0.152	27.5	-5.09 *
37	80.16	-1.0855	0.368	19.3	-7.48 *
38	63.50	-0.0893	0.003	19.1	-0.49
39	73.65	-0.1234	0.005	23.1	-0.68
40	65.64	-0.1349	0.007	21.5	-0.74

FIGURE 12. Examples of data trending in rows.



Weak stationarity means that all random variables (in the cotton seed example the yield, y, as a function of distance) have the same mean, variance, covariance, and correlation. If, all higher-order moments remain equal or the skewness and kurtosis are the same, then the series is said to be "strictly" stationary (Agterberg, 1974). Stationary random functions are also called "homogeneous" (Hinze, 1959) or "temporary-homogeneous" random functions if the data set is not known to be continuous.

Autocorrelation

The methodological development of the autocorrelation function was followed by extensive mathematical development, which began with a series of studies on air flow (Schlichting, 1968). The first attempts to understand the process of flight and wind flow over an airfoil has led to the development of precision wind tunnels and the need to characterize and define turbulence. A breakthrough into the statistical nature of turbulence in wind tunnels and the atmosphere was provided by G. I. Taylor in 1921 (Pasquill, 1962). By 1935, Taylor had extended turbulent theories to the Eulerian description of spatial correlation and autocorrelation techniques to describe the homogeneity of turbulent eddies within a given boundary layer. These same statistical techniques have now been used to estimate the extent or range of a measured soil parameter, i.e., a test of soil variability.

In this section, the autocorrelation[6] between measured values of a fluctuating quantity, such as the yield component in a given direction, will be examined following the presentation of Perrier, et al (1972) and Arkin and Perrier (1974). To specify the character of a fluctuating quantity, the mutually related methods of autocorrelation and spectral analysis have become standardized. The measurement of the mean values of soil and plant parameters are usually sufficient for practical applications but only through the actual measurement of the variance components is it possible to gain an understanding of the variation about the mean (Priestley, 1959).

The measurements of the transformed and detrended data set of the cotton seed yield, y, can be partitioned into a mean yield, Y, and the fluctuations or perturbations from the mean values, y'. Whereupon, these components of total y can be written as

$$y = Y + y' \qquad \text{(EQ. 2)}$$

Therefore, the mean yield, Y, and the standard deviation, s, can be computed by standard methods. The autocorrelation coefficient, R_L, can be expressed as a function of the lag, L, as follows:

$$R_L = \frac{\overline{y'_x \times y'_{x+L}}}{[\overline{y'^2_x} \times \overline{y'^2_{x+L}}]^{1/2}} = \frac{\overline{y'_x \times y'_{x+L}}}{\overline{y'^2}}$$

where, the numerator is termed the autocovariance function and the denominator is the variance. Following Taylor's discussion of the autocorrelation (self-comparison), homogeneity is implied in that the statistical properties of R_L and y'^2 are taken to be independent of position but dependent on the value of y. The autocorrelation exists when the value of a variable at one observation is <u>not</u> independent of the value at adjacent observations (Johnston, 1978). If there is no functional relationship indicated between the variables then there is no correlation between them.

To compute the autocorrelation coefficient R_L on the cotton seed data at a fixed row, an understanding of the lag is needed. The lag, L, is the interval between each calculation, e.g., in this data set, the row spacing = 1.4224m is equal to one lag unit. Lag is the amount of offset between the two series of data being compared (Davis, 1973). Figure 13 shows the approach used to calculate the autocorrelation. The fixed positions are shown for the plot yields in the field (x-axis or abscissa) and the run number (i = n) for the first five autocorrelation coefficients (y-axis or ordinate). If a correlation is calculated on each

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6. Eulerian correlations for time or distance (Hinze, 1959).

called the normalized autocovariance function, i.e., normalized so that its value for lag zero is unity (Blackman and Tukey, 1958). As the autocorrelation is the square root of the ratio of the autocovariance to the variance, it is the ratio of the "explained or lack of fit" variation to the "total or pure error" variation. When $R_L = 1$ all the variance is "explained" and when $R_L = 0$ then there is no "explained" variance.

When the autocorrelation coefficient, R_L, is equal to 1 (perfectly correlated) then each value is correlated with itself for the equidistant data set. For additional explanation, Figure 14 shows a plot y_x versus y_{x+1} for the cotton seed data, the 1:1 line is for $R_L = 1$. The scatter diagram is for row 28, lag, $L = 1$ and $R_L = 0.65$. These data are normally distributed and positively correlated with a mean of $Y_x = 112$ and the standard deviation, $s_x = 37$ whereas $Y_{x+1} = 115$ and $s_{x+1} = 38$. Figure 15 shows a plot of y_x versus y_{x+8} for row = 28, $L = 8$, and $R_L = 0.05$. For this data set $Y_x = 98$ and $s_x = 25$ whereas $y_{x+8} = 118$ and $s_{x+8} = 42$. The scatter diagram shows a poor correlation between these two variables and a nonsignificant test of linearity of $F = 0.56$, 1/23 degrees of freedom. Figure 16 is a scatter diagram of row = 6, $L = 1$ and $R_L = -0.41$ where $Y_x = 87$ and $s_x = 28$ whereas $Y_{x+1} = 89$ and $s_{x+1} = 23$. This scatter diagram has a negative slope and a negative autocorrelation coefficient.

FIGURE 14. Scatter diagram: autocorrelation.

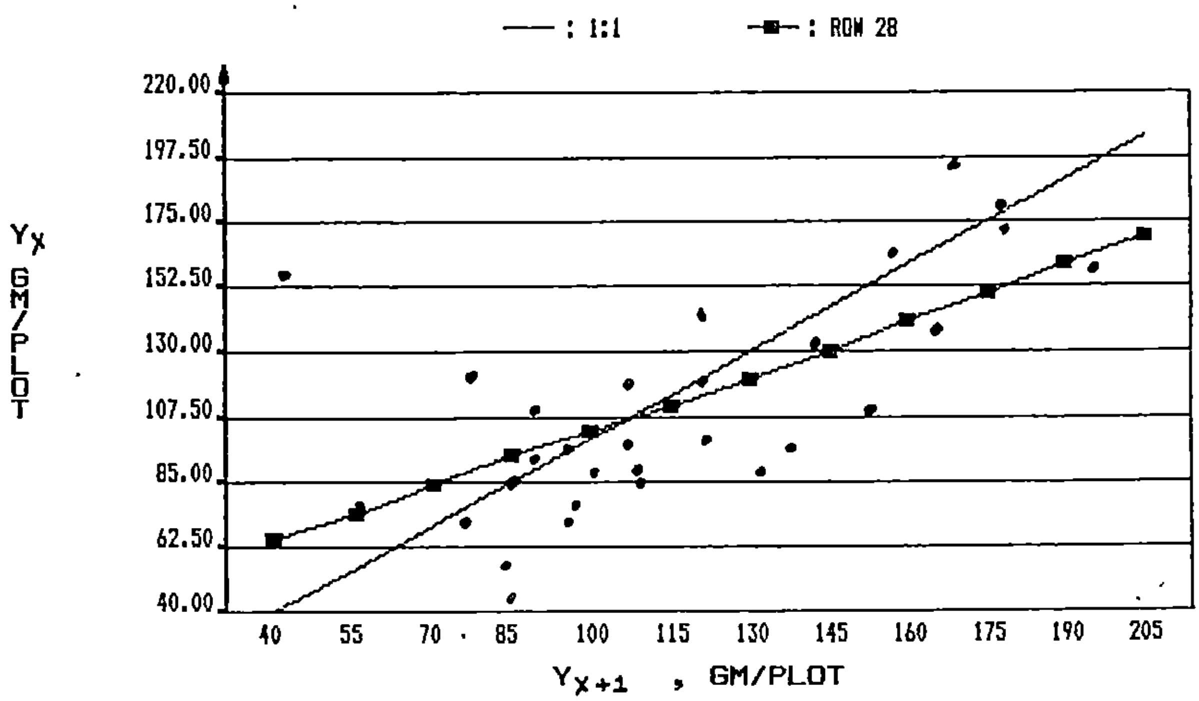


FIGURE 15. Scatter diagram: autocorrelation.

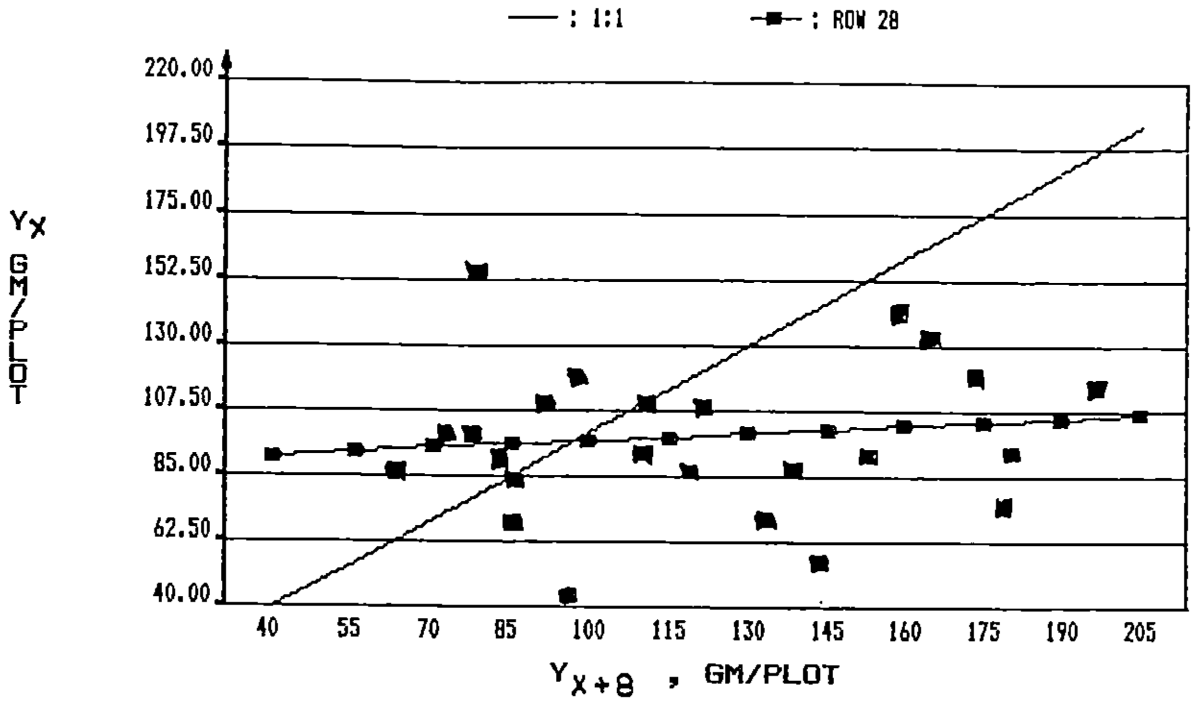
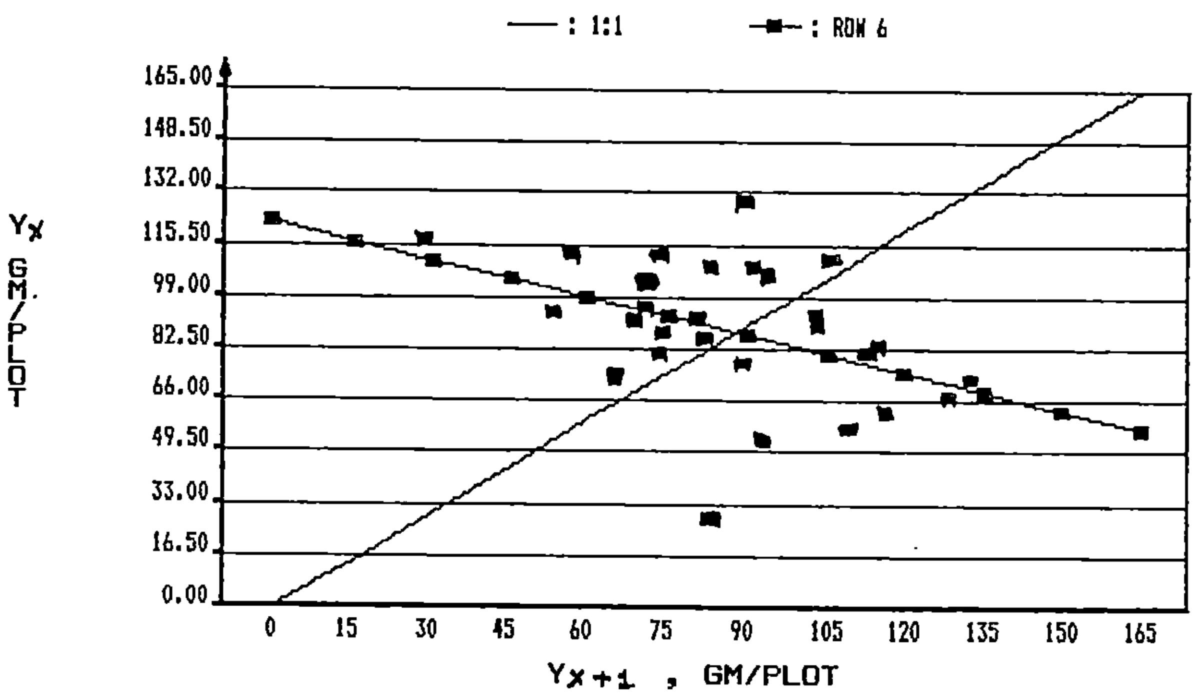


FIGURE 16. Scatter diagram: autocorrelation.



When a data set is positively correlated as in Figure 14, it infers that contiguous plots at y_{x+1} increase in yield in a functional relation with y_x. However, in Figure 15, when lag = 8, the correlation approached zero because as y_{x+8} increased there was no functional relation with y_x. For Row = 28, lag = 8 was the limit of the dependency of adjacent plots and lags greater than 8 were of no interest in determining field plot variability.

In Figure 16, the data is negatively (inversely) correlated as y_x increases and y_{x+1} decreases. This is not a problem for a field plot uniformity study unless the autocorrelation becomes either zero or positive with increasing lags. When this occurs, the limit of plot dependence has been found and, with increasing lags, additional analysis presents no added information.

Another difficulty when interpreting autocorrelation data is the level of significance for R_L with n-2 degrees of freedom. To test the hypothesis that a correlation coefficient is equal to zero, use can be made of the Student t-test where

$$t_{0.05} = \frac{R_L(n-2)^{1/2}}{(1 - R_L^2)^{1/2}}$$

with n-2 degrees of freedom (Li, 1964). Using this test, values less than R_L = 0.26 with 38 degrees of freedom for the column data and R_L = 0.30 with 30 degrees of freedom for the row data, are not significant at the 5% level. However, when determining the autocorrelation coefficient where Y is correlated at certain distances, there is an assumed dependency between these values when $R_L > 0$. Therefore, the usual correlation tests for levels of significance may not apply (Lanyon and Hall, 1981).

The autocorrelation coefficient for individual columns and rows in Figures 17 and 18 shows that the yield sequence does not repeat itself for these data even though the mean yield shown in Figures 1 and 2 shows the existence of cyclic or periodic functions. Nonetheless, the autocorrelation can detect cyclic functions when they exist in the data such as columns = 10 and 27. By calculating the autocorrelation, a measure of the degree of similarity between yield values is determined at each position or lag. The magnitude of this measure is the autocorrelation coefficient. The concept of "self-comparison" is shown for rows = 28 and 35 of Figure 17 and for columns = 2 and 5 of Figure 18, i.e., there is correlation between a given lag and an increasing lag interval. Therefore, the autocorrelation taken at "fixed" distances does imply a causal relation between the two variables of y_x and y_{x+L}. However, the rapid decline for row = 5 and column = 17 shows a large amount of random variance (noise). It is important to examine the individual rows and columns before drawing final conclusions for the total data set.

FIGURE 17. Correlogram for row data.

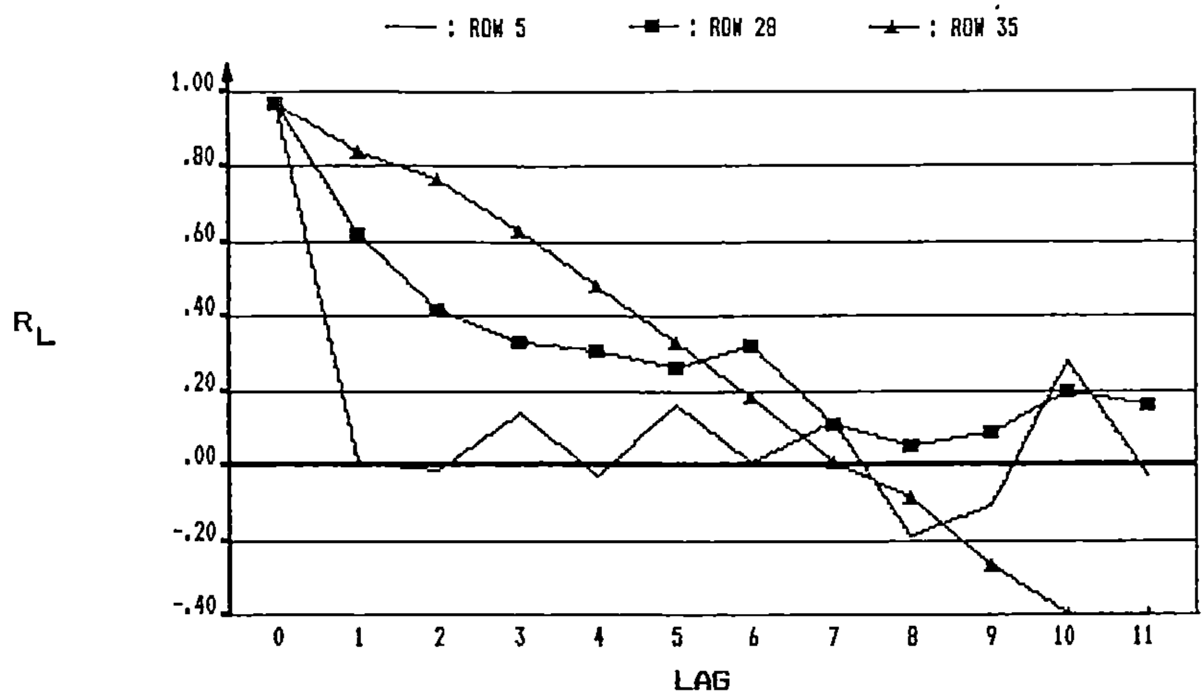


FIGURE 18. Correlogram for column data.

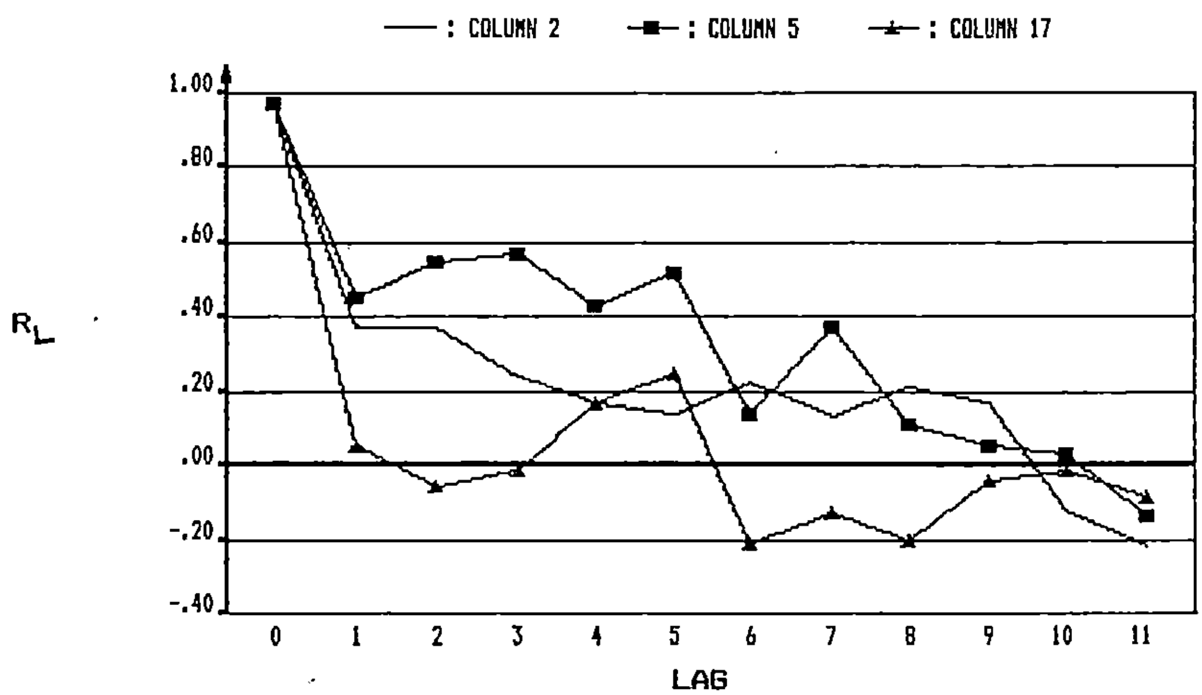


TABLE 5. Autocorrelation coefficients for part of the data set.

LAG METERS	1 1.4	2 2.8	3 4.3	4 5.7	5 7.1	6 8.5	7 10.0	8 11.4	9 12.8
COLUMN									
1	.066	.296	.201	-.018	.250	-.224	.291	.075	-.108
2	.366	.371	.242	.167	.144	.233	.132	.207	.171
3	.429	.413	.502	.309	.321	.436	.309	.057	.128
4	.420	.247	.173	.125	.239	.162	.277	.280	.134
5	.446	.549	.566	.429	.523	.143	.371	.107	.050
6	-.109	.169	-.128	.162	.140	.114	.126	-.080	-.192
7	.180	-.285	-.139	.197	-.004	-.056	.178	.011	-.181
8	.032	.242	-.050	.088	-.065	.245	.052	-.067	-.301
9	.159	.346	.235	.239	.207	-.043	.035	.003	-.215
10	.331	.037	-.168	-.293	-.239	.073	.414	.083	-.179
11	.197	.108	.037	.341	.196	-.034	.060	-.012	.078
12	.133	.201	.161	.393	.072	.013	.045	.193	-.109
13	.232	-.151	-.231	-.024	.013	.209	-.043	-.329	-.161
14	-.116	.080	.138	-.004	.262	-.093	-.137	.035	-.076
15	.470	.266	.338	.286	.130	.140	.046	-.233	-.318
16	.353	.222	.295	.285	.204	.122	.071	.115	.187
17	.050	-.056	-.008	.174	.256	-.214	-.127	-.199	-.039
18	.384	.244	.302	.047	.063	-.054	.228	.030	-.135
19	.356	.285	.143	.122	.031	.130	.166	.115	-.146
20	.365	.139	.097	.115	.221	.207	-.103	-.086	-.039
21	.621	.396	.226	.037	-.143	-.225	-.320	-.337	-.292
22	.422	.288	.109	.059	-.170	-.050	-.246	-.051	.021
23	.151	.573	.146	.256	.213	-.035	.025	-.009	-.021
24	.394	.400	.126	.114	.052	-.012	.131	-.086	.002
25	.489	.600	.406	.324	.164	.112	.068	.074	.044
26	.475	.372	.336	.040	-.209	-.228	-.340	-.345	-.231
27	.293	.179	.098	.082	-.150	-.054	.272	-.130	-.123
28	.193	.445	.302	.071	.166	-.191	-.028	-.185	-.214
29	.335	.293	.343	.179	.141	-.005	-.213	-.222	-.315
30	.212	.143	.336	-.073	-.111	-.137	-.209	.030	-.020
31	.397	.164	.342	.005	-.096	.076	-.251	-.387	-.404
32	.345	.242	-.075	-.062	-.109	-.076	-.098	-.362	-.364

TABLE 5. cont.

LAG METERS	1 1.4	2 2.8	3 4.3	4 5.7	5 7.1	6 8.5	7 10.0	8 11.4	9 12.8
ROW									
1	.001	-.288	-.149	.421	-.110	-.276	-.060	.157	-.249
2	-.041	-.065	-.114	.058	-.105	-.026	.065	-.276	-.178
3	.074	.123	.092	-.216	.013	.078	-.015	.364	.225
4	.340	.341	.008	.048	-.287	-.135	-.182	-.204	-.173
5	.005	-.009	.135	-.026	.156	.005	.120	.187	-.113
6	-.400	.113	-.141	-.100	.204	-.163	.134	-.029	-.369
7	-.166	-.134	-.083	.039	.196	-.231	-.085	-.008	-.085
8	.083	.295	.109	.359	-.181	.047	-.031	-.134	-.252
9	.033	-.053	.028	.122	-.070	-.045	-.526	.003	-.166
10	.413	.361	.437	.278	.373	-.072	.071	.022	-.054
11	.329	-.026	.138	.104	-.029	-.067	.005	.288	-.039
12	-.040	.204	.052	-.018	-.322	-.011	-.026	-.381	.261
13	.105	.428	.076	-.111	.132	-.254	.096	.046	-.168
14	-.195	.131	-.096	.114	-.133	-.061	.023	-.137	-.011
15	-.195	.058	-.016	-.058	-.024	-.091	.286	-.202	-.134
16	.334	.437	.149	.223	.086	-.126	-.156	-.221	-.197
17	.084	.272	.331	.136	.102	.131	-.023	.113	-.183
18	.069	.155	.138	-.052	.084	-.069	-.001	-.001	.142
19	.155	.152	-.163	-.155	-.117	-.646	-.115	-.257	-.070
20	.158	.114	.201	.153	-.187	.142	-.257	-.162	.036
21	.469	.211	.267	.110	-.176	-.416	-.282	-.328	-.549
22	.188	.132	.213	.151	-.077	-.200	-.291	-.077	-.214
23	.060	.288	.192	.107	-.023	.335	-.038	.168	-.067
24	.592	.462	.376	.355	.361	.221	.227	.190	.210
25	.122	.209	.314	.054	.109	-.052	-.038	.361	.009
26	.150	-.082	.281	.056	-.107	-.007	.114	-.167	-.395
27	.169	.080	.499	.245	-.019	.512	.182	-.051	.198
28	.618	.419	.327	.313	.256	.318	.107	.051	.087
29	.046	-.169	.254	-.026	-.213	-.334	.049	.147	.109
30	.164	.042	-.133	-.225	-.008	-.375	-.227	-.094	.123
31	.550	.325	.005	-.079	-.187	-.042	.062	.145	.210
32	.256	.184	.176	.117	-.055	.220	-.051	-.142	.164
33	.256	.439	.226	.257	.186	.148	.160	-.144	-.186
34	.355	.134	.359	.130	.018	.019	-.239	-.091	-.029
35	.841	.768	.631	.477	.325	.178	.007	-.088	-.274
36	.394	.726	.341	.449	.113	.308	-.104	.026	-.300
37	.610	.548	.394	.308	.363	.339	.225	.246	.068
38	.075	.082	.173	-.297	-.057	-.246	-.161	.074	-.219
39	-.020	.041	-.351	-.126	-.035	-.244	.104	.116	.298
40	-.144	.219	.141	.116	-.202	-.246	.011	-.379	-.097

Table 5 presents the autocorrelation coefficients for the columns and rows as a function of lag and distance. Although 2/3rds of the data set were computed, only the values for 9 lags are presented. Most of the cotton seed data is independent beyond the first plot boundary (1.4m x 1.4m), i.e., the autocorrelation rapidly approaches zero. Therefore, the data set contains a large amount of random error or unexplained variance (noise).

Table 6 shows the lag and distance where the values of y_x remain dependent. The data set shows that the field has greater uniformity for columns (from top to bottom) with a mean = 5.5m than for rows (from left to right) with a mean = 3.9m. Nineteen percent of the data for columns and 55% of the data for rows showed that the autocorrelation went to zero at L = 1 with these plots being independent of each other.

When reexamining Tables 5 and 6, the autocorrelation technique does not present a clear understanding of field plot uniformity. Although some rows and columns show a high relation to adjacent plot values, autocorrelation analysis does not partition the random variance or noise into manageable levels.

TABLE 6. Estimated distance of dependency or range.

COLUMN	LAG	DISTANCE OF DEPENDENCE (METERS)
1	3	4.3
2	9	12.8
3	7	10.0
4	10	14.2
5	8	11.4
6	1	1.4
7	1	1.4
8	1	1.4
9	5	7.1
10	2	2.8
11	5	7.1
12	5	7.1
13	1	1.4
14	1	1.4
15	6	8.5
16	6	8.5
17	1	1.4
18	3	4.3
19	4	5.7
20	2	2.8
21	3	4.3
22	3	4.3
23	4	5.7
24	4	5.7
25	7	10.0
26	3	4.3
27	2	2.8
28	3	4.3
29	5	7.1
30	3	4.3
31	3	4.3
32	2	2.8
MEAN	4.	5.5

TABLE 6. cont.

ROW	LAG	DISTANCE OF DEPENDENCE (METERS)
1	1	1.4
2	1	1.4
3	1	1.4
4	2	2.8
5	1	1.4
6	1	1.4
7	1	1.4
8	1	1.4
9	1	1.4
10	5	7.1
11	1	1.4
12	1	1.4
13	2	2.8
14	1	1.4
15	1	1.4
16	4	5.7
17	1	1.4
18	1	1.4
19	2	2.8
20	4	5.7
21	4	5.7
22	4	5.7
23	1	1.4
24	11	15.6
25	6	8.5
26	1	1.4
27	1	1.4
28	8	11.4
29	1	1.4
30	1	1.4
31	2	2.8
32	4	5.7
33	7	10.0
34	4	5.7
35	6	8.5
36	6	8.5
37	8	11.4
38	1	1.4
39	1	1.4
40	1	1.4
MEAN	3	3.9

Spectral Analysis[7]

An alternative description of the structure of a sampled data set is obtained when a frequency analysis is provided instead of a correlation function. If the spectral function, P_f, represents the Fourier transform of the autocorrelation (Blackman and Tukey, 1958), then, P_f represents the contribution of the variance between frequencies f and f + df, which satisfies the condition where

$$\overline{y'^2} = \int P_f \, df.$$

Recalling from equation 2 that y' is the fluctuation from the mean yield, Y, then $\overline{y'^2}$ is the root-mean-square value or variance of the fluctuation. Pasquill (1962) suggests four methods are available to resolve a data series into a spectral distribution:

1. Classical harmonic analysis,

2. Fourier-transform of the autocorrelation correlogram,

3. Numerical filter techniques, and

4. Electrical filters.

For our purposes, the harmonic analysis, method 1, will be used which concentrates on the Fourier integral of a periodic function and will be discussed in greater detail later. Method 2 has been widely used in the evaluation of the power spectrum for air turbulence. Although there is the advantage of a smoothed spectrum, there are other difficulties of data manipulation which, for our purposes, are not advantageous over standard harmonic analysis techniques. Methods 3 and 4 are techniques developed by specific scientific disciplines and, in general, have not been used extensively in evaluating spatial and time series data. For those interested in further details, Hinze (1973) and Pasquill (1962) could provide a start.

To understand harmonic analysis, a review of a general physics book for the definition of terms would be helpful (Sears and Zemansky, 1960 or Weber, et al, 1959). A review is presented in Appendix A for terms such as wavelength, λ, frequency, f, period, T, amplitude, A, and phase angle, ϕ, which are terms

----

7. "When resorting to this device, however, it must be borne in mind that there is a gain in formality and precision but not always in physical relevance, and at times more is to be learned from a visual study of an original record than from its mathematical transformations (Priestley, 1959)."

associated with cyclic phenomenon such as the sine or cosine wave. These terms can be defined as: λ = distance between wave points or peaks, f = the number of wave forms in a unit length and is the reciprocal of the wavelength, T = the time for one cycle and is the reciprocal of the frequency, A = one-half the height of the wave form, and ϕ = the offset between two wave forms (ϕ = 90° is the cosine).

The data set for the series analysis must be detrended. Also, the distance series is considered to have two components:

1. the periodic component (deterministic, sequential, or signal); and,

2. a random component (error or noise).

The harmonic analysis method using the Fourier integral is designed to examine the principal periodic components and to eliminate gross error or noise. To review the application of Fourier series to periodic phenomena, a review of mathematical books such as Sokolnikoff and Sokolnikoff (1941) and Kaplan (1952) are extremely helpful. In addition, a complete and thorough review is presented by Davis (1973) for geostatisticians.

The problem to be resolved is to fit a finite trigonometric sum to a set of detrended periodic values, y. For the cotton seed data, the values, X_i, are equally spaced intervals (where i = 1, 2, ...) and the Fourier integral can be reduced to:

$$A = \alpha_f \cos \frac{2\pi f X_i}{\lambda} + \beta_f \sin \frac{2\pi f X_i}{\lambda}$$

where α_f and β_f are the Fourier coefficients of y with respect to the amplitude, A, of the system at X_i (Pasquill, 1962 and Davis, 1973). The coefficients are solved for n/2 harmonics using computer program number 4, CORR.BAS, of Appendix B.

A power spectrum is a method of displaying values of the variance, P_f, plotted against harmonic numbers, n. In general, these graphs are composed of two curves termed: raw spectrum and smoothed spectrum. Smoothing is usually achieved by a weighted average technique such as described by the Hanning filter where:

$$P_f = 0.25(y'^2_{n-1}) + 0.5(y'^2_n) + 0.25(y'^2_{n+1})$$

which produces a smoothed power spectrum. The raw or unweighted power spectrum may give reasonable estimates of the variance, however, "their transforms are very respectable estimates of <u>smoothed</u> values of the true spectral density (Blackman and Tukey, 1958)."

FIGURE 19. Raw and smoothed power spectrums.

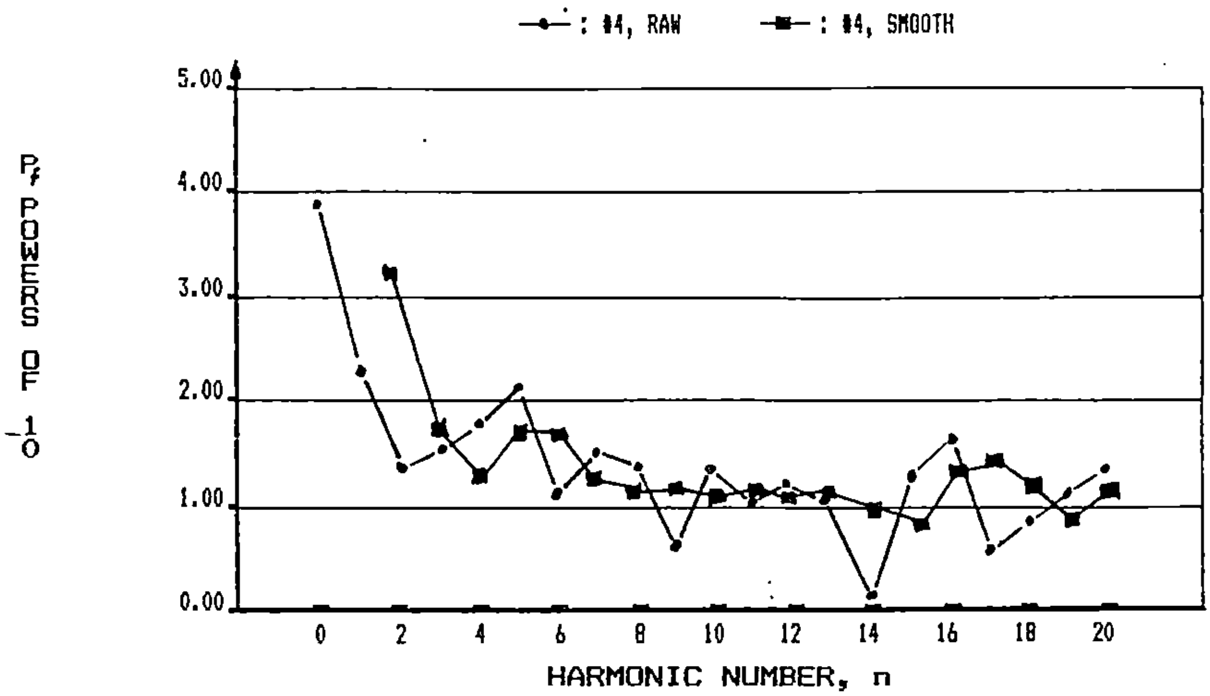
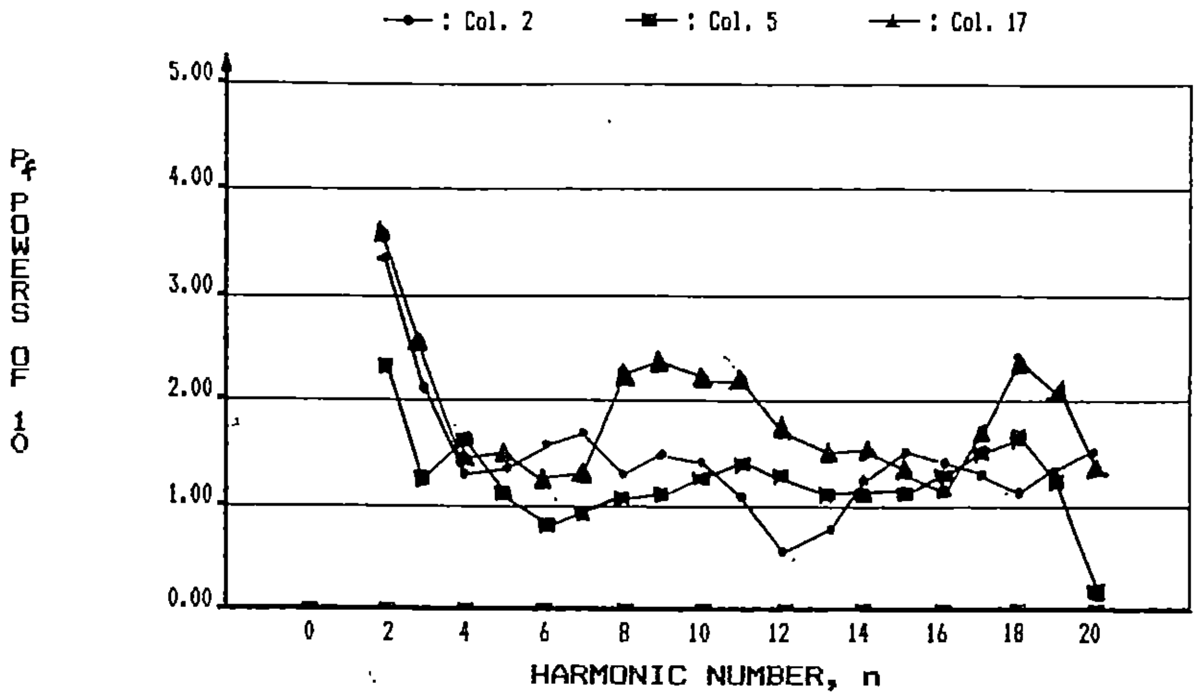


Figure 19 presents an example of the power spectrum of the cotton seed yield for the raw and smoothed data. If the lines were perfectly smooth then the higher variance would be associated with the lower harmonic numbers or the greater distances. The distance is calculated from the total length of column divided by the harmonic number, e.g., the total length of column equals 57m therefore at a harmonic distance of 20, 12, and 4 the distance would be 2.9m, 4.7m, and 14.2m respectively. The raw power spectrum shows that many periodicities are present and that the successive values of P_f vary greatly. However, the smoothed power spectrum shows the filtered data and represents a more realistic periodic structure of the series and only the more prominent peaks. If systematic variation persists then the peaks of the power spectrum delineates its recurrence distance. For example, suppose a sand lens had traversed the field from top to bottom at 15m increments, harmonic number = 4, then a peak in the power spectrum would have been expected at that distance.

Figures 20 and 21 show representative smooth power spectrums for the columns and rows of the cotton seed data. The spectral analysis of the $\overline{y'^2}$ fluctuations show how the peaks and valleys are distributed over these harmonic numbers. The highest value of P_f always occurs at the lowest calculated harmonic number, i.e., the greatest distance. As the harmonic number increases, P_f decreases because of the spatial influence of adjacent plots. If no yield irregularities were recurring or cyclic then the power spectrum would be a smooth continuous line throughout the range of harmonic numbers. In this case, the power spectrum would reduce to the lowest value for the region as the plots approach uniformity.

FIGURE 20. Smoothed power spectrums: columns.



The data presented in Figure 20 shows many recurring periodicities. Column = 2 shows a peak at a harmonic number = 6 (9.5m) but the other lesser peaks appear to be multiples or harmonics of this major peak, e.g., at the valley with a harmonic number = 12, distance = 4.7m, which is a multiple of 9.5m. The data of column = 5 shows a peak at 5.2m and the second peak at 3.2m which is not a harmonic multiple of the first peak. In addition, column = 17 shows a peak at 6.3m with another peak at 3.15m which is a multiple of the first peak.

Figure 21 shows similar relations with row = 28 having the first peak at 6.5m and a secondary peak at 4.1m with the last peak a harmonic multiple of the other two. Row = 35 has a peak at 5.7m and another at 4.1m which suggests that there may be a relation between the two peaks at 4.1m. Row = 5 shows a series of peaks at 6.5m, 4.6m, and 3.25m where the last peak is a harmonic of the first peak.

Table 7 presents the estimated positions of the harmonic peaks and valleys for both column and row data. For the column data, there is a break in the harmonic numbers = 10 and 16. Also, the greater number of peaks start at harmonic number = 6 (9.5m) and reach a maximum number of peaks at n = 8 (7.1m) and another at n = 18 (3.2m). For the row data, there is a break at harmonic number = 12 (3.8m). The greater number of peaks start at n = 4 (11.4m) with many peaks at n = 9 (5.1m) or a maximum number of peaks at n = 10 (4.6m) and n = 16 (2.8m).

FIGURE 21. Smoothed power spectrums: rows.

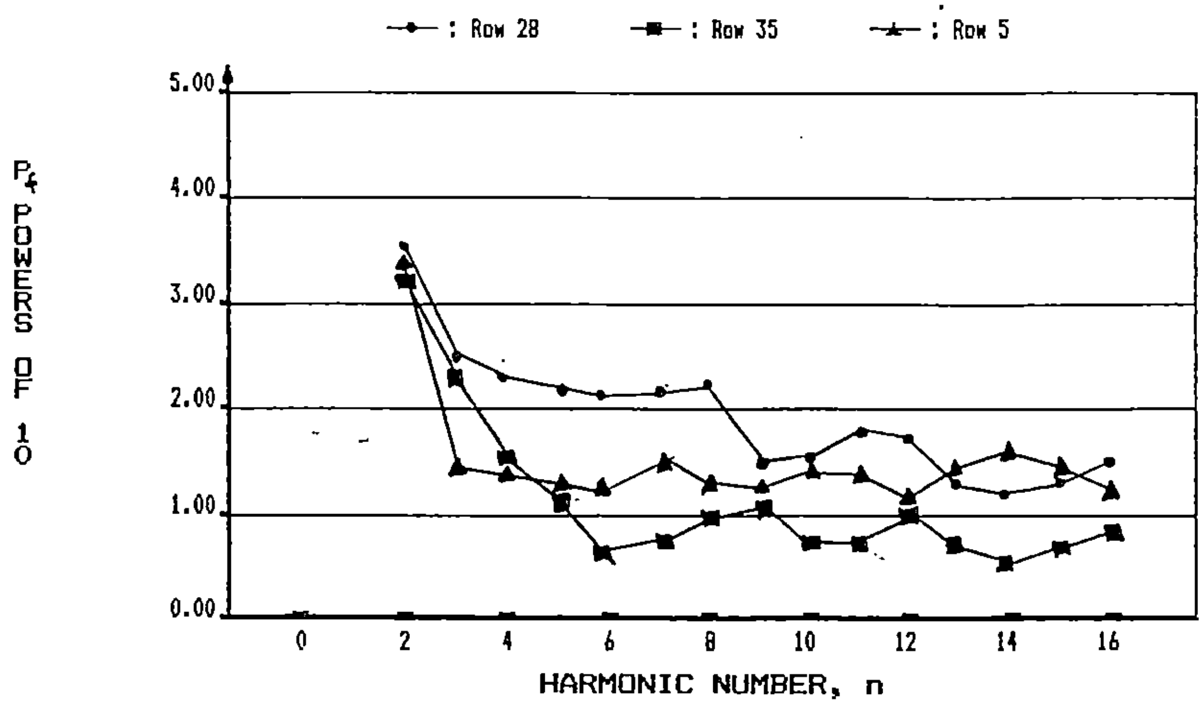


Table 7 shows a possibility of a systematic variation of spatial variability in multiples of 4.4m and 7.1m distances across the rows, i.e., at 4.4m, 7.1m, 8.8m, 13.2m, 14.2m, and 21.3m. This implies that the field has regular cycles of soil or fertilizer bands with axes coinciding with the axes of the field which increase the plot variances at these distances. However, cyclic patterns for the column data are difficult to interpret and do not produce a unique distribution of the power spectrum.

TABLE 7. Estimated positions of the harmonic peaks and valleys.

HARMONIC	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COLUMN																			
1					*						*						*		
2					*											*			*
3						*							*			*			
4					*											*			
5										*							*		
6							*				*						*		
7							*				*							*	
8							*					*							*
9								*			*					*			
10						*						*							
11								*										*	
12						*				*					*				
13							*							*					*
14									*								*		
15							*					*							
16					*				*				*						
17								*									*		
18					*							*				*			
19					*					*									*
20						*		*					*						
21										*									
22							*						*						*
23									*								*		
24											*						*		
25							*												*
26										*			*				*		
27							*							*					*
28							*										*		
29								*				*			*				
30											*			*				*	
31						*				*									
32							*												*

TABLE 7. cont.

HARMONIC	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ROW															
1			*					*							*
2						*								*	
3				*				*				*			
4									*						*
5						*			*				*		
6								*					*		
7							*						*		
8					*				*						*
9							*					*			*
10				*			*						*		
11				*				*							
12			*			*				*				*	
13				*									*		
14									*						*
15				*					*				*		
16							*							*	
17									*			*			
18								*						*	
19			*					*						*	
20										*					*
21									*						
22								*			*				
23					*							*			*
24						*							*		
25			*					*				*			
26						*			*						
27						*				*					*
28						*				*					*
29									*						
30			*				*						*		
31				*						*					
32										*					
33					*				*						*
34							*			*					
35								*			*				
36												*			*
37				*							*				*
38			*						*			*			
39			*		*									*	
40											*			*	

Spatial Correlation

In the computation of the spatial correlation, the same assumptions of homogeneity and no existing trends are implied as for autocorrelation. The autocorrelation compares an equally spaced data series in a line; whereas, the spatial correlation compares several equally spaced data series along equally spaced lines, i.e., the correlation structure of a two dimensional data set. It is similar to cross-correlation which compares two distance series; however, spatial correlation compares two distance series throughout the two dimensional data set. If the series of the data matrix are identical, then the spatial correlation will approach unity. If the field is uniform with random error attached to all unit plots, the true spatial correlations will be zero. Therefore, the spatial correlation is a measure of the extent of field plot uniformity.

Actually, the spatial correlation is a modification of the cross-correlation techniques and can provide information that the autocorrelation cannot. By this technique, the equidistant values in one line of data are compared with the next line until all columns or rows have been compared. With each series of computations, a correlation coefficient, R_s, is obtained. As an example, for the test data set, row = 1 can be correlated with row = 2, then row = 1 can be correlated with row = 3, followed by row = 1 being correlated with row = 4 and so on until row = 1 has been correlated with all 40 rows of data. The next relation to be evaluated is row = 2 to be correlated with row = 3, then row = 2 is correlated with row = 4, followed by row = 2 being correlated with row = 5, and so forth. This sequential process is continued until at least two thirds of the data set has been analyzed.

As the distance between rows increases, the spatial correlation function may decrease rapidly in magnitude and it is not unusual to find negative values over a range of equally spaced lines. Correlograms show the amount of field plot uniformity that exists between rows and columns across a field. The data sets are inverted for additional evaluation of the field plot uniformity, i.e., for columns, they are analyzed from bottom to top, and for rows, they are analyzed from right to left. Therefore, if a correlatable relation exists between adjacent columns or adjacent rows of equidistant, detrended data, the spatial correlation could interpret the extent of the relation's dependency. Intuitively, for a field plot uniformity study such as the cotton seed yield example, there should exist some correlatable relation between columns or rows of data when they are spaced only one, two, or three meters apart.

The equation for the spatial correlation coefficient, R_s, differs somewhat from the equation for the autocorrelation coefficient and can be expressed as:

$$R_x = \frac{\overline{y'_x \times y'_{x+L}}}{[\overline{y'^2_x} \times \overline{y'^2_{x+L}}]^{1/2}}$$

However, the assumption of homogeneity cannot be implied in that the statistical properties of $\overline{y'^2_x}$ cannot be taken independent of position. If the field is completely homogeneous then the areal extent of uniformity is exactly the same for both the autocorrelation and the spatial correlation techniques.

Figures 22, 23, 24, and 25 present examples of the relation of the spatial correlation coefficient to lag (distance) for the cotton seed data. The analyses were made using computer program number 5, SPACORR.BAS, in Appendix B. Unlike the analysis for the autocorrelation coefficient where a relation may exist when a coefficient is negative, no relation between adjacent plots exists when the spatial correlation coefficient goes to zero or changes sign. Whether the sign is positive or negative (increasing or decreasing yield trend) is not particularly important in the analysis of these data sets; but, when $R_x = 0$ then no further analysis is necessary. The extent of the dependency of contiguous plots is the important factor and not the magnitude or extent of independence.

Figures 22 and 23 are reflections of one another except for the direction of sweep. Columns 10, 21, and 31 in Figure 22 are exactly the same columns as 31, 21, and 10 of the inverted data set in Figure 23, i.e., the data is viewed from both directions. In Figure 22, column = 10 shows an adjacent plot dependency to nearly 5 lags or 7.1m and the same column = 31 in Figure 23 shows an adjacent plot dependency of about 6 lags or 8.5m. Similarly, column = 21 of Figure 22 shows a plot dependency of 4 lags or 5.6m and column = 21 of Figure 23 shows a plot dependency of 3 lags or 4.2m. Column = 31 of Figure 22 and column = 10 of Figure 23 show little plot dependency with lags = 2.

FIGURE 22. Spatial correlation coefficient.

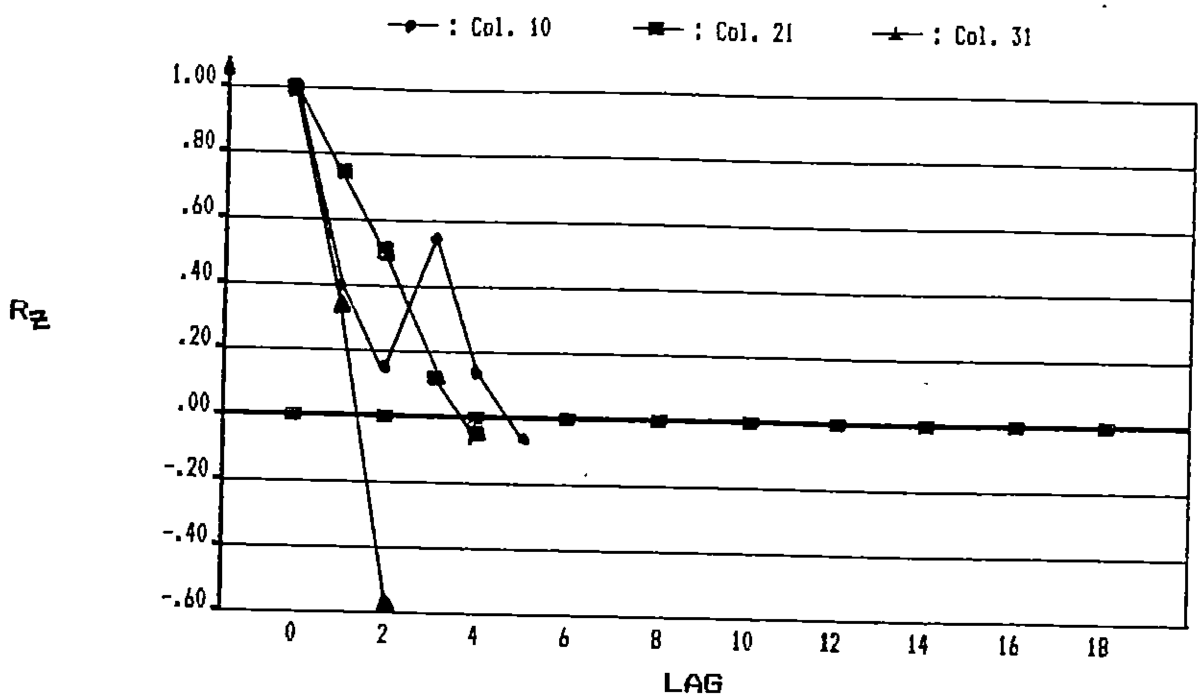
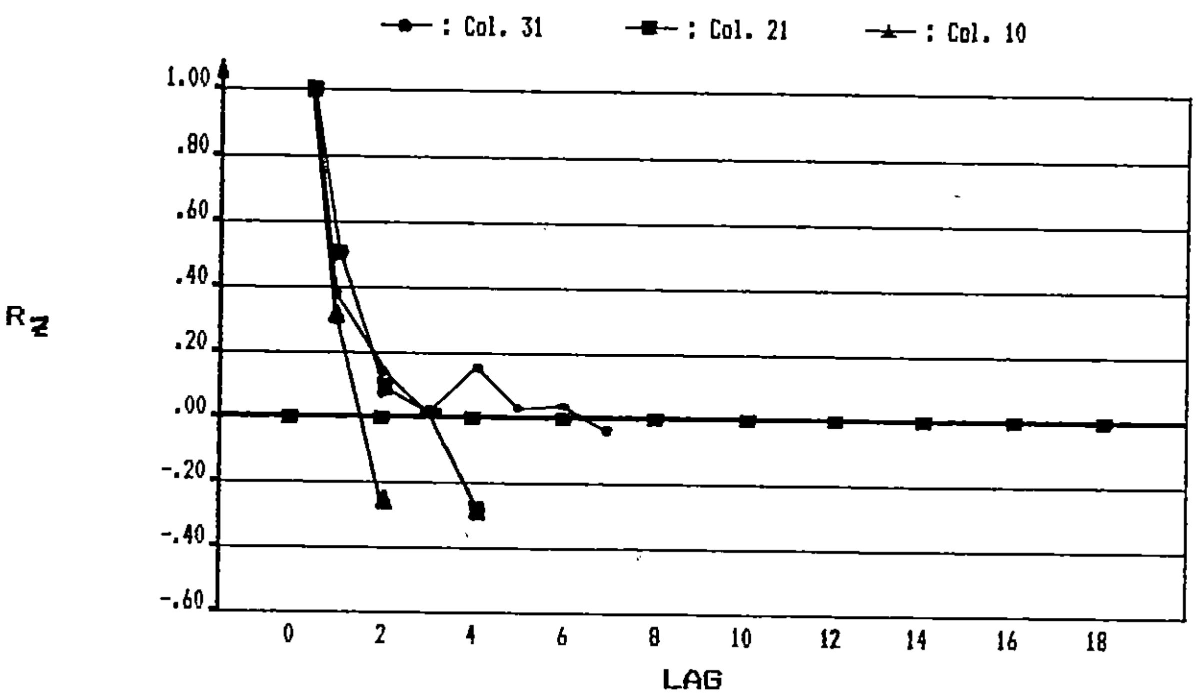


FIGURE 23. Spatial correlation: Inverse F 22.



Figures 24 and 25 show the spatial correlation coefficients for row data and illustrate that the plot dependency is greater for rows than for columns. Comparing row = 18 of Figure 24 to row = 15 of Figure 25 shows that each has a dependency at lag = 14. Row = 22 of Figure 24 shows a greater amount of random variance (noise) with lag = 4 than does its inverse direction row = 6 of Figure 25 with lag = 7. A similar but opposite relation is shown by comparing row = 8 of Figure 24 to row = 25 of Figure 25 where the lags = 9 and 5, respectively.

The mean distance of dependency, M_x, for a specified column or row can be given by the integral of R_x over the spatial increment as follows:

$$M_x = \int_0^L R_x \, dz$$

where z is the total distance as $R_x \rightarrow 0$. The integral for the average distance is a method for weighting the magnitude of the spatial correlation coefficient; therefore, a low R_x would not have the same influence as a high R_x. In Table 8, the mean distance of dependency is presented which gives the influence of each column and row on adjacent columns or rows. The data were computed to five less than the total number of columns or rows as the remaining data was inadequate to determine a distance of plot dependency. The column data suggests that columns 30, 31, and 32 have a large amount of random variance with an adjacent distance of only 2.8m or two plots but that columns 7, 8, 9, 11, 17, 18, 33, 34, and 35 all have an adjacent distance of more than 12m or eight plots. The mean distance of plot dependency for the columns is 8.2m or about six plots.

The data for rows is much better, showing much less random error than the column data. For example, rows 14, 15, 18, 19, and 21 have distances of dependency greater than 25m, or 18 plots, with row = 6 having a minimum value of about 7m or 5 plots. The mean distance is about 16m or 11 plots. The spatial correlation shows that random variance is greater in columns than in rows. Therefore, if the plots are to be arranged in the direction of greater variance, then plots should be oriented with the longest plot dimension in the vertical direction.

FIGURE 24. Spatial correlation coefficients.

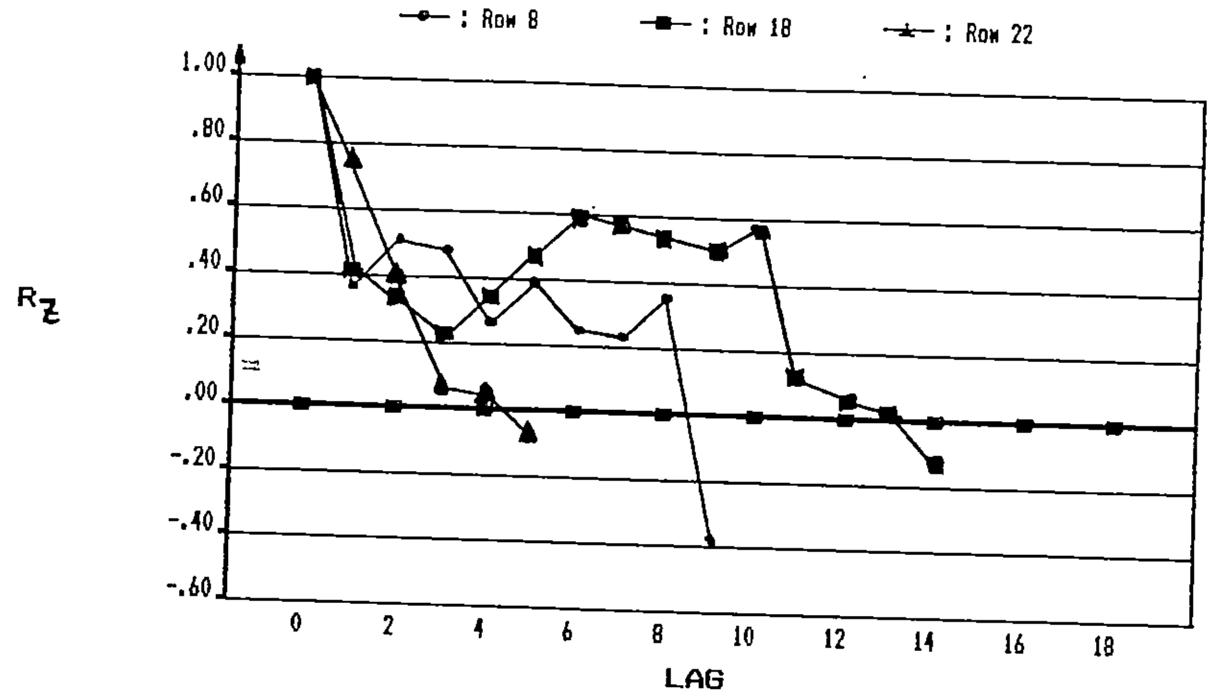


FIGURE 25. Spatial correlation: Inverse F 24.

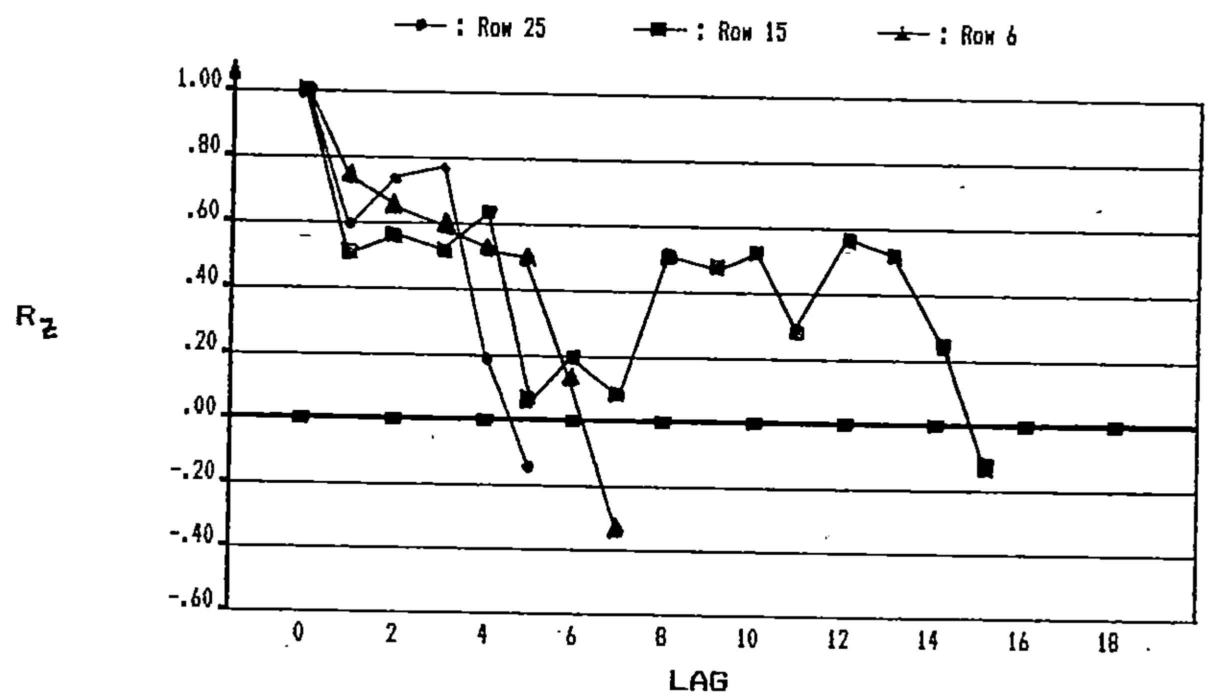


TABLE 8. Mean distance of dependency or range (meters).

COLUMN	DISTANCE	INVERTED DISTANCE	TOTAL DISTANCE	ROW	DISTANCE	INVERTED DISTANCE	TOTAL DISTANCE
1	13.1			1	0.6		
2	12.0			2	3.8		
3	7.3			3	12.0		
4	0.6			4	2.2		
5	8.8			5	11.1		
6	8.2	6.1	14.3	6	2.3	4.6	6.9
7	7.8	7.6	15.4	7	6.8	5.9	12.7
8	7.0	8.9	15.9	8	8.2	5.0	13.2
9	5.4	1.3	6.7	9	2.4	6.3	8.7
10	4.4	5.5	9.9	10	6.1	9.3	15.4
11	3.4	9.3	12.7	11	0.7	9.3	10.0
12	1.6	1.3	2.9	12	4.6	10.4	15.0
13	1.3	2.2	3.6	13	3.1	11.5	14.6
14	0.7	2.7	3.4	14	13.5	12.3	25.8
15	6.0	3.1	9.1	15	14.5	12.1	16.6
16	2.3	3.4	5.7	16	0.7	13.7	14.4
17	7.3	4.6	11.9	17	0.7	13.8	14.5
18	10.0	2.4	12.4	18	13.3	14.6	27.9
19	4.5	2.2	6.7	19	12.2	15.9	28.1
20	3.8	3.0	6.8	20	11.6	7.7	19.3
21	3.3	2.9	6.2	21	10.3	17.5	27.8
22	3.4	3.4	6.8	22	9.5	1.4	10.9
23	6.2	2.4	8.6	23	9.2	10.3	19.5
24	5.4	3.8	9.2	24	6.3	3.5	9.8
25	4.2	4.1	8.3	25	5.0	4.9	9.9
26	3.4	2.3	5.7	26	6.1	6.2	12.3
27	2.8	4.8	7.6	27	4.4	7.0	11.4
28	1.5	5.8	7.3	28		17.6	
29	1.4	3.2	4.6	29		9.4	
30	1.5	1.4	2.9	30		9.7	
31	1.2	1.5	2.7	31		11.4	
32	0.4	2.4	2.8	32		12.3	
33	8.9	3.9	12.8				
34	7.5	4.6	12.1				
35	6.1	5.9	12.0				
36		7.2					
37		8.1					
38		8.6					
39		0.7					
40		10.5					
MEAN			8.2				16.1

SEMIVARIOGRAMS AND KRIGING ANALYSIS

The theory of regionalized variables has been used by geostatisticians to determine the spatial variability of ore deposits (Vander Zaag, et al, 1981). Spatial dependence of a measured parameter can be determined from the semivariogram using precision information from scattered samples of field data (Campbell, 1978). The conceptual understanding of the semivariogram follows the general explanation for the covariance and correlogram of the autocorrelation coefficient.

The use of various geostatistical techniques to evaluate field plot uniformity depends upon the mathematical manipulation of measured data. There are many techniques available which "weight" each sample according to its distance from the point being estimated, i.e., the weight depends on the distance and not the quantitative value of the sample. Usually, the method of weighting depends upon the variable being measured, e.g., porosity, soil moisture, hydraulic conductivity, fertility, yield, etc. The method known as "kriging"[8] is based upon the theory of regionalized variables and was initially developed by Matheron in 1963 (Matheron, 1971). Since that time many papers and texts have become available which review the procedure in depth (Agterberg, 1974; Journel and Huijbregts, 1978; Clark, 1979; Royle, et al, 1980; and, Burgess and Webster, 1980). The kriging method requires two steps to obtain the solution of the "estimated or kriged value" and the "estimated or kriged variance". The first step is to determine the semivariogram and the second step is to determine the "best" set of weights, kriging.

Semivariograms

The development of semivariograms examines the difference between the position of two values of measurement where the difference in these values is dependent on the distance of separation (lag) and the relative orientation (x,y). The difference obtained by this arrangement would be from the same probability distribution and it is assumed that locally within the region of measurement there is no trend. These assumptions are not as strong for the semivariogram as were the assumptions of continuity, trending, and stationarity for the autocorrelation coefficient. For the semivariogram, the mean and variance of the differences depends only on the relative spatial orientation; however, detrending the data set is required. The distribution of the sample values for calculating the semivariogram are

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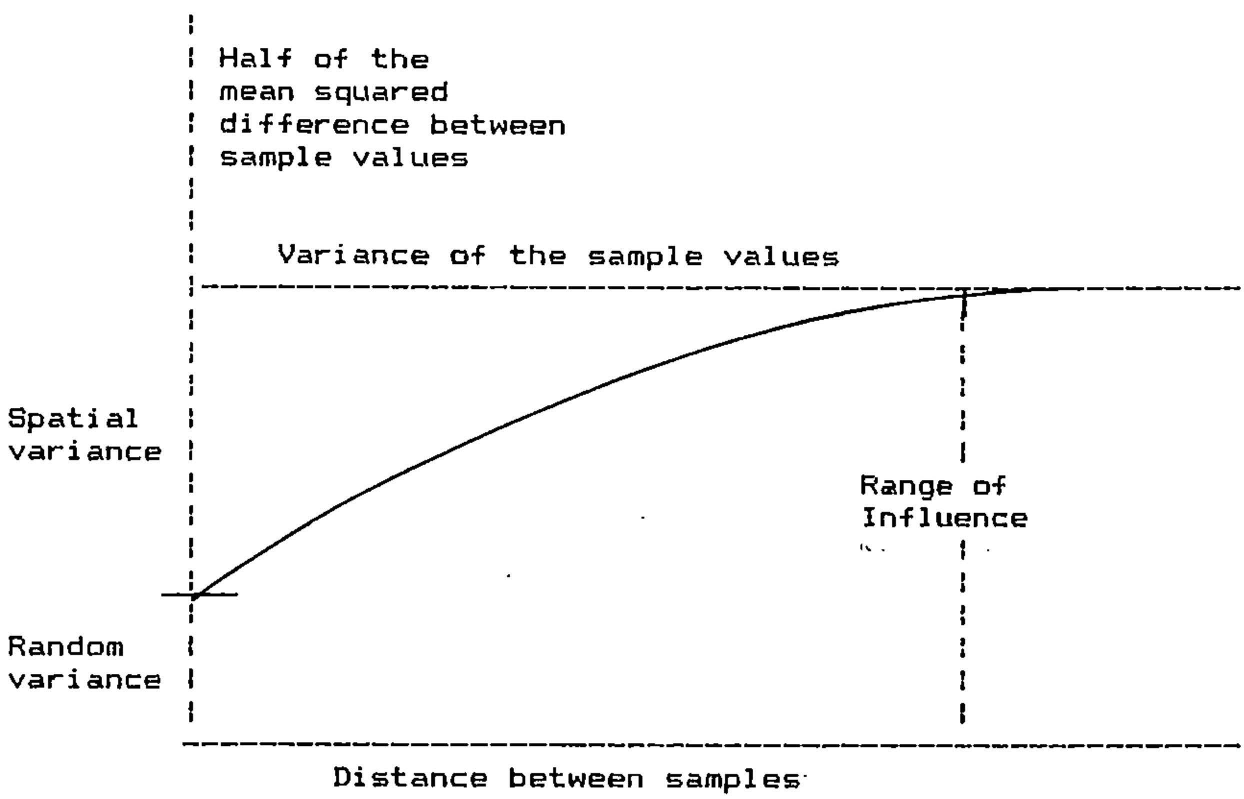
8. Oftentimes the French pronunciation is used, i.e., kridging as in ridging.

assumed to be isotropic. If the semivariogram is not the same for each computed direction, e.g., horizontally, vertically and diagonally, then the data structure is said to be anisotropic and the design for kriging analysis becomes more difficult but not impossible (Davis, 1973).

Figure 26 shows the general characteristics of a semivariogram where the sample variability is increasing at distances between samples (Royle, et al, 1980). The range of influence is at the leveling-off point of the curve. This point also indicates the sample variance which is partitioned into spatial and random variance.

FIGURE 26. The general characteristics of a semivariogram.



To develop semivariograms, the following steps using the cotton seed data will be used:

1. Describe the distance at regular intervals between samples and the relative orientation as h or lag h; therefore, the difference in the value between the two samples depends only on the lag (h = 1.4224m).

2. Calculate the mean squared difference, $\gamma(h)$, between samples using 1/2 of the expected value:

$$\gamma(h) = 1/2\ E\ [y(x) - y(x + h)]^2$$

where
y = yield (gm)
x = position of one sample
$x + h$ = position of other sample

3. The variance of the differences is $2\gamma(h)$, and the semivariogram, $\gamma(h)$, can be calculated from:

$$\gamma(h) = 1/2\,n \sum^{n} [y(x) - y(x + h)]^2$$

where n = the number of sample pairs.

These computations which are similar to those made for the autocorrelation coefficient were made using computer program number 6, KRIG1.BAS, of Appendix B. The program detrends each data set separately and computes the horizontal, vertical, and diagonal semivariograms. The various models of the semivariograms, $\gamma(h)$, are shown in Figure 27 where a = the range of influence of a sample and C = the "sill" or the value where $\gamma(h)$ levels off. Each model can be expressed mathematically as follows:

for the spherical model

$$\gamma(h) = C\left[\frac{3h}{2a} - \frac{h^3}{2a^3}\right] \qquad \text{when } h <= a, \text{ and}$$

$$\gamma(h) = C \qquad \text{when } h >= a$$

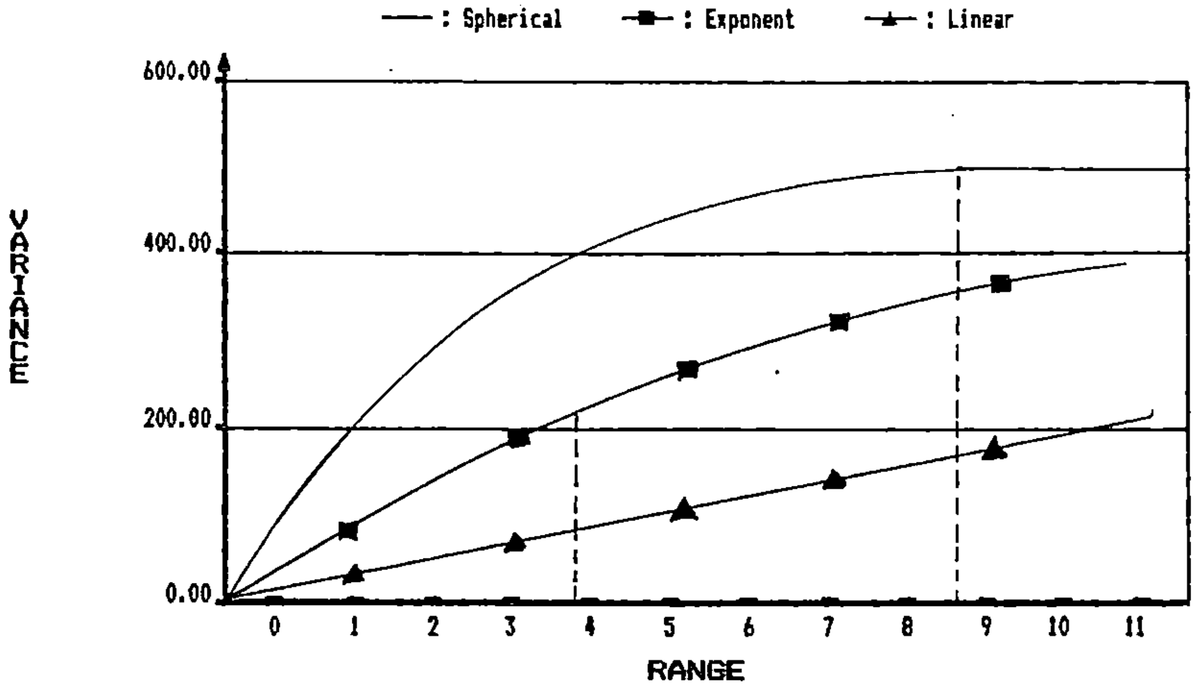
for the exponential model

$$\gamma(h) = C\ [1 - \exp(-h/a)]$$

However, the exponential model never approaches the sill, C; but drawing a straight line through the first linear portion of the plotted data intersects a hypothetical sill at the distance equal to the range of influence, a (Clark, 1979). For models with a sill, $C = s^2$, where s^2 is the sample variance. The linear model which has no sill is given by $\gamma(h) = b \times h$, where b = the slope of the line.

These three examples, spherical, exponential, and linear are the most commonly used models. Clark (1979) and Royle et al (1980) have presented many other polynomial models and approaches

FIGURE 27. Variogram for 'ideal' models.



the solution of a semivariogram. The relation of the semivariogram, $\gamma(h)$, to the autocorrelation coefficient, R_L, at lag h can be given by:

$$\gamma(h) = s^2(1 - R_L)$$

or

$$R_L = 1 - \frac{\gamma(h)}{s^2}$$

Conceptually, the autocorrelation is dependent on the variance, which must be finite (Burgess and Webster, 1980).

To solve the semivariogram for the cotton seed data, the method chosen for analysis was the spherical model. The analysis follows the techniques developed for the autocorrelation which were presented in Figure 13. The data set was detrended and used to compute the semivariogram. The data set was normally distributed and, after detrending, was isotropic. For these analyses, at least 2/3rds of the data were used to determine the semivariogram in the row, column, and diagonal directions to insure many paired samples as shown in Tables 9 and 10. Clark (1979) has stated that the standard rule is the fewer pairs used in computation, the less the reliability.

TABLE 9. Experimental semivariogram (gm/plot)² for column and row cotton seed data (1280 Plots).

	ROW			COLUMN		
DISTANCE BETWEEN SAMPLES (meters)	Number of Pairs	Experimental Semivariogram RAW	DETRENDED	Number of Pairs	Experimental Semivariogram RAW	DETRENDED
1.4	1248	395.9	395.8	1240	389.0	388.8
2.8	1216	427.8	428.0	1200	393.1	393.1
4.3	1184	471.8	471.6	1160	404.4	405.2
5.7	1152	510.5	509.9	1120	431.9	434.9
7.1	1120	539.3	538.8	1080	475.0	478.7
8.5	1088	573.0	572.0	1040	488.5	494.1
10.0	1056	593.6	592.6	1000	505.3	513.6
11.4	1024	624.5	622.6	960	499.4	508.8
12.8	992	644.2	641.0	920	519.0	531.4
14.2	960	624.0	619.4	880	517.1	531.0
15.6	928	629.4	622.4	840	527.2	542.0
17.1	896	622.2	613.4	800	544.5	559.1
18.5	864	614.5	605.6	760	568.7	582.9
19.9	832	596.2	585.6	720	578.7	588.8
21.3	800	584.6	571.7	680	580.2	590.5
22.8	768	587.2	573.0	640	596.2	608.1
24.2	736	555.9	540.4	600	549.1	569.9
25.6	704	583.8	566.4	560	550.0	569.0
27.0	672	603.3	583.7	520	537.7	550.5
28.4	640	630.8	607.1	480	528.1	540.5
29.9	608	613.2	585.1	440	550.3	560.8
31.3	576	708.3	678.3	400	516.4	526.3
32.7	544	688.8	657.7	360	509.2	510.2
34.1	512	743.6	708.1	320	552.8	552.0
35.6	480	803.1	767.9	280	518.6	503.5
37.0	448	817.6	780.3	240	575.0	553.2
38.4	416	875.0	836.6	200	525.8	496.5
39.8	384	803.8	765.7	160	612.4	568.3
41.2	352	874.8	834.4	120	580.2	532.4
42.7	320	855.4	816.6	80	653.9	577.2
44.1	288	844.1	804.1	40	708.8	621.2
45.5	256	927.1	885.5			
46.9	224	822.7	782.8			
48.4	192	853.0	813.9			
49.8	160	768.8	733.6			
51.2	128	753.0	724.7			
52.6	96	830.5	803.1			
54.1	64	569.9	536.7			
55.4	32	1036.2	969.2			

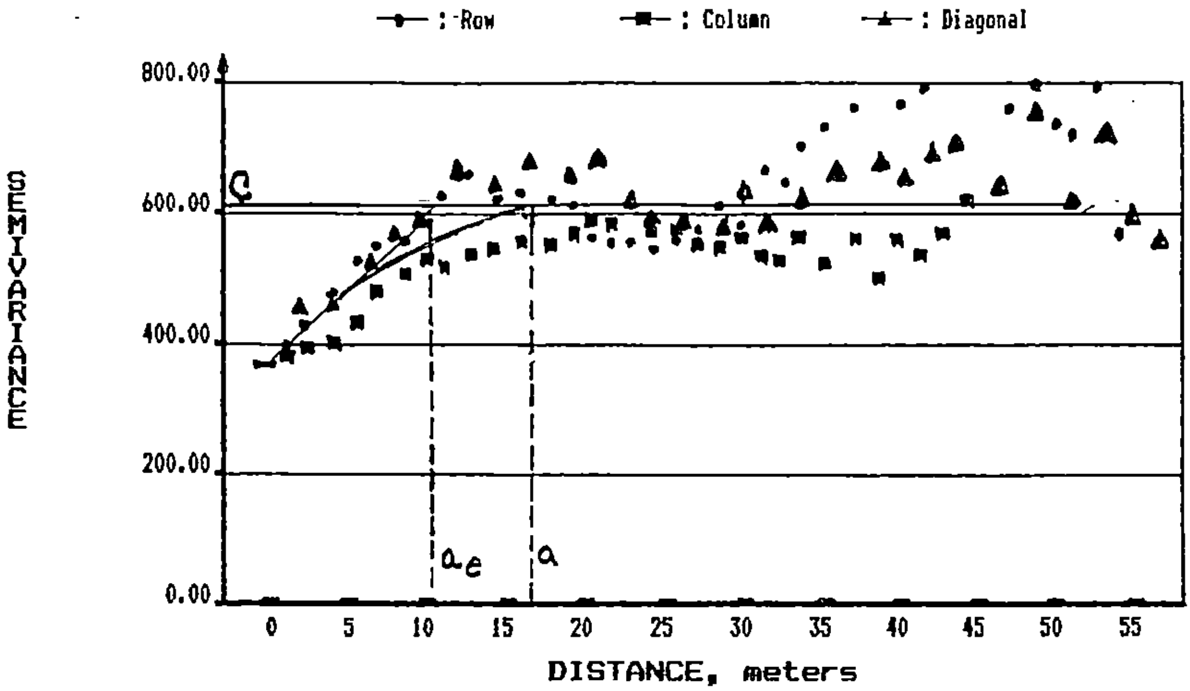
TABLE 10. Experimental semivariogram $(gm/plot)^2$ for diagonal cotton seed data (1280 Plots).

DISTANCE BETWEEN SAMPLES (meters)	DIAGONAL Number of Pairs	Experimental Semivariogram RAW	DETRENDED
2.0	1209	461.5	461.1
4.0	1140	470.2	469.2
6.0	1073	529.1	527.7
8.0	1008	574.1	572.6
10.0	945	593.8	590.8
12.0	884	664.3	660.7
14.0	825	646.9	641.6
16.1	768	686.7	680.4
18.1	713	672.7	665.4
20.1	660	698.8	690.8
22.1	609	624.8	616.2
24.1	560	605.7	596.8
26.1	513	604.9	597.1
28.1	468	585.2	577.4
30.1	425	645.6	639.4
32.1	384	591.9	592.1
34.1	345	617.1	619.9
36.1	308	650.1	651.2
38.2	273	670.1	672.4
40.2	240	659.9	657.7
42.2	209	684.5	680.2
44.2	180	705.6	691.3
46.2	153	657.1	639.2
48.2	128	778.4	781.3
50.2	105	647.0	614.5
52.2	84	778.4	741.5
54.2	65	649.5	604.2
56.2	48	618.3	575.2
58.2	33	605.8	561.2
60.2	20	222.8	192.5
62.3	9	464.2	456.7

Tables 9 and 10 presents the semivariogram computed from the raw data and from the detrended data. The data were detrended using a linear equation; however, there are other methods for detrending data (Davis, 1973). The data set, either raw or detrended, is nearly isotropic but because of the importance of the isotropic assumption, further analysis will be performed only on detrended data.

A plot of the semivariogram in the three major directions; row, column, and diagonal for the detrended data are shown in Figure 28. There are only minor differences between the row, column, and diagonal semivariograms; therefore, they are spatially isotropic.

FIGURE 28. Semivariogram for cotton seed data



The semivariogram initially increases at a rapid rate and levels off at about 20m which suggests a polynomial trend in the yield data. Beyond 35m a different type of trend starts which could require a different method for analysis. However, if the analysis is restricted to 35m, then the spherical model can be used. By drawing a straight line through the first points and drawing another horizontally through the leveling-off portion of the curve, the range is determined from the intersection of the two drawn lines and the estimated range is read from the x-axis as a_e = 11 (gm/plot)^2. The range is computed from a = $3a_e/2$ = 16.5 (gm/plot)^2. The intercept of the horizontal line and the y-axis gives the value of the sill at the variance of the sample values = 608 (gm/plot)^2. The range shows that plots further apart than 16.5m (12 plots) are independent; whereas, plots within the range are spatially dependent. The range is dependent on the size of the area sampled, i.e., a smaller field would give a smaller range (Clark, 1979).

The semivariograms start at a constant value greater than zero [y-axis intercept = 370 (gm/plot)^2]. This constant, C_o, is known as the "nugget effect". The position of the nugget effect implies a zone of complete, unpredictable random variance. However, even with complete random variance, all curves must intersect zero at distance zero, i.e., two identical values measured at <u>exactly</u> the same position must have the same value, zero. These analyses show a sill of spatial variance, C = 238 (gm/plot)^2 and a nugget effect, C_o = 370 (gm/plot)^2 where the line intersects the y-axis. Therefore, 61% of the sample variance is random and unpredictable, i.e., 370 x 100/608 = 61%.

Another way of stating this is: a plot, which is 16.5m distant, would be expected to have a yield difference of 19.2 gm/plot, i.e., $(370)^{1/2} = 19.2$.

The semivariogram presents a better range and standard deviation than most other methods, e.g., the standard deviation for the semivariogram = 19.2 gm/plot; whereas, the data in Table 3 using the method of moments showed a standard deviation of 25 gm/plot. The semivariogram gives a range of dependency of 16.5m; whereas, for spatial correlation the distance of dependency was 8.2m for columns and 16.1m for rows. Similar relations were obtained for the autocorrelation where columns = 8.5m and rows = 28.4m and for spectral analysis methods where columns = 11.4m and rows = 11.3m. A distance of dependency = 14.2m was obtained using Smith's method.

To evaluate the spherical model, the following values were taken from the semivariogram in Figure 28:

$$\text{estimated range} = a_e = 11\text{m}$$

$$\text{range} = a = 16.5\text{m}$$

$$\text{nugget effect} = C_o = 370\ (\text{gm/plot})^2$$

$$\text{sill} = C = 238\ (\text{gm/plot})^2.$$

Therefore, for the spherical case:

$$\gamma(h) = 370 + 238\left[\frac{3}{2}\,\frac{h}{16.5} - \frac{1}{2}\left(\frac{h}{16.5}\right)^3\right]$$

when h <= 16.5m, and if h = 2m, then $\gamma(h) = 413\ (\text{gm/plot})^2$. In addition,

$$\gamma(h) = 370 + 238 = 608\ (\text{gm/plot})^2 \text{ when } h > 16.5\text{m}.$$

Using this information, the spherical model was computed using computer program number 7, SPHER.BAS, of Appendix B. These results are presented in Table 11 which is plotted as the solid line on Figure 28. The spherical model for the semivariogram gives a good fit.

As the kriged values depend only on the nearest points, then a semivariogram has to be accurate only over the first few lags (Burgess and Webster, 1980). It is logical then that an exponential model or a simple linear model could be used. However, the nugget effect is large: $C_o = 370\ (\text{gm/plot})^2$, and when the exponential model and linear model were attempted for kriging analysis of the cotton seed data, they produced undesirable effects.

TABLE 11. Semivariogram computed for the spherical model for the cotton seed data.

DISTANCE BETWEEN PLOTS, meters	COMPUTED SEMIVARIOGRAM, $(gm/plot)^2$
1.4	400.7
2.8	430.9
4.3	460.3
5.7	488.2
7.1	514.3
8.5	538.2
10.0	559.3
11.4	557.2
12.8	591.4
14.2	601.5
15.6	607.1
17.1	608.0
.	.
.	.
.	.
44.1	608.0

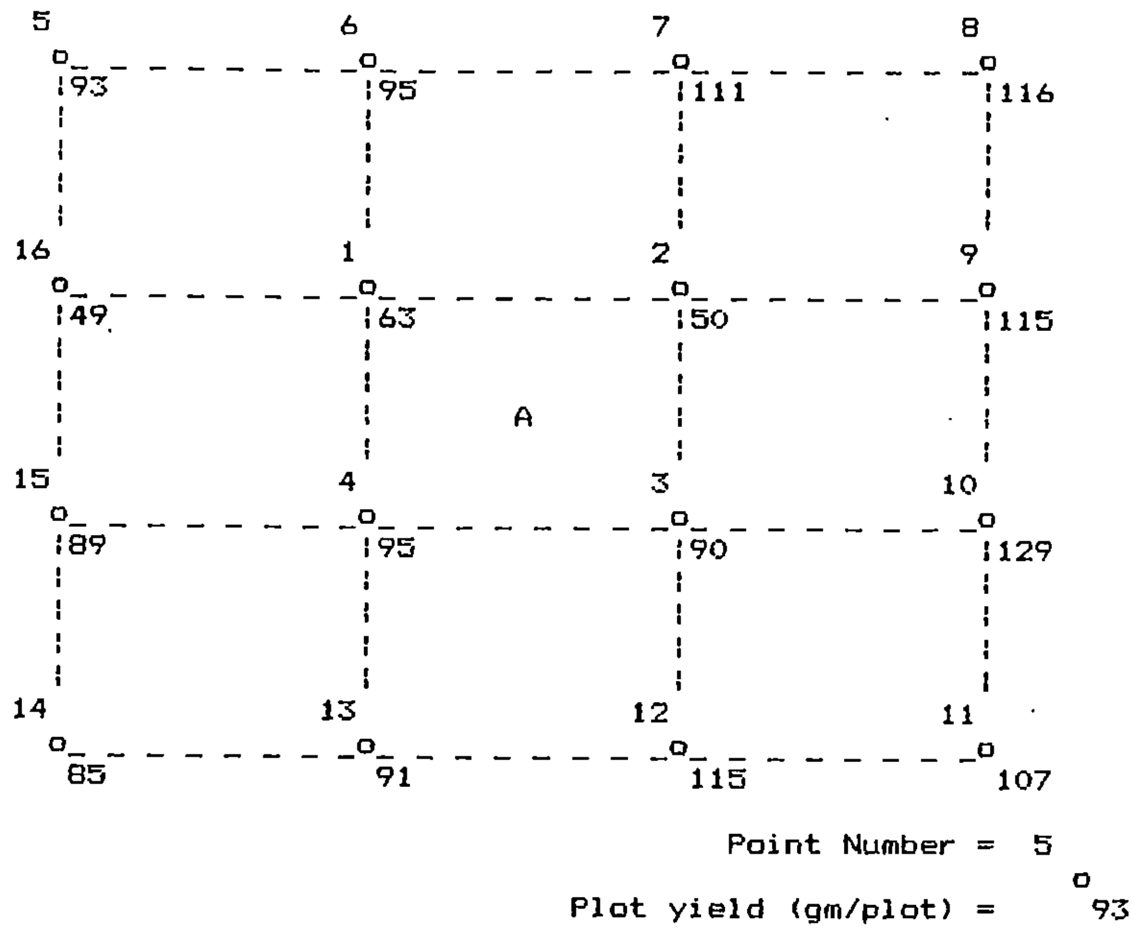
Kriging

After computing an accurate semivariogram, these values are used to determine the weights for calculating the kriged yields and the kriged variance. Although many authors discuss the simple, simplistic, rudimentary, easy approaches to understanding kriging analysis; in general, the solution techniques are confusing and are only simple, after a thorough study is accomplished. Often the method is lost when the authors lament on their favorable aspects of using kriged values. These favorable aspects are yet to be seen....

To enter the realm of kriging, the "simplistic" approach presented by Clark (1979) will be followed. However, the methodological development will be highly augmented and supported by the manuscripts of Matheron (1963, 1971), Agterberg (1974), David (1977),Journel and Huijbregts (1978), Burgess and Webster (1980), and Royle et al (1980) and many, many others. Also, the French literature from Fontainebleau is filled with many geophysical examples and solutions.

The method of kriging depends upon the "local" or "neighborhood" estimation of values. Although different neighborhoods may have different means and standard deviations, the semivariogram is the same over the entire area or data set. Figure 29 presents the neighborhood of values for the upper lefthand corner portion of the cotton seed data (see Appendix A). The area or panel, A, was interpreted using the nearest 16 data points. The kriging method followed is called "block" or "two-dimensional" kriging and relates point values to areas or panels.

FIGURE 29. Neighborhood or grid used to determine kriged values.



To determine the estimation value, T^*, (for the cotton seed data example, T^* = yield), there is an area, A, over which the yield is to be summed and averaged. The 16 values of yield, y_i, were added and divided by the number of samples, n, to determine the mean:

$$T^* = \sum^{n} w_i y_i = \sum^{n} \frac{y_i}{n}$$

Another way of stating the same thing is as follows:

$$T^* = w_1 y_1 + w_2 y_2 + w_3 y_3 + \ldots + w_n y_n$$

where all the weights, w_i, are the same and T^* is the arithmetic mean of the yield.

It will be recalled that the semivariogram was equal to the sample variance divided by two:

$$\gamma(h) = \frac{s^2}{2}$$

or

$$s^2 = 2\gamma(h).$$

However, to account for the variance of each area, A, and the data point, y, three terms of the variance must be defined. Theoretical developments appear in Journel and Huijbregts (1978). The estimation of the variance of the error associated with the sample values, the semivariogram, and the sample values describe the spatial variability:

$$s^2 = 2w_i \gamma(S_i,A) - w_i w_j \gamma(S_i,S_j) - \gamma(A,A)$$

where $S_{i,j}$ is the value of a point in the sample set; A is the value of each point in the area; and each term, γ, on the righthand of the equation is an average semivariogram. For example, David (1977), Clark (1979), and Royle et al (1980) define the terms as:

$\gamma(S_i,A)$ = Sum of all the semivariogram values between the sample point, S_i, and every point in the area divided by the area, A.

= The average semivariogram between each yield point, S_i, and the entire area, A.

$\gamma(S_i,S_j)$ = The average semivariogram value between every pair of points in the sample set (S_i) and every other point in the sample set (S_j).

= A measure of the variability in values between samples.

$\gamma(A,A)$ = The average semivariogram value between every point in the area, A, and every other point in the area, A.

= The average semivariogram which is removed from the system when only the average value over the area, A, is considered.

= The variance of the values within the area, A.

These average semivariograms are simply numbers for a given data set where the estimation variance is a function of the weights associated with each of the samples, $S_{i,j}$. They can be solved, for the cotton seed data, by using various spherical auxiliary functions. When the auxiliary function is determined for each component, they are put into a matrix form and solved by the solution for simultaneous equations. Kriging selects the set of coefficients that minimize the estimation variance and produces the best estimator; i.e., the lower values of variance. The equation for the estimation variance, s^2, can be resolved to the following set of linear equations for kriging:

$$w_1 \gamma(S_1,S_1) + w_2 \gamma(S_1,S_2) + .. + w_n \gamma(S_1,S_n) + L = \gamma(S_1,A)$$

$$w_1 \gamma(S_2,S_1) + w_2 \gamma(S_2,S_2) + .. + w_n \gamma(S_2,S_n) + L = \gamma(S_2,A)$$

$$\begin{array}{ccccc} -- & -- & -- & - & -- \\ -- & -- & -- & - & -- \\ -- & -- & -- & - & -- \end{array}$$

$$w_1 \gamma(S_n,S_1) + w_2 \gamma(S_n,S_2) + .. + w_n \gamma(S_n,S_n) + L = \gamma(S_n,A)$$

$$w_1 + w_2 + .. + w_n + 0 = 1$$

and solving gives:

$$s^2 = w_1 \gamma(S_1,A) + w_2 \gamma(S_2,A) + .. + w_n \gamma(S_n,A) + L - \gamma(A,A)$$

$$T = w_1,y_1 + w_2,y_2 + .. + w_n,y_n$$

For the cotton seed data and for each neighborhood of 16 values, there will be 17 equations in the kriging system, i.e., 16 on the lefthand side of the above set of linear equations plus one Lagrangian multiplier, L. For the cotton seed data, the $\gamma(S_i,S_j)$ terms are "point-to-point" solutions and the $\gamma(S_i,A)$ terms are "point-to-area" solutions and, the latter, are written in combinations of the auxiliary function, H(d,b). The auxiliary function is defined for a particular matrix or field geometry.

The task remains to solve this set of equations into the auxiliary terms and finally into the weights. The spherical model of the semivariogram was given by:

$$\gamma(h) = C\left[\frac{3}{2}\frac{h}{a} - \frac{1}{2}\left(\frac{h}{a}\right)^3\right] \qquad \text{when } h <= a$$

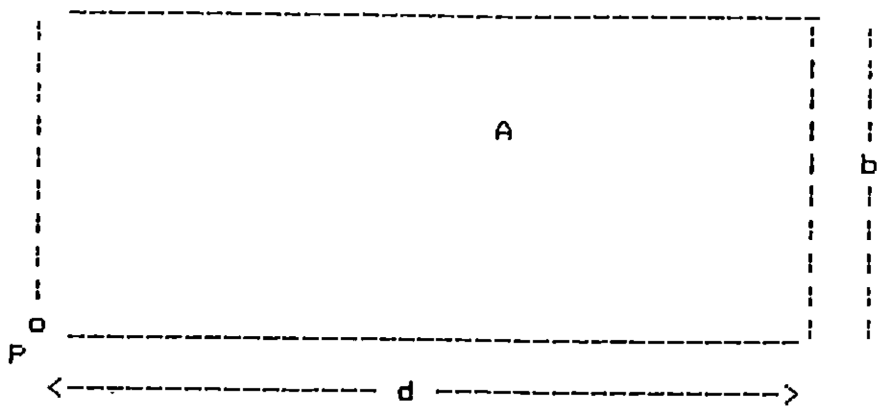
$$= C \qquad \text{when } h > a$$

and as shown in Figure 30 (which is an example of the center portion of Figure 29):

H(d,b) = Average semivariogram value between an area, A, and a point, P, at one corner of the panel.

Clark (1979) presents many examples of other auxiliary functions for ready solution to other types of models. The two-dimensional H(d,b) function is solved by using the tables in Appendix A. For the spherical model, distances are given as

FIGURE 30. Two-dimensional auxiliary function, H(d,b).



relative to the range, a, therefore H(d,b) with range = a is the same as H(d/a,b/a) with a range = 1. The tables in Appendix A include all spherical models and can be solved as follows:

1. Divide the lengths of the sides (d,b) of the area, A, by the range of influence, a, i.e., H(d,b) = H(d/a,b/a).

2. Read the corresponding values of d/a and b/a in the Tables and use proportionate interpolation to find unlisted values.

3. Multiply the Table value by the sill, C.

4. Add the nugget effect, C_o, to the final value.

For the cotton seed data, when a = 16.5m, d = 2.8m, and b = 4.27m, where C = 238 $(gm/plot)^2$ and C_o = 370 $(gm/plot)^2$, then from the table:

$$H(2.8/16.5, 4.27/16.5) = H(0.17, 0.26) = 0.236$$

thus,

$$H(d,b) = 0.236 \times 238 + 370 = 426.2 \ (gm/plot)^2$$

The table for the two-dimensional auxiliary function, H(d,b), is for the "standardized" spherical model where the order of d and b is not important as this table is symmetric.

To solve the set of linear equations for kriging, the right hand side of the equations are the average semivariograms for $\gamma(S_1,A)$ between the area, d x b. The method for obtaining H(d,b) is presented in Figures 29 and 30; therefore, at point #1:

$$H(1.4/16.5, 1.4/16.5) = H(0.085, 0.085) = 0.105.$$

then,

$$H(d,b) = 0.105 \times 238 + 370 = 395 \text{ (gm/plot)}^2$$

H(d,b) represents situations where the area is only one side of the panel as shown in Figure 29 for points 1 through 4. For the outer points, 5 through 16, then H(d,b) must be calculated twice, once for each area in the panel. For example, point number 10 needs two sets of numbers at two orientations of the area:

$$H(2.8/16.5, 4.27/16.5) = H(0.17, 0.26) = 0.236$$

then,

$$H(d,b) = 0.236 \times 238 + 370 = 426.2 \text{ (gm/plot)}^2$$

$$H(4.27/16.5, 1.4/16.5) = H(0.26, 0.09) = 0.210$$

then,

$$H(d,b) = 0.210 \times 238 + 370 = 420.0 \text{ (gm/plot)}^2$$

The 16 values for the grid positions shown in Figure 29, for H(d,b), are presented in Table 12.

These values are then solved for the appropriate $\gamma(S_i,A)$ as follows:

an example of one area in a panel is,

$$\gamma(S_i,A) = d \times b \times H(d,b)/(d \times b)$$

for point number 1,

$$\gamma(S_1,A) = 1.4 \times 1.4 \times 395.0/(1.4 \times 1.4) = 395.0 \text{ gm}^2$$

an example of two areas in a panel is,

$$\gamma(S_i,A) = \frac{d1 \times b1 \times H(d1,b1) + d2 \times b2 \times H(d2,b2)}{(d1 \times b1) + (d2 \times b2)}$$

for point number 10,

$$\gamma(S_{10},A) = \frac{(2.8 \times 4.27 \times 447.6) + (4.27 \times 1.4 \times 420.0)}{(2.8 \times 4.27) + (4.27 \times 1.4)}$$

$$= 431.2 \text{ (gm/plot)}^2$$

The 16 values computed for the grid positions shown in Figure 29 for $\gamma(S_i,A)$ are presented in Table 13.

TABLE 12. Values of H(d,b) for the 16 grid positions (gm/plot)[a].

GRID POSITION	
1	H(0.085, 0.085); 0.105 x 238 + 370 = 395.0
2	H(0.085, 0.085); 0.105 x 238 + 370 = 395.0
3	H(0.085, 0.085); 0.105 x 238 + 370 = 395.0
4	H(0.085, 0.085); 0.105 x 238 + 370 = 395.0
5	H(0.259, 0.259); 0.262 x 238 + 370 = 432.4
6	H(0.259, 0.170); 0.236 x 238 + 370 = 426.2,
	H(0.085, 0.259); 0.210 x 238 + 370 = 420.0
7	H(0.170, 0.259); 0.236 x 238 + 370 = 426.2,
	H(0.259, 0.085); 0.210 x 238 + 370 = 420.0
8	H(0.259, 0.259); 0.262 x 238 + 370 = 432.4
9	H(0.259, 0.170); 0.236 x 238 + 370 = 426.2,
	H(0.085, 0.259); 0.210 x 238 + 370 = 420.0
10	H(0.170, 0.259); 0.236 x 238 + 370 = 426.2,
	H(0.259, 0.085); 0.210 x 238 + 370 = 420.0
11	H(0.259, 0.259); 0.262 x 238 + 370 = 432.4
12	H(0.085, 0.259); 0.210 x 238 + 370 = 420.0,
	H(0.259, 0.170); 0.236 x 238 + 370 = 426.2
13	H(0.170, 0.259); 0.236 x 238 + 370 = 426.2,
	H(0.259, 0.085); 0.210 x 238 + 370 = 420.0
14	H(0.259, 0.259); 0.262 x 238 + 370 = 432.4
15	H(0.085, 0.259); 0.210 x 238 + 370 = 420.0,
	H(0.259, 0.170); 0.236 x 238 + 370 = 426.2
16	H(0.170, 0.259); 0.236 x 238 + 370 = 426.2,
	H(0.259, 0.085); 0.210 x 238 + 370 = 420.0

TABLE 13. Method of calculating the $\gamma(S_1, A)$, $(gm/plot)^2$

GRID POSITION	
1	(1.4 * 1.4 * 395.0) / (2.0) = 395.0
2	(1.4 * 1.4 * 395.0) / (2.0) = 395.0
3	(1.4 * 1.4 * 395.0) / (2.0) = 395.0
4	(1.4 * 1.4 * 395.0) / (2.0) = 395.0
5	(4.27 * 4.27 * 432.4) / (18.2) = 432.4
6	[(4.27 x 2.8 x 426.2) + (1.4 x 4.27 x 420.0)]/(18.2) = 417.2
7	[(2.8 x 4.27 x 426.2) + (4.27 x 1.4 x 420.0)]/(18.2) = 417.2
8	(4.27 x 4.27 x 432.4) / (18.2) = 432.4
9	[(4.27 x 2.8 x 426.2) + (1.4 x 4.27 x 420.0)]/(18.2) = 417.2
10	[(2.8 x 4.27 x 426.2) + (4.27 x 1.4 x 420.0)]/(18.2) = 417.2
11	(4.27 x 4.27 x 432.4) / (18.2) = 432.4
12	[(1.4 x 4.27 x 420.0) + (4.27 x 2.8 x 426.2)]/(18.2) = 417.2
13	[(2,8 x 4.27 x 426.2) + (4.27 x 1.4 x 420.0)]/(18.2) = 417.2
14	(4.27 x 4.27 x 432.4) / (18.2) = 432.4
15	[(1.4 x 4.27 x 420.0) + (4.27 x 2.8 x 426.2)]/(18.2) = 417.2
16	[(2.8 x 4.27 x 426.2) + (4.27 x 1.4 x 420.0)]/(18.2) = 417.2

To aid in the explanation of obtaining the H(d,b) values, Figure 31 shows the arrangement of the model presented in Figure 30. Here, there is one area to the panel where b is the length

FIGURE 31. Estimation of area average from one yield 'point'.

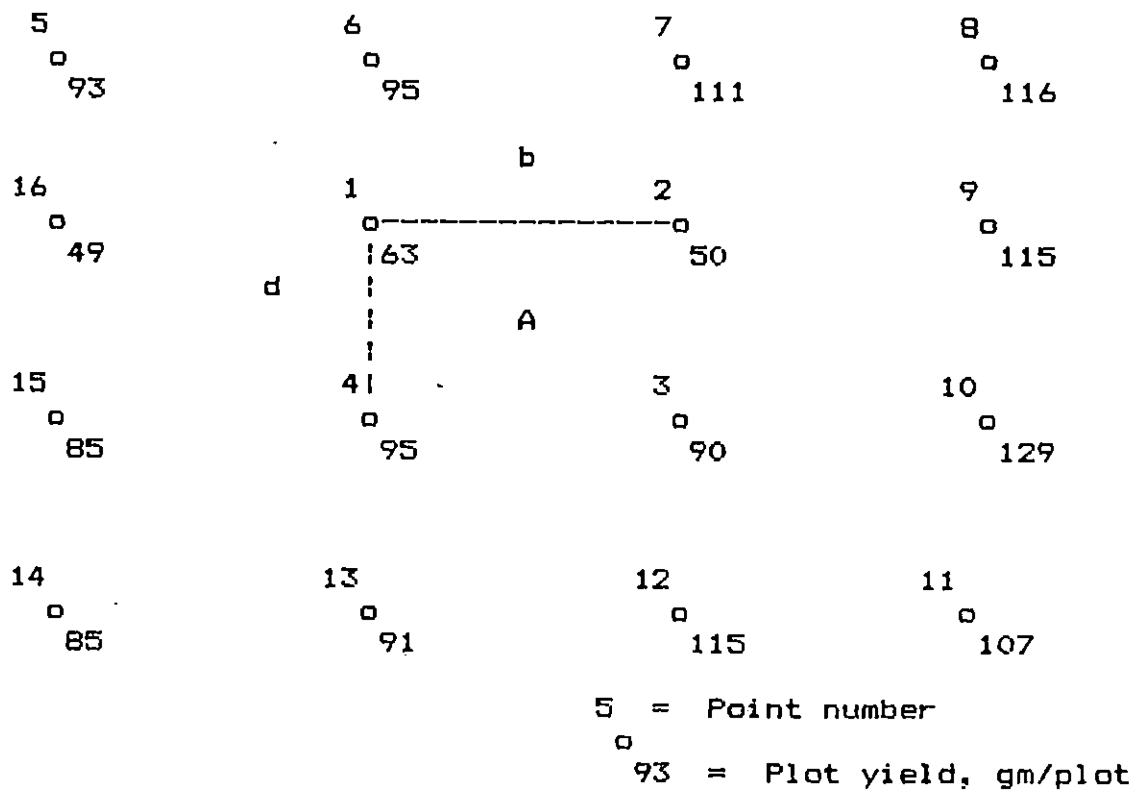
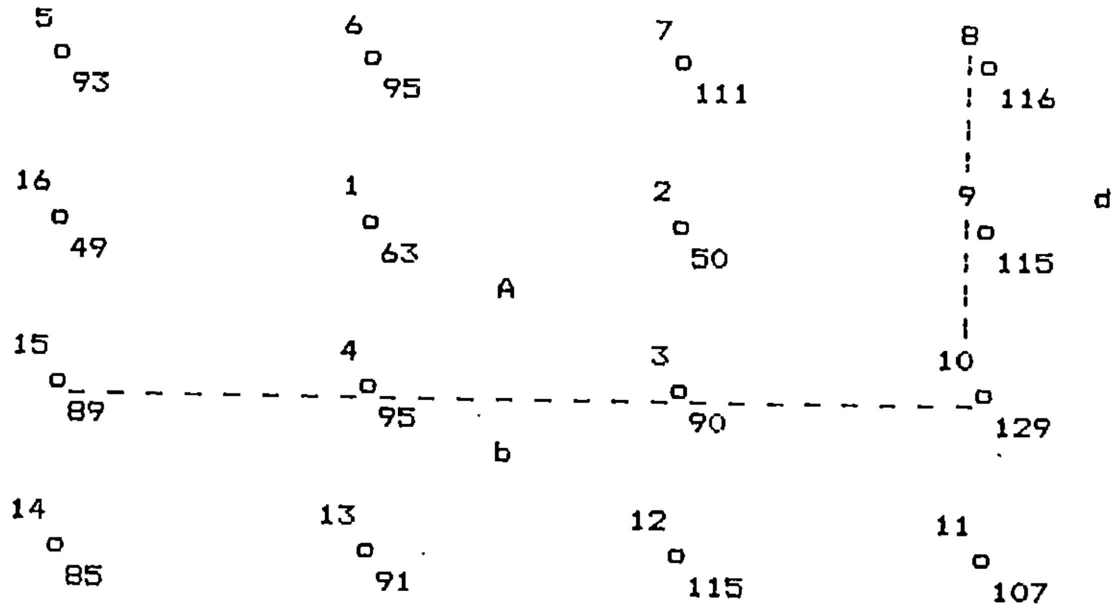
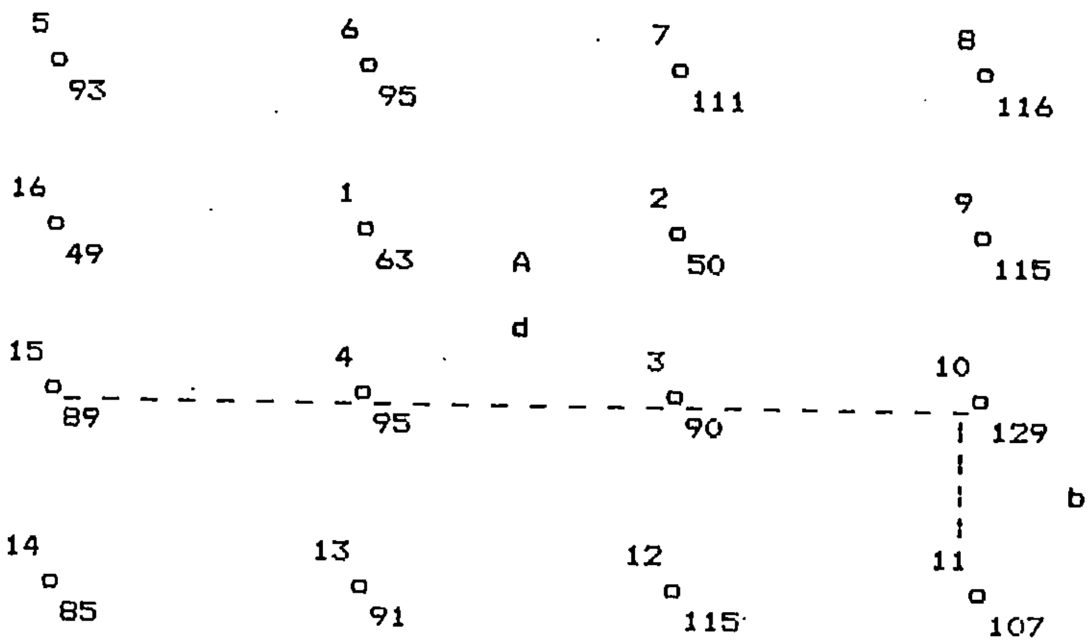


FIGURE 32. Image values of area estimation for block kriging.



5 = Point number

o
93 = Plot yield, gm/plot



and point 4; then, the area, A, is the length, d, times the length, b. At point 10, the system is slightly different and the two areas for the panel are shown in Figure 32. In the upper grid, d is equal to the distance between points 10 and 8 and b is equal to the distance between points 10 and 15. In the lower grid, d is equal to the distance between points 10 and 15 and b is equal to the distance between points 10 and 11. Each average semivariogram value, $\gamma(S_i,A)$, is configured in the same manner.

To calculate the distances between pairs for the $\gamma(S_i,S_j)$ terms on the lefthand side of the set of linear equations, use is made of the average semivariogram, $\gamma(S_i,S_j)$, which measures the variation in yield values between plots and takes into account the different weights associated with each sample. Since there are 16 points in this set there are 256 such terms. Each of the individual terms is a semivariogram between a pair of points. By definition, when the lag is zero, h = 0, and the diagonal terms, $\gamma(S_1,S_1)$, $\gamma(S_2,S_2)$, $\gamma(S_3,S_3)$, ... , $\gamma(S_n,S_n)$ are zero. Also, the image terms of the set of linear equations are the same, e.g., $\gamma(S_1,S_2) = \gamma(S_2,S_1)$, $\gamma(S_2,S_3) = \gamma(S_3,S_2)$, etc. The $\gamma(S_1,S_2)$ term is solvable by the auxiliary function, $\gamma(h)$, for the spherical model within the range, a, where:

$$\gamma(h) = C\left[\frac{3}{2}\frac{h}{a} - \frac{1}{2}\left(\frac{h}{a}\right)^3\right] \quad \text{when } h < a$$

$$= C \quad \text{when } h >= a$$

For example, the average semivariogram for $\gamma(S_1,S_2)$ can be given by:

$$\gamma(S_1,S_2) = \quad (h) + C_o$$

$$= 238 \quad \frac{3}{2}\frac{1.4}{16.5} - \frac{1}{2}\frac{1.4}{16.5}^3 \quad + 370$$

$$= 400.2 \ (\text{gm/plot})^2$$

Figure 31 shows the distance of h between points 1 and 2 where the plot distance = 1.4224m. For the average semivariogram between points 1 and 11, the length of the diagonal is computed using the Pythagoras theorem and $\gamma(S_1,S_{11})$ is,

$$\gamma(S_1,S_{11}) = 238 \quad \frac{3}{2}\frac{3.87}{16.5} - \frac{1}{2}\frac{3.87}{16.5}^3 \quad + 370$$

$$= 452.2 \ (\text{gm/plot})^2$$

A similar computation is needed between points 5 and 11 where,

$$\gamma(S_5,S_{11}) = 238\left[\frac{3}{2}\frac{3.87}{16.5} - \frac{1}{2}\left(\frac{3.87}{16.5}\right)^3\right] + 370$$

$$= 494.9 \text{ (gm/plot)}^2$$

Each of the computed average semivariograms are presented in in Appendix A. However, the coefficients needed to solve the weights for the set of linear equations is presented in Table 14. The computer program number 8, WEIGHTS.BAS, in Appendix B was used to compute the coefficients.

The coefficients for the set of linear equations were placed on random file using program number 1, ENTDAT.BAS, in Appendix B. Then computer program number 9, SIMULT2.BAS, in Appendix B, was used to compute the weights, w_i, and the Lagrangian parameter, L:

$$w_1 = 0.095$$
$$w_2 = 0.095$$
$$w_3 = 0.095$$
$$w_4 = 0.093$$
$$w_5 = 0.046$$
$$w_6 = 0.049$$
$$w_7 = 0.051$$
$$w_8 = 0.048$$
$$w_9 = 0.057$$
$$w_{10} = 0.057$$
$$w_{11} = 0.050$$
$$w_{12} = 0.051$$
$$w_{13} = 0.051$$
$$w_{14} = 0.050$$
$$w_{15} = 0.057$$
$$w_{16} = 0.057$$

$$L = 15.9$$

To solve for the average semivariogram, $\gamma(A,A)$, use is made of the auxiliary function, F(d,b) and for the two-dimensional case, $\gamma(A,A) = F(d,b)$. The Table of F(d,b) values appears in Appendix A and is included in computer program number 10, KRIG3.BAS. The final term for the cotton seed data is calculated as follows:

$$F\left[\frac{1.42}{16.5}\ \frac{1.42}{16.5}\right] = F(0.085,0.085) = 238 \times 0.106 + 370$$

$$\gamma(A,A) = 395.3 \text{ (gm/plot)}^2$$

TABLE 14. Matrix of coefficients for $\overline{\gamma}(A,A)$, of the kriging set of linear equations.

W_i	W_j 1	2	3	4	5	6	7	8	9
1	0.0	400.7	400.7	413.3	413.3	400.7	413.3	438.0	430.9
2	400.7	0.0	413.3	400.7	438.0	413.3	400.7	413.3	400.7
3	400.7	413.3	0.0	400.7	438.0	430.9	438.0	455.3	438.0
4	413.3	400.7	400.7	0.0	438.0	438.0	430.9	438.0	413.3
5	413.3	438.0	438.0	438.0	0.0	400.7	430.9	460.3	464.9
6	400.7	413.3	430.9	438.0	400.7	0.0	400.7	413.3	438.0
7	413.3	400.7	438.0	430.9	430.9	400.7	0.0	400.7	413.3
8	438.0	413.3	455.3	438.0	460.3	413.3	400.7	0.0	400.7
9	430.9	400.7	438.0	413.3	464.9	438.0	413.3	400.7	0.0
10	438.0	413.3	430.9	400.7	477.4	455.3	438.0	430.9	400.7
11	455.3	438.0	438.0	413.3	494.7	477.4	464.9	460.3	430.9
12	438.0	430.9	413.3	400.7	477.4	464.9	460.3	464.9	438.0
13	430.9	438.0	400.7	413.3	464.9	460.3	464.9	477.4	455.3
14	438.0	455.3	413.3	438.0	460.3	464.9	477.4	494.7	477.4
15	413.3	438.0	400.7	430.9	430.9	438.0	455.3	477.4	464.9
16	400.7	430.9	413.3	438.0	400.7	413.3	438.0	464.9	460.3
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

	10	11	12	13	14	15	16	L	CONSTANT
1	438.0	455.3	438.0	430.9	438.0	413.3	400.7	1.0	395.3
2	413.3	438.0	430.9	438.0	455.3	438.0	430.9	1.0	395.3
3	430.9	438.0	413.3	400.7	413.3	400.7	413.3	1.0	395.3
4	400.7	413.3	400.7	413.3	438.0	430.9	438.0	1.0	395.3
5	477.4	494.7	477.4	464.9	460.3	430.9	400.7	1.0	438.5
6	455.3	477.4	464.9	460.3	464.9	438.0	413.3	1.0	426.3
7	438.0	464.9	460.3	464.9	477.4	455.3	438.0	1.0	426.3
8	430.9	460.3	464.9	477.4	494.7	477.4	464.9	1.0	438.5
9	400.7	430.9	438.0	455.3	477.4	464.9	460.3	1.0	423.9
10	0.0	400.7	413.3	438.0	464.9	460.3	464.9	1.0	423.9
11	400.7	0.0	400.7	430.9	460.3	464.9	477.4	1.0	438.5
12	413.3	400.7	0.0	400.7	430.9	438.0	455.3	1.0	426.3
13	438.0	430.9	400.7	0.0	400.7	413.3	438.0	1.0	426.3
14	464.9	460.3	430.9	400.7	0.0	400.7	430.9	1.0	438.5
15	460.3	464.9	438.0	413.3	400.7	0.0	400.7	1.0	423.9
16	464.9	477.4	455.3	438.0	430.9	400.7	0.0	1.0	423.9
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0

And the kriging variance would be:

$$s^2 = \sum_{i}^{n} w_i \gamma(S_i, A) + L - F(d,b)$$

$$= 416.4 + 15.9 - 395.3 = 36.9 \ (\text{gm/plot})^2$$

Therefore, the kriged standard deviation, s = 6.1 gm/plot. The estimated kriged value at T(1,1) = 90.0 ± 6.1 gm/plot. The effect of weighting can be seen by comparing the weighting values, w_i, to their relative positions as shown in Figure 31. The nearest points to the unknown position, A, have the largest weights. The smallest weights are at the farthest corners, 5, 8, 11, and 14, as expected. The kriging method automatically adjusts for the spatial relations between points.

The cotton seed data was found to have a normal distribution and it was possible to use the student-t value to determine the 95% confidence interval. Therefore, as $T^*(i,j) = \pm 1.96$ s, it follows that for T(1,1) the range is 79.2 to 103.0 gm/plot. To determine the kriged yield values, the kriged weights were entered into computer program number 11, KRIG2.BAS, in Appendix B. The values for the kriged cotton seed yield were calculated from:

$$T(i,j) = \sum^{n} w_i y_i \quad \text{where } n = 1, 2, 3, \ldots, 16.$$

The kriged values are presented in Table 15 and are offset by a small distance, i.e., T(1,1) is positioned at 2.1m and 2.1m and T(1,2) is at 3.6m and 2.1m.

Table 15 shows the interior kriged cotton seed yield for the data set. Examination of this table emphasizes the definition for a "regionalized variable" as given by Davis (1973) where a variable is considered to be regionalized if it varies from one place to another with apparent continuity. The regionalized variable differs from an ordinary scaler random variable in that its usual distribution parameters have a well defined spatial location (Henley, 1981).

TABLE 15. Kriged yield averages for the cotton seed data.

i	j									
	1	2	3	4	5	6	7	8	9	10
1	90.0	96.7	100.0	94.9	90.0	87.8	87.1	86.0	82.2	77.2
2	88.4	95.5	98.5	96.3	91.7	87.4	84.4	83.0	83.6	77.2
3	90.8	95.4	95.8	93.3	91.1	86.1	84.5	83.0	83.6	79.8
4	87.3	91.5	90.6	86.6	86.2	84.3	86.2	83.8	82.5	81.8
5	87.6	93.1	91.3	85.9	87.4	86.6	88.8	84.6	80.7	82.4
6	92.1	98.8	95.3	90.4	89.9	86.2	86.9	78.7	75.4	75.8
7	90.9	99.3	99.5	92.0	90.4	86.6	80.3	71.8	67.9	68.9
8	89.7	98.6	97.3	89.7	86.0	81.1	75.4	67.8	65.0	67.3
9	82.9	89.3	89.9	86.1	80.3	75.1	75.7	70.9	67.6	69.7
10	79.4	85.1	87.4	82.3	78.2	74.3	75.4	74.8	73.9	73.6
11	82.1	84.9	87.2	83.9	80.9	77.9	78.2	77.1	76.8	77.1
12	83.4	84.1	88.2	85.4	82.9	78.5	76.2	74.8	72.7	75.9
13	84.4	86.3	88.3	84.6	81.4	75.3	71.7	70.0	71.4	72.8
14	78.6	79.3	83.0	79.6	75.3	72.2	66.5	65.3	67.2	66.5
15	73.9	74.6	76.7	74.6	72.8	72.3	67.9	67.0	67.1	66.4
16	69.4	71.7	75.1	74.8	73.2	72.0	70.0	67.5	65.8	64.6
17	65.7	70.7	76.7	77.6	76.7	75.3	73.3	70.9	67.8	65.9
18	65.9	71.5	77.7	78.6	77.4	76.5	73.8	73.4	71.5	70.6
19	65.9	70.1	73.7	73.7	73.6	71.8	70.1	73.5	73.5	74.6
20	64.9	66.7	67.1	68.7	68.6	68.5	69.8	74.7	76.8	77.9
21	65.8	65.3	65.2	65.0	62.9	66.4	67.0	72.1	74.2	76.7
22	64.1	67.2	65.1	66.3	66.8	69.9	71.9	74.8	75.4	77.6
23	62.5	68.2	69.0	70.4	74.0	77.9	79.3	80.3	78.0	79.9
24	62.0	67.5	71.4	75.1	79.4	83.0	84.2	85.4	83.2	83.9
25	60.5	68.2	74.1	78.0	81.0	82.4	83.8	86.8	86.0	83.5
26	62.1	69.0	75.9	75.9	78.0	77.3	78.3	83.2	81.5	79.8
27	63.9	68.7	71.7	73.4	72.9	73.5	75.8	76.5	77.8	80.4
28	65.7	70.1	71.2	73.4	75.4	77.3	75.9	74.2	77.7	82.8
29	65.6	70.4	73.1	75.5	79.0	78.2	76.6	76.7	77.9	82.6
30	63.2	71.0	74.6	77.9	77.1	75.8	78.7	78.5	80.1	80.8
31	63.6	68.8	76.0	78.7	76.5	76.4	80.3	81.9	81.1	74.8
32	62.5	65.7	71.4	74.0	73.7	75.3	80.8	83.3	80.0	72.9
33	66.2	67.8	70.6	73.2	76.3	82.2	87.3	88.9	83.6	76.0
34	69.9	67.7	70.5	75.1	80.8	89.6	92.6	90.6	83.9	74.4
35	68.2	66.1	68.0	74.9	83.3	93.5	91.9	87.2	79.2	67.8
36	69.2	64.9	65.5	72.8	83.6	95.0	90.0	84.0	71.0	60.0
37	67.7	64.8	64.4	69.4	76.8	86.9	83.8	78.0	65.6	55.7

Table 15. cont.

i	j 11	12	13	14	15	16	17	18	19	20
1	79.0	85.1	88.9	91.1	84.0	76.7	71.9	68.2	70.5	76.7
2	75.7	82.5	86.6	90.0	87.7	80.3	74.0	66.2	69.6	76.9
3	80.5	86.8	88.0	95.1	93.5	85.7	81.3	77.6	81.1	85.8
4	79.1	84.4	89.7	93.2	95.0	87.3	86.0	88.8	90.9	93.1
5	80.1	85.3	89.6	95.3	101.0	94.6	96.3	96.4	99.2	100.7
6	75.8	82.8	83.5	89.3	102.0	99.5	97.4	97.7	97.9	98.8
7	71.6	75.6	76.8	82.4	94.5	98.5	96.7	96.4	97.4	99.7
8	70.9	73.0	74.9	81.7	91.4	97.5	98.3	98.1	99.3	99.6
9	70.7	71.7	73.3	79.8	89.1	95.8	94.3	96.2	97.0	92.5
10	71.6	72.2	73.2	80.7	90.7	96.5	96.9	95.1	93.7	90.9
11	73.7	73.4	74.8	80.9	88.4	91.9	92.7	88.1	88.1	87.6
12	73.7	72.9	73.1	77.0	80.3	80.1	82.5	82.2	84.8	85.2
13	72.6	75.2	74.3	76.6	79.0	78.5	81.9	84.2	87.9	89.4
14	69.3	70.9	70.0	74.8	75.2	76.9	82.1	85.0	89.7	90.8
15	68.0	68.7	66.8	73.8	75.7	80.0	88.8	89.1	92.8	92.9
16	66.0	69.3	68.3	74.9	79.8	85.7	93.7	90.0	89.0	86.9
17	67.9	73.1	76.0	84.4	86.9	90.0	94.8	86.3	81.9	78.7
18	71.4	77.4	85.4	94.4	94.8	93.2	93.4	83.5	76.5	70.9
19	76.7	83.5	92.6	98.9	96.6	94.3	91.4	80.9	74.6	67.6
20	80.5	84.5	90.0	97.0	94.9	93.4	90.5	84.1	76.2	68.4
21	80.6	81.8	86.2	92.7	94.8	97.7	98.1	94.6	87.3	77.4
22	81.3	85.5	87.2	92.0	97.4	105.0	107.0	105.0	98.7	89.5
23	82.6	86.0	86.1	89.8	95.4	101.0	107.6	109.3	100.3	94.2
24	85.4	85.9	88.2	92.0	94.6	98.5	106.6	106.4	100.8	98.5
25	80.1	81.1	83.2	89.7	94.0	95.4	97.6	97.5	99.9	100.2
26	79.8	77.4	79.2	92.3	94.2	89.7	89.4	88.5	96.4	100.6
27	83.8	81.7	81.5	91.6	88.5	80.8	77.9	75.7	91.2	98.4
28	87.7	87.0	81.0	80.5	73.1	68.8	65.5	63.5	80.8	89.3
29	87.3	82.1	74.5	75.3	66.6	64.8	65.8	60.2	71.6	78.0
30	75.3	71.6	66.1	69.5	67.2	66.1	65.9	61.3	67.2	62.7
31	66.2	63.5	62.2	69.2	70.7	68.9	67.7	61.5	56.9	50.1
32	66.1	63.0	60.9	64.6	63.8	62.7	59.5	48.8	42.6	38.6
33	68.9	63.7	58.7	56.2	53.8	51.8	48.1	37.1	33.3	33.2
34	67.9	61.5	57.0	54.0	51.1	46.3	41.4	34.6	31.5	34.0
35	63.5	56.1	53.2	54.1	50.7	45.8	42.0	37.1	39.0	39.9
36	57.6	52.1	52.6	57.9	57.4	55.5	53.6	48.4	53.3	52.8
37	55.1	52.7	52.3	55.1	57.7	59.2	58.3	55.8	62.1	62.4

TABLE 15. cont.

i	j 21	22	23	24	25	26	27	28	29
1	85.6	87.9	84.2	81.5	78.3	77.2	74.7	75.0	76.7
2	83.0	86.3	82.2	81.0	80.7	79.6	79.8	80.0	82.4
3	86.4	87.5	84.9	83.8	87.9	85.3	86.3	85.3	86.5
4	88.0	87.0	84.7	86.8	90.5	88.9	91.9	90.8	92.4
5	95.8	94.7	92.5	92.2	92.9	91.1	95.3	96.8	95.7
6	97.7	97.9	95.3	94.1	92.0	88.1	90.6	92.5	93.9
7	102.0	98.9	100.1	100.3	94.1	92.4	90.8	93.9	94.2
8	101.0	99.9	102.9	104.3	98.6	91.9	89.2	91.5	87.6
9	94.2	94.8	97.4	98.3	93.3	90.2	86.0	84.2	84.8
10	91.8	89.8	91.7	92.4	91.9	91.6	87.3	88.0	86.6
11	83.7	83.4	82.3	83.9	84.9	83.7	83.3	85.5	84.4
12	81.9	78.7	77.9	77.5	77.9	80.7	82.6	83.7	83.9
13	84.8	82.0	79.9	78.6	79.8	80.6	81.0	81.7	82.0
14	86.2	82.2	80.0	80.4	79.5	79.4	77.8	76.2	76.5
15	89.1	89.6	88.9	87.6	87.2	86.7	81.0	76.2	75.5
16	84.7	89.0	88.0	88.7	87.7	87.3	83.2	76.7	73.3
17	77.1	82.8	83.3	82.8	81.5	85.0	81.6	75.6	70.3
18	67.4	73.6	73.7	72.0	73.2	78.0	77.6	75.3	72.3
19	62.4	64.6	64.3	63.9	64.8	69.7	74.8	78.2	78.7
20	66.3	66.3	68.8	67.8	66.0	73.4	77.8	84.3	92.5
21	74.3	75.4	79.3	78.0	77.7	85.3	88.5	97.1	106.1
22	87.0	82.8	87.7	89.6	87.5	94.4	97.7	106.6	116.1
23	92.2	86.0	91.2	95.7	96.1	100.4	100.5	107.5	113.5
24	94.5	89.7	97.0	99.2	100.7	106.8	102.1	105.3	107.0
25	94.9	89.1	96.1	101.0	104.8	112.6	109.6	108.9	110.6
26	97.1	93.1	97.1	103.4	108.4	114.1	109.5	109.3	109.6
27	97.5	94.1	93.0	95.1	97.9	105.5	102.6	102.9	102.7
28	90.3	84.9	78.6	78.0	80.8	88.0	87.5	86.6	89.1
29	77.1	68.2	60.1	59.0	61.4	66.8	69.2	71.7	71.0
30	56.7	50.2	43.7	43.3	47.2	53.6	62.4	66.9	65.0
31	44.0	39.4	38.0	36.9	41.0	49.2	58.6	65.0	66.4
32	36.6	34.8	33.3	32.0	36.5	45.2	56.7	62.6	67.6
33	35.3	34.3	32.6	33.4	38.8	48.6	60.5	65.9	72.1
34	36.7	33.5	32.2	35.0	38.2	47.1	55.3	61.8	68.7
35	41.3	39.7	36.5	39.3	40.8	45.8	51.4	57.3	64.9
36	52.3	48.4	46.0	50.0	49.9	55.3	57.5	58.5	63.7
37	62.2	57.3	54.0	59.2	58.4	63.7	60.3	59.0	62.0

A contour map of the area was determined using computer program number 12, PLOT1.BAS, in Appendix B. Figure 33 shows that the lefthand side of the field (first 10 columns), is less variable than the other sections. The bottom half of the field (Rows 16 through 32) are more variable than the upper half. There are isolated pockets of high yields, 100 gm/plot or more, on the righthand side of the field and pockets of low yields, about 32 gm/plot in the lower righthand corner. In these areas of the field, plot variability would be expected to be large and these areas should be avoided for precision plot work.

FIGURE 33. Contour map kriged from cotton seed data, gm/plot.

Minimum = 31 Mean = 79 Maximum = 114

I = 31-40, * = 51-60, # = 71-80, 0 = 91-100, X > 111

Character = 0.76m, Line = 1.4m

```
0       000000000    00000000   #####   000000
0        000000       00000000   ####   000000
0       0000000000   0000    000     0000000000000000000000
00 000000000000000   00000   00000000  0000000000000 00 0
00   00000000000 00   0000   X         X           0
      00000000        00000 XX                   0000
0      00000  #######     00           XX           0
0     0000   #########     0            X  XXXXX   000 0 0
00000000      #########    00                      00000000
 000000             ###    00          00 000       0000000
00000000                   000   00000000000000000000000000
000000000       #               00000000           0000000
00000000    ######  #            0000000000            0 0
    0     ################      00000000000
          ################     00000   0000000000000
###       ################   000  0000000000000000000
###          #########    00000  000      000000 000
###            ######   00       00   ####    #
####      ####        00          0  ###    ###########
##############       0000          000  #############   0000
######## ######        000           000              000  X X
#############        00000   XXXXXXX  000000000000   XXXXX
 #######            0000000   XXXXXXX    000        X XXXXXX
 ####     0000000000000000     XXXXXX     0     XXXXXXXXXX
 ###     00000000000   0000               0   XXXXXXXXXXXX
 ###          00         0    00000       X       XXXXXXXXXXXX
#####              000 0 0 000        0             XXXXXXXXX
######            000000     ##### # 0000000      000000000
####              00000    ######  ##     ##      #########
 ##                   ############ ###   ***    ***  #####
 ###                ###   #########   ***          **  ####
 ####        000   ###    ###     ***    IIIIII    *   # #
######    0000000  ####      *****  IIIIIIIIIIIII  *   ####
#####    000  000  ###    *****    IIIIII IIIIII  **   # #
######  00   000  ##     *******                   ****
######  00  000 ##    ***        ******************
#######  0000  ##    *****                   *     #
```

Figure 34 shows a plot of the original data set suggesting that contour lines would be difficult to draw around the data set because of the extreme variability. However, after viewing the kriged data as displayed in Figure 33, the areas of greatest variability can be found.

FIGURE 34. Contour map of original cotton seed data, gm/plot.

Minimum = 5 Mean = 78 Maximum = 165

I = 5-22, * = 41-58, # = 77-94, O = 113-130, X > 149

Character = 0.76m, Line = 1.4m

Niger Example: At the ICRISAT Sahelien Centre near Niamey, Niger, a field of 190m x 190m was measured to a 10m grid. The field was planted to local millet and intercropped with cowpea. No fertilizer was added. Within each plot the number of established pockets were counted and, from 5 randomly chosen pockets along the diagonal, the number and length of tillers present per pocket was recorded. The total length of tillers/plot was divided by the total number of tillers/plot and this number was multiplied by the number of pockets/plot which represents a yield index (Klay, 1984).

Figure 35 shows the contour distribution for the kriged yield index values. For this data set, the kriged variance = 97.9 $(\text{cm/plot})^2$ with a kriged standard deviation = 9.9 cm/plot. The semivariogram had a range = 39.3m, a sill = 502 $(\text{cm/plot})^2$, and a nugget effect = 318 $(\text{cm/plot})^2$, i.e., 38.8% of the data had complete random behavior. The high areas of variability in the graph confirms fertility residues from research studies of the previous season.

FIGURE 35. Contour map kriged from yield index values, cm/plot.

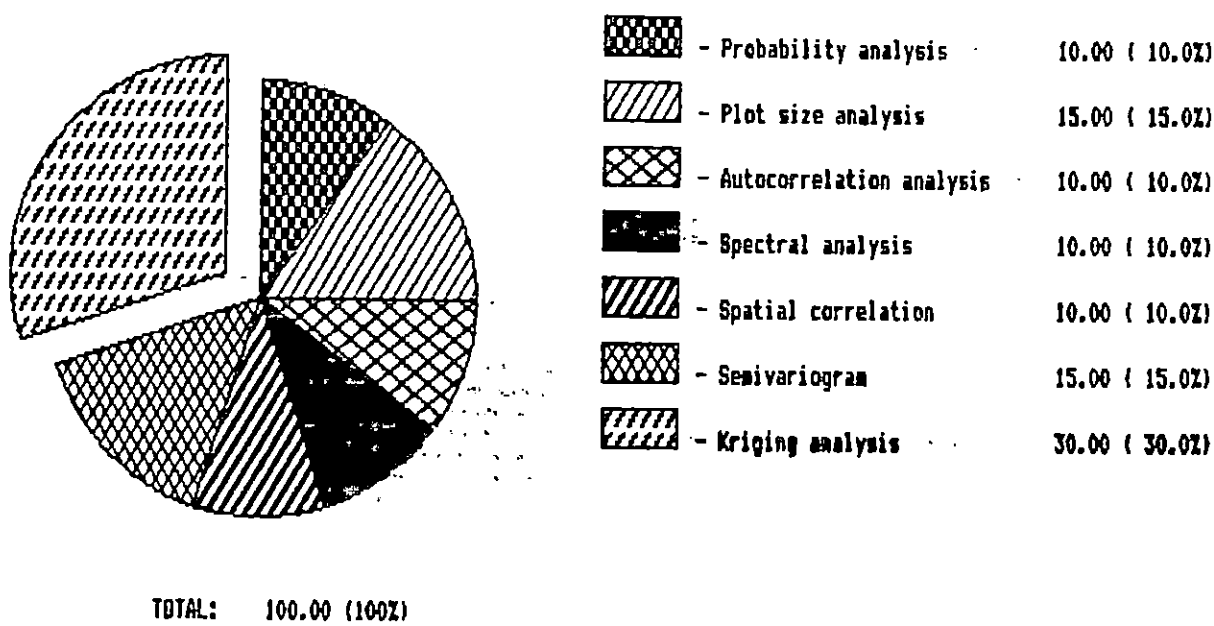
Minimum = 24 Mean = 71 Maximum = 127
I = 24-35, * = 48-59, # = 72-83, O = 96-107, X > 120
Character = 5m, Line = 10m

```
# ** * ## *  II *   *  #    # #
**    *      II  ** ## ### #####
    I  *####*    *** ######## # #
  III   ****** #  ####      ####
***       ***  #O OO# ###
 ###        *** ##  #    # OO
 ####### * **         *   OOO ####
 ** ## ##         #######    #
   ###  O  #  ###    #   ##### #
     O   O #   ####### ###### #
  OO XXXXO    ### ##### ##  #####
#    XXX  O   OO    *   ##  O
 O XXX     OOOO #  *  #OOOOOO O O
  OO  XXX  OO # ** # O   OOOOOOO
 ### # O  OO ##     ## OOO
 *****  #     ###     #      ####
```

CONCLUSIONS

At this point one feels like the new car salesman with instructions to select the world's "best" automobile for a rich client. Cost is no object. Oh yes, when he surveys the lot, he finds a Cadillac, a Mercedes, a Lincoln Continental, an Alpha Romeo, a Porsche, etc., etc., but look all he might, he cannot find a Rolls Royce anywhere on the lot. He knows that each of the other automobiles has many outstanding features but "only" a Rolls Royce puts it all together in one package. Alas, like the car salesman, these researchers, search as they might, could find no "Rolls Royce" within these statistical computer techniques for handling and analysis of the data; and yet, each computer package has several redeeming features.

FIGURE 37. Information by method of analysis.



Evaluation of the various methods of analyses presented in this paper demonstrates that each contributes towards the total explanation of field plot uniformity. Figure 37 shows the proportion of information gleaned when each of the various methods of analyses has been computed on a single data set. Whether any particular method is better than another for any given data would depend upon the "nature" of the data set. For example, if the data set contained cyclic information then the techniques of autocorrelation and spectral analysis would yield more information than plot size or probability analysis.

However, it is possible that kriging analysis might detect the cycles also. To thoroughly examine a data set, a complete analysis using all methods would give the most information.

The total cotton seed data was normally distributed but in need of detrending in all directions. The individual columns and rows showed that 28% of each data set had a log-normal distribution. Using the coefficient of variation as an indicator of field plot variance showed that random error was too large to permit establishment of precision field plots. For example, if a nominal plot size of 5m by 10m was used for a research study, 51 experimental plots would be available for treatment and replication. However, this plot size had a coefficient of variation of 17%; and, if a 10% difference in yield could be tolerated, then 22 replications would be required and only 2 treatments would be available for study. In the past, this type of statistical analysis has been used by many investigators to scoff at the need for replication, i.e., when the sample variance is known "then the whole field is needed for one treatment." It is equally possible that the method of moments does not give an adequate estimate of field uniformity to develop an experimental research design.

The analysis for plot size for the cotton seed data showed that plots greater than 14m distance or 10 plots were independent of each other. A plot size of 14m x 14m would be an optimal size for this field as larger plot areas do not significantly reduce the variance. However, plots of this size had a coefficient of variation of 16% which is large for precision field plot work.

The results of the autocorrelation method for the cotton seed data on individual rows and columns showed high variability with an average range of 5.5m for columns and 3.9m for rows. In all cases, the rapid decline of the autocorrelation coefficient versus lag suggested a large amount of unmanageable random variation. However, this analysis showed that some cyclic phenomena were present in the data set.

The autocorrelation method analyzes only one line of data. However, if only one line of the cotton seed data had been used for analysis to determine the range of dependency, the specific row or column used may or may not have reflected the "true" characteristics of the field. If row = 14 or 15 had been selected arbitrarily then it would have been concluded that only 1 plot or 1.4m would be the range of dependency, i.e., the random variance would have been unmanageable. But, if, by chance, row = 17 had been selected for the analysis then the range would have been 7 plots or 10m distance, i.e., the possibility for a larger experimental plot size.

The spectral analysis method is generally used to determine the location and magnitude of the cyclic nature of events in a data series. However, in this analysis, its use was extended to determine the range of dependency of a data set. The results for the cotton seed data showed an average range of 8 plots for rows and 10 plots for columns. The autocorrelation method had greater variation in the column data than in the row data whereas spectral analysis had greater variation in the row data than in the column data. Spectral analysis of individual rows and columns, once again, showed the presence of high random variability. In addition, some cyclic effects were noted in the analysis of individual rows and columns; however, there was no consistent pattern of cycles.

The spatial correlation method presents a different way of viewing the data of field plot uniformity. This method of analysis for the cotton seed data gave an average range of 6 plots for column data and 11 plots for row data. A technique of solving for the spatial correlation coefficient on the inverse data set permits the investigator to evaluate each row or column in two directions which identifies the problem areas within an experimental field (areas of high variability). These areas could then be avoided or additional management controls could be applied to minimize the effect of these problem areas.

The spatial correlation method and the method of moments both require a large data set which has a normal frequency distribution. The spatial correlation method requires a detrended data set. The problem of trends within a data set affects all covariance methods.

In spite of their complexity, the methods that give the investigator the most information is the semivariogram and kriging. The semivariogram separates the variance into two parts. First, there is the sill, C, which is the variance of the data, and second, there is the nugget effect, C_o, which is a measure of completely random or unpredictable behavior. The semivariogram for the cotton seed data showed the total variance, s^2 = 608 (gm/plot)^2 which was nearly the same as that found using the method of moments where s^2 = 610 (gm/plot)^2. However, the semivariogram partitioned the total variance and showed that 61% was attributed to the nugget effect.

The selection of the correct model for the semivariogram demands experience. Many authors in the literature suggest that wherever the opportunity exists, the "simplest" model should be used, i.e., do not complicate matters. Nevertheless, for the cotton seed data, both linear and exponential models gave few, if any, results because the large nugget effect overshadowed the sample variance. Consequently, it was necessary to use the spherical model in block kriging to obtain an evaluation of the data set.

Kriging is a regionalized method of weighting sample values which "adds in" the results of the semivariogram. For the geostatistician, the smaller the variance the greater the reliability of the kriged estimates. The covariance is computed for the total data set and kriging partitions this variance to determine the kriged variance and kriged sample estimates. Following the contour maps and tables of kriged sample estimates, it is easy to determine the exact location of field uniformity, e.g., the lower righthand corner of the cotton field had the greatest variability. Also, within the range of dependency, 16.5m, all the kriged sample values are computed (neighborhood) which presents a statistical evaluation of the regionalized yield in relation to the sample and nugget effect.

To reduce the nugget effect, C_o, other aspects of sample variability would have to be controlled and studied. For the cotton seed example, techniques would have to be developed to reduce the variability of the following factors: cotton seed to be planted, seedbed preparation, fertilization, planting, soil surface management, germination, thinning, weeding, fertilizer sidedressing, plant diseases, insect damage, harvesting, ginning, weighing and probably many, many more controls should be applied so that a minimum error could be spread uniformly over the entire field. When field research operations are usually performed by hand, rigid controls are beyond the concept of minimum variation and the investigator must be satisfied with "real" variation. Therefore, a high nugget effect also implies management variability, soil variability, climatic or irrigation variability, etc., etc. However, the semivariogram performs a valuable service by measuring the amount of variance attributable to the nugget effect.

Although the method of kriging partitions the variance better than the other methods, the investigator is inevitably left with managing the effects of total variance. Maybe the "best" variance is the kriged variance for a geophysicist's contour map , but it is the total variance that the agricultural scientist must deal with whose statistical methods are patterned on analysis of variance.

Many studies in the literature suggest that kriging could be done on only a few samples or, at the least, half of the original data set. In general, these analyses are performed on large data sets and the arbitrary or random reduction permits a comparison to the "true" or "ideal" size of data set. To estimate the required size of the data set before measurement is the difficult part; albeit, hindsight breeds expertise. Inevitably, large data sets for all analyses are preferable to small or adequate data sets when determining field plot uniformity.

The statistical measures of field plot uniformity, including kriging, do not satisfy the insatiable quest for management alternatives that researchers demand. True, a range of dependency is calculated which varies with the method, but the question of "How does one apply this information?" is not particularly answered in a straight forward manner. If within the range of dependency, it is assumed that the variance is minimum and uniform, then all plot work should be done within this area given by the range of dependency. Therefore, for the cotton seed data, it would be safest to use the upper half of the field for precision research plots.

Recommendations

When agricultural research precision fields are planned, the objective is to measure and compare plant characteristics and soil parameters on a rectangular grid pattern to evaluate field plot uniformity. To measure the variability, the sampling frequency within a grid or along a transect must be determined by using various statistical methods. Since sampling distance could be different for each plant characteristic or soil property, the decision of sample size should reflect the minimum number of samples or plots which would result in the optimal data set for statistical analysis. A micro survey should be performed on each precision field to identify the location of brush, trees, termite mounds, and any other irregularities before implementation of a uniformity study. The types of measurements which could be made are as follows:

A. Soil Measurements:

1. Soil moisture content in each plot for the top 20 cm of the soil surface following a rainfall.

2. Soil penetrometer measurements at 2 depths (0-10cm and 10-20cm, for example).

3. Soil bulk density measured at 2 depths (A and B horizons, for example).

4. Disturbed soil samples taken in the plow layer to determine the 15-bar desorption moisture content.

B. Plant Characteristics:

1. Plant height measured at 2 week intervals with one plant/plot and measurements discontinued at 50% flowering.

2. Total number of established hills/plot at harvest.

3. Total number of heads/plot at harvest.

4. Total threshed grain weight/plot at harvest.

5. Total plant dry matter/plot after grain harvest.

The precision fields should receive a uniform application of fertilizer if it is important to mask the effects of fertility history. Each statistical measure discussed in this paper should be used on each data set for an evaluation of the existing field plot uniformity. If the fields have not been in use as research plots, it can be anticipated that the uniformity will improve with continuous use. Therefore, after a 5 year period, each field should be reevaluated to measure the expected reduction in field variability.

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APPENDIX A

These are the data files, examples, tables and computer output that are too voluminous to enter in the text but useful for a comprehensive understanding of the statistical methods presented in this paper.

1. Cotton seed yield data, collected 1926.

2. Probability output from program number 2. FREQ.BAS.

3. Wave motion and harmonics.

4. Tables for kriging.

    a. Average semivariogram, $\gamma[B_i, S_j]$

    b. Auxiliary function, F(d,b)

    c. Auxiliary function, H(d,b)

1. COTTON SEED YIELD DATA, COLLECTED 1926.

ROW	COLUMN 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	93	95	111	116	97	82	80	131	80	102	97	95	87	136	118	89
2	49	63	50	115	83	78	69	93	85	84	64	69	51	44	115	61
3	89	90	95	129	97	133	72	115	97	76	91	106	40	147	119	66
4	85	91	115	107	99	77	76	63	70	71	59	78	58	85	61	104
5	63	96	68	69	101	120	96	100	70	110	88	75	101	61	106	113
6	86	82	113	74	117	28	83	81	109	91	53	108	83	74	129	89
7	62	86	119	80	79	92	72	103	89	77	67	88	97	50	101	111
8	94	76	119	75	125	96	95	74	90	63	68	66	96	66	85	74
9	45	96	115	130	99	77	104	116	64	77	32	88	67	76	72	87
10	51	79	111	79	84	84	67	63	66	40	56	80	58	68	52	76
11	81	80	72	102	104	81	42	76	85	80	56	74	93	88	60	111
12	74	51	66	86	71	73	98	87	61	111	81	61	73	61	63	85
13	85	89	112	88	105	76	76	78	72	92	59	81	90	52	82	68
14	84	64	101	90	69	101	87	70	63	75	63	88	74	81	68	87
15	85	55	88	87	73	119	60	76	60	73	77	44	83	82	74	52
16	82	83	102	80	88	57	81	55	75	69	70	84	59	73	77	81
17	46	54	83	60	57	75	73	50	66	31	56	66	43	70	59	35
18	71	68	39	80	73	86	64	89	101	88	63	83	74	78	74	50
19	58	52	85	99	72	96	67	86	37	71	62	48	63	64	106	90
20	65	45	77	78	93	60	94	82	72	81	84	64	75	97	114	109
21	57	52	60	71	55	89	71	53	64	74	95	59	68	94	85	90
22	60	90	65	66	59	55	51	79	80	62	95	94	95	96	114	105
23	59	69	39	79	74	68	54	72	69	67	81	72	56	63	92	62
24	63	78	60	83	51	60	60	72	75	45	75	69	93	89	75	87
25	23	67	47	83	74	58	95	108	81	86	88	99	82	90	133	97
26	39	57	83	70	77	89	79	113	77	102	101	74	79	97	100	41
27	79	29	57	77	75	82	87	77	61	85	108	65	64	95	56	81
28	51	54	74	87	71	74	62	62	90	80	83	60	68	53	82	107
29	58	47	86	69	81	60	73	96	73	59	83	83	89	130	74	76
30	56	78	62	55	60	58	111	54	57	76	82	103	114	92	70	39
31	42	70	68	87	79	89	87	91	85	74	67	98	89	69	50	57
32	57	41	81	80	90	78	61	76	78	87	106	41	49	61	70	78
33	44	68	44	71	75	79	64	68	62	118	60	78	63	53	67	51
34	99	33	65	85	64	74	96	74	95	101	56	59	61	77	57	44
35	58	63	68	71	54	59	84	71	94	87	82	73	73	73	48	42
36	79	66	95	74	81	77	94	106	132	80	142	30	83	46	56	29
37	89	51	66	48	65	82	119	101	90	53	69	66	45	54	61	68
38	62	69	58	66	45	77	94	84	98	41	57	58	17	68	45	39
39	81	106	43	84	46	74	56	109	115	61	60	39	66	61	57	37
40	31	87	69	64	76	82	61	64	87	59	99	31	81	45	50	31

1. COTTON SEED YIELD DATA, CONT.

ROW	COLUMN 17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	57	106	118	97	72	120	117	117	66	123	116	86	87	79	78	56
2	54	54	36	88	62	75	52	91	74	66	76	79	54	54	109	87
3	122	63	72	34	47	106	132	97	70	78	56	81	59	81	78	61
4	84	104	59	56	70	66	51	83	77	64	97	87	62	80	87	107
5	93	62	92	109	84	117	101	75	100	104	129	96	107	116	82	101
6	79	89	75	114	106	94	93	71	103	70	63	114	55	92	67	126
7	100	96	66	113	98	86	97	69	105	76	87	73	108	104	116	73
8	160	148	84	110	110	110	83	154	101	103	89	137	79	111	120	82
9	59	123	67	59	113	131	55	101	105	98	98	57	69	78	62	99
10	87	72	91	81	153	82	70	133	96	108	68	92	127	91	110	88
11	128	124	117	118	77	84	104	105	119	101	104	129	53	62	99	75
12	115	80	82	76	86	97	65	75	68	98	67	69	75	89	72	88
13	88	94	68	106	87	106	80	88	71	85	82	108	104	98	95	90
14	82	80	64	105	67	70	58	79	88	58	73	53	85	64	96	86
15	97	65	59	75	110	79	101	74	66	84	87	100	67	83	61	70
16	98	74	95	110	119	93	95	81	102	82	74	82	80	75	85	99
17	90	62	89	96	87	72	80	88	67	67	107	69	79	48	89	59
18	126	98	104	109	45	106	107	100	137	110	102	79	134	45	60	78
19	91	86	83	104	55	70	73	67	67	50	91	88	89	70	56	66
20	111	74	107	86	53	52	90	53	72	70	43	53	106	49	67	62
21	98	94	84	62	60	54	50	35	64	70	54	62	85	77	78	76
22	113	49	123	104	60	71	83	81	79	50	69	76	111	79	108	119
23	103	89	98	64	115	41	73	99	78	72	104	56	121	80	128	157
24	114	147	138	118	106	106	86	85	95	154	78	98	133	125	133	101
25	85	113	137	82	130	82	106	96	53	102	103	82	124	108	116	108
26	77	98	71	98	102	75	77	83	112	106	95	106	93	68	94	103
27	153	116	45	132	103	88	94	123	76	145	103	107	122	94	108	121
28	152	40	80	124	130	105	103	60	75	115	138	129	165	135	143	138
29	133	30	43	81	96	85	86	140	103	92	88	93	97	38	82	103
30	87	35	46	39	52	157	80	63	59	69	63	72	64	68	102	62
31	56	54	71	70	69	92	47	41	29	52	46	79	87	74	73	65
32	145	40	79	103	71	29	51	28	30	37	37	53	49	81	28	36
33	84	40	64	46	34	15	33	56	32	35	42	37	35	97	56	66
34	88	91	29	50	40	32	61	47	8	27	54	72	76	67	89	99
35	28	36	31	13	17	35	18	23	14	22	33	42	52	82	60	72
36	82	25	41	30	23	46	47	35	40	58	63	61	63	92	57	78
37	47	44	32	32	50	37	32	53	17	30	43	5	42	36	62	61
38	82	61	33	72	65	86	37	57	53	44	47	56	76	56	75	87
39	109	71	81	52	79	92	45	62	49	87	111	73	93	58	56	51
40	52	40	50	53	57	97	52	81	82	76	54	55	91	12	50	80

2. PROBABILITY OUTPUT FROM PROGRAM NUMBER 2,FREQ.BAS

COLUMN 7

MEAN OF V(J,I) = 77.875
STANDARD DEVIATION OF V(J,I) = 17.0429
SKEWNESS COEFFICIENT = .226515
KURTOSIS COEFFICIENT = 2.54317
COEFFICIENT OF VARIATION = 21.8849

LOGARITHMIC COTTON SEED YIELD -- GM/PLOT
LOG OF MEAN = 4.33074
LOG OF STANDARD DEVIATION = .224588
LOG OF SKEWNESS COEFFICIENT = -.299029
LOG OF KURTOSIS COEFFICIENT = 2,87882
LOG OF COEFFICIENT OF VARIATION = 5.18623

PROBABILITY FOR NON-LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY = -2.326
VARIABLE V(J,I) = 38.2332 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY = -1.282
VARIABLE V(J,I) = 56.026 AT PROBABILITY = .9
EXCEEDANCE PROBABILITY = -.524
VARIABLE V(J,I) = 68.9445 AT PROBABILITY = .7
EXCEEDANCE PROBABILITY = 0
VARIABLE V(J,I) = 77.875 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY = .524
VARIABLE V(J,I) = 86.8055 AT PROBABILITY = .3
EXCEEDANCE PROBABILITY = 1.282
VARIABLE V(J,I) = 99.724 AT PROBABILITY = .1
EXCEEDANCE PROBABILITY = 1.96
VARIABLE V(J,I) = 111.279 AT PROBABILITY = .025
EXCEEDANCE PROBABILITY = 2.326
VARIABLE V(J,I) = 117.517 AT PROBABILITY = .01

PROBABILITY FOR LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY VALUE = -2.472
VARIABLE V(J,I) = 43.61 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY VALUE = -1.301
VARIABLE V(J,I) = 56.7286 AT PROBABILITY = .9
EXCEEDANCE PROBABILITY VALUE = .033
VARIABLE V(J,I) = 76.545 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY VALUE = 1.258
VARIABLE V(J,I) = 100.786 AT PROBABILITY = .1
EXCEEDANCE PROBABILITY VALUE = 1.945
VARIABLE V(J,I) = 117.6 AT PROBABILITY = .02
EXCEEDANCE PROBABILITY VALUE = 2.178
VARIABLE V(J,I) = 123.918 AT PROBABILITY = .01

RANK	ORDER	PROBABILITY	RECURRENCE
42	40	.97561	1.025
51	39	.95122	1.05128
54	38	.926829	1.07895
56	37	.902439	1.10811
60	36	.878049	1.13889
60	35	.853659	1.17143
61	34	.829268	1.20588
61	33	.804878	1.24242
62	32	.780488	1.28125
64	31	.756098	1.32258
64	30	.731707	1.36667
67	29	.707317	1.41379
67	28	.682927	1.46429
69	27	.658537	1.51852
71	26	.634146	1.57692
72	25	.609756	1.64
72	24	.585366	1.70833
73	23	.560976	1.78261
73	22	.536585	1.86364
76	21	.512195	1.95238
76	20	.487805	2.05
79	19	.463415	2.15789
80	18	.439024	2.27778
81	17	.414634	2.41176
83	16	.390244	2.5625
84	15	.365854	2.73333
87	14	.341463	2.92857
87	13	.317073	3.15385
87	12	.292683	3.41667
94	11	.268293	3.72727
94	10	.243902	4.1
94	9	.219512	4.55556
95	8	.195122	5.125
95	7	.170732	5.85714
96	6	.146341	6.83333
96	5	.121951	8.2
98	4	.097561	10.25
104	3	.0731707	13.6667
111	2	.0487805	20.5
119	1	.0243902	41

INTERVAL	FREQUENCY
42 - 49.7	1
49.7 - 57.4	3
57.4 - 65.1	7
65.1 - 72.8	6
72.8 - 80.5	6
80.5 - 88.2	6
88.2 - 95.9	5
95.9 - 103.6	3
103.6 - 111.3	2
111.3 - 119	1

COLUMN 14

MEAN OF V(J,I) = 76.475
STANDARD DEVIATION OF V(J,I) = 23.267
SKEWNESS COEFFICIENT = 1.14236
KURTOSIS COEFFICIENT = 4.37918
COEFFICIENT OF VARIATION = 30.4243

LOGARITHMIC COOTON SEED YIELD -- GM/PLOT
LOG OF MEAN = 4.29496
LOG OF STANDARD DEVIATION = .285394
LOG OF SKEWNESS COEFFICIENT = .343969
LOG OF KURTOSIS COEFFICIENT = 2.8981
LOG OF COEFFICIENT OF VARIATION = 6.64485

PROBABILITY FOR NON-LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY = -2.326
VARIABLE V(J,I) = 22.3561 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY = 1.282
VARIABLE V(J,I) = 46.6468 AT PROBABILITY = .9
EXCEEDANCE PROBABILITY = -.524
VARIABLE V(J,I) = 64.2831 AT PROBABILITY = .7
EXCEEDANCE PROBABILITY = 0
VARIABLE V(J,I) = 76.475 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY = .524
VARIABLE V(J,I) = 88.6669 AT PROBABILITY = .3
EXCEEDANCE PROBABILITY = 1.282
VARIABLE V(J,I) = 106.303 AT PROBABILITY = .1
EXCEEDANCE PROBABILITY = 1.96
VARIABLE V(J,I) = 122.078 AT PROBABILITY = .025
EXCEEDANCE PROBABILITY = 2.326
VARIABLE V(J,I) = 130.594 AT PROBABILITY = .01

PROBABILITY FOR LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY VALUE = -2.029
VARIABLE V(J,I) = 41.0953 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY VALUE = -1.231

VARIABLE V(J,I) = 51.606 AT PROBABILITY = .9
EXCEEDANCE PROBABILITY VALUE = -.066
VARIABLE V(J,I) = 71.9608 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY VALUE = 1.137
VARIABLE V(J,I) = 101.438 AT PROBABILITY = .1
EXCEEDANCE PROBABILITY VALUE = 2.261
VARIABLE V(J,I) = 139.803 AT PROBABILITY = .02
EXCEEDANCE PROBABILITY VALUE = 2.615
VARIABLE V(J,I) = 154.665 AT PROBABILITY = .01

RANK	ORDER	PROBABILITY	RECURRENCE
44	40	.97561	1.025
45	39	.95122	1.05128
46	38	.926829	1.07895
50	37	.902439	1.10811
52	36	.878049	1.13889
53	35	.853659	1.17143
53	34	.829268	1.20588
54	33	.804878	1.24242
61	32	.780488	1.28125
61	31	.756098	1.32258
61	30	.731707	1.36667
61	29	.682927	1.41379
63	28	.682927	1.46429
64	27	.658537	1.51852
66	26	.634146	1.57692
68	25	.609756	1.64
68	24	.585366	1.70833
69	23	.560976	1.78261
70	22	.536585	1.86364
73	21	.512195	1.95238
73	20	.487805	2.05
74	19	.463415	2.15789
76	18	.439024	2.27778
77	17	.414634	2.41176
78	16	.390244	2.5625
81	15	.365854	2.73333
82	14	.341463	2.92857
85	13	.317073	3.15385
88	12	.292683	3.41667
89	11	.268293	3.72727
90	10	.243902	4.1
92	9	.219512	4.55556
94	8	.195122	5.125
95	7	.170732	5.85714
96	6	.146341	6.83333
97	5	.121951	8.2
97	4	.097561	10.25
130	3	.0731707	13.6667
136	2	.0487805	20.5
147	1	.0243902	41

INTERVAL			FREQUENCY)
44	--	54.3	8
54.3	--	64.6	6
64.6	--	74.9	8
74.9	--	85.2	6
85.2	--	95.5	6
95.2	--	105.8	3
105.8	--	116.1	0
116.1	--	126.4	0
126.4	--	136.7	2
136.7	--	147	1

ROW 19

MEAN OF V(J,I) = 73.8125
STANDARD DEVIATION OF V(J,I) = 17.1801
SKEWNESS COEFFICIENT = .01007
KURTOSIS COEFFICIENT = 2.19568
COEFFICIENT OF VARIATION = 23.2753

LOGARITHMIC COTTON SEED YIELD -- GM/PLOT
LOG OF MEAN = 4.2726
LOG OF STANDARD DEVIATION = .245721
LOG OF SKEWNESS COEFFICIENT = -.507035
LOG OF KURTOSIS COEFFICIENT = 2.79592
LOG OF COEFFICIENT OF VARIATION = 5.7511

PROBABILITY FOR NON-LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY = -2.326
VARIABLE V(I,J = 33.8517 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY = -1.282
VARIABLE V(I,J) = 51.7877 AT PROBABILITY = .9
EXCEEDANCE PROBABILITY = -.524
VARIABLE V(I,J) = 64.8102 AT PROBABILITY = .7
EXCEEDANCE PROBABILITY = 0
VARIABLE V(I,J) = 73.8125 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY = .524
VARIABLE V(I,J) = 82.8149 AT PROBABILITY = .3
EXCEEDANCE PROBABILITY = 1.282
VARIABLE V(I,J) = 95.8373 AT PROBABILITY = .1
EXCEEDANCE PROBABILITY = 1.96
VARIABLE V(I,J) = 107.485 AT PROBABILITY = .025
EXCEEDANCE PROBABILITY = 2.326
VARIABLE V(I,J) = 113.773 AT PROBABILITY = .01

PROBABILITY FOR LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY VALUE = -2.686
VARIABLE V(I,J) = 37.062 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY VALUE = -1.323

VARIABLE V(I,J) = 51.8062 AT PROBABILITY = .09
EXCEEDANCE PROBABILITY VALUE = .083
VARIABLE V(I,J) = 73.A853 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY VALUE = 1.216
VARIABLE V(I,J) = 96.6791 AT PROBABILITY = .1
EXCEEDANCE PROBABILITY VALUE = 1.777
VARIABLE V(I,J) = 110.969 AT PROBABILITY = .02
EXCEEDANCE PROBABILITY VALUE = 1.955
VARIABLE V(I,J) = 115.93 AT PROBABILITY = .01

RANK	ORDER	PROBABILITY	RECURRENCE
37	32	.969697	1.03125
48	31	.939394	1.06452
50	30	.909091	1.1
52	29	.878788	1.13793
55	28	.848485	1.17857
56	27	.818182	1.22222
58	26	.787879	1.26923
62	25	.757576	1.32
63	24	.727273	1.375
64	23	.69697	1.43478
66	22	.666667	1.5
67	21	.636364	1.57143
67	20	.606061	1.65
67	19	.575758	1.73684
70	18	.545455	1.83333
70	17	.515152	1.94118
71	16	.484849	2.0625
72	15	.454545	2.2
73	14	.424242	2.358714
83	13	.393939	2.53846
85	12	.363636	2.75
86	11	.333333	3
86	10	.30303	3.3
88	9	.272727	3.66667
89	8	.242424	4.125
90	7	.212121	4.71429
91	6	.181818	5.5
91	5	.151515	6.6
96	4	.121212	8.25
99	3	.0909091	11
104	2	.0606061	16.5
106	1	.030303	33

INTERVAL			FREQUENCY
37	--	43.9	1
43.9	--	50.8	2
50.8	--	57.7	3
57.7	--	64.6	4
64.6	--	71.5	7
71.5	--	78.4	2
78.4	--	85.3	2
85.3	--	92.2	7
92.2	--	99.1	2
99.1	--	106	2

ROW 23

MEAN OF V(I,J) = 79.8125
STANDARD DEVIATION OF V(I,J) = 25.2059
SKEWNESS COEFFICIENT = 1.02498
KURTOSIS COEFFICIENT = 4.09181
COEFFICIENT OF VARIATION = 31.5814

LOGARITHMIC COTTON SEED YIELD -- GM/PLOT
LOG OF MEAN = 4.33318
LOG OF STANDARD DEVIATION = .303052
LOG OF SKEWNESS COEFFICIENT = .12116
LOG OF KURTOSIS COEFFICIENT = 3.06814
LOG OF COEFFICIENT OF VARIATION = 6.99377

PROBABILITY FOR NON-LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY = -2.326
VARIABLE V(I,J) = 21.1835 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY = -1.282
VARIABLE V(I,J) = 47.4985 AT PROBABILITY = .9
EXCEEDANCE PROBABILITY = -.524
VARIABLE V(I,J) = 66.6046 AT PROBABILITY = .7
EXCEEDANCE PROBABILITY = 0
VARIABLE V(I,J) = 79.8125 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY = .524
VARIABLE V(I,J) = 93.0204 AT PROBABILITY = .3
EXCEEDANCE PROBABILITY = 1.282
VARIABLE V(I,J)S = 112.127 AT PROBABILITY = .1
EXCEEDABCE PROBABILITY = 1.96
VARIABLE V(I,J) = 129.216 AT PROBABILITY = .025
EXCEEDANCE PROBABILITY = 2.326
VARIABLE V(I,J) = 138.442 AT PROBABILITY = .01

PROBABILITY FOR LOGARITHMIC VALUES
EXCEEDANCE PROBABILITY VALUE = -2.178
VARIABLE V(I,J) = 39.375 AT PROBABILITY = .99
EXCEEDANCE PROBABILITY VALUE = -1.258

VARIABLE V(I,J) = 52.0362 AT PROBABILITY = .9
EXCEEDANCE PROBABILITY VALUE = -.033
VARIABLE V(I,J) = 75.428 AT PROBABILITY = .5
EXCEEDANCE PROBABILITY VALUE = 1.301
VARIABLE V(I,J) = 113.007 AT PROBABILITY = .1
EXCEEDANCE PROBABILITY VALUE = 2.159
VARIABLE V(I,J) = 146.565 AT PROBABILITY = .02
EXCEEDANCE PROBABILITY VALUE = 2.472
VARIABLE V(I,J) = 161.148 AT PROBABILITY = .01

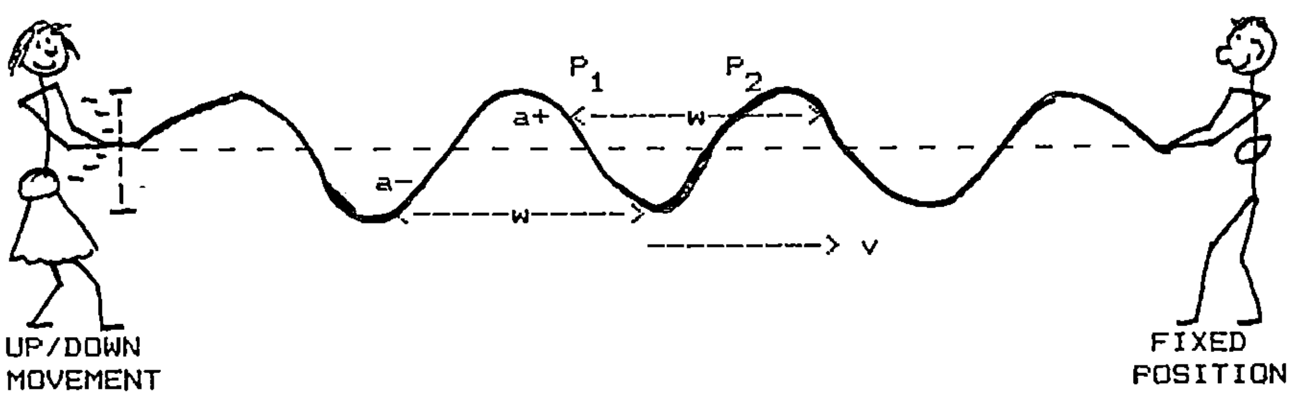
RANK	ORDER	PROBABILITY	RECURRENCE
39	32	.969697	1.03125
41	31	.939394	1.06452
54	30	.909091	1.1
56	29	.878788	1.13793
56	28	.848485	1.17857
59	27	.818182	1.22222
62	26	.787879	1.26923
63	25	.757576	1.32
64	24	.727273	1.375
67	23	.69697	1.43478
68	22	.666667	1.5
69	21	.636364	1.57143
69	20	.606061	1.65
72	19	.575758	1.73684
72	18	.545455	1.8333
72	17	.515152	1.94118
73	16	.484849	2.0625
74	15	.454545	2.2
78	14	.424242	2.35714
79	13	.393939	2.53846
80	12	.363636	2.75
81	11	.333333	3
89	10	.30303	3.3
92	9	.272727	3.66667
98	8	.242424	4.125
99	7	.212121	4.71429
103	6	.181818	5.5
104	5	.151515	6.6
115	4	.121212	8.25
121	3	.0909091	11
128	2	.0606061	16.5
157	1	.030303	33

INTERVAL			FREQUENCY
39	--	50.8	2
50.8	--	62.6	5
62.6	--	74.4	11
74.4	--	86.2	4
86.2	--	98	3
98	--	109.8	3
109.8	--	121.6	2
121.6	--	133.4	1
133.4	--	145.2	0
145.2	--	157	1

3. WAVE MOTION AND HARMONICS

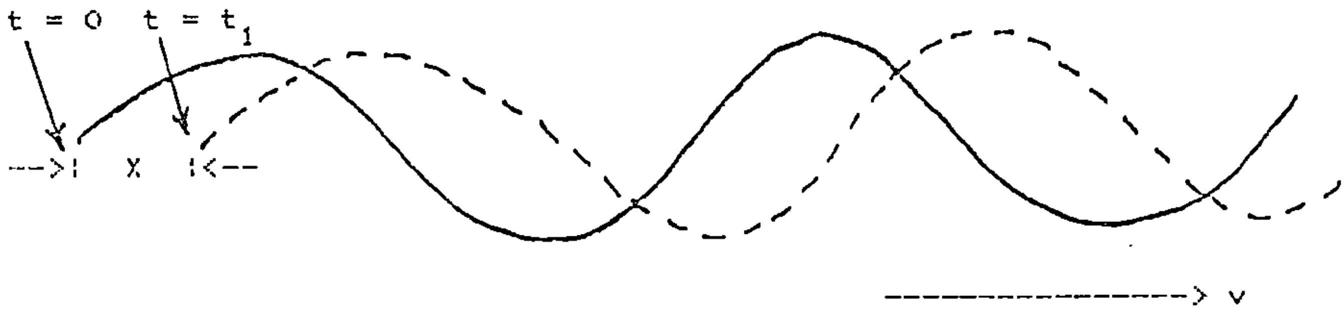
The vibrating rope model, as a hypothetical example of a continuous repeating wave, can be produced by two children and a stretched long rope. At one end, the child holds fast and remains as rigid as possible while at the other end, the child raises and lowers the stretched rope with mechanical repetition. If the child vibrates the rope with simple harmonic motion, then the waves in the rope will also be sinusoidal and at any particular instant of time, say t = 0, the wave produced can be represented by a sine curve as shown in Figure 3A. The maximum displacement of the rope above or below the equilibrium position is the amplitude of the wave a, i.e., half the height of the wave form. The distance between the two crests or from a point on one wave, P_1, to an equivalent point on the next wave, P_2, is called the wave length, w. The number of waves that pass any point per unit of time or length is the frequency, f, and the reciprocal of the wavelength is the frequency, or f = 1/w.

FIGURE 3A. Waves traveling along a stretched rope to the right at velocity, v, away from a continuous source.



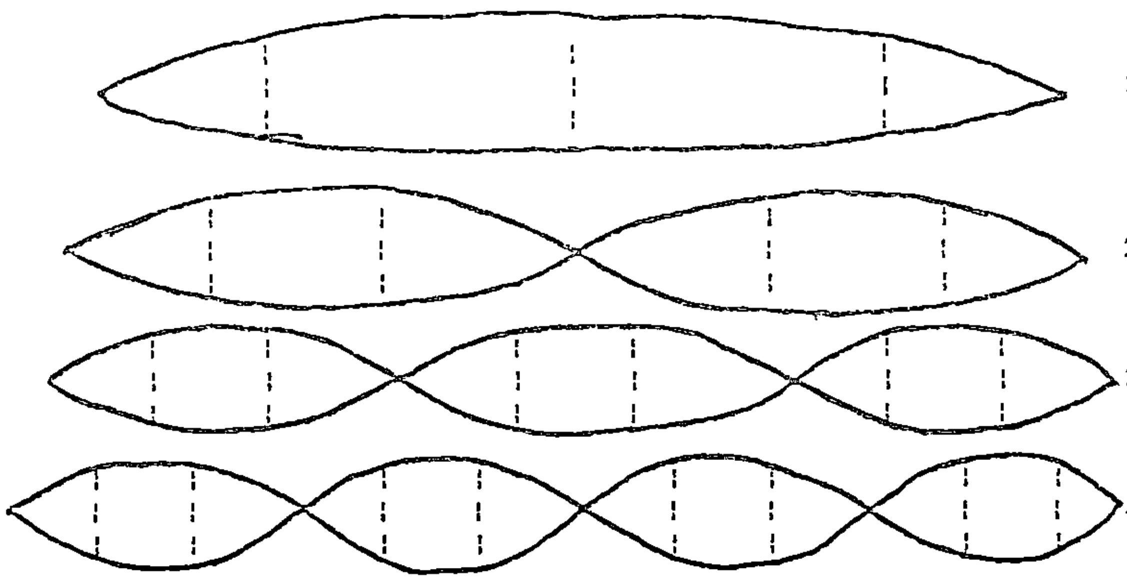
If a photograph is taken at another time, say at t = t_1, then two wave patterns would appear displaced laterally through a distance X as shown in Figure 3B. In order to move the graph at time t = t_1 to coincide with that at t = 0, it would be moved backwards along the horizontal axis a distance X. The offset of this distance X is called the phase angle,Ø.

FIGURE 3B. Waves traveling at successive instants, t = 0 and $t = t_1$.



When two exact similar waves meet which are traveling in opposite directions, a standing pattern can be formed. This could occur if both children in Figure 3A were vibrating the rope at the same rate but at 180^{0} difference, i.e., when one moves the hands up the other moves the hands down while maintaining a tight rope. If someone could stand back and view this or take a picture, they would see a "standing" pattern formed and the sine waves would appear to be stationary rather than traveling. Now, if another child were to stand exactly midway and hold the rope at a point so that no motion could occur (known as a "node") then conceivably two waves would occur. If more children were added at equidistant positions along the stretched rope then a variety of standing wave patterns could be developed as shown in Figure 3C.

FIGURE 3C. Standing wave patterns in a stretched rope.



It will be noticed that as more nodes are added, the amplitude of the vibration decreases; however, to maintain the oscillation, the frequency has to be increased. When the rope vibrates in one segment, as shown in Figure 3C (1), then this wave is known as the fundamental frequency (fundamental mode) and is designated as the first harmonic. The next frequency above the fundamental frequency at which a standing wave pattern appears is shown in Figure 3C (2) where the wavelength is equal to the length of the rope. This wave pattern vibrates in two segments which is twice the fundamental frequency and is known as the second harmonic (first overtone). Also shown in Figure 3C are the standing wave forms (3) the third harmonic (second overtone) and (4) the fourth harmonic (third overtone). These harmonics can be added together to give additional complex wave forms.

The importance of any harmonic is the magnitude of its amplitude, a. If the amplitude disappears, then the harmonic is not present in the wave. In reality, the actual wavelength is not known and the length of the data set to be analyzed is taken for the fundamental length of the first harmonic. Then by manipulation of the Fourier equation, the power spectrum at the various harmonics can be evaluated.

4. TABLES FOR KRIGING

TABLE 4A: Average semivariogram, $\gamma(S_i, S_j)$, for the set of linear equations for kriging.

$$\gamma(1,1) = 0$$

$$\gamma(1,2) = 238\left[\frac{3}{2}\,\frac{1.4}{16.5} - \frac{1}{2}\left(\frac{1.3}{16.5}\right)^3\right] + 370 = 400.2gm^2$$

$$\gamma(1,3) = \gamma(1,2)$$

$$\gamma(1,4) = 238\left[\frac{3}{2}\,\frac{1.98}{16.5} - \frac{1}{2}\left(\frac{1.98}{16.5}\right)^3\right] + 370 = 412.6gm^2$$

$$\gamma(1,5) = \gamma(1,4)$$
$$\gamma(1,6) = \gamma(1,2)$$
$$\gamma(1,7) = \gamma(1,4)$$

$$\gamma(1,8) = 238\left[\frac{3}{2}\,\frac{3.13}{16.5} - \frac{1}{2}\left(\frac{3.13}{16.5}\right)^3\right] + 370 = 436.9gm^2$$

$$\gamma(1,9) = 238\left[\frac{3}{2}\,\frac{2.8}{16.5} - \frac{1}{2}\left(\frac{2.8}{16.5}\right)^3\right] + 370 = 430.0gm^2$$

$$\gamma(1,10) = \gamma(1,8)$$

$$\gamma(1,11) = 238\left[\frac{3}{2}\,\frac{3.87}{16.5} - \frac{1}{2}\left(\frac{3.87}{16.5}\right)^3\right] + 370 = 452.2gm^2$$

$$\gamma(1,12) = \gamma(1,8)$$
$$\gamma(1,13) = \gamma(1,9)$$
$$\gamma(1,14) = \gamma(1,8)$$
$$\gamma(1,15) = \gamma(1,4)$$
$$\gamma(1,16) = \gamma(1,2)$$

TABLE 4A. CONT.

γ(2,1)	=	γ(1, 2)	γ(3,1)	=	γ(1,2)	γ(4,1)	=	γ(1,4)
γ(2,2)	=	0	γ(3,2)	=	γ(1,4)	γ(4,2)	=	γ(1,2)
γ(2,3)	=	γ(1,4)	γ(3,3)	=	0	γ(4,3)	=	γ(1,2)
γ(2,4)	=	γ(1,2)	γ(3,4)	=	γ(1,2)	γ(4,4)	=	0
γ(2,5)	=	γ(1,8)	γ(3,5)	=	γ(1,8)	γ(4,5)	=	γ(1,11)
γ(2,6)	=	γ(1,4)	γ(3,6)	=	γ(1,9)	γ(4,6)	=	γ(1,8)
γ(2,7)	=	γ(1,2)	γ(3,7)	=	γ(1,8)	γ(4,7)	=	γ(1,9)
γ(2,8)	=	γ(1,4)	γ(3,8)	=	γ(1,11)	γ(4,8)	=	γ(1,8)
γ(2,9)	=	γ(1,2)	γ(3,9)	=	γ(1,8)	γ(4,9)	=	γ(1,4)
γ(2,10)	=	γ(1,4)	γ(3,10)	=	γ(1,9)	γ(4,10)	=	γ(1,2)
γ(2,11)	=	γ(1,8)	γ(3,11)	=	γ(1,8)	γ(4,11)	=	γ(1,4)
γ(2,12)	=	γ(1,9)	γ(3,12)	=	γ(1,4)	γ(4,12)	=	γ(1,2)
γ(2,13)	=	γ(1,8)	γ(3,13)	=	γ(1,2)	γ(4,13)	=	γ(1,4)
γ(2,14)	=	γ(1,11)	γ(3,14)	=	γ(1,4)	γ(4,14)	=	γ(1,8)
γ(2,15)	=	γ(1,8)	γ(3,15)	=	γ(1,2)	γ(4,15)	=	γ(1,9)
γ(2,16)	=	γ(1,9)	γ(3,16)	=	γ(1,4)	γ(4,16)	=	γ(1,8)

γ(5,1) = γ(1,2)
γ(5,2) = γ(1,8)
γ(5,3) = γ(1,8)
γ(5,4) = γ(1,11)
γ(5,5) = 0
γ(5,6) = γ(1,2)
γ(5,7) = γ(1,9)

$$\gamma(5,8) = 238\left[\frac{3}{2}\,\frac{4.27}{16.5} - \frac{1}{2}\left(\frac{4.27}{16.5}\right)^3\right] + 370 = 460.3\text{gm}^2$$

$$\gamma(5,9) = 238\left[\frac{3}{2}\,\frac{4.49}{16.5} - \frac{1}{2}\left(\frac{4.49}{16.5}\right)^3\right] + 370 = 464.8\text{gm}^2$$

$$\gamma(5,10) = 238\left[\frac{3}{2}\,\frac{5.11}{16.5} - \frac{1}{2}\left(\frac{5.11}{16.5}\right)^3\right] + 370 = 477.0\text{gm}^2$$

$$\gamma(5,11) = 238\left[\frac{3}{2}\,\frac{6.04}{16.5} - \frac{1}{2}\left(\frac{6.04}{16.5}\right)^3\right] + 370 = 494.9\text{gm}^2$$

γ(5,12) = γ(5,10)
γ(5,13) = γ(5,9)
γ(5,14) = γ(5,8)
γ(5,15) = γ(1,9)
γ(5,16) = γ(1,2)

TABLE 4A. CONT.

√(6,1)	=	√(1,2)	√(7,1)	=	√(1,4)	√(8,1)	=	√(1,8)
√(6,2)	=	√(1,4)	√(7,2)	=	√(1,2)	√(8,2)	=	√(1,4)
√(6,3)	=	√(1,9)	√(7,3)	=	√(1,8)	√(8,3)	=	√(1,11)
√(6,4)	=	√(1,8)	√(7,4)	=	√(1,9)	√(8,4)	=	√(1,8)
√(6,5)	=	√(1,2)	√(7,5)	=	√(1,9)	√(8,5)	=	√(5,8)
√(6,6)	=	0	√(7,6)	=	√(1,2)	√(8,6)	=	√(1,9)
√(6,7)	=	√(1,2)	√(7,7)	=	0	√(8,7)	=	√(1,2)
√(6,8)	=	√(1,9)	√(7,8)	=	√(1,2)	√(8,8)	=	0
√(6,9)	=	√(1,8)	√(7,9)	=	√(1,4)	√(8,9)	=	√(1,2)
√(6,10)	=	√(1,11)	√(7,10)	=	√(1,8)	√(8,10)	=	√(1,9)
√(6,11)	=	√(5,10)	√(7,11)	=	√(5,9)	√(8,11)	=	√(5,8)
√(6,12)	=	√(5,9)	√(7,12)	=	√(5,8)	√(8,12)	=	√(5,9)
√(6,13)	=	√(5,8)	√(7,13)	=	√(5,9)	√(8,13)	=	√(5,10)
√(6,14)	=	√(5,9)	√(7,14)	=	√(5,10)	√(8,14)	=	√(5,11)
√(6,15)	=	√(1,8)	√(7,15)	=	√(1,11)	√(8,15)	=	√(5,10)
√(6,16)	=	√(1,4)	√(7,16)	=	√(1,8)	√(8,16)	=	√(5,9)
√(9,1)	=	√(1,9)	√(10,1)	=	√(1,8)	√(11,1)	=	√(1,11)
√(9,2)	=	√(1,2)	√(10,2)	=	√(1,4)	√(11,2)	=	√(1,8)
√(9,3)	=	√(1,8)	√(10,3)	=	√(1,9)	√(11,3)	=	√(1,8)
√(9,4)	=	√(1,4)	√(10,4)	=	√(1,2)	√(11,4)	=	√(1,4)
√(9,5)	=	√(5,9)	√(10,5)	=	√(5,10)	√(11,5)	=	√(5,11)
√(9,6)	=	√(1,8)	√(10,6)	=	√(1,11)	√(11,6)	=	√(5,10)
√(9,7)	=	√(1,4)	√(10,7)	=	√(1,8)	√(11,7)	=	√(5,9)
√(9,8)	=	√(1,2)	√(10,8)	=	√(1,9)	√(11,8)	=	√(5,8)
√(9,9)	=	0	√(10,9)	=	√(1,2)	√(11,9)	=	√(1,9)
√(9,10)	=	√(1,2)	√(10,10)	=	0	√(11,10)	=	√(1,2)
√(9,11)	=	√(1,9)	√(10,11)	=	√(1,2)	√(11,11)	=	0
√(9,12)	=	√(1,8)	√(10,12)	=	√(1,4)	√(11,12)	=	√(1,2)
√(9,13)	=	√(1,11)	√(10,13)	=	√(1,8)	√(11,13)	=	√(1,9)
√(9,14)	=	√(5,10)	√(10,14)	=	√(5,9)	√(11,14)	=	√(5,8)
√(9,15)	=	√(5,9)	√(10,15)	=	√(5,8)	√(11,15)	=	√(5,9)
√(9,16)	=	√(5,8)	√(10,16)	=	√(5,9)	√(11,16)	=	√(5,10)

TABLE 4A. CONT.

√(12,1) =	√(1,8)	√(13,1) =	√(1,9)	√(14,1) =	√(1,8)
√(12,2) =	√(1,9)	√(13,2) =	√(1,8)	√(14,2) =	√(1,11)
√(12,3) =	√(1,4)	√(13,3) =	√(1,2)	√(14,3) =	√(1,4)
√(12,4) =	√(1,2)	√(13,4) =	√(1,4)	√(14,4) =	√(1,8)
√(12,5) =	√(5,10)	√(13,5) =	√(5,9)	√(14,5) =	√(5,8)
√(12,6) =	√(5,9)	√(13,6) =	√(5,8)	√(14,6) =	√(5,9)
√(12,7) =	√(5,8)	√(13,7) =	√(5,9)	√(14,7) =	√(5,10)
√(12,8) =	√(5,9)	√(13,8) =	√(5,10)	√(14,8) =	√(5,11)
√(12,9) =	√(1,8)	√(13,9) =	√(1,11)	√(14,9) =	√(5,10)
√(12,10)=	√(1,4)	√(13,10)=	√(1,8)	√(14,10)=	√(5,9)
√(12,11)=	√(1,2)	√(13,11)=	√(1,9)	√(14,11)=	√(5,8)
√(12,12)=	0	√(13,12)=	√(1,2)	√(14,12)=	√(1,9)
√(12,13)=	√(1,2)	√(13,13)=	0	√(14,13)=	√(1,2)
√(12,14)=	√(1,9)	√(13,14)=	√(1,2)	√(14,14)=	0
√(12,15)=	√(1,8)	√(13,15)=	√(1,4)	√(14,15)=	√(1,2)
√(12,16)=	√(1,11)	√(13,16)=	√(1,8)	√(14,16)=	√(1,9)

√(15,1) =	√(1,4)	√(16,1) =	√(1,2)
√(15,2) =	√(1,8)	√(16,2) =	√(1,9)
√(15,3) =	√(1,2)	√(16,3) =	√(1,4)
√(15,4) =	√(1,9)	√(16,4) =	√(1,8)
√(15,5) =	√(1,9)	√(16,5) =	√(1,2)
√(15,6) =	√(1,8)	√(16,6) =	√(1,4)
√(15,7) =	√(1,11)	√(16,7) =	√(1,8)
√(15,8) =	√(5,10)	√(16,8) =	√(5,9)
√(15,9) =	√(5,9)	√(16,9) =	√(5,8)
√(15,10)=	√(5,8)	√(16,10)=	√(5,9)
√(15,11)=	√(5,9)	√(16,11)=	√(5,10)
√(15,12)=	√(1,8)	√(16,12)=	√(1,11)
√(15,13)=	√(1,4)	√(16,13)=	√(1,8)
√(15,14)=	√(1,2)	√(16,14)=	√(1,9)
√(15,15)=	0	√(16,15)=	√(1, 2)
√(15,16)=	√(1,2)	√(16,16)=	0

TABLE 4B: Auxiliary function F(d,b) for spherical model with range, a = 1.0 and sill, C = 1.0.

d	b = .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
.10	.078	.120	.165	.211	.256	.300	.342	.383	.422	.457
.20	.120	.155	.196	.237	.280	.321	.362	.401	.438	.473
.30	.165	.196	.231	.270	.309	.349	.387	.424	.460	.493
.40	.211	.237	.270	.305	.342	.379	.415	.451	.484	.516
.50	.256	.280	.309	.342	.376	.411	.445	.479	.511	.541
.60	.300	.321	.349	.379	.411	.443	.476	.507	.538	.566
.70	.342	.362	.387	.415	.445	.476	.506	.536	.565	.591
.80	.383	.401	.424	.451	.479	.507	.536	.564	.591	.616
.90	.422	.438	.460	.484	.511	.538	.565	.591	.616	.640
1.00	.457	.473	.493	.516	.541	.566	.591	.616	.640	.662
1.20	.520	.534	.551	.572	.593	.616	.638	.660	.682	.701
1.40	.572	.584	.600	.618	.367	.657	.677	.697	.716	.733
1.60	.614	.625	.639	.655	.673	.691	.709	.727	.744	.760
1.80	.650	.659	.672	.687	.703	.719	.736	.752	.767	.782
2.00	.679	.688	.700	.713	.728	.743	.758	.773	.787	.800
2.50	.735	.743	.752	.763	.775	.788	.800	.813	.824	.835
3.00	.775	.781	.789	.799	.809	.820	.830	.841	.851	.860
3.50	.804	.810	.817	.825	.834	.843	.852	.861	.870	.878
4.00	.827	.832	.838	.845	.853	.861	.870	.878	.885	.892
5.00	.860	.864	.869	.874	.881	.887	.894	.901	.907	.913

d	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	5.0
.10	.520	.572	.614	.650	.679	.735	.775	.804	.827	.860
.20	.534	.584	.625	.659	.688	.743	.781	.810	.832	.864
.30	.551	.600	.639	.672	.700	.752	.789	.817	.838	.869
.40	.572	.618	.655	.687	.713	.763	.799	.825	.845	.874
.50	.593	.637	.673	.703	.728	.775	.809	.834	.853	.881
.60	.616	.657	.691	.719	.743	.788	.820	.843	.861	.887
.70	.638	.677	.709	.736	.758	.800	.830	.852	.870	.894
.80	.660	.697	.727	.752	.773	.813	.841	.861	.878	.901
.90	.682	.716	.744	.767	.787	.824	.851	.870	.885	.907
1.00	.701	.733	.760	.782	.800	.835	.860	.878	.892	.913
1.20	.736	.764	.788	.807	.823	.854	.876	.892	.905	.923
1.40	.764	.790	.811	.828	.842	.870	.890	.904	.915	.931
1.60	.788	.811	.829	.845	.858	.883	.901	.914	.924	.938
1.80	.807	.828	.845	.859	.871	.894	.910	.921	.931	.944
2.00	.823	.842	.858	.871	.882	.903	.917	.928	.936	.948
2.50	.854	.870	.883	.894	.903	.920	.932	.941	.948	.957
3.00	.876	.890	.901	.910	.917	.932	.942	.950	.955	.964
3.50	.892	.904	.914	.921	.928	.941	.950	.956	.961	.969
4.00	.905	.915	.924	.931	.936	.948	.955	.961	.966	.972
5.00	.923	.931	.938	.944	.948	.957	.964	.969	.972	.977

Table 4C: Auxiliary function H(d,b) for spherical model with range, a = 1 and sill C = 1.

d	b: .1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
.10	.114	.177	.243	.310	.374	.436	.494	.546	.593	.633
.20	.177	.227	.285	.346	.406	.464	.518	.568	.613	.651
.30	.243	.285	.336	.390	.445	.499	.550	.597	.639	.674
.40	.310	.346	.390	.439	.489	.539	.586	.629	.668	.701
.50	.374	.406	.445	.489	.535	.580	.623	.663	.698	.728
.60	.436	.464	.499	.539	.580	.621	.660	.697	.728	.755
.70	.494	.518	.550	.586	.623	.660	.696	.729	.757	.781
.80	.546	.568	.597	.629	.663	.697	.729	.758	.783	.805
.90	.593	.613	.639	.668	.698	.728	.757	.783	.806	.826
1.00	.633	.651	.674	.701	.728	.755	.781	.805	.826	.843
1.20	.694	.709	.729	.751	.774	.796	.818	.837	.855	.869
1.40	.738	.751	.767	.786	.806	.825	.844	.861	.875	.888
1.60	.771	.782	.797	.813	.830	.847	.863	.878	.891	.902
1.80	.796	.806	.819	.834	.849	.864	.879	.892	.903	.913
2.00	.817	.826	.837	.850	.864	.878	.891	.902	.913	.921
2.50	.853	.860	.870	.880	.891	.902	.913	.922	.930	.937
3.00	.878	.884	.891	.900	.909	.918	.927	.935	.942	.948
3.50	.895	.900	.907	.914	.922	.930	.938	.944	.950	.955
4.00	.908	.913	.919	.925	.932	.939	.945	.951	.956	.961
5.00	.927	.930	.935	.940	.946	.951	.956	.961	.965	.969

d	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	5.0
.10	.694	.738	.771	.796	.817	.853	.878	.895	.908	.729
.20	.709	.751	.782	.806	.826	.860	.884	.900	.913	.930
.30	.729	.767	.797	.819	.837	.870	.891	.907	.919	.935
.40	.751	.786	.813	.834	.850	.880	.900	.914	.925	.940
.50	.774	.806	.830	.849	.864	.891	.909	.922	.932	.946
.60	.796	.825	.847	.864	.878	.902	.918	.930	.939	.951
.70	.818	.844	.863	.879	.891	.913	.927	.938	.945	.956
.80	.837	.861	.878	.892	.902	.922	.935	.944	.951	.961
.90	.855	.875	.891	.903	.913	.930	.942	.950	.956	.965
1.00	.869	.888	.902	.913	.921	.937	.948	.955	.961	.969
1.20	.891	.907	.918	.927	.935	.948	.956	.963	.967	.974
1.40	.907	.920	.930	.938	.944	.955	.963	.968	.972	.978
1.60	.918	.930	.939	.945	.951	.961	.967	.972	.975	.980
1.80	.927	.938	.945	.952	.956	.965	.971	.975	.978	.983
2.00	.935	.944	.951	.956	.961	.969	.974	.978	.980	.984
2.50	.948	.955	.961	.965	.969	.975	.979	.982	.984	.987
3.00	.956	.963	.967	.971	.974	.979	.983	.985	.987	.990
3.50	.963	.968	.972	.975	.978	.982	.985	.987	.989	.991
4.00	.967	.972	.975	.978	.980	.984	.987	.989	.990	.992
5.00	.974	.978	.980	.983	.984	.987	.990	.991	.992	.994

APPENDIX B

INTRODUCTION

This is a collection of practical programs written in the microsoft BASIC (MBASIC) programming language[1]. Remarks are included in the listing to help programmers understand how each program works. They also assist you in identifying parts of programs the programmer may be able to use in other programs. All programs in this appendix have been tested, run and listed on a Kaypro IV, 64k memory, CP/M and microsoft BASIC. The data and program listings were printed on an Epson MX80 printer.

BASIC (Beginners' All-purpose Symbolic Instruction Code) was invented and developed in 1964 by Kemey, J. and T. Kurtz of Dartmouth College. In general, the most widely used versions of BASIC have been developed by the Microsoft Company, Bellevue, Washington [2]. However, the language is implemented differently on each computer system and the programmer should be cognizant of a number of possible language differences appearing in these programs. Especially observe the disk input and the print output statements. It is possible, that these programs are not written using the simplest nor the most conservative programming techniques; thus, the programmer should feel free to improve or otherwise enhance the utility of these programs.

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1. Disclaimer: The authors have taken due care in preparing these programs including research, development, and testing to ascertain their effectiveness. No claim of any kind with regard to these programs is made in the performance or use of any of these programs

2. Finkel, L. and J. R. Brown, Data File Programming in BASIC John Wiley & Sons, Inc., New York, 1981

Program number 1. ENTDAT.BAS

The program named ENTDAT.BAS was written to enter data on a random file ("R" mode) disk storage. The data is entered to the file name of your choice. Old files can be reviewed, added to, and edited as well as new files can be created. This program has been written specifically for the Kaypro II portable computer and minor changes in the M-BASIC may be needed for other computers, e.g., in the FIELD statement.

```
100 REM    ***   DATA ENTRY PROGRAM FOR RANDOM ACCESS DATA FILES    ***
110 :
120 REM              PROGRAM NAME IS     ---ENTDAT.BAS---
130 :
140 PRINT CHR$(26)
150 PRINT"              FIELD PLOT UNIFORMITY STUDY DATA ENTRY PROGRAM"
160 PRINT
170 PRINT"          FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
180 PRINT"           KAYPRO IV COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
190 PRINT:PRINT
200 PRINT"                                 WRITTEN May, 1983"
210 PRINT:PRINT:PRINT:PRINT:PRINT
220 PRINT"                         INSERT DATA DISK IN DRIVE B OR ONE (1)"
230 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
240 PRINT"                            PRESS 'ENTER' OR <CR> TO CONTINUE"
250 LINE INPUT R$
260 CLEAR:PRINT CHR$(26)
270 DIM DA$(205),MA(5),LJ$(3),N$(3),JJ$(3)
280 KJ = 0
290 INPUT"ENTER DISK FILE NAME FOR DATA (7 LETTERS MAX.)";E$
300 IF E$="" THEN PRINT CHR$(26): GOTO 290
310 OPEN "R", 1, E$
320 PRINT CHR$(26)
330 PRINT"TO IDENTIFY THE DATA SET TO BE INPUT, A 'CODE' CAN BE USED."
340 PRINT"FOR EXAMPLE:  FOR A DATA SET COLLECTED IN 1984, THE CODE COULD"
350 PRINT"BE = 1984, THEREFORE, THE CODE LENGTH WOULD BE = 4.  EACH DATA"
360 PRINT"LINE WOULD THEN HAVE 1984 IN THE FIRST FOUR (4) COLUMNS."
370 PRINT
380 PRINT"   IF 'NO' CODE IS NEEDED, THEN PRESS 'ENTER' OR <CR>"
390 PRINT:PRINT
400 INPUT"WHAT IS THE CODE LENGTH FOR THIS DATA SET";L
410 PRINT
420 INPUT"WHAT IS THE TOTAL LENGTH OF DATA LINE (TOTAL DATA FIELD)";L1
430 PRINT CHR$(26)
440 PRINT"           THESE ARE THE VALUES THAT YOU HAVE SELECTED"
```

```
450 PRINT
460 PRINT"           CODE LENGTH IS SET AT ";L
470 PRINT
480 PRINT"           LINE LENGTH IS SET AT ";L1
490 X = L + L1
500 PRINT"                               ----------"
510 PRINT
520 PRINT"    TOTAL STRING LENGTH REQUIRED =";X
530 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
540 PRINT"                   PRESS 'ENTER' OR <CR> TO CONTINUE"
550 LINE INPUT R$
560 PRINT CHR$(26)
570 PRINT"PLEASE ENTER CODE, IF NO CODE PRESS 'ENTER' OR <CR>"
580 LINE INPUT LAB$
590 IF LEN(LAB$) <> L THEN GOSUB 1210: GOTO 560
600 PRINT:PRINT:PRINT
610 PRINT"TO CHANGE TO ANOTHER PROGRAM MODE -- ENTER 'C'"
620 PRINT"           ON NEXT PROMPT"
630 PRINT:PRINT
640 PRINT"PLEASE ENTER DATA LINE"
650 LINE INPUT LN$
660 IF LN$ = "C" THEN GOSUB 790: GOTO 600
670 IF LEN(LN$) <> L1 THEN GOSUB 1290: GOTO 600
680 PRINT:PRINT:PRINT
690 LJ$ = LAB$ + LN$:GOSUB 1390
700 PRINT:PRINT:PRINT"         LAST LINE OF RECORD"
710 PRINT LJ$
720 PRINT:PRINT:PRINT
730 PRINT"                     LINE NUMBER = ";LR
740 LN$ = ""
750 GOTO 600
760 PRINT CHR$(26)
770 PRINT:PRINT:PRINT:PRINT
780 CLOSE:PRINT"               NORMAL PROGRAM END":END
790 PRINT CHR$(26)
800 PRINT"SELECT OPTION TO CHANGE PROGRAM MODE:":PRINT
810 PRINT"       (1)   ENTER NEW CODE"
820 PRINT"       (2)   REVIEW DATA STRINGS"
830 PRINT"       (3)   EXIT PROGRAM"
840 PRINT
850 INPUT"OPTION ";CD
860 IF CD > 3 THEN GOTO 790
870 IF CD < 1 THEN GOTO 790
880 IF CD = 1 THEN LAB$="":GOTO 560
890 IF CD = 2 THEN GOTO 910
900 IF CD = 3 THEN GOTO 760
910 PRINT:PRINT:PRINT
920 INPUT"WHICH RECORD OR DATA LINE DO YOU WANT ";NR%
930 IF NR% = 0 THEN GOTO 910
940 FIELD 1, 128 AS N$
```

```
950 GET 1, NR%
960 JJ$ = N$
970 PRINT:PRINT:PRINT NR%;:PRINT JJ$
980 INPUT"CORRECT (1), CONTINUE (2), OR RETURN (3) ";OP
990 IF OP = 1 THEN GOTO 1020
1000 IF OP = 2 THEN PRINT CHR$(26):NR% = NR% + 1: GOTO 950
1010 RETURN
1020 PRINT CHR$(26)
1030 PRINT JJ$
1040 PRINT
1050 PRINT"TO CORRECT THE NUMBER, COUNT THE NUMBER OF CHARACTERS FROM"
1060 PRINT"THE BEGINNING OF THE LINE TO THE NUMBER TO BE CORRECTED."
1070 PRINT"ENTER THIS NUMBER, YOUR COUNT, AT THE PROMPT."
1080 PRINT:PRINT:INPUT I
1090 IF I > LEN(JJ$) THEN PRINT"NUMBER TOO LARGE, TRY AGAIN":GOTO 1080
1100 INPUT"WHAT IS THE NUMBER (MISTAKE) YOU WISH TO CORRECT";O$
1110 O = INSTR(I,JJ$,O$)
1120 IF O=0 THEN PRINT"NUMBER NOT FOUND":GOTO 1050
1130 PRINT"YOU MAY ABORT BY ENTERING 'ABORT' OR ENTER CORRECTION"
1140 LINE INPUT OO$
1150 IF OO$="ABORT" THEN PRINT CHR$(26):PRINT"LINE NO. ABORT=";NR%:GOTO92
1160 MID$(JJ$,O) = OO$
1170 OO$ = "": O = 0
1180 LSET N$ = JJ$
1190 PUT 1, NR%
1200 PRINT CHR$(26):PRINT:PRINT"CORRECTED LINE";JJ$
1210 PRINT:PRINT"LINE NUMBER CORRECTED =";NR%:GOTO 920
1220 PRINT"A CODING ERROR HAS OCCURED"
1230 PRINT"PRESENT CODE EXCEEDS REQUIRED LENGTH BY ";LEN(LAB$) - L
1240 PRINT"CODE MUST BE ";L;" CHARACTERS LONG"
1250 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
1260 PRINT"                         PRESS 'ENTER' OR <CR> TO CONTINUE"
1270 LINE INPUT R$
1280 RETURN
1290 PRINT CHR$(26)
1300 PRINT"A DATA LINE ERROR HAS OCCURED."
1310 PRINT
1320 PRINT"PRESENT DATA LINE EXCEEDS REQUIRED LENGTH BY  ";LEN(LN$) - L1
1330 PRINT"DATA LINE MUST BE ";L1;" CHARACTERS LONG."
1340 PRINT"                         PRESS 'ENTER' OR <CR> TO CONTINUE"
1350 LINE INPUT R$
1360 PRINT CHR$(26)
1370 RETURN
1380 '
1390 REM   ***   SUBROUTINE TO FIELD AND STORE DATA   ***
1400 '
1410 FIELD 1, 128 AS N$
1420 LSET N$ = LJ$
1430 LR = LOF(1)
1440 LR = LR + 1
```

```
1450 PUT 1, LR
1460 PRINT CHR$(26)
1470 RETURN
```

Program number 2, FREQ.BAS

```
100 REM ***  PROGRAM FOR FREQUENCY DISTRIBUTIONS  ***
110 REM          INCLUDES PEARSONS TYPE III
120 REM                  GIVES
130 REM        PROBABILITY OF EXCEEDANCE ALSO
140 '
150 REM   ***   THIS PROGRAM IS FOR A HORIZONTAL SET (I=40, J=32)   ***
160 '
170 :
180 REM              PROGRAM IS NAMED  ---FREQ.BAS---
190 '
200 REM          DATA FILE IS NAMED ---B:YLDSEED.DAT---
210 :
220 PRINT CHR$(26)
230 PRINT"        FIELD PLOT UNIFORMITY STUDY FOR FREQUENCY DISTRIBUTIONS"
240 PRINT
250 PRINT"        FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
260 PRINT"         KAYPRO II COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
270 PRINT:PRINT
280 PRINT"                       WRITTEN May, 1983"
290 PRINT:PRINT:PRINT:PRINT:PRINT
300 PRINT"                    INSERT DATA DISK IN DRIVE B OR ONE (1)"
310 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
320 PRINT"                    PRESS 'ENTER' OR <CR> TO CONTINUE"
330 LINE INPUT R$
340 CLEAR:PRINT CHR$(26)
350 INPUT"ENTER NAME OR DESCRIPTION OF PROGRAM";A$
360 PRINT A$:PRINT:PRINT
370 LPRINT A$:LPRINT:LPRINT
380 INPUT"ENTER NUMBER OF HORIZONTAL ROWS ON DATA SET";H
390 PRINT
400 INPUT"ENTER NUMBER OF VERTICAL COLUMNS ON DATA SET";K
410 PRINT
420 INPUT"ENTER THE DESIRED START OF THE VARIABLE LIST (NORMALLY = 1)";AZ
430 PRINT
440 INPUT"ENTER DESIRED END OF THE VARIABLE LIST (END ROW OR COLUMN)";AX
450 DIM V(40,40),P(40),T(40),C(40),P1(31,6),K1(31,6)
460 DIM P2(8),K2(8),D$(40)
470 PRINT CHR$(26):INPUT"ENTER DATA FILE NAME";F$
480 '
490 REM     *****     DISK READ SEGMENT     *****
500 '
510 OPEN "R",#1,F$,128
```

```
520 FIELD #1, 4 AS D$(1), 4 AS D$(2), 4 AS D$(3), 4 AS D$(4), 4 AS D$(5)
530 FIELD #1, 20 AS DU$, 4 AS D$(6), 4 AS D$(7), 4 AS D$(8), 4 AS D$(9)
540 FIELD #1, 36 AS DU$, 4 AS D$(10), 4 AS D$(11), 4 AS D$(12), 4 AS D$(13)
550 FIELD #1, 52 AS DU$, 4 AS D$(14), 4 AS D$(15), 4 AS D$(16), 4 AS D$(17)
560 FIELD #1, 68 AS DU$, 4 AS D$(18), 4 AS D$(19), 4 AS D$(20), 4 AS D$(21)
570 FIELD #1, 84 AS DU$, 4 AS D$(22), 4 AS D$(23), 4 AS D$(24), 4 AS D$(25)
580 FIELD #1, 100 AS DU$,4 AS D$(26),4 AS D$(27),4 AS D$(28), 4 AS D$(29)
590 FIELD #1, 116 AS DU$, 4 AS D$(30), 4 AS D$(31), 4 AS D$(32)
600 '
610 FOR I = 1 TO 40
620 GET #1, I
630 FOR J = 1 TO 32
640 V(I,J) = VAL(D$(J))
650 NEXT J
660 NEXT I
670 CLOSE #1
680 '
690 REM    ***   LINEAR REGRESSION ROUTINE   ***
700 '              FOR DETRENDING ANALYSIS
710 '
720 PRINT CHR$(26)
730 LPRINT:LPRINT"REGRESSION EQUATION FOR TRENDING ANALYSIS"
740 PRINT:PRINT"REGRESSION EQUATION FOR TRENDING ANALYSIS"
750 Y1=0:Y2=0:Y3=0:Y4=0:Y5=0
760 FOR I = 1 TO 40
770 FOR J = 1 TO 32
780 XX = J
790 Y1 = Y1 + 1.4224*XX
800 Y2 = Y2 + V(I,J)
810 Y3 = Y3 + (1.4224*XX)^2
820 Y4 = Y4 + V(I,J)^2
830 Y5 = Y5 + 1.4224*XX*V(I,J)
840 NEXT J
850 B1 = (32*Y5 - Y2*Y1)/(32*Y3 - Y1^2)
860 A1 = (Y2 - B1*Y1)/32
870 PRINT:PRINT"THE REGRESSION EQUAION FOR ";I;" IS:":PRINT
880 LPRINT:LPRINT"THE REGRESSION EQUATION FOR ";I;" IS:":LPRINT
890 PRINT  "V(I,J) = ";A1;" + (";B1;" * DISTANCE )"
900 LPRINT "V(I,J) = ";A1;" + (";B1;" * DISTANCE )"
910 Z1 = B1*(Y5 - Y1*Y2/32)
920 Z2 = Y4 - Y2^2/32
930 Z3 = Z2 - Z1
940 Z4 = Z1/Z2
950 Z5 = SQR(Z4)
960 Y6 = Z3/30
970 Z6 = SQR(Y6)
980 PRINT:PRINT"COEFFICIENT OF DETERMINATION (R^2) = ";Z4
990 LPRINT:LPRINT"COEFFICIENT OF DETERMINATION (R^2) = ";Z4
1000 PRINT"COEFFICIENT OF CORRELATION = ";Z5
1010 LPRINT"COEFFICIENT OF CORRELATION = ";Z5
```

```
1020 PRINT"STANDARD ERROR OF ESTIMATE = ";Z6
1030 LPRINT"STANDARD ERROR OF ESTIMATE = ";Z6
1040 PRINT:LPRINT
1050 UU = 1 - Z4
1060 U2 = SQR(UU)
1070 U3 = SQR(30)
1080 ZT = B1*U3/U2
1090 PRINT"TEST OF HYPOTHESIS THAT B1=0:  IF T>2.05 THEN B1>0, T =";ZT
1100 LPRINT"TEST OF HYPOTHESIS THAT B1=0: IF T>2.05 THEN B1>0, T =";ZT
1110 PRINT:LPRINT:PRINT"----------":LPRINT"----------"
1120 Y1=0:Y2=0:Y3=0:Y4=0:Y5=0
1130 NEXT I
1140 :
1150 REM   ***   READ PEARSON TABLE FOR K VALUES   ***
1160 :
1170 FOR EE = 1 TO 31
1180 FOR E1 = 1 TO 6
1190 READ P1(EE,E1), K1(EE,E1)
1200 NEXT E1
1210 NEXT EE
1220 FOR I = 1 TO 8
1230 READ P2(I),K2(I)
1240 NEXT I
1250 PRINT:PRINT:PRINT:PRINT
1260 PRINT"                       ENTERING COMPUTATIONS"
1270 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
1280 :
1290 REM   ***   COMPUTING FIRST 4 MOMENTS, SKEWNESS AND KURTOSIS   ***
1300 '
1310 FOR I = 1 TO 40
1320 A1=0:B1=0:C1=0:D1=0
1330 A2=0:B2=0:C2=0:D2=0
1340 PRINT:PRINT:PRINT"RUNNING VARIABLE NUMBER ";I
1350 LPRINT:LPRINT:LPRINT"RUNNING VARIABLE NUMBER ";I
1360 LPRINT
1370 FOR J = 1 TO 32
1380 A1 = A1 + V(I,J)
1390 B1 = B1 + V(I,J)^2
1400 C1 = C1 + V(I,J)^3
1410 D1 = D1 + V(I,J)^4
1420 A2 = A2 + LOG(V(I,J))
1430 B2 = B2 + (LOG(V(I,J)))^2
1440 C2 = C2 + (LOG(V(I,J)))^3
1450 D2 = D2 + (LOG(V(I,J)))^4
1460 NEXT J
1470 Z = 32
1480 T1 = A1/Z
1490 T2 = (B1/Z) - T1^2
1500 T3 = (C1/Z) - 3*T1*B1/Z + 2*T1^3
1510 T4 = (D1/Z) - 4*T1*C1/Z
```

```
1520 T5 = T4 + 6*T1^2*B1/Z - 3*T1^4
1530 ZZ = SQR(T2)
1540 ZW = ZZ^3
1550 T6 = T3/ZW
1560 T7 = T5/(T2^2)
1570 W1 = A2/Z
1580 W2 = (B2/Z) - W1^2
1590 W3 = (C2/Z) - 3*W1*B2/Z + 2*W1^3
1600 W4 = (D2/Z) - 4*W1*C2/Z
1610 W5 = W4 + 6*W1^2*B2/Z - 3*W1^4
1620 ZX = SQR(W2)
1630 QX = ZX^3
1640 W6 = W3/QX
1650 W7 = W5/(W2^2)
1660 BZZ = B1/Z - (A1/Z)^2
1670 ST = SQR(BZZ)
1680 BXX = B2/Z - (A2/Z)^2
1690 SD = SQR(BXX)
1700 COV = 100*ST/T1
1710 LCOV = 100*SD/W1
1720 PRINT "MEAN OF V(J,I) = ";T1
1730 LPRINT"MEAN OF V(J,I) = ";T1
1740 PRINT "STANDARD DEVIATION OF V(J,I) = ";ST
1750 LPRINT"STANDARD DEVIATION OF V(J,I) = ";ST
1760 PRINT "SKEWNESS COEFFICIENT = ";T6
1770 LPRINT"SKEWNESS COEFFICIENT = ";T6
1780 PRINT "KURTOSIS COEFFICIENT = ";T7
1790 LPRINT"KURTOSIS COEFFICIENT = ";T7
1800 PRINT "COEFFICIENT OF VARIATION = ";COV
1810 LPRINT"COEFFICIENT OF VARIATION = ";COV
1820 LPRINT:PRINT:LPRINT:PRINT
1830 PRINT "LOGARITHMIC COTTON SEED YIELD (GM/PLOT)"
1840 LPRINT"LOGARITHMIC COTTON SEED YIELD (GM/PLOT)"
1850 LPRINT:PRINT
1860 PRINT "LOG OF MEAN = ";W1
1870 LPRINT"LOG OF MEAN = ";W1
1880 PRINT "LOG OF STANDARD DEVIATION = ";SD
1890 LPRINT"LOG OF STANDARD DEVIATION = ";SD
1900 PRINT "LOG OF SKEWNESS COEFFICIENT = ";W6
1910 LPRINT"LOG OF SKEWNESS COEFFICIENT = ";W6
1920 PRINT "LOG OF KURTOSIS COEFFICIENT = ";W7
1930 LPRINT"LOG OF KURTOSIS COEFFICIENT = ";W7
1940 PRINT "LOG OF COEFFICIENT OF VARIATION = ";LCOV
1950 LPRINT"LOG OF COEFFICIENT OF VARIATION = ";LCOV
1960 PRINT CHR$(26):LPRINT"----------------------------------------------------"
1970 LPRINT
1980 :
1990 REM   ***   CALCULATING THE PROBABILITY FOR NON-LOGARITHMIC DATA
2000 :
2010 LPRINT:PRINT
```

```
2020 PRINT "PROBABILITY FOR NON-LOGARITHMIC VALUES ":PRINT
2030 LPRINT"PROBABILITY FOR NON-LOGARITHMIC VALUES ":LPRINT
2040 FOR N = 1 TO 8
2050 NQ = T1 + K2(N)*ST
2060 PRINT "EXCEEDANCE PROBABILITY =";K2(N)
2070 PRINT "VARIABLE V(J,I) = ";NQ;"  AT PROBABILITY = ";P2(N)
2080 LPRINT"EXCEEDANCE PROBABILITY =";K2(N)
2090 LPRINT"VARIABLE V(J,I) = ";NQ;"  AT PROBABILITY = ";P2(N)
2100 NEXT N
2110 :
2120 REM   ***   CALCULATION OF TABULAR K VALUES   ***
2130 :
2140 IF W6 > 3 THEN PRINT"ERROR IN DATA SET":M = 1:GOTO 2470
2150 IF W6<=3 AND W6>2.5 THEN M=1:GOTO 2470
2160 IF W6<=2.5 AND W6>2 THEN M=2:GOTO 2470
2170 IF W6<=2 AND W6>1.5 THEN M=3:GOTO 2470
2180 IF W6<=1.5 AND W6>1.2 THEN M=4:GOTO 2470
2190 IF W6<=1.2 AND W6>1 THEN M=5:GOTO 2470
2200 IF W6<=1 AND W6>.9 THEN M=6:GOTO 2470
2210 IF W6<=.9 AND W6>.8 THEN M=7:GOTO 2470
2220 IF W6<=.8 AND W6>.7 THEN M=8:GOTO 2470
2230 IF W6<=.7 AND W6>.6 THEN M=9:GOTO 2470
2240 IF W6<=.6 AND W6>.5 THEN M=10:GOTO 2470
2250 IF W6<=.5 AND W6>.4 THEN M=11:GOTO 2470
2260 IF W6<=.4 AND W6>.3 THEN M=12:GOTO 2470
2270 IF W6<=.3 AND W6>.2 THEN M=13:GOTO 2470
2280 IF W6<=.2 AND W6>.1 THEN M=14:GOTO 2470
2290 IF W6<=.1 AND W6>0 THEN M=15:GOTO 2470
2300 IF W6<=0 AND W6>-.1 THEN M=16:GOTO 2470
2310 IF W6<=-.1 AND W6>-.2 THEN M=17:GOTO 2470
2320 IF W6<=-.2 AND W6>-.3 THEN M=18:GOTO 2470
2330 IF W6<=-.3 AND W6>-.4 THEN M=19:GOTO 2470
2340 IF W6<=-.4 AND W6>-.5 THEN M=20:GOTO 2470
2350 IF W6<=-.5 AND W6>-.6 THEN M=21:GOTO 2470
2360 IF W6<=-.6 AND W6>-.7 THEN M=22:GOTO 2470
2370 IF W6<=-.7 AND W6>-.8 THEN M=23:GOTO 2470
2380 IF W6<=-.8 AND W6>-.9 THEN M=24:GOTO 2470
2390 IF W6<=-.9 AND W6>-1 THEN M=25:GOTO 2470
2400 IF W6<=-1 AND W6>-1.2 THEN M=26:GOTO 2470
2410 IF W6<=-1.2 AND W6>-1.5 THEN M=27:GOTO 2470
2420 IF W6<=-1.5 AND W6>-2 THEN M=28:GOTO 2470
2430 IF W6<=-2 AND W6>-2.5 THEN M=29:GOTO 2470
2440 IF W6<=-2.5 AND W6>-3 THEN M=30:GOTO 2470
2450 IF W6=-3 THEN M=31:GOTO 2470
2460 IF W6<-3 THEN PRINT"ERROR IN DATA SET (NEGATIVE)":M=31:GOTO 2470
2470 PRINT:PRINT:LPRINT:LPRINT
2480 PRINT "PROBABILITY FOR LOGARITHMIC VALUES":PRINT
2490 LPRINT"PROBABILITY FOR LOGARITHMIC VALUES":LPRINT
2500 PRINT:LPRINT
2510 FOR N = 1 TO 6
```

```
2520 LQ = W1 + K1(M,N)*SD
2530 Q1 = EXP(LQ)
2540 PRINT "EXCEEDANCE PROBABILITY VALUE = ";K1(M,N)
2550 LPRINT"EXCEEDANCE PROBABILITY VALUE = ";K1(M,N)
2560 PRINT "VARIABLE V(J,I) = ";Q1;"  AT PROBABILITY = ";P1(M,N)
2570 LPRINT"VARIABLE V(J,I) = ";Q1;"  AT PROBABILITY = ";P1(M,N)
2580 NEXT N
2590 NEXT I
2600 :
2610 REM   ***   SORT ROUTINE   ***
2620 PRINT CHR$(26):LPRINT
2630 PRINT "ENTERING SORT ROUTINE -- DATA NOT LOGARITHMIC"
2640 LPRINT"ENTERING SORT ROUTINE -- DATA NOT LOGARITHMIC"
2650 PRINT "REARRANGEMENT OF DATA INTO ASCENDING SEQUENCE"
2660 LPRINT"REARRANGEMENT OF DATA INTO ASCENDING SEQUENCE"
2670 LPRINT
2680 FOR I = 1 TO 40
2690 PRINT:PRINT"RUN NUMBER =";I
2700 LPRINT:LPRINT"RUN NUMBER =";I
2710 NS = 1
2720 LI = H - 1
2730 IN = NS
2740 FOR L = NS TO LI
2750 IF V(I,L) <= V(I,L+1) THEN GOTO 2800
2760 TE = V(I,L)
2770 V(I,L) = V(I,L+1)
2780 V(I,L+1) = TE
2790 IN = L
2800 NEXT L
2810 IF IN = NS THEN GOTO 2870
2820 LI = IN - 1
2830 GOTO 2730
2840 :
2850 REM   ***   RANK AND PROBABILITY   ***
2860 :
2870 PRINT TAB(2) "RANK" TAB(16) "ORDER" TAB(32) "PROBABILITY";
2880 PRINT TAB(46) "RECURRENCE"
2890 LPRINT TAB(2) "RANK" TAB(16) "ORDER" TAB(23) "PROBABILITY";
2900 LPRINT TAB(46) "RECURRENCE"
2910 FOR KK = 1 TO 32
2920 NK = H - KK + 1
2930 P(NK) = NK/(H+1)
2940 T(NK) = 1/P(NK)
2950 PRINT V(I,KK),NK,P(NK),T(NK)
2960 LPRINT V(I,KK),NK,P(NK),T(NK)
2970 NEXT KK
2980 :
2990 REM   ***   DETERMINATION OF THE INTERVAL   ***
3000 :
3010 NN = 10
```

```
3020 PRINT CHR$(26)
3030 ZI = (V(I,H) - V(I,1))/NN
3040 FOR IJ = 1 TO NN
3050 IF IJ > 1 THEN GOTO 3080
3060 C(IJ) = V(I,1) + ZI
3070 GOTO 3090
3080 C(IJ) = C(IJ-1) + ZI
3090 CN(IJ) = 0
3100 NEXT IJ
3110 PRINT:LPRINT
3120 FOR II = 1 TO NN
3130 PRINT "INTERVAL = ";C(II),II
3140 LPRINT"INTERVAL = ";C(II),II
3150 NEXT II
3160 :
3170 REM   ***   FREQUENCY ROUTINE   ***
3180 :
3190 PRINT CHR$(26):LPRINT:PRINT
3200 PRINT "DETERMINING FREQUENCY"
3210 PRINT
3220 FOR MM = 1 TO NN
3230 FOR AA = 1 TO H
3240 IF V(I,AA) > C(MM) THEN GOTO 3280
3250 IF MM < 2 THEN GOTO 3270
3260 IF V(I,AA) <= C(MM-1) THEN GOTO 3280
3270 CN(MM) = CN(MM) + 1
3280 NEXT AA
3290 NEXT MM
3300 TW=0:TL=H-1
3310 FOR BG = 1 TO NN
3320 TW = TW + CN(BG)
3330 NEXT BG
3340 IF TW > TL THEN GOTO 3360
3350 CN(NN) = CN(NN) + 1
3360 FOR CC = 1 TO NN
3370 PRINT "FREQUENCY COUNTER = ";CN(CC),CC
3380 LPRINT"FREQUENCY COUNTER = ";CN(CC),CC
3390 NEXT CC
3400 NEXT I
3410 LPRINT:LPRINT"PROGRAM IS TERMINATED"
3420 PRINT:PRINT  "PROGRAM IS TERMINATED"
3430 PRINT CHR$(26)
3440 PRINT:PRINT:PRINT:PRINT
3450 PRINT"                   NORMAL PROGRAM END":END
3460 DATA 0.99,-0.667,0.90,-0.660,0.50,-0.396,0.10,1.180,0.02,3.152,0.01
3470 DATA 4.051
3480 DATA 0.99,-0.799,0.90,-0.771,0.50,-0.360,0.10,1.250,0.02,3.048,0.01
3490 DATA 3.845
3500 DATA 0.99,-0.990,0.90,-0.895,0.50,-0.307,0.10,1.302,0.02,2.912,0.01
3510 DATA 3.605
```

```
3520 DATA 0.99,-1.256,0.90,-1.018,0.50,-0.240,0.10,1.333,0.02,2.743,0.01
3530 DATA 3.330
3540 DATA 0.99,-1.449,0.90,-1.086,0.50,-0.195,0.10,1.340,0.02,2.626,0.01
3550 DATA 3.149
3560 DATA 0.99,-1.588,0.90,-1.128,0.50,-0.164,0.10,1.340,0.02,2.542,0.01
3570 DATA 3.022
3580 DATA 0.99,-1.660,0.90,-1.147,0.50,-0.148,0.10,1.339,0.02,2.498,0.01
3590 DATA 2.957
3600 DATA 0.99,-1.733,0.90,-1.166,0.50,-0.132,0.10,1.336,0.02,2.453,0.01
3610 DATA 2.891
3620 DATA 0.99,-1.806,0.90,-1.183,0.50,-0.116,0.10,1.333,0.02,2.407,0.01
3630 DATA 2.824
3640 DATA 0.99,-1.880,0.90,-1.200,0.50,-0.099,0.10,1.328,0.02,2.359,0.01
3650 DATA 2.755
3660 DATA 0.99,-1.955,0.90,-1.216,0.50,-0.083,0.10,1.323,0.02,2.311,0.01
3670 DATA 2.686
3680 DATA 0.99,-2.029,0.90,-1.231,0.50,-0.066,0.10,1.137,0.02,2.261,0.01
3690 DATA 2.615
3700 DATA 0.99,-2.104,0.90,-1.245,0.50,-0.050,0.10,1.309,0.02,2.211,0.01
3710 DATA 2.544
3720 DATA 0.99,-2.178,0.90,-1.258,0.50,-0.033,0.10,1.301,0.02,2.159,0.01
3730 DATA 2.472
3740 DATA 0.99,-2.252,0.90,-1.270,0.50,-0.017,0.10,1.292,0.02,2.107,0.01
3750 DATA 2.400
3760 DATA 0.99,-2.326,0.90,-1.282,0.50,0.000,0.10,1.282,0.02,2.054,0.01
3770 DATA 2.326
3780 DATA 0.99,-2.400,0.90,-1.292,0.50,0.017,0.10,1.270,0.02,2.000,0.01
3790 DATA 2.252
3800 DATA 0.99,-2.472,0.90,-1.301,0.50,0.033,0.10,1.258,0.02,1.945,0.01
3810 DATA 2.178
3820 DATA 0.99,-2.544,0.90,-1.309,0.50,0.050,0.10,1.245,0.02,1.890,0.01
3830 DATA 2.104
3840 DATA 0.99,-2.615,0.90,-1.317,0.50,0.066,0.10,1.231,0.02,1.834,0.01
3850 DATA 2.029
3860 DATA 0.99,-2.686,0.90,-1.323,0.50,0.083,0.10,1.216,0.02,1.777,0.01
3870 DATA 1.955
3880 DATA 0.99,-2.755,0.90,-1.328,0.50,0.099,0.10,1.200,0.02,1.720,0.01
3890 DATA 1.880
3900 DATA 0.99,-2.824,0.90,-1.333,0.50,0.116,0.10,1.183,0.02,1.663,0.01
3910 DATA 1.806
3920 DATA 0.99,-2.891,0.90,-1.336,0.50,0.132,0.10,1.166,0.02,1.606,0.01
3930 DATA 1.733
3940 DATA 0.99,-2.957,0.90,-1.339,0.50,0.148,0.10,1.147,0.02,1.549,0.01
3950 DATA 1.660
3960 DATA 0.99,-3.022,0.90,-1.340,0.50,0.164,0.10,1.128,0.02,1.492,0.01
3970 DATA 1.588
3980 DATA 0.99,-3.149,0.90,-1.340,0.50,0.195,0.10,1.086,0.02,1.379,0.01
3990 DATA 1.449
4000 DATA 0.99,-3.330,0.90,-1.333,0.50,0.240,0.10,1.018,0.02,1.217,0.01
4010 DATA 1.256
```

```
4020 DATA 0.99,-3.605,0.90,-1.302,0.50,0.307,0.10,0.895,0.02,0.980,0.01
4030 DATA 0.990
4040 DATA 0.90,-3.845,0.90,-1.250,0.50,0.360,0.10,0.771,0.02,0.798,0.01
4050 DATA 0.799
4060 DATA 0.90,-4.051,0.90,-1.180,0.50,0.396,0.10,0.660,0.02,0.666,0.01
4070 DATA 0.667
4080 :
4090 DATA 0.99,-2.326,0.90,-1.282,0.70,-0.524,0.50,0.000,0.30,0.524,0.10
4100 DATA 1.282
4110 DATA 0.025,1.960,0.01,2.326
```

<u>Program number 3. MEVAST.BAS</u>

```
100 REM *** PROGRAM FOR MEAN, STANDARD DEVIATION, AND COEF. OF VARIATION
110 REM           THIS IS FOR THE NIAMEY STATION VARIABILITY TRIAL
120 :
130 REM     DATA FROM "STATISTICAL METHODS FOR AGRICULTURAL WORKERS"
140 REM                    -----PAGES 132-133-----
150 :
160 REM            NAME OF PROGRAM ---- MEVAST.BAS ----
170 '
180 REM                 DATA DISK NAMED --YLDSEED.DAT--
190 :
200 PRINT CHR$(26)
210 PRINT"           FIELD PLOT UNIFORMITY STUDY FOR PLOT SIZE VARIANCE"
220 PRINT
230 PRINT"         FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
240 PRINT"          KAYPRO II COMPUTER WITH 64K MEMORY, CP/M, REV. 2.2"
250 PRINT:PRINT
260 PRINT"                      WRITTEN BY Eugene R. Perrier"
270 PRINT"                              May, 1983"
280 PRINT:PRINT:PRINT:PRINT:PRINT
290 PRINT"                    INSERT DATA DISK IN DRIVE B OR ONE (1)"
300 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
310 PRINT"                    PRESS 'ENTER' OR <CR> TO CONTINUE"
320 LINE INPUT R$
330 CLEAR:PRINT CHR$(26)
340 DIM D$(40),U(40,40),V(40,40),UM(40),STD(40),COV(40)
350 DIM Y(40),VR(40),GM(40),C2(40)
360 INPUT "ENTER FILE NAME FOR DATA";F$
370 REM     *****    DISK READ SEGMENT    *****
380 OPEN "R",#1,F$,128
390 FIELD #1, 4 AS D$(1), 4 AS D$(2), 4 AS D$(3), 4 AS D$(4), 4 AS D$(5)
400 FIELD #1, 20 AS DU$, 4 AS D$(6), 4 AS D$(7), 4 AS D$(8), 4 AS D$(9)
410 FIELD #1,36 AS DU$,4 AS D$(10), 4 AS D$(11), 4 AS D$(12), 4 AS D$(13)
420 FIELD #1,52 AS DU$,4 AS D$(14), 4 AS D$(15), 4 AS D$(16), 4 AS D$(17)
430 FIELD #1,68 AS DU$,4 AS D$(18), 4 AS D$(19), 4 AS D$(20), 4 AS D$(21)
440 FIELD #1,84 AS DU$,4 AS D$(22), 4 AS D$(23), 4 AS D$(24), 4 AS D$(25)
450 FIELD #1,100 AS DU$,4 AS D$(26),4 AS D$(27), 4 AS D$(28), 4 AS D$(29)
460 FIELD #1, 116 AS DU$, 4 AS D$(30), 4 AS D$(31), 4 AS D$(32)
470 '
480 FOR I = 1 TO 40
490 GET #1,I
500 FOR J = 1 TO 32
510 U(J,I) = VAL(D$(J))
```

```
520 NEXT J
530 NEXT I
540 CLOSE #1
550 XX = 1
560 GOSUB 1380
570 '
580 REM   ***   PRINT OUT DATA SET USED IN TABLE OF VALUES   ***
590 '
600 FOR I = 1 TO C1
610 CNT = 1
620 IF C2=40 AND CNT=1 THEN JS=1:JF=10:GOTO 740
630 IF C2=40 AND CNT=2 THEN JS=11:JF=20:GOTO 740
640 IF C2=40 AND CNT=3 THEN JS=21:JF=30:GOTO 740
650 IF C2=40 AND CNT=4 THEN JS=31:JF=40:GOTO 740
660 IF C2=20 AND CNT=1 THEN JS=1:JF=10:GOTO 740
670 IF C2=20 AND CNT=2 THEN JS=11:JF=20:GOTO 740
680 IF C2=10 AND CNT=1 THEN JS=1:JF=10:GOTO 740
690 IF C2=8 AND CNT=1 THEN JS=1:JF=8:GOTO 740
700 IF C2=5 AND CNT=1 THEN JS=1:JF=5:GOTO 740
710 IF C2=4 AND CNT=1 THEN JS=1:JF=4:GOTO 740
720 IF C2=2 AND CNT=1 THEN JS=1:JF=2:GOTO 740
730 GOTO 830
740 FOR J = JS TO JF
750 PRINT USING "#######";V(I,J);
760 LPRINT USING "#######";V(I,J);
770 NEXT J
780 PRINT"       "
790 LPRINT"       "
800 CNT = CNT + 1
810 IF CNT > 4 THEN GOTO 830
820 GOTO 620
830 PRINT:PRINT:LPRINT:LPRINT
840 NEXT I
850 '
860 PRINT CHR$(26)
870 :
880 REM ***  DETERMINATION OF MEAN, STANDARD DEVIATION AND COEFFICIENT
890 REM             OF VARIATION FOR EACH LINE (40)
900 :
910 LPRINT "ROW" TAB(10) "MEAN" TAB(22) "STD DEV" TAB(35) "COVAR";
920 LPRINT TAB(45) "TOTAL" TAB(55) "N"
930 LPRINT"------------------------------------------------------------"
940 PRINT  "ROW" TAB(10) "MEAN" TAB(22) "STD DEV" TAB(35) "COVAR";
950 PRINT  TAB(45) "TOTAL" TAB(55) "N"
960 PRINT"--------------------------------------------------------------"
970 S4=0:S5=0:KNT=1
980 FOR I = 1 TO C1
990 S1=0:S2=0
1000 FOR J = 1 TO C2
1010 S1 = S1 + V(I,J)
```

```
1020 NEXT J
1030 S4 = S4 + S1
1040 UM(I) = S1/C2
1050 FOR L = 1 TO C2
1060 S2 = S2 + (V(I,L) - UM(I))^2
1070 NEXT L
1080 S5 = S5 + S2
1090 X9 = S2/(C2 - 1)
1100 STD(I) = SQR(X9)
1110 COV(I) = 100*STD(I)/UM(I)
1120 LPRINT I TAB(8) UM(I) TAB(21) STD(I) TAB(34) COV(I) TAB(44) S1, C2
1130 PRINT  I TAB(8) UM(I) TAB(21) STD(I) TAB(34) COV(I) TAB(44) S1, C2
1140 NEXT I
1150 LPRINT"-----------------------------------------------------":LPRINT
1160 PRINT"------------------------------------------------------":PRINT
1170 GM(KNT) = S4/(C1*C2)
1180 FOR I = 1 TO C1: FOR J = 1 TO C2
1190 T2 = T2 + (V(I,J) - GM(KNT))^2
1200 NEXT J,I
1210 VAR = T2/(C1*C2 - 1)
1220 VR(KNT) = VAR/(Y*Y)
1230 MS = SQR(VAR)
1240 C2(KNT) = 100*MS/GM(KNT)
1250 PRINT"GM =";GM(KNT);" S = ";MS;" VAR = ";VAR;" COVAR = ";C2(KNT)
1260 LPRINT"GM =";GM(KNT)" S = ";MS;" VAR = ";VAR;" COVAR = ";C2(KNT)
1270 PRINT "VAR/UNIT AREA = ";VR(KNT);"GRAND TOTAL =";S4:PRINT:PRINT
1280 LPRINT"VAR/UNIT AREA = ";VR(KNT);"GRAND TOTAL =";S4:LPRINT:LPRINT
1290 S1=0:S2=0:S4=0:S5=0:T2=0:KNT = KNT + 1
1300 GOTO 560
1310 :
1320 REM   ***  ROUTINE TO CHANGE THE PLOT SIZE   ***
1330 :
1340 REM         U(I,J) IS THE ARRAY OF EQUALLY SPACED DATA POINTS
1350 REM         I IS THE COLUMN (VERTICAL) INTEGER
1360 REM         J IS THE ROW (HORIZONTAL) INTEGER
1370 :
1380 PRINT  TAB(10) "RUN NUMBER: ";XX:PRINT
1390 LPRINT TAB(10) "RUN NUMBER: ";XX:LPRINT
1400 IF XX=1 THEN Y=1:C1=32:C2=40:D=32:E=40:A=1:B=1:GOSUB 1850:XX=XX+1
     :RETURN
1410 IF XX=2 THEN Y=2:C1=16:C2=40:D=31:E=40:A=2:B=1:GOSUB 1850:XX=XX+1
     :RETURN
1420 IF XX=3 THEN Y=4:C1=8:C2=40:D=29:E=40:A=4:B=1:GOSUB 1850:XX=XX+1
     :RETURN
1430 IF XX=4 THEN Y=8:C1=4:C2=40:D=25:E=40:A=8:B=1:GOSUB 1850:XX=XX+1
     :RETURN
1440 IF XX=5 THEN Y=16:C1=2:C2=40:D=17:E=40:A=16:B=1:GOSUB 1850:XX=XX+1
     :RETURN
1450 '
1460 IF XX=6 THEN Y=2:C1=32:C2=20:D=32:E=39:A=1:B=2:GOSUB 1850:XX=XX+1
```

```
     :RETURN
1470 IF XX=7 THEN Y=4:C1=16:C2=20:D=31:E=39:A=2:B=2:GOSUB 1850:XX=XX+1
     :RETURN
1480 IF XX=8 THEN Y=8:C1=8:C2=20:D=29:E=39:A=4:B=2:GOSUB 1850:XX=XX+1
     :RETURN
1490 IF XX=9 THEN Y=16:C1=4:C2=20:D=25:E=39:A=8:B=2:GOSUB 1850:XX=XX+1
     :RETURN
1500 IF XX=10 THEN Y=32:C1=2:C2=20:D=17:E=39:A=16:B=2:GOSUB 1850:XX=XX+1
     :RETURN
1510 '
1520 IF XX=11 THEN Y=4:C1=32:C2=10:D=32:E=37:A=1:B=4:GOSUB 1850:XX=XX+1
     :RETURN
1530 IF XX=12 THEN Y=8:C1=16:C2=10:D=31:E=37:A=2:B=4:GOSUB 1850:XX=XX+1
     :RETURN
1540 IF XX=13 THEN Y=16:C1=8:C2=10:D=29:E=37:A=4:B=4:GOSUB 1850:XX=XX+1
     :RETURN
1550 IF XX=14 THEN Y=32:C1=4:C2=10:D=25:E=37:A=8:B=4:GOSUB 1850:XX=XX+1
     :RETURN
1560 IF XX=15 THEN Y=64:C1=2:C2=10:D=17:E=37:A=16:B=4:GOSUB 1850:XX=XX+1
     :RETURN
1570 '
1580 IF XX=16 THEN Y=5:C1=32:C2=8:D=32:E=36:A=1:B=5:GOSUB 1850:XX=XX+1
     :RETURN
1590 IF XX=17 THEN Y=10:C1=16:C2=8:D=31:E=36:A=2:B=5:GOSUB 1850:XX=XX+1
     :RETURN
1600 IF XX=18 THEN Y=20:C1=8:C2=8:D=29:E=36:A=4:B=5:GOSUB 1850:XX=XX+1
     :RETURN
1610 IF XX=19 THEN Y=40:C1=4:C2=8:D=25:E=36:A=8:B=5:GOSUB 1850:XX=XX+1
     :RETURN
1620 IF XX=20 THEN Y=80:C1=2:C2=8:D=17:E=36:A=16:B=5:GOSUB 1850:XX=XX+1
     :RETURN
1630 '
1640 IF XX=21 THEN Y=8:C1=32:C2=5:D=32:E=33:A=1:B=8:GOSUB 1850:XX=XX+1
     :RETURN
1650 IF XX=22 THEN Y=16:C1=16:C2=5:D=31:E=33:A=2:B=8:GOSUB 1850:XX=XX+1
     :RETURN
1660 IF XX=23 THEN Y=32:C1=8:C2=5:D=29:E=33:A=4:B=8:GOSUB 1850:XX=XX+1
     :RETURN
1670 IF XX=24 THEN Y=64:C1=4:C2=5:D=25:E=33:A=8:B=8:GOSUB 1850:XX=XX+1
     :RETURN
1680 IF XX=25 THEN Y=128:C1=2:C2=5:D=17:E=33:A=16:B=8:GOSUB 1850:XX=XX+1
     :RETURN
1690 '
1700 IF XX=26 THEN Y=10:C1=32:C2=4:D=32:E=31:A=1:B=10:GOSUB 1850:XX=XX+1
     :RETURN
1710 IF XX=27 THEN Y=20:C1=16:C2=4:D=31:E=31:A=2:B=10:GOSUB 1850:XX=XX+1
     :RETURN
1720 IF XX=28 THEN Y=40:C1=8:C2=4:D=29:E=31:A=4:B=10:GOSUB 1850:XX=XX+1
     :RETURN
1730 IF XX=29 THEN Y=80:C1=4:C2=4:D=25:E=31:A=8:B=10:GOSUB 1850:XX=XX+1
```

```
     :RETURN
1740 IF XX=30 THEN Y=160:C1=2:C2=4:D=17:E=31:A=16:B=10:GOSUB 1850:XX=XX+1
     :RETURN
1750 '
1760 IF XX=31 THEN Y=20:C1=32:C2=2:D=32:E=21:A=1:B=20:GOSUB 1850:XX=XX+1
     :RETURN
1770 IF XX=32 THEN Y=40:C1=16:C2=2:D=31:E=21:A=2:B=20:GOSUB 1850:XX=XX+1
     :RETURN
1780 IF XX=33 THEN Y=80:C1=8:C2=2:D=29:E=21:A=4:B=20:GOSUB 1850:XX=XX+1
     :RETURN
1790 IF XX=34 THEN Y=160:C1=4:C2=2:D=25:E=21:A=8:B=20:GOSUB 1850:XX=XX+1
     :RETURN
1800 IF XX=35 THEN Y=320:C1=2:C2=2:D=17:E=21:A=16:B=20:GOSUB 1850:XX=XX+1
     :RETURN
1810 END
1820 :
1830 REM   ***   DETERMINING THE NEW VARIABLES   ***
1840 :
1850 PRINT CHR$(26)
1860 PRINT"                              CALCULATING NEW V(K,L)'S"
1870 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
1880 K=1:L=1:CT=0:KT=0
1890 FOR I = 1 TO D STEP A
1900 CT = CT + 1:II = I
1910 FOR J = 1 TO E STEP B
1920 KT = KT + 1:JJ = J
1930 V(K,L) = U (I,J)
1940 IF A = 1 AND B = 1 THEN GOTO 2000
1950 IF CT < A THEN II=II+1:V(K,L)=V(K,L)+U(II,J):CT=CT+1:GOTO 1950
1960 II=I:CT=1:KT=1
1970 IF KT < B THEN JJ=JJ+1:V(K,L)=V(K,L)+U(I,JJ):KT=KT+1:GOTO 1970
1980 JJ=J:CT=1:KT=1
1990 IF CT < A AND KT < B THEN GOSUB 2060
2000 L=L+1:KT=0:NEXT J
2010 L=1:K=K+1:CT=0:NEXT I
2020 RETURN
2030 :
2040 REM   ***   REORDER VARIABLES V(K,L) AND U(K,L)   ***
2050 :
2060 FOR M = 1 TO A-1
2070 II=II+1:CT=CT+1
2080 FOR N = 1 TO B-1
2090 JJ=JJ+1:KT=KT+1
2100 V(K,L) = V(K,L) + U(II,JJ)
2110 IF KT = B THEN GOTO 2130
2120 NEXT N
2130 KT=1:JJ=J
2140 IF CT = A THEN CT = 1:GOTO 2160
2150 NEXT M
2160 II=I:JJ=J
```

```
2170 RETURN
```

Program number 4. CORR.BAS

```
100 REM  ***   PROGRAM FOR AUTOCORRELATION COEFFICIENTS AND
110 REM                THE SPECTRAL ANALYSIS
120 :
130 REM  ***  FOR THE NIAMEY STATION VARIABILITY STUDY  ***
140 :
150 REM  ***  DATA FROM "STATISTICAL METHODS FOR AGRICULTURAL WORKERS
160 REM                 -----PAGES 132-133-----
170 :
180 REM  ***   PROGRAM NAME IS   --- CORR.BAS ---
190 '
200 REM        DATA DISK IS NAMED  --YLDSEED.DAT--
210 '
220 REM        FILE NAME FOR DETRENDING DATA   ---CURVE1.DAT---
230 :
240 PRINT CHR$(26)
250 PRINT"          FIELD PLOT UNIFORMITY STUDY FOR AUTO-CORRELATION AND"
260 PRINT"                            SPECTRAL ANALYSIS"
270 PRINT
280 PRINT"          FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
290 PRINT"           KAYPRO II COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
300 PRINT:PRINT
310 PRINT"                       WRITTEN April, 1983"
320 PRINT
330 PRINT:PRINT:PRINT:PRINT:PRINT
340 PRINT"                     INSERT DATA DISK IN DRIVE B OR ONE (1)"
350 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
360 PRINT"                     PRESS 'ENTER' OR <CR> TO CONTINUE"
370 LINE INPUT R$
380 CLEAR:PRINT CHR$(26)
390 DIM D$(40),U(40,40),UM(40),STD(40),COV(40),R(40)
400 DIM VY(40),XO(40),XS(40)
410 INPUT "ENTER FILE NAME FOR DATA";F$
420 PRINT
430 INPUT"ENTER FILE NAME FOR DETRENDING DATA ";G$
440 '
450 REM     *****      DISK READ SEGMENT     *****
460 '
470 OPEN "R",#1,F$,128
480 FIELD #1, 4 AS D$(1), 4 AS D$(2), 4 AS D$(3), 4 AS D$(4), 4 AS D$(5)
490 FIELD #1, 20 AS DU$, 4 AS D$(6), 4 AS D$(7), 4 AS D$(8), 4 AS D$(9)
500 FIELD #1, 36 AS DU$,4 AS D$(10), 4 AS D$(11), 4 AS D$(12), 4 AS D$(13)
510 FIELD #1, 52 AS DU$,4 AS D$(14), 4 AS D$(15), 4 AS D$(16), 4 AS D$(17)
```

```
520 FIELD #1, 68 AS DU$,4 AS D$(18), 4 AS D$(19), 4 AS D$(20), 4 AS D$(21)
530 FIELD #1, 84 AS DU$,4 AS D$(22), 4 AS D$(23), 4 AS D$(24), 4 AS D$(25)
540 FIELD #1,100 AS DU$,4 AS D$(26), 4 AS D$(27), 4 AS D$(28), 4 AS D$(29)
550 FIELD #1,116 AS DU$,4 AS D$(30), 4 AS D$(31), 4 AS D$(32)
560 '
570 FOR I = 1 TO 40
580 GET #1,I
590 FOR J = 1 TO 32
600 U(I,J) = VAL(D$(J))
610 NEXT J
620 NEXT I
630 CLOSE #1
640 PRINT CHR$(26)
650 :
660 REM   ***   DETRENDING THE DATA SET   ***
670 '
680 OPEN "R", #2, G$, 128
690 FIELD #2, 9 AS A$, 11 AS B$, 7 AS C$
700 FOR I = 1 TO 40
710 GET #2,I
720 A1 = VAL(A$)
730 B1 = VAL(B$)
740 MEAN = VAL(C$)
750 PRINT A1,B1, MEAN
760 FOR J = 1 TO 32
770 XX = J
780 CON = A1 + B1*1.4224*XX
790 DIF = CINT(CON - MEAN)
800 IF DIF <= 0 THEN GOTO 830
810 U(I,J) = U(I,J) + DIF
820 GOTO 840
830 U(I,J) = U(I,J) - DIF
840 NEXT J
850 NEXT I
860 CLOSE #2
870 '
880 REM   ***   PRINT NEW DETRENDED DATA SET   ***
890 '
900 PRINT"                          DETRENDED DATA SET":PRINT
910 LPRINT"                          DETRENDED DATA SET":LPRINT
920 FOR I = 1 TO 40
930 FOR J = 1 TO 16
940 PRINT USING "####";U(I,J);
950 LPRINT USING "####";U(I,J);
960 NEXT J
970 PRINT "     "
980 LPRINT "     "
990 NEXT I
1000 PRINT:PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
1010 FOR I = 1 TO 40
```

```
1020 FOR J = 17 TO 32
1030 PRINT USING "####";U(I,J);
1040 LPRINT USING "####";U(I,J);
1050 NEXT J
1060 PRINT"     "
1070 LPRINT"     "
1080 NEXT I
1090 LPRINT"----------"
1100 LPRINT:LPRINT:PRINT CHR$(26)
1110 '
1120 REM   ***   VALUES NEEDED FOR AUTOCORRELATION CALCULATION   ***
1130 '
1140 FOR I = 1 TO 40
1150 S1=0:S3=0
1160 FOR J = 1 TO 32
1170 IF I = 8 THEN 1260
1180 IF I = 10 THEN 1260
1190 IF I = 23 THEN 1260
1200 IF I = 26 THEN 1260
1210 IF I = 30 THEN 1260
1220 IF I = 32 THEN 1260
1230 S1 = S1 + U(I,J)
1240 S3 = S3 + U(I,J)^2
1250 GOTO 1290
1260 XX = LOG(U(I,J))
1270 S1 = S1 + XX
1280 S3 = S3 + XX^2
1290 NEXT J
1300 VY(I) = (32*S3 - S1^2)/(32*30)
1310 NEXT I
1320 '
1330 :
1340 REM  ***   DETERMINATION OF THE AUTOCORRELATION COEFFICIENT
1350 REM             1.  FOR EACH OF 40 ROWS, AND
1360 REM             2.  FOR EACH OF 32 COLUMNS.
1370 :
1380 REM              LAG RANGES FROM 0 TO 1/3RD OF ROW OR COLUMN
1390 :
1400 LPRINT "ROW" TAB(15) "LAG" TAB(33) "AUTOCORRELATION"
1410 LPRINT TAB(35) "COEFFICIENT"
1420 LPRINT"-----------------------------------------------------------"
1430 PRINT  "ROW" TAB(15) "LAG" TAB(33) "AUTOCORRELATION"
1440 PRINT  TAB(35) "COEFFICIENT"
1450 PRINT"-------------------------------------------------------------"
1460 FOR I = 1 TO 40
1470 XN = CINT((32/3) + 1)
1480 FOR L = 1 TO XN
1490 T1=0:T2=0:T3=0
1500 LA = 32 - L + 1
1510 FOR J = 1 TO LA
```

```
1520 K = J + L - 1
1530 IF I = 8 THEN 1630
1540 IF I = 10 THEN 1630
1550 IF I = 23 THEN 1630
1560 IF I = 26 THEN 1630
1570 IF I = 30 THEN 1630
1580 IF I = 32 THEN 1630
1590 T1 = T1 + U(I,J)
1600 T2 = T2 + U(I,K)
1610 T3 = T3 + U(I,J)*U(I,K)
1620 GOTO 1680
1630 XX = LOG(U(I,J))
1640 YY = LOG(U(I,K))
1650 T1 = T1 + XX
1660 T2 = T2 + YY
1670 T3 = T3 + XX*YY
1680 NEXT J
1690 AL = LA
1700 R(I) = ((AL*T3 - T1*T2)/(AL*(AL - 1)))/VY(I)
1710 I1 = L - 1
1720 IF I1 > 0 THEN GOTO 1760
1730 PRINT TAB(2) I TAB(16) I1 TAB(36) R(I)
1740 LPRINT TAB(2) I TAB(16) I1 TAB(36) R(I)
1750 GOTO 1780
1760 PRINT TAB(16) I1 TAB(36) R(I)
1770 LPRINT TAB(16) I1 TAB(36) R(I)
1780 NEXT L
1790 PRINT"--------------------------------------------------------"
1800 LPRINT"-------------------------------------------------------"
1810 NEXT I
1820 :
1830 REM  ***  ROUTINE FOR FOURIER SERIES ANALYSIS  ***
1840 :
1850 REM           U(I,J) = ARRAY OF EQUALLY SPACED DATA POINTS
1860 REM           XO(I)  = RAW POWER SPECTRUM
1870 REM           XS(I)  = SMOOTHED POWER SPECTRUM
1880 :
1890 REM           ROW SPACING = 1 LAG UNIT = 142.24CM
1900 :
1910 CC = 6.2832/32
1920 R = 2/32
1930 N2 = 1 + 32/2
1940 FOR K = 1 TO 40
1950 PRINT:PRINT
1960 PRINT "ROW" TAB(8) "HARMONIC" TAB(23) "A1" TAB(37)"B1" TAB(54) "RAW"
1970 PRINT TAB(8) "NUMBER" TAB(22) "COEF" TAB(36) "COEF", "SPECTRUM"
1980 PRINT"---------------------------------------------------------"
1990 LPRINT:LPRINT
2000 LPRINT "ROW" TAB(8) "HARMONIC" TAB(23) "A1" TAB(37)"B1" TAB(54)"RAW"
2010 LPRINT TAB(8) "NUMBER" TAB(22) "COEF" TAB(36) "COEF", "SPECTRUM"
```

```
2020 LPRINT"------------------------------------------------------------"
2030 FOR I = 1 TO N2
2040 S1=0:S2=0
2050 FOR J = 1 TO 32
2060 ARG = (I - 1)*(J - 1)*CC
2070 S1 = S1 + U(K,J)*COS(ARG)
2080 S2 = S2 + U(K,J)*SIN(ARG)
2090 NEXT J
2100 A1 = S1*R
2110 IF I = 1 THEN A1 = A1/2
2120 B1 = S2*R
2130 S = A1^2 + B1^2
2140 XO(I) = S
2150 I1 = I - 1
2160 IF I1 > 0 THEN GOTO 2200
2170 PRINT TAB(2) K TAB(10) I1 TAB(20) A1 TAB(35) B1 TAB(52) S
2180 LPRINT TAB(2) K TAB(10) I1 TAB(20) A1 TAB(35) B1 TAB(52) S
2190 GOTO 2220
2200 PRINT TAB(10) I1 TAB(20) A1 TAB(35) B1 TAB(52) S
2210 LPRINT TAB(10) I1 TAB(20) A1 TAB(35) B1 TAB(52) S
2220 NEXT I
2230 :
2240 REM  ***   COMPUTING SMOOTHED POWER SPECTRUM   ***
2250 :
2260 PRINT:PRINT
2270 PRINT TAB(8) "HARMONIC" TAB(25) "SMOOTHED SPECTRUM"
2280 PRINT TAB(9) "NUMBER":PRINT
2290 LPRINT:LPRINT
2300 LPRINT TAB(8) "HARMONIC" TAB(25) "SMOOTHED SPECTRUM"
2310 LPRINT TAB(9) "NUMBER":LPRINT
2320 N3 = N2 - 2
2330 FOR KK = 1 TO N3
2340 XS(KK) = XO(KK)/4 + XO(KK+1)/2 + XO(KK+2)/4
2350 PRINT TAB(10) KK+1 TAB(29) XS(KK)
2360 LPRINT TAB(10) KK+1 TAB(29) XS(KK)
2370 NEXT KK
2380 PRINT"----------------------------------------------------------"
2390 LPRINT"---------------------------------------------------------"
2400 NEXT K
2410 END
```

Program number 5. SPACORR.BAS

```
100 REM   ***   PROGRAM FOR SPATIAL CORRELATION COEFFICIENTS   ***
110 :
120 REM  ***  FOR THE NIAMEY STATION VARIABILITY STUDY  ***
130 :
140 REM  ***  DATA FROM "STATISTICAL METHODS FOR AGRICULTURAL WORKERS
150 REM                  -----PAGES 132-133-----
160 :
170 REM  ***   PROGRAM NAME IS   --- SPACORR.BAS ---
180 '
190 REM          DATA DISK IS NAMED  --YLDSEED.DAT--
200 '
210 REM          FILE NAME FOR DETRENDING DATA   ---CURVE2.DAT---
220 :
230 PRINT CHR$(26)
240 PRINT"            FIELD PLOT UNIFORMITY STUDY FOR SPATIAL CORRELATION"
250 PRINT"                                VERTICAL ANALYSIS"
260 PRINT
270 PRINT"          FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
280 PRINT"           KAYPRO II COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
290 PRINT:PRINT
300 PRINT"                           WRITTEN April, 1983"
310 PRINT:PRINT:PRINT:PRINT:PRINT
320 PRINT"                         INSERT DATA DISK IN DRIVE B OR ONE (1)"
330 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
340 PRINT"                         PRESS 'ENTER' OR <CR> TO CONTINUE"
350 LINE INPUT R$
360 CLEAR:PRINT CHR$(26)
370 DIM D$(40),U(40,40),R(40,40),UMEAN(40)
380 DIM A1(40),B1(40),MEAN(40)
390 INPUT "ENTER FILE NAME FOR DATA";F$
400 PRINT
410 INPUT "ENTER FILE NAME FOR DETRENDING DATA ";P$
420 '
430 PRINT"THIS IS THE VERTICAL ANALYSIS (COLUMN)"
440 LPRINT"          THIS IS THE VERTICAL ANALYSIS -- COLUMN DATA":LPRINT
450 '
460 REM     *****     DISK READ SEGMENT     *****
470 '
480 PRINT "READING THE DATA DISK"
490 OPEN "R",#1,F$,128
500 FIELD #1,4 AS D$(1), 4 AS D$(2), 4 AS D$(3), 4 AS D$(4), 4 AS D$(5)
510 FIELD #1,20 AS DU$, 4 AS D$(6), 4 AS D$(7), 4 AS D$(8), 4 AS D$(9)
```

```
520 FIELD #1,36 AS DU$,4 AS D$(10), 4 AS D$(11), 4 AS D$(12), 4 AS D$(13)
530 FIELD #1,52 AS DU$,4 AS D$(14), 4 AS D$(15), 4 AS D$(16), 4 AS D$(17)
540 FIELD #1,68 AS DU$,4 AS D$(18), 4 AS D$(19), 4 AS D$(20), 4 AS D$(21)
550 FIELD #1,84 AS DU$,4 AS D$(22), 4 AS D$(23), 4 AS D$(24), 4 AS D$(25)
560 FIELD #1,100 AS DU$,4 AS D$(26),4 AS D$(27), 4 AS D$(28), 4 AS D$(29)
570 FIELD #1, 116 AS DU$, 4 AS D$(30), 4 AS D$(31), 4 AS D$(32)
580 '
590 FOR I = 1 TO 40
600 GET #1,I
610 FOR J = 1 TO 32
620 U(J,I) = VAL(D$(J))
630 NEXT J
640 NEXT I
650 CLOSE #1
660 PRINT CHR$(26)
670 :
680 REM   ***   DETRENDING THE DATA SET   ***
690 '
700 PRINT "DETRENDING THE DATA SET"
710 OPEN "R",#2,P$,128
720 FIELD #2, 9 AS A$, 11 AS B$, 7 AS C$
730 FOR I = 1 TO 32
740 GET #2,I
750 A1(I) = VAL(A$)
760 B1(I) = VAL(B$)
770 MEAN(I) = VAL(C$)
780 NEXT I
790 CLOSE #2
800 FOR I = 1 TO 32
810 PRINT A1(I),B1(I),MEAN(I)
820 FOR J = 1 TO 40
830 XX = J
840 CON = A1(I) + B1(I)*1.4224*XX
850 DIF = CINT(CON - MEAN(I))
860 IF DIF <= 0 THEN GOTO 890
870 U(I,J) = U(I,J) + DIF
880 GOTO 900
890 U(I,J) = U(I,J) - DIF
900 NEXT J.
910 NEXT I
920 PRINT "INVERTED DATA SET"
930 LPRINT"INVERTED DATA SET"
940 FOR I = 0 TO 31
950 L = 32 - I
960 FOR J = 0 TO 39
970 K = 40 - J
980 U(I+1,J+1) = U(L,K)
990 NEXT J
1000 NEXT I
1010 '
```

```
1020 REM   ***   PRINT NEW DETRENDED DATA SET   ***
1030 '
1040 PRINT"                    DETRENDED DATA SET":PRINT
1050 LPRINT"                    DETRENDED DATA SET":LPRINT
1060 FOR I = 1 TO 32
1070 FOR J = 1 TO 20
1080 PRINT USING "####";U(I,J);
1090 LPRINT USING "####";U(I,J);
1100 NEXT J
1110 PRINT "    "
1120 LPRINT "    "
1130 NEXT I
1140 PRINT:PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
1150 FOR I = 1 TO 32
1160 FOR J = 21 TO 40
1170 PRINT USING "####";U(I,J);
1180 LPRINT USING "####";U(I,J);
1190 NEXT J
1200 PRINT"    "
1210 LPRINT"    "
1220 NEXT I
1230 LPRINT"----------"
1240 LPRINT:LPRINT:PRINT CHR$(26)
1250 '
1260 REM   ***   VALUES NEEDED FOR SPATIAL CORRELATION CALCULATION   ***
1270 '
1280 FOR I = 1 TO 32
1290 S1=0
1300 FOR J = 1 TO 40
1310 S1 = S1 + U(I,J)
1320 NEXT J
1330 UMEAN(I) = S1/40
1340 NEXT I
1350 '
1360 :
1370 REM   ***   DETERMINATION OF THE SPATIAL COEFFICIENT
1380 REM           1.  FOR EACH ROW OF 32 OBSERVATIONS, AND
1390 REM           2.  FOR EACH COLUMN OF 40 OBSERVATIONS.
1400 :
1410 REM              LAG RANGES FROM 0 TO M-1 OF ROW OR COLUMN
1420 :
1430 LPRINT "COLUMN" TAB(15) "LAG" TAB(31) "SPATIAL CORRELATION"
1440 LPRINT TAB(35) "COEFFICIENT"
1450 LPRINT"-------------------------------------------------------"
1460 PRINT  "COLUMN" TAB(15) "LAG" TAB(31) "SPATIAL CORRELATION"
1470 PRINT  TAB(35) "COEFFICIENT"
1480 PRINT"--------------------------------------------------------"
1490 FOR J = 1 TO 39
1500 KNT = 0
1510 L = J + 1
```

```
1520 IK = L
1530 CNT=0:T1=0:T2=0:T3=0
1540 FOR I = 1 TO 32
1550 T1 = T1 + (U(I,J) - UMEAN(J))*(U(I,L) - UMEAN(L))
1560 T2 = T2 + (U(I,J) - UMEAN(J))^2
1570 T3 = T3 + (U(I,L) - UMEAN(L))^2
1580 CNT = CNT + 1
1590 NEXT I
1600 C1 = SQR(T2/CNT)
1610 C2 = SQR(T3/CNT)
1620 R(L,J) = (T1/CNT)/(C1*C2)
1630 L = L + 1
1640 IF L > 40 THEN 1660
1650 GOTO 1530
1660 FOR L = IK TO 40
1670 IF KNT > 0 THEN 1720
1680 KNT = KNT + 1
1690 PRINT TAB(4) J; TAB(15) L-J; TAB(37) R(L,J)
1700 LPRINT TAB(4) J; TAB(15) L-J; TAB(37) R(L,J)
1710 GOTO 1740
1720 PRINT TAB(15) L-J; TAB(37) R(L,J)
1730 LPRINT TAB(15) L-J; TAB(37) R(L,J)
1740 NEXT L
1750 PRINT:LPRINT
1760 NEXT J
1770 PRINT "MEAN DISTANCE OF UNIFORMITY"
1780 LPRINT "MEAN DISTANCE OF UNIFORMITY"
1790 PRINT:PRINT "COLUMN"; TAB(12) "DISTANCE"
1800 LPRINT:LPRINT "COLUMN";TAB(12) "DISTANCE"
1810 FOR J = 1 TO 39
1820 XX = J: BB = 0: KK = 1
1830 A1=0:A2=0:CTR=1
1840 FOR I = J TO 39
1850 XZ = I
1860 IF BB > 0 THEN 1930
1870 IF R(I,J) < 0 THEN BB = 10: KK = I: GOTO 1940
1880 IF CTR > 1 THEN 1920
1890 A1 = A1 + ((1+R(I,J))/2)*(1.422*(XZ+1)-1.4224*XZ)
1900 CTR = + 1
1910 GOTO 1930
1920 A1 = A1 + ((R(I,J)+R(I+1,J))/2)*(1.4224*(XZ+1)-1.4224*XZ)
1930 NEXT I
1940 A2 = A1 + (R(KK,J)/2)*(1.4224*(XZ+1)-1.4224*XZ)
1950 PRINT TAB(3) J; TAB(15)A2
1960 LPRINT TAB(3) J; TAB(15)A2
1970 NEXT J
1980 END
```

Program number 6. KRIG1.BAS

```
100 REM    ***          PROGRAM FOR SEMIVARIOGRAMS          ***
110 '
120 REM            NAME OF THE PROGRAM IS --- KRIG1.BAS ---
130 '
140 REM             DATA FILE IS NAMED --- YLDSEED.DAT ---
150 '
160 PRINT CHR$(26)
170 PRINT"             FIELD PLOT UNIFORMITY STUDY FOR SEMIVARIOGRAMS"
180 PRINT
190 PRINT"          FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
200 PRINT"           KAYPRO IV COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
210 PRINT:PRINT
220 PRINT"                               WRITTEN April, 1983"
230 PRINT:PRINT:PRINT:PRINT:PRINT
240 PRINT"                     INSERT DATA DISK IN DRIVE B OR ONE (1)"
250 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
260 PRINT"                    PRESS 'ENTER' OR <CR> TO CONTINUE"
270 LINE INPUT R$
280 CLEAR:PRINT CHR$(26)
290 INPUT"ENTER NUMBER OF HORIZONTAL ROWS  ON DATA SET (40)";H
300 PRINT
310 INPUT"ENTER NUMBER OF VERTICAL COLUMNS ON DATA SET (32)";K
320 PRINT
330 INPUT"ENTER THE HORIZONTAL (ROW) GRID SPACING";XH
340 PRINT
350 INPUT"ENTER THE VERTICAL (COLUMN) GRID SPACING";XK
360 PRINT
370 DIM D$(K),U(H,K),V(H,K),Z(H,K)
380 INPUT"ENTER 'SEQUENTIAL' FILE NAME FOR DATA SET";F$
390 PRINT:PRINT"READING DISK"
400 '
410 REM     ****    DISK READ SEGMENT    ****
420 '
430 OPEN "I", #1, F$
440 FOR I = 1 TO H
450 FOR J = 1 TO K
460 INPUT#1,U(I,J)
470 V(J,I) = U(I,J)
480 Z(I,J) = U(I,J)
490 NEXT J, I
500 CLOSE #1
```

```
510 '
520 REM    ***   PRINTING THE DATA SET   ***
530 '
540 PRINT
550 LINE INPUT"DO YOU WANT TO PRINT THE DATA SET?";R$
560 IF LEFT$(R$,1) = "N" GOTO 710
570 DB = 1:DD = 8
580 FOR I = 1 TO H
590 FOR J = DB TO DD
600 PRINT U(I,J);
610 LPRINT U(I,J);
620 NEXT J
630 PRINT" ":LPRINT" "
640 NEXT I
650 PRINT:PRINT:LPRINT:LPRINT
660 DB = DB + 8: DD = DD + 8
670 IF DD < K GOTO 580
680 IF DD < K+8 AND DD >= K THEN DD = K: GOTO 580
690 LPRINT"--------------------"
700 LPRINT:LPRINT
710 PRINT CHR$(26)
720 '
730 REM    ***   LINEAR REGRESSION FOR HORIZONTAL DETRENDING   ***
740 '
750 Y1=0:Y2=0:Y3=0:Y4=0:Y5=0:KN=0
760 FOR I = 1 TO H
770 FOR J = 1 TO K
780 IF U(I,J) = 0 THEN GOTO 840
790 XX = I
800 KN = KN + 1
810 Y1 = Y1 + XH*XX
820 Y2 = Y2 + U(I,J): Y3 = Y3 + (XH*XX)^2
830 Y4 = Y4 + U(I,J)^2: Y5 = Y5 + XH*XX*U(I,J)
840 NEXT J, I
850 B1 = (KN*Y5 - Y2*Y1)/(KN*Y3 - Y1^2)
860 A1 = (Y2 - B1*Y1)/KN
870 MEAN = Y2/KN
880 PRINT A1, B1, MEAN
890 LPRINT:LPRINT
900 LPRINT"LINEAR EQUATION IS  DETRENDED VALUE = A1 + B1*(FILE) WHERE:"
910 LPRINT
920 LPRINT:LPRINT"A1 =  ";A1;"  B1 =  ";B1;"  MEAN =  ";MEAN:LPRINT
930 '
940 REM    ***   DETRENDING THE DATA SET   ***
950 '
960 PRINT "DETRENDING THE HORIZONTAL DATA SET"
970 FOR I = 1 TO H
980 FOR J = 1 TO K
990 IF U(I,J) = 0 THEN GOTO 1070
1000 XX = J
```

```
1010 CON = A1 + XH*B1*XX
1020 DIF = CINT(CON - MEAN)
1030 IF DIF <= 0 THEN GOTO 1060
1040 U(I,J) = U(I,J) + DIF
1050 GOTO 1070
1060 U(I,J) = U(I,J) - DIF
1070 NEXT J
1080 NEXT I
1090 '
1100 REM    ***   DETERMINATION OF THE SEMI-VARIANCE    ***
1110 REM              FOR THE HORIZONTAL DIRECTION
1120 PRINT CHR$(26)
1130 LPRINT:LPRINT"HORIZONTAL SEMI-VARIANCE":LPRINT
1140 LPRINT"SEMI-VARIANCE";TAB(17)"DISTANCE";TAB(30)"N PAIRS"
1150 LPRINT"-------------------------------------------------------------"
1160 PRINT "SEMI-VARIANCE";TAB(17)"DISTANCE";TAB(30)"N PAIRS"
1170 PRINT "------------------------------------------------------------"
1180 KT=1:S1=0:NE=K-1:KN=0
1190 FOR I = 1 TO H
1200 FOR J = 1 TO NE
1210 IF U(I,J) = 0 THEN GOTO 1250
1220 IF U (I,J+KT) = 0 THEN GOTO 1250
1230 KN = KN + 1
1240 S1 = S1 + (U(I,J) - U(I,J+KT))^2
1250 NEXT J, I
1260 G = S1/(2*KN)
1270 LPRINT TAB(1) G;TAB(17) KT*XH; TAB(30) KN
1280 PRINT TAB(1) G;TAB(17) KT*XH; TAB(30) KN
1290 KT = KT + 1:NE = NE - 1:S1=0:KN=0
1300 IF KT < K GOTO 1190
1310 PRINT CHR$(26)
1320 '
1330 REM    ***   LINEAR REGRESSION FOR VERTICAL DETRENDING    ***
1340 '
1350 Y1=0:Y2=0:Y3=0:Y4=0:Y5=0:KN=0
1360 FOR I = 1 TO K
1370 FOR J = 1 TO H
1380 IF V(I,J) = 0 THEN GOTO 1440
1390 KN = KN + 1
1400 XX = I
1410 Y1 = Y1 + XK*XX
1420 Y2 = Y2 + V(I,J): Y3 = Y3 + (XK*XX)^2
1430 Y4 = Y4 + V(I,J)^2: Y5 = Y5 + XK*XX*V(I,J)
1440 NEXT J, I
1450 B1 = (KN*Y5 - Y2*Y1)/(KN*Y3 - Y1^2)
1460 A1 = (Y2 - B1*Y1)/KN
1470 MEAN = Y2/KN
1480 PRINT A1, B1, MEAN
1490 LPRINT:LPRINT
1500 LPRINT"VERTICAL SEMI-VARIANCE"
```

```
1510 LPRINT:LPRINT"A1 = ";A1;"  B1 = ";B1;"  MEAN =  ";MEAN:LPRINT
1520 '
1530 REM   ***   DETRENDING VERTICAL DATA SET   ***
1540 '
1550 PRINT"DETRENDING VERTICAL DATA SET"
1560 FOR I = 1 TO K
1570 FOR J = 1 TO H
1580 IF V(I,J) = 0 THEN GOTO 1660
1590 XX = J
1600 CON = A1 + B1*XK*XX
1610 DIF = CINT(CON - MEAN)
1620 IF DIF <= 0 THEN GOTO 1650
1630 V(I,J) = V(I,J) + DIF
1640 GOTO 1660
1650 V(I,J) = V(I,J) - DIF
1660 NEXT J
1670 NEXT I
1680 '
1690 REM   ***   VERTICAL DATA SET   **
1700 '
1710 PRINT CHR$(26)
1720 PRINT "CALCULATING VERTICAL SEMI-VARIANCE"
1730 LPRINT:LPRINT
1740 LPRINT"SEMI-VARIANCE";TAB(17)"DISTANCE";TAB(30)"N PAIRS";TAB(42)"G2";
1750 LPRINT TAB(55)"G3"
1760 PRINT "SEMI-VARIANCE";TAB(17)"DISTANCE";TAB(30)"N PAIRS";TAB(42)"G2";
1770 PRINT TAB(55)"G3"
1780 LPRINT"------------------------------------------------------------"
1790 PRINT "------------------------------------------------------------"
1800 NE=H-1:KT=1:S2=0:KN=0:D=0:F=0:S4=0:S5=0:G2=0:G3=0
1810 FOR I = 1 TO K
1820 FOR J = 1 TO NE
1830 IF V(I,J) = 0 THEN GOTO 1870
1840 IF V(I,J+KT) = 0 THEN GOTO 1870
1850 KN = KN + 1
1860 S2 = S2 + (V(I,J) - V(I,J+KT))^2
1870 NEXT J, I
1880 G1 = S2/(2*KN)
1890 S4 = S4 + G1
1900 S5 = S5 + G1
1910 D = D + 1: F = F + 1
1920 IF D = 2 THEN G2 = S4/2: D=0:S4=0
1930 IF F = 3 THEN G3 = S5/3: F=0:S5=0
1940 LPRINT TAB(1) G1;TAB(17) KT*XK; TAB(30) KN;TAB(40)G2;TAB(53) G3
1950 PRINT  TAB(1) G1;TAB(17) KT*XK;TAB(30) KN;TAB(40) G2; TAB(53) G3
1960 KT = KT + 1:NE = NE - 1: S2=0: KN=0
1970 IF KT < H THEN GOTO 1810
1980 '
1990 REM   ***   DIAGONAL   ***
2000 '
```

```
2010 PRINT CHR$(26)
2020 '
2030 REM    ***   LINEAR REGRESSION FOR DIAGONAL DETRENDING    ***
2040 '
2050 Y1=0:Y2=0:Y3=0:Y4=0:Y5=0:KN=0:XR = SQR(XK^2 + XH^2)
2060 FOR I = 1 TO H
2070 FOR J = 1 TO K
2080 IF Z(I,J) = 0 THEN GOTO 2150
2090 KN = KN + 1
2100 IF J <= I THEN XX = J - 1: GOTO 2120
2110 IF J > I THEN XX = I - 1
2120 Y1 = Y1 + XR*XX
2130 Y2 = Y2 + Z(I,J): Y3 = Y3 + (XR*XX)^2
2140 Y4 = Y4 + Z(I,J)^2: Y5 = Y5 + XR*XX*Z(I,J)
2150 NEXT J
2160 NEXT I
2170 B1 = (KN*Y5 - Y2*Y1)/(KN*Y3 - Y1^2)
2180 A1 = (Y2 - B1*Y1)/KN
2190 MEAN = Y2/KN
2200 PRINT A1, B1, MEAN
2210 LPRINT"--------------------------"
2220 LPRINT:LPRINT:LPRINT
2230 LPRINT "A1 =  ";A1;"  B1 =  ";B1;"  MEAN =  ";MEAN
2240 PRINT "DETRENDING DIAGONAL DATA SET"
2250 FOR I = 1 TO H
2260 FOR J = 1 TO K
2270 IF J <= I THEN XX = J - 1:GOTO 2290
2280 IF J > I THEN XX = I - 1
2290 CON = A1 + B1*XR*XX
2300 DIF = CINT(CON - MEAN)
2310 IF DIF <= 0 THEN GOTO 2340
2320 Z(I,J) =  Z(I,J) + DIF
2330 GOTO 2350
2340 Z(I,J) = Z(I,J) - DIF
2350 NEXT J
2360 NEXT I
2370 PRINT"CALCULATING DIAGONAL SEMI-VARIANCE"
2380 LPRINT:LPRINT
2390 LPRINT"DIAGONAL SEMI-VARIANCE":LPRINT
2400 LPRINT"SEMI-VARIANCE";TAB(17)"DISTANCE";TAB(30)"N PAIRS"
2410 PRINT "SEMI-VARIANCE";TAB(17)"DISTANCE";TAB(30)"N PAIRS"
2420 LPRINT"---------------------------------------------------------"
2430 PRINT "---------------------------------------------------------"
2440 KN=0:KT=1:NS=K-1:NE=H-1
2450 FOR I = 1 TO NE
2460 FOR J = 1 TO NS
2470 IF Z(I,J) = 0 THEN GOTO 2510
2480 IF Z(I+KT,J+KT) = 0 THEN GOTO 2510
2490 KN = KN + 1
2500 S3 = S3 + (Z(I,J) - Z(I+KT,J+KT))^2
```

```
2510 NEXT J, I
2520 G4 = S3/(2*KN)
2530 PRINT TAB(1)G4;TAB(17)KT*XR;TAB(32)KN
2540 LPRINT TAB(1)G4;TAB(17)KT*XR;TAB(32)KN
2550 KT = KT + 1: NS = NS - 1: NE = NE - 1:S3=0:KN=0
2560 IF KT < 19 THEN GOTO 2450
2570 PRINT"PROGRAM IS TERMINATED"
2580 END
```

Program number 7. SPHER.BAS

```
100 REM   ***   PROGRAM FOR SPHERICAL MODEL SEMIVARIOGRAMS   ***
110 REM                  PROGRAM IS NAMED  ---SPHER.BAS---
120 '
130 PRINT CHR$(26)
140 PRINT"            FIELD PLOT UNIFORMITY STUDY FOR SEMI-VARIOGRAMS"
150 PRINT
160 PRINT"         FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
170 PRINT:PRINT
180 PRINT"                            WRITTEN May, 1983"
190 PRINT:PRINT:PRINT:PRINT:PRINT
200 PRINT"                       INSERT DATA DISK IN DRIVE B OR ONE (1)"
210 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
220 PRINT"                       PRESS 'ENTER OR <CR> TO CONTINUE"
230 LINE INPUT R$
240 CLEAR:PRINT CHR$(26)
250 PRINT"AT EACH PROMPT, ENTER (IN STRICT ORDER) THE 'NUGGET EFFECT', Co"
260 PRINT"                                              THEN THE SILL, C"
270 INPUT CO
280 INPUT C1
290 PRINT:PRINT
300 PRINT"AT PROMPT, ENTER (IN STRICT ORDER) THE COLUMN SPACING, LAG = H"
310 PRINT"                                              THEN THE RANGE = A"
320 INPUT H
330 NS = 20
340 INPUT NS
350 DIM G1(NS),G2(NS),G3(NS)
360 PRINT:PRINT:LPRINT:LPRINT
370 PRINT TAB(5)"GAMMA";TAB(23)"h"
380 LPRINT TAB(5)"GAMMA";TAB(23)"h"
390 FOR I = 1 TO NS
400 H1 = H*I
410 IF H1 > A1 THEN GOTO 440
420 G1(I) = CO + C1*(1.5*H1/A1 - .5*(H1/A1)^3)
430 GOTO 450
440 G1(I) = CO + C1
450 PRINT TAB(5)G1(I);TAB(25)H1
460 LPRINT TAB(5)G1(I);TAB(25)H1
470 NEXT I
480 PRINT:PRINT:LPRINT:LPRINT
490 PRINT "THE DATA SET ENTERED IS AS FOLLOWS:"
500 PRINT
510 LPRINT"THE DATA SET ENTERED IS AS FOLLOWS:"
```

```
520 LPRINT
530 PRINT "NUGGET, Co = ";CO;"SILL, C = ";C1;
540 LPRINT"NUGGET, Co =";CO;" SILL, C = ";C1;
550 PRINT "RANGE, A =";A1
560 LPRINT"RANGE, A =";A1
570 PRINT"------------------------------------------------------------"
580 LPRINT"-------------------------------------------------------------"
590 PRINT:PRINT:PRINT"PROGRAM IS TERMINATED"
600 END
```

Program number 8. WEIGHTS.BAS

```
100 REM    ***   PROGRAM FOR DETERMINING KRIGED WEIGHTS    ***
110 REM      DATA IS FROM "STATISTICAL METHODS FOR AGRICULTURAL
120 REM                 WORKERS" ---PAGES 132-133 ---
130 '
140 REM    ***    NAME OF THE PROGRAM IS --- WEIGHTS.BAS ---
150 '
160 REM             DATA FILE IS NAMED --- YLDSEED.DAT ---
170 '
180 PRINT CHR$(26)
190 PRINT"               FIELD PLOT UNIFORMITY STUDY FOR KRIGED WEIGHTS"
200 PRINT
210 PRINT"           FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
220 PRINT"            KAYPRO IV COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
230 PRINT:PRINT
240 PRINT"                              WRITTEN March 27, 1984"
250 PRINT:PRINT:PRINT:PRINT:PRINT
260 PRINT"                         INSERT DATA DISK IN DRIVE B OR ONE (1)"
270 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
280 PRINT"                         PRESS 'ENTER' OR <CR> TO CONTINUE"
290 LINE INPUT R$
300 CLEAR: PRINT CHR$(26)
310 PRINT"THIS PROGRAM WORKS ONLY ON THE 16-POINT NEIGHBORHOOD TECHNIQUE"
320 PRINT"AS SHOWN IN FIGURE 25 FOR THE GRID TO DETERMINE KRIGED VALUES."
330 PRINT:PRINT
340 INPUT"ENTER THE RANGE OF INFLUENCE, 'A' (FROM SEMIVARIOGRAM)";ZZ
350 PRINT
360 INPUT"ENTER THE VALUE FOUND FOR THE SILL, 'C'";XX
370 PRINT
380 INPUT"ENTER THE VALUE FOR THE 'NUGGET' EFFECT, 'Co'";YY
390 PRINT
400 INPUT"ENTER THE HORIZONTAL (ROW) GRID SPACING";X1
410 PRINT
420 INPUT"ENTER THE VERTICAL (COLUMN) GRID SPACING";Y1
430 PRINT CHR$(26)
440 PRINT"             THESE ARE THE VALUES THAT YOU HAVE SELECTED"
450 PRINT
460 PRINT"                   THE RANGE OF INFLUENCE , 'A', IS SET AT";ZZ
470 PRINT
480 PRINT"                   THE SILL, 'C', IS SET AT                ";XX
490 PRINT
500 PRINT"                   THE 'NUGGET' EFFECT, 'Co', IS SET AT    ";YY
510 PRINT
```

```
520 PRINT"                    THE HORIZONTAL GRID SPACING IS SET AT   ";X1
530 PRINT
540 PRINT"                    THE VERTICAL GRID SPACING IS SET AT     ";Y1
550 PRINT
560 PRINT:PRINT
570 PRINT"DO YOU WANT TO USE THEM?   ANSWER YES OR NO."
580 INPUT"OPTION ";C$
590 IF C$ <> "NO" THEN IF C$ <> "YES" GOTO 570
600 IF C$ = "NO" THEN GOTO 310
610 '
620 REM    ***   WRITING DATA INTO A SEQUENTIAL FILE    ***
630 '
640 OPEN "O", #2, "B:CONST1.DAT"
650 PRINT#2,ZZ;",";XX;",";YY;",";X1;",";Y1
660 CLOSE #2
670 DIM G(20),GS(20,20),D(20,20)
680 PRINT CHR$(26)
690 PRINT"READING H(d,b) TABLE"
700 FOR I = 1 TO 20
710 FOR J = 1 TO 20
720 READ D(I,J)
730 NEXT J, I
740 PRINT
750 PRINT"CALCULATING THE CONSTANT"
760 CNT = 0
770 '
780 REM    ***   SOLVING FOR H(d,b) VALUES    ***
790 '             WHERE X = d AND Y = b
800 '
810 FOR I = 1 TO 16
820 PRINT"     ";I
830 X = X1/ZZ:Y = Y1/ZZ
840 CNT = CNT + 1:XN = 4
850 IF I <=4 THEN Y = Y:X = X:M=1:N=1: GOTO 1000
860 IF I = 5 THEN Y = 3*Y:X = 3*X:M=3:N=3:GOTO 1000
870 IF I = 6 AND CNT = 1 THEN Y = 3*Y:X = X:M = 3:N=1:GOTO 1000
880 IF I = 6 AND CNT = 2 THEN Y = 3*Y:X = 2*X:M=3:N=2:GOTO 1000
890 IF I = 7 THEN G(7) = G(6): GOTO 1440
900 IF I = 8 THEN G(8) = G(5): GOTO 1440
910 IF I = 9 AND CNT = 1 THEN Y = Y: X = 3*X:M=1:N=3:GOTO 1000
920 IF I = 9 AND CNT = 2 THEN Y = 2*Y:X = 3*X:M=2:N=3:GOTO 1000
930 IF I = 10 THEN G(10) = G(9): GOTO 1440
940 IF I = 11 THEN G(11) = G(5): GOTO 1440
950 IF I = 12 THEN G(12) = G(6): GOTO 1440
960 IF I = 13 THEN G(13) = G(6): GOTO 1440
970 IF I = 14 THEN G(14) = G(5): GOTO 1440
980 IF I = 15 THEN G(15) = G(9): GOTO 1440
990 IF I = 16 THEN G(16) = G(9): GOTO 1440
1000 IF X < .1 THEN W1 = .05 + .653 * X:W2 = 0: GOTO 1140
1010 IF X >= .1 AND X < 1 THEN X2=FIX(X*10): X3=(X2/10)+.1:DB=.1:GOTO 1140
```

```
1020 IF X >= 1 AND X <= 5 THEN X4=FIX(X*10):GOTO 1040
1030 IF X > 5 THEN PRINT"IRREFUTABLE ERROR IN H(d,b) FUNCTION; b > 5":END
1040 IF X4 >= 10 AND X4 < 12 THEN X2 = 10: X3 = FIX(X4/10) + .2:DB = .2
1050 IF X4 >= 12 AND X4 < 14 THEN X2 = 11: X3 = FIX(X4/10) + .2:DB = .2
1060 IF X4 >= 14 AND X4 < 16 THEN X2 = 12: X3 = FIX(X4/10) + .2:DB = .2
1070 IF X4 >= 16 AND X4 < 18 THEN X2 = 13: X3 = FIX(X4/10) + .2:DB = .2
1080 IF X4 >= 18 AND X4 < 20 THEN X2 = 14: X3 = FIX(X4/10) + .2:DB = .2
1090 IF X4 >= 20 AND X4 < 25 THEN X2 = 15: X3 = FIX(X4/10) + .5:DB = .5
1100 IF X4 >= 25 AND X4 < 30 THEN X2 = 16: X3 = FIX(X4/10) + .5:DB = .5
1110 IF X4 >= 30 AND X4 < 35 THEN X2 = 17: X3 = FIX(X4/10) + .5:DB = .5
1120 IF X4 >= 35 AND X4 < 40 THEN X2 = 18: X3 = FIX(X4/10) + .5:DB = .5
1130 IF X4 >= 40 AND X4 < 50 THEN X2 = 19: X3 = FIX(X4/10) + 1:DB = 1
1140 IF Y < .1 THEN W3 = .05 + .653*Y:W4 = 0:GOTO 1340
1150 IF Y >= .1 AND Y < 1 THEN Y2=FIX(Y*10):Y3=(Y2/10)+.1:DD=.1:GOTO 1280
1160 IF Y >= 1 AND Y <=5 THEN Y4=FIX(Y*10):GOTO 1180
1170 IF Y > 5 THEN PRINT"IRREFUTABLE ERROR IN H(d,b) FUNCTION; D > 5":END
1180 IF Y4 >= 10 AND Y4 < 12 THEN Y2 = 10: Y3 = FIX(Y4/10) + .2:DD = .2
1190 IF Y4 >= 12 AND Y4 < 14 THEN Y2 = 11: Y3 = FIX(Y4/10) + .2:DD = .2
1200 IF Y4 >= 14 AND Y4 < 16 THEN Y2 = 12: Y3 = FIX(Y4/10) + .2:DD = .2
1210 IF Y4 >= 16 AND Y4 < 18 THEN Y2 = 13: Y3 = FIX(Y4/10) + .2:DD = .2
1220 IF Y4 >= 18 AND Y4 < 20 THEN Y2 = 14: Y3 = FIX(Y4/10) + .2:DD = .2
1230 IF Y4 >= 20 AND Y4 < 25 THEN Y2 = 15: Y3 = FIX(Y4/10) + .5:DD = .5
1240 IF Y4 >= 25 AND Y4 < 30 THEN Y2 = 16: Y3 = FIX(Y4/10) + .5:DD = .5
1250 IF Y4 >= 30 AND Y4 < 35 THEN Y2 = 17: Y3 = FIX(Y4/10) + .5:DD = .5
1260 IF Y4 >= 35 AND Y4 < 40 THEN Y2 = 18: Y3 = FIX(Y4/10) + .5:DD = .5
1270 IF Y4 >= 40 AND Y4 < 50 THEN Y2 = 19: Y3 = FIX(Y4/10) + 1:DD = 1
1280 IF X < .1 GOTO 1310
1290 W1 = D(X2+1,Y2) - ((D(X2+1,Y2) - D(X2,Y2)) * (X3 - X)/DB)
1300 W2 = D(X2+1,Y2+1) - ((D(X2+1,Y2+1) - D(X2,Y2+1)) * (X3 - X)/DB)
1310 IF Y < .1 GOTO 1340
1320 W3 = D(X2,Y2+1) - ((D(Y2+1,X2) - D(X2,Y2)) * (Y3 - Y)/DD)
1330 W4 = D(X2+1,Y2+1) - ((D(X2+1,Y2+1) - D(X2+1,Y2)) * (Y3 - Y)/DD)
1340 IF W1 = 0 THEN XN = XN - 1
1350 IF W2 = 0 THEN XN = XN - 1
1360 IF W3 = 0 THEN XN = XN - 1
1370 IF W4 = 0 THEN XN = XN - 1
1380 W = (W1 + W2 + W3 + W4)/XN
1390 IF I > 5 GOTO 1410
1400 G(I) = (N*X1 * M*Y1) * ((XX * W) + YY)/(N*X1 * M*Y1):GOTO 1440
1410 IF CNT = 1 THEN W6 = (N*X1 * M*Y1)*((XX * W) + YY):GOTO 830
1420 IF CNT = 2 THEN W7 = (N*X1 * M*Y1) * ((XX * W) + YY)
1430 G(I) = (W6 + W7)/(3*X1 * 3*Y1)
1440 CNT = 0
1450 NEXT I
1460 X2=0:X3=0:X4=0:Y2=0:Y3=0:Y4=0
1470 PRINT
1480 PRINT"CALCULATING COEFFICIENTS"
1490 FOR I = 1 TO 16
1500 PRINT I
1510 FOR J = 1 TO 16
```

```
1520 PRINT"                              ";J
1530 IF I = J THEN GS(I,J) = 0:GOTO 2750
1540 IF I = 1 AND J = 2 THEN XZ = X1:GOTO 2740
1550 IF I = 1 AND J = 3 THEN XZ = Y1:GOTO 2740
1560 IF I = 1 AND J = 4 THEN XZ = SQR(X1^2 + Y1^2):GOTO 2740
1570 IF I = 1 AND J = 5 THEN GS(1,5) = GS(1,4):GOTO 2750
1580 IF I = 1 AND J = 6 THEN GS(1,6) = GS(1,3):GOTO 2750
1590 IF I = 1 AND J = 7 THEN GS(1,7) = GS(1,4):GOTO 2750
1600 IF I = 1 AND J = 8 THEN XZ = SQR((2*X1)^2 + Y1^2):GOTO 2740
1610 IF I = 1 AND J = 9 THEN XZ = 2*X1:GOTO 2740
1620 IF I = 1 AND J = 10 THEN GS(1,10) = GS(1,8):GOTO 2750
1630 IF I = 1 AND J = 11 THEN XZ = SQR((2*X1)^2 + (2*Y1)^2):GOTO 2740
1640 IF I = 1 AND J = 12 THEN GS(1,12) = GS(1,8):GOTO 2750
1650 IF I = 1 AND J = 13 THEN XZ = 2*Y1:GOTO 2740
1660 IF I = 1 AND J = 14 THEN XZ = SQR(X1^2 + (2*Y1)^2):GOTO 2740
1670 IF I = 1 AND J = 15 THEN GS(1,15) = GS(1,4):GOTO 2750
1680 IF I = 1 AND J = 16 THEN GS(1,16) = GS(1,2):GOTO 2750
1690 IF I = 2 AND J = 3 THEN GS(2,3) = GS(1,4):GOTO 2750
1700 IF I = 2 AND J = 4 THEN GS(2,4) = GS(1,3):GOTO 2750
1710 IF I = 2 AND J = 5 THEN GS(2,5) = GS(1,8):GOTO 2750
1720 IF I = 2 AND J = 6 THEN GS(2,6) = GS(1,4):GOTO 2750
1730 IF I = 2 AND J = 7 THEN GS(2,7) = GS(1,3):GOTO 2750
1740 IF I = 2 AND J = 8 THEN GS(2,8) = GS(1,4):GOTO 2750
1750 IF I = 2 AND J = 9 THEN GS(2,9) = GS(1,2):GOTO 2750
1760 IF I = 2 AND J = 10 THEN GS(2,10) = GS(1,4):GOTO 2750
1770 IF I = 2 AND J = 11 THEN GS(2,11) = GS(1,14):GOTO 2750
1780 IF I = 2 AND J = 12 THEN GS(2,12) = GS(1,13):GOTO 2750
1790 IF I = 2 AND J = 13 THEN GS(2,13) = GS(1,14):GOTO 2750
1800 IF I = 2 AND J = 14 THEN GS(2,14) = GS(1,11):GOTO 2750
1810 IF I = 2 AND J = 15 THEN GS(2,15) = GS(1,8):GOTO 2750
1820 IF I = 2 AND J = 16 THEN GS(2,16) = GS(1,9):GOTO 2750
1830 IF I = 3 AND J = 4 THEN GS(3,4) = GS(1,2):GOTO 2750
1840 IF I = 3 AND J = 5 THEN GS(3,5) = GS(1,14):GOTO 2750
1850 IF I = 3 AND J = 6 THEN GS(3,6) = GS(1,13):GOTO 2750
1860 IF I = 3 AND J = 7 THEN GS(3,7) = GS(1,14):GOTO 2750
1870 IF I = 3 AND J = 8 THEN GS(3,8) = GS(1,11):GOTO 2750
1880 IF I = 3 AND J = 9 THEN GS(3,9) = GS(1,8):GOTO 2750
1890 IF I = 3 AND J = 10 THEN GS(3,10) = GS(1,9):GOTO 2750
1900 IF I = 3 AND J = 11 THEN GS(3,11) = GS(1,8):GOTO 2750
1910 IF I = 3 AND J = 12 THEN GS(3,12) = GS(1,4):GOTO 2750
1920 IF I = 3 AND J = 13 THEN GS(3,13) = GS(1,3):GOTO 2750
1930 IF I = 3 AND J = 14 THEN GS(3,14) = GS(1,4):GOTO 2750
1940 IF I = 3 AND J = 15 THEN GS(3,15) = GS(1,2):GOTO 2750
1950 IF I = 3 AND J = 16 THEN GS(3,16) = GS(1,4):GOTO 2750
1960 IF I = 4 AND J = 5 THEN GS(4,5) = GS(1,8):GOTO 2750
1970 IF I = 4 AND J = 6 THEN GS(4,6) = GS(1,12):GOTO 2750
1980 IF I = 4 AND J = 7 THEN GS(4,7) = GS(1,13):GOTO 2750
1990 IF I = 4 AND J = 8 THEN GS(4,8) = GS(1,12):GOTO 2750
2000 IF I = 4 AND J = 9 THEN GS(4,9) = GS(1,4):GOTO 2750
2010 IF I = 4 AND J = 10 THEN GS(4,10) = GS(1,2):GOTO 2750
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2020 IF I = 4 AND J = 11 THEN GS(4,11) = GS(1,4):GOTO 2750
2030 IF I = 4 AND J = 12 THEN GS(4,12) = GS(1,3):GOTO 2750
2040 IF I = 4 AND J = 13 THEN GS(4,13) = GS(1,4):GOTO 2750
2050 IF I = 4 AND J = 14 THEN GS(4,14) = GS(1,8):GOTO 2750
2060 IF I = 4 AND J = 15 THEN GS(4,15) = GS(1,9):GOTO 2750
2070 IF I = 4 AND J = 16 THEN GS(4,16) = GS(1,8):GOTO 2750
2080 IF I = 5 AND J = 6 THEN GS(5,6) = GS(1,2):GOTO 2750
2090 IF I = 5 AND J = 7 THEN GS(5,7) = GS(1,9):GOTO 2750
2100 IF I = 5 AND J = 8 THEN XZ = 3*X1:GOTO 2740
2110 IF I = 5 AND J = 9 THEN XZ = SQR((3*X1)^2 + Y1^2):GOTO 2740
2120 IF I = 5 AND J = 10 THEN XZ = SQR((3*X1)^2 + (2*Y1)^2):GOTO 2740
2130 IF I = 5 AND J = 11 THEN XZ = SQR((3*X1)^2 + (3*Y1)^2):GOTO 2740
2140 IF I = 5 AND J = 12 THEN XZ = SQR((2*X1)^2 + (3*Y1)^2):GOTO 2740
2150 IF I = 5 AND J = 13 THEN XZ = SQR(X1^2 + (3*Y1)^2):GOTO 2740
2160 IF I = 5 AND J = 14 THEN XZ = 3*Y1:GOTO 2740
2170 IF I = 5 AND J = 15 THEN GS(5,15) = GS(1,13):GOTO 2750
2180 IF I = 5 AND J = 16 THEN GS(5,16) = GS(1,3):GOTO 2750
2190 IF I = 6 AND J = 7 THEN GS(6,7) = GS(1,2):GOTO 2750
2200 IF I = 6 AND J = 8 THEN GS(6,8) = GS(1,4):GOTO 2750
2210 IF I = 6 AND J = 9 THEN GS(6,9) = GS(1,8):GOTO 2750
2220 IF I = 6 AND J = 10 THEN GS(6,10) = GS(1,11):GOTO 2750
2230 IF I = 6 AND J = 11 THEN GS(6,11) = GS(5,12):GOTO 2750
2240 IF I = 6 AND J = 12 THEN GS(6,12) = GS(5,13):GOTO 2750
2250 IF I = 6 AND J = 13 THEN GS(6,13) = GS(5,14):GOTO 2750
2260 IF I = 6 AND J = 14 THEN GS(6,14) = GS(5,13):GOTO 2750
2270 IF I = 6 AND J = 15 THEN GS(6,15) = GS(1,14):GOTO 2750
2280 IF I = 6 AND J = 16 THEN GS(6,16) = GS(1,4):GOTO 2750
2290 IF I = 7 AND J = 8 THEN GS(7,8) = GS(1,2):GOTO 2750
2300 IF I = 7 AND J = 9 THEN GS(7,9) = GS(1,4):GOTO 2750
2310 IF I = 7 AND J = 10 THEN GS(7,10) = GS(1,14):GOTO 2750
2320 IF I = 7 AND J = 11 THEN GS(7,11) = GS(5,13):GOTO 2750
2330 IF I = 7 AND J = 12 THEN GS(7,12) = GS(5,14):GOTO 2750
2340 IF I = 7 AND J = 13 THEN GS(7,13) = GS(5,13):GOTO 2750
2350 IF I = 7 AND J = 14 THEN GS(7,14) = GS(5,12):GOTO 2750
2360 IF I = 7 AND J = 15 THEN GS(7,15) = GS(1,11):GOTO 2750
2370 IF I = 7 AND J = 16 THEN GS(7,16) = GS(1,8):GOTO 2750
2380 IF I = 8 AND J = 9 THEN GS(8,9) = GS(1,3):GOTO 2750
2390 IF I = 8 AND J = 10 THEN GS(8,10) = GS(1,13):GOTO 2750
2400 IF I = 8 AND J = 11 THEN GS(8,11) = GS(5,14):GOTO 2750
2410 IF I = 8 AND J = 12 THEN GS(8,12) = GS(5,13):GOTO 2750
2420 IF I = 8 AND J = 13 THEN GS(8,13) = GS(5,12):GOTO 2750
2430 IF I = 8 AND J = 14 THEN GS(8,14) = GS(5,11):GOTO 2750
2440 IF I = 8 AND J = 15 THEN GS(8,15) = GS(5,10):GOTO 2750
2450 IF I = 8 AND J = 16 THEN GS(8,16) = GS(5,9):GOTO 2750
2460 IF I = 9 AND J = 10 THEN GS(9,10) = GS(1,3):GOTO 2750
2470 IF I = 9 AND J = 11 THEN GS(9,11) = GS(1,13):GOTO 2750
2480 IF I = 9 AND J = 12 THEN GS(9,12) = GS(1,12):GOTO 2750
2490 IF I = 9 AND J = 13 THEN GS(9,13) = GS(1,11):GOTO 2750
2500 IF I = 9 AND J = 14 THEN GS(9,14) = GS(5,10):GOTO 2750
2510 IF I = 9 AND J = 15 THEN GS(9,15) = GS(5,9):GOTO 2750
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2520 IF I = 9 AND J = 16 THEN GS(9,16) = GS(5,8):GOTO 2750
2530 IF I = 10 AND J = 11 THEN GS(10,11) = GS(1,3):GOTO 2750
2540 IF I = 10 AND J = 12 THEN GS(10,12) = GS(1,4):GOTO 2750
2550 IF I = 10 AND J = 13 THEN GS(10,13) = GS(1,10):GOTO 2750
2560 IF I = 10 AND J = 14 THEN GS(10,14) = GS(5,9):GOTO 2750
2570 IF I = 10 AND J = 15 THEN GS(10,15) = GS(5,8):GOTO 2750
2580 IF I = 10 AND J = 16 THEN GS(10,16) = GS(5,9):GOTO 2750
2590 IF I = 11 AND J = 12 THEN GS(11,12) = GS(1,2):GOTO 2750
2600 IF I = 11 AND J = 13 THEN GS(11,13) = GS(1,9):GOTO 2750
2610 IF I = 11 AND J = 14 THEN GS(11,14) = GS(5,8):GOTO 2750
2620 IF I = 11 AND J = 15 THEN GS(11,15) = GS(5,9):GOTO 2750
2630 IF I = 11 AND J = 16 THEN GS(11,16) = GS(5,10):GOTO 2750
2640 IF I = 12 AND J = 13 THEN GS(12,13) = GS(1,2):GOTO 2750
2650 IF I = 12 AND J = 14 THEN GS(12,14) = GS(1,9):GOTO 2750
2660 IF I = 12 AND J = 15 THEN GS(12,15) = GS(1,10):GOTO 2750
2670 IF I = 12 AND J = 16 THEN GS(12,16) = GS(1,11):GOTO 2750
2680 IF I = 13 AND J = 14 THEN GS(13,14) = GS(1,2):GOTO 2750
2690 IF I = 13 AND J = 15 THEN GS(13,15) = GS(1,4):GOTO 2750
2700 IF I = 13 AND J = 16 THEN GS(13,16) = GS(1,12):GOTO 2750
2710 IF I = 14 AND J = 15 THEN GS(14,15) = GS(1,3):GOTO 2750
2720 IF I = 14 AND J = 16 THEN GS(14,16) = GS(1,13):GOTO 2750
2730 IF I = 15 AND J = 16 THEN GS(15,16) = GS(1,3):GOTO 2750
2740 GS(I,J) = (XX * (1.5*XZ/ZZ - .5*(XZ/ZZ)^3)) + YY:GOTO 2750
2750 NEXT J, I
2760 FOR I = 1 TO 16
2770 FOR J = 1 TO 16
2780 GS(J,I) = GS(I,J)
2790 NEXT J, I
2800 PRINT:PRINT:LPRINT
2810 PRINT "Wi/Wj";TAB(12)"1";TAB(22)"2";TAB(32)"3";TAB(42)"4";TAB(52)"5"
2820 LPRINT "Wi/Wj";TAB(12)"1";TAB(22)"2";TAB(32)"3";TAB(42)"4";TAB(52)"5"
2830 PRINT"------------------------------------------------------------"
2840 LPRINT"-----------------------------------------------------------"
2850 FOR I = 1 TO 17
2860 CKT = 0
2870 PRINT I;: LPRINT I;
2880 FOR J = 1 TO 5
2890 CKT = CKT + 10
2900 IF I = 17 THEN GS(I,J) = 1
2910 PRINT TAB(CKT)GS(I,J);
2920 LPRINT TAB(CKT)GS(I,J);
2930 NEXT J
2940 PRINT" ": LPRINT" "
2950 NEXT I
2960 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
2970 PRINT "Wi/Wj";TAB(12)"6";TAB(22)"7";TAB(32)"8";TAB(42)"9";TAB(52)"10"
2980 LPRINT"Wi/Wj";TAB(12)"6";TAB(22)"7";TAB(32)"8";TAB(42)"9";TAB(52)"10"
2990 PRINT"-----------------------------------------------------------"
3000 LPRINT"----------------------------------------------------------"
3010 FOR I = 1 TO 17
```

```
3020 CKT = 0
3030 PRINT I;: LPRINT I;
3040 FOR J = 6 TO 10
3050 CKT = CKT + 10
3060 IF I = 17 THEN GS(I,J) = 1
3070 PRINT TAB(CKT)GS(I,J);
3080 LPRINT TAB(CKT)GS(I,J);
3090 NEXT J
3100 PRINT" ": LPRINT" "
3110 NEXT I
3120 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
3130 PRINT "Wi/Wj";TAB(12)"11";TAB(22)"12";TAB(32)"13";TAB(42)"14","15"
3140 LPRINT"Wi/Wj";TAB(12)"11";TAB(22)"12";TAB(32)"13";TAB(42)"14","15"
3150 PRINT"-------------------------------------------------------------"
3160 LPRINT"------------------------------------------------------------"
3170 FOR I = 1 TO 17
3180 CKT = 0
3190 PRINT I;: LPRINT I;
3200 FOR J = 11 TO 15
3210 CKT = CKT + 10
3220 IF I = 17 THEN GS(I,J) = 1
3230 PRINT TAB(CKT)GS(I,J);
3240 LPRINT TAB(CKT)GS(I,J);
3250 NEXT J
3260 PRINT" ": LPRINT" "
3270 NEXT I
3280 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
3290 PRINT "Wi/Wj";TAB(12)"16";TAB(22)"L";TAB(32)"CONSTANT"
3300 LPRINT"Wi/Wj";TAB(12)"16";TAB(22)"L";TAB(32)"CONSTANT"
3310 PRINT"-------------------------------------------------------"
3320 LPRINT"------------------------------------------------------"
3330 FOR I = 1 TO 17
3340 CKT = 0
3350 PRINT I;: LPRINT I;
3360 FOR J = 16 TO 18
3370 CKT = CKT + 10
3380 IF J = 17 THEN GS(I,J) = 1
3390 IF J = 18 THEN GS(I,J) = G(I)
3400 IF I = 17 THEN GS(I,J) = 1:GS(17,17) = 0: GS(17,18) = 1
3410 PRINT TAB(CKT)GS(I,J);
3420 LPRINT TAB(CKT)GS(I,J);
3430 NEXT J
3440 PRINT" ": LPRINT" "
3450 NEXT I
3460 LPRINT:LPRINT:LPRINT:LPRINT
3470 '
3480 REM   ***   RANDOM DISK WRITE SEGMENT   ***
3490 '
3500 PRINT CHR$(26)
3510 DIM E$(20,20)
```

```
3520 OPEN "R", #1, "B:DATA1.DAT"
3530 FOR I = 1 TO 17
3540 FIELD 1, 6 AS E$(I,1), 6 AS E$(I,2), 6 AS E$(I,3), 6 AS E$(I,4)
3550 FIELD 1,24 AS DU$,6 AS E$(I,5),6 AS E$(I,6),6 AS E$(I,7),6 AS E$(I,8)
3560 FIELD 1, 48 AS DU$, 6 AS E$(I,9), 6 AS E$(I,10), 6 AS E$(I,11)
3570 FIELD 1, 66 AS DU$, 6 AS E$(I,12), 6 AS E$(I,13), 6 AS E$(I,14)
3580 FIELD 1, 84 AS DU$, 6 AS E$(I,15), 6 AS E$(I,16), 6 AS E$(I,17)
3590 FIELD 1, 102 AS DU$, 6 AS E$(I,18)
3600 FOR J = 1 TO 18
3610 LSET E$(I,J) = STR$(GS(I,J))
3620 NEXT J
3630 PUT #1, I
3640 NEXT I
3650 CLOSE #1
3660 PRINT:PRINT"DATA ENTERED FOR 'SIMULT2.BAS' PROGRAM"
3670 PRINT
3680 LINE INPUT"DO YOU WANT TO CHAIN TO B:SIMULT2.BAS?";R$
3690 IF LEFT$(R$,1) = "N" GOTO 3710
3700 CHAIN "B:SIMULT2.BAS",100,ALL
3710 END
3720 DATA .114,.177,.243,.310,.374,.436,.494,.546,.593,.633,.694,.738,.771
3730 DATA .796,.817,.853,.878,.895,.908,.729
3740 DATA .177,.227,.285,.346,.406,.464,.518,.568,.613,.651,.709,.751,.782
3750 DATA .806,.826,.860,.884,.900,.913,.930
3760 DATA .243,.285,.336,.390,.445,.499,.550,.597,.639,.674,.729,.767,.797
3770 DATA .819,.837,.870,.891,.907,.919,.935
3780 DATA .310,.346,.390,.439,.489,.539,.586,.629,.668,.701,.751,.786,.813
3790 DATA .834,.850,.880,.900,.914,.925,.940
3800 DATA .374,.406,.445,.489,.535,.580,.623,.663,.698,.728,.774,.806,.830
3810 DATA .849,.864,.891,.909,.922,.932,.946
3820 DATA .436,.464,.499,.539,.580,.621,.660,.697,.728,.755,.796,.825,.847
3830 DATA .864,.878,.902,.918,.930,.939,.951
3840 DATA .494,.518,.550,.586,.623,.660,.696,.729,.757,.781,.818,.844,.863
3850 DATA .879,.891,.913,.927,.938,.945,.956
3860 DATA .546,.568,.597,.629,.663,.697,.729,.758,.783,.805,.837,.861,.878
3870 DATA .892,.902,.922,.935,.944,.951,.961
3880 DATA .593,.613,.639,.668,.698,.728,.757,.783,.806,.826,.855,.875,.891
3890 DATA .903,.913,.930,.942,.950,.956,.965
3900 DATA .633,.651,.674,.701,.728,.755,.781,.805,.826,.843,.869,.888,.902
3910 DATA .913,.921,.937,.948,.955,.961,.969
3920 DATA .694,.709,.729,.751,.774,.796,.818,.837,.855,.869,.891,.907,.918
3930 DATA .927,.935,.948,.956,.963,.967,.974
3940 DATA .738,.751,.767,.786,.806,.825,.844,.861,.875,.888,.907,.920,.930
3950 DATA .938,.944,.955,.963,.968,.972,.978
3960 DATA .771,.782,.797,.813,.830,.847,.863,.878,.891,.902,.918,.930,.939
3970 DATA .945,.951,.961,.967,.972,.975,.980
3980 DATA .796,.806,.819,.834,.849,.864,.879,.892,.903,.913,.927,.938,.945
3990 DATA .952,.956,.965,.971,.975,.978,.983
4000 DATA .817,.826,.837,.850,.864,.878,.891,.902,.913,.921,.935,.944,.951
4010 DATA .956,.961,.969,.974,.978,.980,.984
```

```
4020 DATA .853,.860,.870,.880,.891,.902,.913,.922,.930,.937,.948,.955,.961
4030 DATA .965,.969,.975,.979,.982,.984,.987
4040 DATA .878,.884,.891,.900,.909,.918,.927,.935,.942,.948,.956,.963,.967
4050 DATA .971,.974,.979,.983,.985,.987,.990
4060 DATA .895,.900,.907,.914,.922,.930,.938,.944,.950,.955,.963,.968,.972
4070 DATA .975,.978,.982,.985,.987,.989,.991
4080 DATA .908,.913,.919,.925,.932,.939,.945,.951,.956,.961,.967,.972,.975
4090 DATA .978,.980,.984,.987,.989,.990,.992
4100 DATA .927,.930,.935,.940,.946,.951,.956,.961,.965,.969,.974,.978,.980
4110 DATA .983,.984,.987,.990,.991,.992,.994
```

Program number 9. SIMULT2.BAS

```
100 REM   ***   PROGRAM FOR SIMULTANEOUS EQUATIONS FOR KRIGING   ***
110 '
120 REM                     NAME OF PROGRAM ---SIMULT2.BAS----
130 '
140 REM                DATA DISK NAMED ---YLDSEED.DAT---
150 '
160 PRINT CHR$(26)
170 PRINT"        FIELD PLOT UNIFORMITY STUDY FOR SIMULTANEOUS EQUATIONS"
180 PRINT
190 PRINT"        FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
200 PRINT"          KAYPRO IV COMPUTER WITH 64K MEMORY, CP/M, REV. 2.2"
210 PRINT:PRINT
220 PRINT"                           WRITTEN May, 1983"
230 PRINT:PRINT:PRINT:PRINT:PRINT
240 PRINT"                    INSERT DATA DISK IN DRIVE B OR ONE (1)"
250 PRINT:PRINT:PRINT:PRINT:PRINT
260 PRINT"                       PRESS 'ENTER' OR <CR> TO CONTINUE"
270 LINE INPUT R$
280 CLEAR
290 PRINT CHR$(26)
300 PRINT:PRINT:PRINT"REMEMBER PROGRAM 'ONLY' WORKS ON A 16 POINT GRID"
310 PRINT"              AND 17 EQUATIONS"
320 PRINT:PRINT:PRINT:PRINT:PRINT
330 PRINT"                       PRESS 'ENTER' OR <CR> TO CONTINUE"
340 LINE INPUT R$
350 N = 17
360 DIM U(17,18),GS(17,18)
370 PRINT CHR$(26)
380 KNT = 1
390 PRINT"  WHICH METHOD WOULD YOU LIKE TO USE TO ENTER DATA?"
400 PRINT.
410 PRINT"               1.  KEYBOARD"
420 PRINT"               2.  READ DISK IN RANDOM MODE"
430 PRINT"               3.  NEW FILE IN SEQUENTIAL MODE"
440 PRINT"               4.  EXIT THE PROGRAM"
450 PRINT"               5.  PROGRAM FROM CHAINING?"
460 PRINT
470 PRINT"               ENTER THE DESIRED NUMBER";
480 INPUT P$
490 IF P$ = "" OR P$ > "5" THEN GOTO 370
500 IF P$ = "2" THEN GOSUB 1240: GOTO 710
510 IF P$ = "3" THEN GOSUB 1650: GOTO 710
```

```
520 IF P$ = "4" THEN GOTO 1200
530 IF P$ = "5" THEN GOTO 700
540 PRINT "COEFFICIENT MATRIX:"
550 FOR J = 1 TO N
560 PRINT "EQUATION";J
570 FOR I = 1 TO N+1
580 IF I = N+1 THEN GOTO 610
590 PRINT"   COEFFICIENT";I;
600 GOTO 620
610 PRINT"   CONSTANT";
620 INPUT U(J,I)
630 NEXT I
640 PRINT" ARE THESE VALUES OKAY?  TYPE YES OR NO."
650 INPUT P$
660 IF P$ = "" OR P$ <> "YES" AND P$ <> "NO" THEN GOTO 640
670 IF P$ = "NO" THEN PRINT CHR$(26): GOTO 560
680 NEXT J
690 GOTO 710
700 F$ = "B:DATA1.DAT":GOSUB 1290
710 FOR J = 1 TO N
720 FOR I = J TO N
730 IF U(I,J) <> 0 THEN GOTO 780
740 NEXT I
750 PRINT"NO UNIQUE SOLUTION, WILL TRY A TRANSPOSE"
760 IF KNT < 2 THEN GOSUB 2000: KNT = KNT + 1: GOTO 710
770 GOTO 1200
780 FOR K = 1 TO N+1
790 X = U(J,K)
800 U(J,K) = U(I,K)
810 U(I,K) = X
820 NEXT K
830 Y = 1/U(J,J) .
840 FOR K = 1 TO N+1
850 U(J,K) = Y*U(J,K)
860 NEXT K
870 FOR I = 1 TO N
880 IF I = J THEN 930
890 Y = -U(I,J)
900 FOR K = 1 TO N+1
910 U(I,K) = U(I,K) + Y*U(J,K)
920 NEXT K
930 NEXT I
940 NEXT J
950 PRINT:LPRINT
960 REM    ***   PRINT SOLUTIONS   ***
970 DIM Z(20): XB=0
980 FOR I = 1 TO N
990 Z(I) = INT(U(I,N+1)*1E+06 + .5)/1E+06
1000 IF I = 17 GOTO 1050
1010 XB = XB + Z(I)
```

```
1020 PRINT "W";I;"=";Z(I)
1030 LPRINT"W";I;" =";Z(I)
1040 GOTO 1070
1050 PRINT "L";I;"=";Z(I)
1060 LPRINT"L";I;"=";Z(I)
1070 NEXT I
1080 PRINT "THE SUM OF THE WEIGHTS, W, =";XB
1090 LPRINT "THE SUM OF THE WEIGHTS, W, =";XB
1100 OPEN "O", #3, "B:DATA2.DAT"
1110 FOR I = 1 TO 17
1120 PRINT#3, Z(I)
1130 NEXT I
1140 CLOSE #3
1150 INPUT"PRESS ENTER TO CONTINUE";R$
1160 PRINT CHR$(26)
1170 LINE INPUT"DO YOU WANT TO CHAIN TO B:KRIG3.BAS?";R$
1180 IF LEFT$(R$,1) = "N" GOTO 1200
1190 CHAIN"B:KRIG3.BAS"
1200 END
1210 '
1220 REM    ***   RANDOM DISK READ SIGMENT   ***
1230 '
1240 PRINT CHR$(26)
1250 PRINT:PRINT:PRINT CHR$(7)
1260 INPUT"ENTER NAME OF RANDOM DATA FILE FOR SET OF COEFFICIENTS";F$
1270 '
1280 PRINT
1290 PRINT"READING THE DATA DISK"
1300 DIM D$(20)
1310 '
1320 OPEN "R", #1, F$, 128
1330 FIELD #1, 6 AS D$(1), 6 AS D$(2), 6 AS D$(3), 6 AS D$(4), 6 AS D$(5)
1340 FIELD #1, 30 AS DU$, 6 AS D$(6), 6 AS D$(7), 6 AS D$(8), 6 AS D$(9)
1350 FIELD #1, 54 AS DU$,6 AS D$(10),6 AS D$(11),6 AS D$(12), 6 AS D$(13)
1360 FIELD #1, 78 AS DU$,6 AS D$(14),6 AS D$(15),6 AS D$(16), 6 AS D$(17)
1370 FIELD #1, 102 AS DU$, 6 AS D$(18)
1380 '
1390 FOR I = 1 TO 17
1400 GET #1, I
1410 FOR J = 1 TO 18
1420 U(I,J) = VAL(D$(J))
1430 NEXT J
1440 NEXT I
1450 CLOSE #1
1460 '
1470 REM    ***   PRINT THE FILE   ***
1480 '
1490 PRINT
1500 LINE INPUT"DO YOU WANT TO PRINT THE DATA SET?";R$
1510 IF LEFT$(R$,1) = "N" GOTO 1640
```

```
1520 DD = 8:DB = 1
1530 FOR I = 1 TO N
1540 FOR J = DB TO DD
1550 PRINT U(I,J);
1560 LPRINT U(I,J);
1570 NEXT J
1580 PRINT" ":LPRINT" "
1590 NEXT I
1600 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
1610 DB = DB + 8: DD = DD + 8
1620 IF DD < N+1 GOTO 1530
1630 IF DD < N+8+1 AND DD >= N+1 THEN DD = N+1:GOTO 1530
1640 RETURN
1650 '
1660 REM    ***   SEQUENTIAL FILE READ SEGMENT   ***
1670 '
1680 INPUT"ENTER NAME OF THE 'SEQUENTIAL' DATA FILE";G$
1690 OPEN "I", #2, G$
1700 FOR I = 1 TO N
1710 FOR J = 1 TO N+1
1720 INPUT#2,U(I,J)
1730 NEXT J, I
1740 CLOSE #2
1750 '
1760 REM    ***   PRINT THE FILE   ***
1770 '
1780 PRINT
1790 LINE INPUT"DO YOU WANT TO PRINT THE DATA SET?";R$
1800 IF LEFT$(R$,1) = "N" GOTO
1810 DB = 1:DD = 8
1820 FOR I = 1 TO N
1830 FOR J = 1 TO N+1
1840 PRINT U(I,J);
1850 LPRINT U(I,J);
1860 NEXT J
1870 PRINT" ":LPRINT" "
1880 NEXT I
1890 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
1900 DB = DB + 8:DD = DD + 8
1910 IF DD < N+1 GOTO 2010
1920 IF DD < N+1+8 AND DD >= N+1 THEN DD = N+1: GOTO 2010
1930 LPRINT"-----------------"
1940 LPRINT:LPRINT
1950 PRINT CHR$(26)
1960 RETURN
1970 '
1980 REM    ***   REARRANGING ONE-HALF OF THE COLUMNS   ***
1990 '
2000 B = INT(N/2)
2010 FOR I = 1 TO N
```

```
2020 FOR J = 1 TO B
2030 K = B - J + 1
2040 U(I,K) = U(I,J)
2050 NEXT J, I
2060 PRINT "THE FIRST";B;" COLUMNS HAVE BEEN SWITCHED"
2070 PRINT "OLD COLUMN 1 IS NOW COLUMN";B
2080 PRINT "OLD COLUMN 2 IS NOW COLUMN";B-1;" ETC."
2090 LPRINT"OLD COLUMN 1 IS NOW COLUMN";B
2100 LPRINT"OLD COLUMN 2 IS NOW COLUMN";B-1;" ETC."
2110 RETURN
```

Program number 10. KRIG3.BAS

```
100 REM    ***   PROGRAM FOR DETERMINING KRIGED VARIANCE    ***
110 REM       DATA IS FROM "STATISTICAL METHODS FOR AGRICULTURAL
120 REM                   WORKERS" ---PAGES 132-133 ---
130 '
140 REM    ***    NAME OF THE PROGRAM IS --- KRIG3.BAS ---
150 '
160 REM              DATA FILE IS NAMED --- YLDSEED.DAT ---
170 '
180 PRINT CHR$(26)
190 PRINT"              FIELD PLOT UNIFORMITY STUDY FOR KRIGED VARIANCE"
200 PRINT
210 PRINT"           FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
220 PRINT"            KAYPRO IV COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
230 PRINT:PRINT
240 PRINT"                                WRITTEN June 22, 1984"
250 PRINT:PRINT:PRINT:PRINT:PRINT
260 PRINT"                           INSERT DATA DISK IN DRIVE B OR ONE (1)"
270 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
280 PRINT"                           PRESS 'ENTER' OR <CR> TO CONTINUE"
290 LINE INPUT R$
300 CLEAR: PRINT CHR$(26)
310 PRINT"THIS PROGRAM WORKS ONLY ON THE 16-POINT NEIGHBORHOOD TECHNIQUE"
320 PRINT"AS SHOWN IN FIGURE 25 FOR THE GRID TO DETERMINE KRIGED VALUES."
330 PRINT:PRINT
340 OPEN "I", #2, "B:CONST1.DAT"
350 INPUT#2,ZZ,XX,YY,X1,Y1
360 CLOSE #2
370 DIM D$(18), U(20,20),Z(20)
380 OPEN "I", #3, "B:DATA2.DAT"
390 FOR I = 1 TO 17
400 INPUT#3,Z(I)
410 NEXT I
420 OPEN "R", #1, "B:DATA1.DAT"
430 FIELD #1, 6 AS D$(1), 6 AS D$(2), 6 AS D$(3), 6 AS D$(4), 6 AS D$(5)
440 FIELD #1, 30 AS DU$, 6 AS D$(6), 6 AS D$(7), 6 AS D$(8), 6 AS D$(9)
450 FIELD #1, 54 AS DU$,6 AS D$(10),6 AS D$(11), 6 AS D$(12), 6 AS D$(13)
460 FIELD #1, 78 AS DU$,6 AS D$(14),6 AS D$(15), 6 AS D$(16), 6 AS D$(17)
470 FIELD #1, 102 AS DU$, 6 AS D$(18)
480 FOR I = 1 TO 17
490 GET #1, I
500 FOR J = 1 TO 18
510 U(I,J) = VAL(D$(J))
```

```
520 NEXT J, I
530 CLOSE #1
540 ERASE D$
550 DIM D(20,20)
560 PRINT CHR$(26)
570 PRINT"READING F(d,b) TABLE"
580 FOR I = 1 TO 20
590 FOR J = 1 TO 20
600 READ D(I,J)
610 NEXT J, I
620 PRINT
630 PRINT"CALCULATING THE CONSTANT"
640 CNT = 0
650 '
660 REM    ***   SOLVING FOR F(d,b) VALUES    ***
670 '              WHERE X = d AND Y = b
680 '
690 X = X1/ZZ:Y = Y1/ZZ
700 XN = 4
710 IF X < .1 THEN W1 = .05 + .653 * X:W2 = 0: GOTO 850
720 IF X >= .1 AND X < 1 THEN X2=FIX(X*10): X3=(X2/10)+.1:DB=.1:GOTO 850
730 IF X >= 1 AND X <= 5 THEN X4=FIX(X*10):GOTO 750
740 IF X > 5 THEN PRINT"IRREFUTABLE ERROR IN F(d,b) FUNCTION; b > 5":END
750 IF X4 >= 10 AND X4 < 12 THEN X2 = 10: X3 = FIX(X4/10) + .2:DB = .2
760 IF X4 >= 12 AND X4 < 14 THEN X2 = 11: X3 = FIX(X4/10) + .2:DB = .2
770 IF X4 >= 14 AND X4 < 16 THEN X2 = 12: X3 = FIX(X4/10) + .2:DB = .2
780 IF X4 >= 16 AND X4 < 18 THEN X2 = 13: X3 = FIX(X4/10) + .2:DB = .2
790 IF X4 >= 18 AND X4 < 20 THEN X2 = 14: X3 = FIX(X4/10) + .2:DB = .2
800 IF X4 >= 20 AND X4 < 25 THEN X2 = 15: X3 = FIX(X4/10) + .5:DB = .5
810 IF X4 >= 25 AND X4 < 30 THEN X2 = 16: X3 = FIX(X4/10) + .5:DB = .5
820 IF X4 >= 30 AND X4 < 35 THEN X2 = 17: X3 = FIX(X4/10) + .5:DB = .5
830 IF X4 >= 35 AND X4 < 40 THEN X2 = 18: X3 = FIX(X4/10) + .5:DB = .5
840 IF X4 >= 40 AND X4 < 50 THEN X2 = 19: X3 = FIX(X4/10) + 1:DB = 1
850 IF Y < .1 THEN W3 = .05 + .653*Y:W4 = 0:GOTO 1050
860 IF Y >= .1 AND Y < 1 THEN Y2=FIX(Y*10):Y3=(Y2/10)+.1:DD=.1:GOTO 990
870 IF Y >= 1 AND Y <=5 THEN Y4=FIX(Y*10):GOTO 890
880 IF Y > 5 THEN PRINT"IRREFUTABLE ERROR IN F(d,b) FUNCTION; D > 5":END
890 IF Y4 >= 10 AND Y4 < 12 THEN Y2 = 10: Y3 = FIX(Y4/10) + .2:DD = .2
900 IF Y4 >= 12 AND Y4 < 14 THEN Y2 = 11: Y3 = FIX(Y4/10) + .2:DD = .2
910 IF Y4 >= 14 AND Y4 < 16 THEN Y2 = 12: Y3 = FIX(Y4/10) + .2:DD = .2
920 IF Y4 >= 16 AND Y4 < 18 THEN Y2 = 13: Y3 = FIX(Y4/10) + .2:DD = .2
930 IF Y4 >= 18 AND Y4 < 20 THEN Y2 = 14: Y3 = FIX(Y4/10) + .2:DD = .2
940 IF Y4 >= 20 AND Y4 < 25 THEN Y2 = 15: Y3 = FIX(Y4/10) + .5:DD = .5
950 IF Y4 >= 25 AND Y4 < 30 THEN Y2 = 16: Y3 = FIX(Y4/10) + .5:DD = .5
960 IF Y4 >= 30 AND Y4 < 35 THEN Y2 = 17: Y3 = FIX(Y4/10) + .5:DD = .5
970 IF Y4 >= 35 AND Y4 < 40 THEN Y2 = 18: Y3 = FIX(Y4/10) + .5:DD = .5
980 IF Y4 >= 40 AND Y4 < 50 THEN Y2 = 19: Y3 = FIX(Y4/10) + 1:DD = 1
990 IF X < .1 GOTO 1020
1000 W1 = D(X2+1,Y2) - ((D(X2+1,Y2) - D(X2,Y2)) * (X3 - X)/DB)
1010 W2 = D(X2+1,Y2+1) - ((D(X2+1,Y2+1) - D(X2,Y2+1)) * (X3 - X)/DB)
```

```
1020 IF Y < .1 GOTO 1050
1030 W3 = D(X2,Y2+1) - ((D(Y2+1,X2) - D(X2,Y2)) * (Y3 - Y)/DD)
1040 W4 = D(X2+1,Y2+1) - ((D(X2+1,Y2+1) - D(X2+1,Y2)) * (Y3 - Y)/DD)
1050 IF W1 = 0 THEN XN = XN - 1
1060 IF W2 = 0 THEN XN = XN - 1
1070 IF W3 = 0 THEN XN = XN - 1
1080 IF W4 = 0 THEN XN = XN - 1
1090 W = (W1 + W2 + W3 + W4)/XN
1100 G1 = (XX * W) + YY
1110 '
1120 REM  *** COMPUTING THE KRIGING VARIANCE  ***
1130 '
1140 S2=0
1150 FOR I = 1 TO 16
1160 S2 = S2 + Z(I) * U(I,18)
1170 NEXT I
1180 S3 = S2 + Z(17) - G1
1190 IF S3 < 0 THEN PRINT"NEGATIVE VALUE; ERROR IN DATA SET":GOTO 1210
1200 ST = SQR(S3)
1210 PRINT: PRINT "AUXILIARY TERM F(d,b) =";G1
1220 LPRINT:LPRINT"AUXILIARY TERM F(d,b) =";G1
1230 PRINT:PRINT"ESTIMATOR T* =";S2
1240 LPRINT:LPRINT"ESTIMATOR T* =";S2
1250 PRINT: PRINT "KRIGED VARIANCE =";S3
1260 LPRINT:LPRINT"KRIGED VARIANCE =";S3
1270 PRINT: PRINT "KRIGED STANDARD DEVIATION =";ST
1280 LPRINT:LPRINT"KRIGED STANDARD DEVIATION =";ST
1290 PRINT:PRINT:INPUT"PRESS ENTER TO CONTINUE";R$
1300 PRINT CHR$(26)
1310 LINE INPUT"DO YOU WANT TO CHAIN TO B:KRIG2.BAS?";R$
1320 IF LEFT$(R$,1) = "N" GOTO 1340
1330 CHAIN "B:KRIG2.BAS"
1340 END
1350 DATA .078,.120,.165,.211,.256,.300,.342,.383,.422,.457,.520,.572,.
1360 DATA .650,.679,.735,.775,.804,.827,.860
1370 DATA .120,.155,.196,.237,.280,.321,.362,.401,.438,.473,.534,.584,.
1380 DATA .659,.688,.743,.781,.810,.832,.864
1390 DATA .165,.196,.231,.270,.309,.349,.387,.424,.460,.493,.551,.600,.
1400 DATA .672,.700,.752,.789,.817,.838,.869
1410 DATA .211,.237,.270,.305,.342,.379,.415,.451,.484,.516,.572,.618,.
1420 DATA .687,.713,.763,.799,.825,.845,.874
1430 DATA .256,.280,.309,.342,.376,.411,.445,.479,.511,.541,.593,.637,.
1440 DATA .703,.728,.775,.809,.834,.853,.881
1450 DATA .300,.321,.349,.379,.411,.443,.476,.507,.538,.566,.616,.657,.
1460 DATA .719,.743,.788,.820,.843,.861,.887
1470 DATA .342,.362,.387,.415,.445,.476,.506,.536,.565,.591,.638,.677,.
1480 DATA .736,.758,.800,.830,.852,.870,.894
1490 DATA .383,.401,.424,.451,.479,.507,.536,.564,.591,.616,.660,.697,.
1500 DATA .752,.773,.813,.841,.861,.878,.901
1510 DATA .422,.438,.460,.484,.511,.538,.565,.591,.616,.640,.682,.716,.
```

```
1520 DATA .767,.787,.824,.851,.870,.885,.907
1530 DATA .457,.473,.493,.516,.541,.566,.591,.616,.640,.662,.701,.733,.760
1540 DATA .782,.800,.835,.860,.878,.892,.913
1550 DATA .520,.534,.551,.572,.593,.616,.638,.660,.682,.701,.736,.764,.788
1560 DATA .807,.823,.854,.876,.892,.905,.923
1570 DATA .572,.584,.600,.618,.637,.657,.677,.697,.716,.733,.764,.790,.811
1580 DATA .828,.842,.870,.890,.904,.915,.931
1590 DATA .614,.625,.639,.655,.673,.691,.709,.727,.744,.760,.788,.811,.829
1600 DATA .845,.858,.883,.901,.914,.924,.938
1610 DATA .650,.659,.672,.687,.703,.719,.736,.752,.767,.782,.807,.828,.845
1620 DATA .859,.871,.894,.910,.921,.931,.944
1630 DATA .679,.688,.700,.713,.728,.743,.758,.773,.787,.800,.823,.842,.858
1640 DATA .871,.882,.903,.917,.928,.936,.948
1650 DATA .735,.743,.752,.763,.775,.788,.800,.813,.824,.835,.854,.870,.883
1660 DATA .894,.903,.920,.932,.941,.948,.957
1670 DATA .775,.781,.789,.799,.809,.820,.830,.841,.851,.860,.876,.890,.901
1680 DATA .910,.917,.932,.942,.950,.955,.964
1690 DATA .804,.810,.817,.825,.834,.843,.852,.861,.870,.878,.892,.904,.914
1700 DATA .921,.928,.941,.950,.956,.961,.969
1710 DATA .827,.832,.838,.845,.853,.861,.870,.878,.885,.892,.905,.915,.924
1720 DATA .931,.936,.948,.955,.961,.966,.972
1730 DATA .860,.864,.869,.874,.881,.887,.894,.901,.907,.913,.923,.931,.938
1740 DATA .944,.948,.957,.964,.969,.972,.977
```

Program number 11, KRIG2.BAS

```
100 REM    ***   PROGRAM FOR KRIGED ESTIMATED VALUES AND WEIGHTS   ***
110 '                    NEIGHBORHOOD OF 16 VALUES
120 '
130 REM    ***   FOR THE NIAMEY STATION UNIFORMITY STUDY  ***
140 '
150 REM    ***   PROGRAM NAME IS ---KRIG2.BAS---
160 '
170 REM    ***   DATA DISK IS NAMED  --YLDSEED.DAT--
180 '
190 PRINT CHR$(26)
200 PRINT"        FIELD PLOT UNIFORMITY STUDY FOR KRIGED ESTIMATED VALUE
210 PRINT"                    WITH A NEIGHBORHOOD OF 16 VALUES"
220 PRINT
230 PRINT"         FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.2
240 PRINT"          KAYPRO IV COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2
250 PRINT:PRINT
260 PRINT"                        WRITTEN May, 1983"
270 PRINT:PRINT:PRINT:PRINT:PRINT
280 PRINT"                     INSERT DATA DISK IN DRIVE B OR ONE (1)"
290 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
300 PRINT"                     PRESS 'ENTER' OR <CR> TO CONTINUE"
310 LINE INPUT R$
320 CLEAR: PRINT CHR$(26)
330 INPUT"ENTER NAME OR DESCRIPTION OF AREA TO BE KRIGED";A$
340 PRINT A$:PRINT:PRINT
350 LPRINT A$:LPRINT:LPRINT
360 INPUT"ENTER NUMBER OF HORIZONTAL ROWS OF DATA (40)";H
370 PRINT
380 INPUT"ENTER NUMBER OF VERTICAL COLUMNS OF DATA (32)";K
390 PRINT
400 DIM D$(K),U(H,K),T(H,K),W(20),S(H,K),Z(20)
410 INPUT"ENTER NAME FOR SEQUENTIAL DATA FILE, EX: B:SYLDCOT.DAT";F$
420 PRINT
430 '
440 REM    ***   DISK READ SEGMENT    ***
450 '
460 OPEN "I", #1, F$
470 FOR I = 1 TO H
480 FOR J = 1 TO K
490 INPUT#1,U(I,J)
500 NEXT J, I
510 CLOSE #1
```

```
520 PRINT CHR$(26)
530 LINE INPUT"HAVE YOU ENTERED THE PROGRAM BY CHAINING?";R$
540 IF LEFT$(R$,1) = "Y" GOTO 650
550 '
560 REM    ***   ENTER THE KRIGED WEIGHTS   ***
570 '
580 N = 16
590 FOR I = 1 TO N
600 PRINT
610 PRINT"ENTER THE WEIGHT FOR COEFFICIENT NUMBER ";I;
620 INPUT W(I)
630 NEXT I
640 GOTO 740
650 OPEN "I", #2, "B:DATA2.DAT"
660 FOR I = 1 TO 17
670 INPUT#2,Z(I)
680 NEXT I
690 PRINT CHR$(26)
700 FOR I = 1 TO 16
710 W(I) = Z(I)
720 NEXT I
730 ERASE Z
740 PRINT CHR$(26)
750 '
760 REM    ***   LOOPS FOR CALCULATING THE 16 POINTS IN THE NEIGHBORHOOD
770 '
780 PRINT:PRINT"CALCULATING T(I,J)'S":PRINT
790 FOR I = 1 TO H-3
800 PRINT I
810 FOR J = 1 TO K-3
820 PRINT"                          ";J
830 T(I,J)=T(I,J)+U(I,J)*W(5)+U(I,J+1)*W(6)+U(I,J+2)*W(7)+U(I,J+3)*W(8)
840 T(I,J)=T(I,J)+U(I+1,J)*W(16)+U(I+1,J+1)*W(1)+U(I+1,J+2)*W(2)
850 T(I,J)=T(I,J)+U(I+1,J+3)*W(9)
860 T(I,J)=T(I,J)+U(I+2,J)*W(15)+U(I+2,J+1)*W(3)+U(I+2,J+2)*W(4)
870 T(I,J)=T(I,J)+U(I+2,J+3)*W(10)
880 T(I,J)=T(I,J)+U(I+3,J)*W(14)+U(I+3,J+1)*W(13)+U(I+3,J+2)*W(12)
890 T(I,J)=T(I,J)+U(I+3,J+3)*W(11)
900 NEXT J
910 PRINT CHR$(26)
920 NEXT I
930 '
940 REM    *** PRINT NEW ESTIMATED T* VALUES   ***
950 '
960 PRINT"                       ESTIMATED VALUES":PRINT
970 LPRINT"                       ESTIMATED VALUES":LPRINT
980 LPRINT
990 LPRINT"REMEMBER T(1,1) POSITIONED 1.5 * ORIGINAL (1,1) POSITION"
1000 LPRINT:LPRINT
1010 DB = 1:DD = 8
```

```
1020 FOR I = 1 TO H-3
1030 FOR J = DB TO DD
1040 PRINT T(I,J);
1050 LPRINT T(I,J);
1060 NEXT J
1070 PRINT" ":LPRINT" "
1080 NEXT I
1090 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
1100 DB = DB + 8: DD = DD + 8
1110 IF DD < K-3 GOTO 1020
1120 IF DD < K-3+8 AND DD >= K-3 THEN DD = K-3: GOTO 1020
1130 PRINT""
1140 LPRINT"----------------------------"
1150 LPRINT:LPRINT:PRINT CHR$(26)
1160 OPEN "O", #3, "B:DATA3.DAT"
1170 FOR I = 1 TO H-3
1180 FOR J = 1 TO K-3
1190 PRINT#3,T(I,J)
1200 NEXT J, I
1210 CLOSE #3
1220 LINE INPUT"DO YOU WANT TO CHAIN TO B:PLOT1.BAS?";R$
1230 IF LEFT$(R$,1) = "N" GOTO 1250
1240 CHAIN "B:PLOT1.BAS"
1250 PRINT"PROGRAM IS TERMINATED"
1260 LPRINT"PROGRAM IS TERMINATED"
1270 END
```

Program number 12. PLOT1.BAS

```
100 '   *** PROGRAM FOR GRAPHING ANY RECTANGULAR GRID VALUES ***
110 REM                          GIVES
120 REM              PLOT OF A CONTOUR MAP ON A LINE PRINTER
130 '
140 REM    ***    THIS PROGRAM IS FOR THE COTTON SEED DATA SET, 32 X 40
150 '
160 :
170 REM                 PROGRAM IS NAMED   ---PLOT1.BAS---
180 '
190 REM              `DATA FILE IS NAMED ---B:YLDSEED.DAT---
200 :
210 PRINT CHR$(26)
220 PRINT"                 FIELD PLOT UNIFORMITY STUDY FOR CONTOUR GRAPHICS"
230 PRINT
240 PRINT"            FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
250 PRINT"             KAYPRO II COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
260 PRINT:PRINT
270 PRINT"                              WRITTEN May, 1983"
280 PRINT:PRINT:PRINT:PRINT:PRINT
290 PRINT"                           INSERT DATA DISK IN DRIVE B OR ONE (1)"
300 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
310 PRINT"                           PRESS 'ENTER' OR <CR> TO CONTINUE"
320 LINE INPUT R$
330 CLEAR:PRINT CHR$(26)
340 INPUT"ENTER NAME OR DESCRIPTION OF AREA TO BE GRAPHED";A$
350 PRINT A$:PRINT:PRINT
360 LPRINT A$:LPRINT:LPRINT
370 PRINT"ENTER NUMBER OF HORIZONTAL ROWS TO BE GRAPHED"
380 INPUT"USUALLY 3 LESS FOR KRIGED VALUES (40 - 3 = 37)";H
390 PRINT
400 PRINT"ENTER NUMBER OF VERTICAL COLUMNS TO BE GRAPHED"
410 INPUT"USUALLY 3 LESS FOR KRIGED VALUES (32 - 3 = 29)";K
420 PRINT
430 INPUT"ENTER NAME OF SEQUENTIAL DATA FILE, EX: B:DATA3.DAT";F$
440 DIM V(H,K),IO$(2*K),IC$(9)
450 IC$(1)="I":IC$(2)=" ":IC$(3)="*":IC$(4)=" ":IC$(5)="#":IC$(6)=" "
460 IC$(7)="O":IC$(8)=" ":IC$(9)="X"
470 '
480 REM  *** READ THE SEQUENTIAL DATA FILE  ***
490 '
500 PRINT"NOW READING DATA FROM THE SEQUENTIAL FILE ";F$
510 S7=0
```

```
520 OPEN "I", #1, F$
530 FOR I = 1 TO H
540 FOR J = 1 TO K
550 INPUT#1,V(I,J)
560 S7 = S7 + V(I,J)
570 NEXT J, I
580 CLOSE #1
590 VM = S7/(H*K)
600 '
610 PRINT:PRINT
620 LINE INPUT"DO YOU WANT TO PRINT THE DATA JUST ENTERED?";R$
630 IF LEFT$(R$,1) = "N" GOTO 810
640 '
650 REM   *** PRINT DATA SET    ***
660 '
670 DB = 1:DD = 8
680 FOR I = 1 TO H
690 FOR J = DB TO DD
700 PRINT V(I,J);
710 LPRINT V(I,J);
720 NEXT J
730 PRINT" ":LPRINT" "
740 NEXT I
750 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
760 DB = DB + 8: DD = DD + 8
770 IF DD < K GOTO 680
780 IF DD < K+8 AND DD >= K THEN DD = K: GOTO 680
790 LPRINT"--------------------"
800 LPRINT:LPRINT:PRINT CHR$(26)
810 DIM XX(K),YY(H,2*K)
820 B=1
830 '
840 REM    *** MAIN PROGRAM    ***
850 '
860 FOR I = 1 TO H
870 FOR J = 1 TO K-1
880 XX(J) = CINT((V(I,J) + V(I,J+1))/2)
890 NEXT J
900 FOR J = 1 TO 2*K STEP 2
910 YY(I,J) = V(I,B):YY(I,J+1) = XX(B)
920 IF B > K-2 GOTO 940
930 B = B + 1
940 NEXT J
950 B = 1
960 NEXT I
970 ERASE V,XX
980 PRINT:PRINT
990 LINE INPUT"DO YOU WANT TO PRINT THE TRANSFORMED VALUES?";R$
1000 IF LEFT$(R$,1) = "N" GOTO 1230
1010 '
```

```
1020 REM   ***  PRINT YY(I,J) THE TRANSFORMED VALUES    ***
1030 '
1040 PRINT:PRINT:LPRINT:LPRINT
1050 DB = 1:DD = 8
1060 FOR I = 1 TO H
1070 FOR J = DB TO DD
1080 PRINT CINT(YY(I,J));
1090 LPRINT CINT(YY(I,J));
1100 NEXT J
1110 PRINT" ":LPRINT" "
1120 NEXT I
1130 PRINT:PRINT:LPRINT:LPRINT
1140 DB = DB + 8:DD = DD + 8
1150 IF DD < 2*K GOTO 1060
1160 IF DD < 2*K+8 AND DD >= 2*K THEN DD = 2*K: GOTO 1060
1170 LPRINT"-------------------"
1180 LPRINT:LPRINT:PRINT CHR$(26)
1190 '
1200 REM  *** PRINT THE MAP
1210 '
1220 PRINT:PRINT
1230 PRINT "PREPARING TO PRINT THE MAP"
1240 PRINT CHR$(26):LPRINT:LPRINT
1250 Y1 = YY(1,1): Y2 = Y1
1260 FOR I = 1 TO H
1270 FOR J = 1 TO 2*K
1280 YT = YY(I,J)
1290 IF YT < Y1 THEN Y1 = YT
1300 IF YT > Y2 THEN Y2 = YT
1310 NEXT J, I
1320 '
1330 REM *** PRINT MAP ONE LINE AT A TIME
1340 '
1350 PRINT CHR$(26)
1360 FOR I = 1 TO H
1370 FOR J = 1 TO 2*K
1380 IY = ((YY(I,J) - Y1)/(Y2 - Y1))*9 + 1
1390 IF IY > 9 THEN IY = 9
1400 IO$(J) = IC$(IY)
1410 NEXT J
1420 FOR J = 1 TO 2*K
1430 PRINT IO$(J);
1440 LPRINT IO$(J);
1450 NEXT J
1460 PRINT"  ":LPRINT"  "
1470 NEXT I
1480 CI = INT((Y2 - Y1)/9)
1490 RC = INT(Y1 + 5*CI)
1500 LPRINT:LPRINT:LPRINT"MINIMUM =";INT(Y1);"  MAXIMUM =";INT(Y2)
1510 PRINT:PRINT"MINIMUM VALUE =";INT(Y1);"  MAXIMUM VALUE =";INT(Y2)
```

```
1520 PRINT:PRINT:PRINT "REFERENCE CONTOUR =";RC;"  CONTOUR INTERVAL =";CI;
1530 PRINT "   MEAN VALUE =";VM
1540 LPRINT:LPRINT"REFERENCE CONTOUR =";RC;"  CONTOUR INTERVAL =";CI;
1550 LPRINT"   MEAN VALUE =";VM
1560 PRINT:PRINT:LPRINT:LPRINT
1570 CR = INT(Y1 + CI)
1580 FOR I = 1 TO 9 STEP 2
1590 PRINT IC$(I);" =";INT(Y1);"-";INT(CR);", ";
1600 LPRINT IC$(I);" =";INT(Y1);"-";INT(CR);", ";
1610 Y1 = Y1 + 2*(CI + 1)
1620 CR = CR + 2*(CI + 1)
1630 NEXT I
1640 END
```

Auxiliary program number 13, CONVERT.BAS

To use the semivariograms and kriging programs use this program to convert from random access to sequential data files.

```
100 REM  *** PROGRAM CONVERTS RANDOM ACCESS FILES TO SEQUENTIAL ***
110 '
120 REM   ***   THIS PROGRAM IS FOR THE COTTON SEED DATA SET, 32 X 40
130 '
140 :
150 REM               PROGRAM IS NAMED  ---CONVERT.BAS---
160 '
170 REM            DATA FILE IS NAMED ---B:YLDSEED.DAT---
180 :
190 PRINT CHR$(26)
200 PRINT"                FIELD PLOT UNIFORMITY STUDY FOR CONTOUR GRAPHICS"
210 PRINT
220 PRINT"           FOR MICROSOFT BASIC (BASIC-80) VERSION CP/M, REV. 5.21"
230 PRINT"            KAYPRO II COMPUTER WITH 64K MEMORY, CP/M VERSION 2.2"
240 PRINT:PRINT
250 PRINT"                          WRITTEN May, 1983"
260 PRINT:PRINT:PRINT:PRINT:PRINT
270 PRINT"                       INSERT DATA DISK IN DRIVE B OR ONE (1)"
280 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
290 PRINT"                       PRESS 'ENTER' OR <CR> TO CONTINUE"
300 LINE INPUT R$
310 CLEAR:PRINT CHR$(26)
320 INPUT"ENTER NUMBER OF HORIZONTAL ROWS ON DATA SET";H
330 PRINT
340 INPUT"ENTER NUMBER OF VERTICAL COLUMNS ON DATA SET";K
350 PRINT
360 DIM V(H,K), D$(K)
370 PRINT CHR$(26):INPUT"ENTER DATA FILE NAME";F$
380 '
390 REM     *****      DISK READ SEGMENT     *****
400 '
410 OPEN "R",#1,F$,128
420 FIELD #1, 4 AS D$(1), 4 AS D$(2), 4 AS D$(3), 4 AS D$(4), 4 AS D$(5)
430 FIELD #1, 20 AS DU$, 4 AS D$(6), 4 AS D$(7), 4 AS D$(8), 4 AS D$(9)
440 FIELD #1,36 AS DU$,4 AS D$(10), 4 AS D$(11), 4 AS D$(12), 4 AS D$(13)
450 FIELD #1,52 AS DU$,4 AS D$(14), 4 AS D$(15), 4 AS D$(16), 4 AS D$(17)
460 FIELD #1,68 AS DU$,4 AS D$(18), 4 AS D$(19), 4 AS D$(20), 4 AS D$(21)
```

```
470 FIELD #1,84 AS DU$,4 AS D$(22), 4 AS D$(23), 4 AS D$(24), 4 AS D$(25)
480 FIELD #1,100 AS DU$,4 AS D$(26),4 AS D$(27), 4 AS D$(28), 4 AS D$(29)
490 FIELD #1, 116 AS DU$, 4 AS D$(30), 4 AS D$(31), 4 AS D$(32)
500 '
510 FOR I = 1 TO H
520 GET #1, I
530 FOR J = 1 TO K
540 V(I,J) = VAL(D$(J))
550 NEXT J, I
560 CLOSE #1
570 '
580 REM  *** READ INTO A SEQUENTIAL DATA FILE
590 '
600 PRINT:PRINT"NOW READING DATA INTO SEQUENTIAL FILE"
610 OPEN "O", #2, "B:SYLDCOT.DAT"
620 FOR I = 1 TO H
630 FOR J = 1 TO K
640 PRINT#2,V(I,J);",";
650 PRINT USING "####";V(I,J);
660 NEXT J
670 PRINT" "
680 NEXT I
690 CLOSE #2
700 '
710 REM  *** READ AND PRINT THE SEQUENTIAL DATA FILE   ***
720 '
730 PRINT:PRINT"NEW READING/PRINTING DATA FROM THE SEQUENTIAL FILE"
740 OPEN "I", #2, "B:SYLDCOT.DAT"
750 IF EOF(2) THEN END
760 FOR I = 1 TO H
770 FOR J = 1 TO K
780 INPUT#2,V(I,J)
790 PRINT V(I,J);
800 NEXT J
810 PRINT" "
820 NEXT I
```

Auxiliary_program_number_14,_REGM.BAS

```
100 REM    *** MULTIPLE LINEAR REGRESSION    ***
110 '
120 REM    *** PROGRAM IS NAMED ---REGM.BAS---
130 '
140 PRINT:PRINT:PRINT
150 PRINT"M U L T I P L E    R E G R E S S I O N"
160 PRINT
170 PRINT"REWRITTEN March, 1982"
180 PRINT"--------------------------------------"
190 PRINT:PRINT:PRINT:
200 INPUT"NUMBER OF VARIABLES                         ";M:PRINT
210 INPUT"NUMBER OF OBSERVATIONS                      ";N:PRINT
220 DIM A$(M),X(M,N),X1(M),S(M,M),S2(M,M),S3(M,M),D$(M)
230 DIM B(M),Y(N),R(N),U(M),C(M,M)
240 PRINT CHR$(26)
250 PRINT"          WOULD YOUR LIKE TO USE THE KEYBOARD (1)"
260 PRINT"                     OR THE DISK (2)"
270 PRINT
280 PRINT"                       ENTER 1 OR 2."
290 INPUT P$
300 IF P$="" OR P$<>"1" AND P$<>"2" THEN 240
310 IF P$="2" THEN 520
320 FOR I = 1 TO M:PRINT"NAME OF THE VARIABLE";I;
330 INPUT A$(I):NEXT I:PRINT
340 PRINT CHR$(26)
350 FOR I = 1 TO M
360 PRINT"OBSERVATIONS OF THE VARIABLE  ";A$(I);":"
370 LPRINT"OBSERVATIONS OF THE VARIABLE ";A$(I);":"
380 FOR J = 1 TO N
390 PRINT"NUMBER";J;TAB(14);
400 LPRINT"NUMBER";J;TAB(14);
410 INPUT X(I,J)
420 LPRINT X(I,J)
430 NEXT J
440 PRINT"ARE THESE VALUES OKAY?  TYPE YES OR NO"
450 INPUT P$
460 IF P$="" OR P$ <>"YES" AND P$<>"NO"THEN 440
470 IF P$="NO" THEN PRINT CHR$(26):LPRINT:LPRINT"ERROR":GOTO 360
480 PRINT:LPRINT
490 IF I = M THEN 520
500 NEXT I
510 GOSUB 2300
```

```
520 PRINT CHR$(26):LPRINT:LPRINT
530 PRINT:PRINT:PRINT:PRINT"CALCULATING VALUES"
540 '
550 REM   ***   MEANS AND STANDARD DEVIATION   ***
560 '
570 FOR I = 1 TO M:T=0:FOR J= 1 TO N
580 T = T + X(I,J)
590 NEXT J
600 X1(I) = T/N
610 NEXT I
620 FOR I = 1 TO M:FOR K = 1 TO M
630 S1 = 0
640 FOR J = 1 TO N
650 S1 = S1 + (X(I,J) - X1(I))*(X(K,J) - X1(K))
660 NEXT J
670 S(I,K) = S1/(N-1)
680 S(K,I) = S(I,K)
690 NEXT K, I
700 M1 = M - 1
710 FOR J = 1 TO M1: FOR K = 1 TO M1:S2(J,K)=S(J+1,K+1):NEXT K,J
720 FOR I = 1 TO M1:FOR J = 1 TO M1
730 IF I<>J GOTO 760
740 S3(I,J)=1
750 GOTO 770
760 S3(I,J)=0
770 NEXT J,I
780 GOSUB 2080
790 '
800 REM   ***   NOW TO CALCULATE THE SLOPE B(I)   ***
810 '
820 PRINT CHR$(26)
830 FOR I = 1 TO M1
840 B(I) = 0
850 FOR J = 1 TO M1
860 B(I) = B(I) + S(1,J+1)*S2(J,I)
870 NEXT J,I
880 B1 = 0
890 FOR I = 1 TO M1:B1 = B1 + X1(I+1)*B(I):NEXT I
900 B1 = X1(1) - B1
910 '
920 REM   *** R2, SSE, F-TEST, CORRELATION, ETC.   ***
930 '
940 PRINT"CALCULATING TESTS"
950 S3 = 0
960 FOR I = 1 TO N: Y(I) = 0
970 FOR J = 2 TO M:Y(I) = Y(I) + B(J-1)*X(J,I):NEXT J
980 Y(I) = Y(I) + B1
990 R(I) = X(1,I) - Y(I)
1000 S3 = S3 + R(I)^2
1010 NEXT I
```

```
1020 S(1,1) = (N-1)*S(1,1)
1030 R2 = (S(1,1)-S3)/S(1,1)
1040 IF R2 = 1 GOTO 650
1050 F = (R2/M1)/((1-R2)/(N-M))
1060 E = SQR(S3/(N-M))
1070 FOR J = 1 TO M1
1080 BQ = ABS(S2(J,J)/(N-1))
1090 U(J) = E*SQR(BQ)
1100 NEXT J
1110 S(1,1) = S(1,1)/(N-1)
1120 C(1,1) = 1
1130 FOR J = 2 TO M
1140 C(J,J) = 1
1150 J1 = J-1
1160 FOR I =1 TO J1
1170 C(I,J) = S(I,J)/SQR(S(I,I)*S(J,J))
1180 C(J,I) = C(I,J)
1190 NEXT I,J
1200 FOR I = 1 TO M
1210 S(I,I) = SQR(S(I,I))
1220 NEXT I
1230 PRINT CHR$(26)
1240 '        OUTPUT
1250 PRINT:PRINT:PRINT:LPRINT:LPRINT STRING$(60,"-")
1260 LPRINT "CORRELATION MATRIX"
1270 PRINT "CORRELATION MATRIX"
1280 LPRINT"------------------------------"
1290 FOR I = 1 TO M:FOR J = 1 TO M
1300 IF I < J THEN 1340
1310 ZZ = INT(100*C(I,J))/100
1320 PRINT ZZ,
1330 LPRINT ZZ,
1340 NEXT J:PRINT:LPRINT
1350 NEXT I
1360 PRINT:PRINT:PRINT:LPRINT:LPRINT
1370 PRINT "VARIABLE        MEAN        STANDARD DEVIATION"
1380 LPRINT STRING$(60,"-")
1390 LPRINT "VARIABLE       MEAN        STANDARD DEVIATION"
1400 PRINT"--------------------------------"
1410 LPRINT"--------------------------------"
1420 FOR I = 1 TO M
1430 PRINT A$(I),X1(I), S(I,I)
1440 LPRINT A$(I),X1(I),S(I,I)
1450 NEXT I
1460 PRINT:PRINT:LPRINT:LPRINT
1470 INPUT "TYPE ANY LETTER THEN <CR> TO CONTINUE";C$
1480 PRINT CHR$(26)
1490 PRINT "REGRESSION EQUATION"
1500 LPRINT "REGRESSION EQUATION"
1510 PRINT STRING$(60,"-")
```

```
1520 LPRINT "---------------------------------"
1530 PRINT "DEPENDENT VARIABLE:     ";A$(1)
1540 LPRINT "DEPENDENT VARIABLE:     ";A$(1)
1550 PRINT STRING$(60,"-")
1560 LPRINT STRING$(60,"-")
1570 PRINT "VARIABLE          COEFFICIENT      BETA";
1580 LPRINT "VARIABLE          COEFFICIENT      BETA";
1590 PRINT"        ERRORS          T-TEST"
1600 LPRINT"        ERRORS          T-TEST"
1610 PRINT "EXPLAINED         ESTIMATED          %"
1620 LPRINT "EXPLAINED         ESTIMATED          %"
1630 PRINT:LPRINT
1640 FOR I = 1 TO M1
1650 ZX = INT(10000*(B(I)*(X1(I+1)/X1(1))))/100
1660 PRINT A$(I+1);TAB(19);B(I);TAB(35);ZX;
1670 LPRINT A$(I+1);TAB(19);B(I);TAB(35);ZX;
1680 ZW = INT(100*(B(I)/U(I)))/100
1690 PRINT TAB(48);U(I);TAB(63);ZW
1700 LPRINT TAB(48);U(I);TAB(63);ZW
1710 NEXT I
1720 PRINT "CONSTANT";TAB(19);B1
1730 LPRINT "CONSTANT";TAB(19);B1
1740 PRINT STRING$(60,"-"):LPRINT STRING$(60,"-")
1750 PRINT:PRINT
1760 INPUT "TYPE ANY LETTER THEN <CR> TO CONTINUE";C$
1770 PRINT CHR$(26):LPRINT:LPRINT
1780 PRINT "COEFFICIENT OF DETERMINATION";TAB(35);"=    ";R2
1790 LPRINT "COEFFICIENT OF DETERMINATION";TAB(35);"=    ";R2
1800 PRINT "CORRELATION COEFFICIENT";TAB(35);"=     ";SQR(R2)
1810 LPRINT "CORRELATION COEFFICIENT";TAB(35);"=     ";SQR(R2)
1820 PRINT "TEST OF LINEARITY (F-TEST)";TAB(35);"=     ";F
1830 LPRINT "TEST OF LINEARITY (F-TEST)";TAB(35);"      ";F
1840 PRINT"DEGREES OF FREEDOM";TAB(35);"=    ";N-K
1850 LPRINT "DEGREES OF FREEDOM";TAB(35);"=    ";N-K
1860 PRINT "SUM OF THE SQUARES";TAB(35);"=    ";E
1870 LPRINT "SUM OF THE SQUARES";TAB(35);"=    ";E
1880 PRINT STRING$(60,"-")
1890 LPRINT STRING$(60,"-")
1900 PRINT:PRINT
1910 INPUT "TYPE ANY LETTER THEN <CR> TO CONTINUE";C$
1920 PRINT CHR$(26):LPRINT:LPRINT
1930 PRINT "RESIDUAL TABLE"
1940 LPRINT "RESIDUAL TABLE"
1950 PRINT STRING$(40,"-"):LPRINT STRING$(40,"-")
1960 LPRINT
1970 PRINT "NO.      OBSERVATIONS      ESTIMATIONS      RESIDUALS"
1980 LPRINT "NO.      OBSERVATIONS      ESTIMATIONS      RESIDUALS"
1990 PRINT STRING$(40,"-")
2000 FOR I = 1 TO N
2010 PRINT I;TAB(13);X(1,I);TAB(27);Y(I);TAB(43);R(I)
```

```
2020 LPRINT I;TAB(13);X(1,I);TAB(27);Y(I);TAB(43);R(I)
2030 NEXT I
2040 PRINT STRING$(40,"-")
2050 LPRINT STRING$(40,"_")
2060 END
2070 REM *****     INVERSION MATRIX
2080 FOR K = 1 TO M1:FOR I = 1 TO M1
2090 IF I > J THEN 1430
2100 PP = S2(K,K)
2110 IF PP = 0 THEN PRINT :PROBLEM OF COLLINEARITY":GO TO 2050
2120 FOR J = 1 TO M1
2130 S2(K,J) = S2(K,J)/PP
2140 S3(K,J) = S3(K,J)/PP
2150 NEXT J
2160 IF I = K GOTO 2220
2170 PP = S2(I,K)
2180 FOR J = 1 TO M1
2190 S2(I,J) = S2(I,J)-S2(K,J)*PP
2200 S3(I,J) = S3(I,J)-S3(K,J)*PP
2210 NEXT J
2220 NEXT I
2230 NEXT K
2240 FOR I =1 TO M1:FOR J = 1 TO M1:S2(I,J) = S3(I,J):NEXT J,I
2250 RETURN
2260 '
2270 REM    ***   WHEN YOU READ THE DISK   ***
2280 '
2290 PRINT CHR$(26)
2300 PRINT "ATTENTION -- ATTENTION -- ATTENTION -- ATTENTION"
2310 PRINT "YOU MUST CHANGE THE 'FIELD' BEFORE STARTING THE"
2320 PRINT "             PROGRAM OF THE DISK."
2330 PRINT "                  LINE = 2370"
2340 PRINT:PRINT:PRINT CHR$(7)
2350 INPUT "ENTER THE FILE NAME";F$
2360 OPEN "R", 1, F$
2370 FIELD 1, 4ASD$(1),4ASD$(2)
2380 FOR J = 1 TO N
2390 GET 1,J
2400 FOR I = 1 TO M
2410 X(I,J) = VAL(D$(I))
2420 NEXT I
2430 NEXT J
2440 CLOSE 1
2450 RETURN
```

1981

Statistical measures of field plot uniformity

Perrier, Eugene