A COMPUTER TECHNIQUE FOR ILLUSTRATING THREE VARIABLES IN A PICTOGRAM[1]

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Abstract. A technique is described for displaying three-dimensional data by using the over-printing capability of digital computer printing units. The procedure is illustrated by mapping the distribution of species-abundance characteristics and physical features on several study areas based on data from systematically placed field sampling points.

Studies of natural communities often include large amounts of information on biotic and abiotic factors from numerous plot or point samples. This report discusses a series of computer programs which produce "pictograms" illustrating the distribution of various characteristics based on data from systematically placed field plots. The pictogram programs also can be used to graphically display three-dimensional tabular data where the values in the table represent one dimension and the column and row headings are two ordered sets of variables representing the other two dimensions.

The programs develop the pictogram by placing the field data in spatially corresponding locations in a matrix in the computer memory. This matrix may be visualized as a grid superimposed over the study area in which only the compartments of the grid which fall over a sample plot actually have values. This matrix, for a single-page pictogram, could have maximum dimensions of about 131 columns by 60 rows (i.e., a grid of 131 compartments wide by 60 compartments high). These dimensions include the approximate number of printing locations on a common 11- by 15-inch computer paper page. For example, in Fig. 1 the pictogram is based on 35 real data points. The real data are located at the 1, 22, 43, 64, 85, 106, and 127 print locations in lines 1, 14, 27, 40, and 53. The number of printing locations between the real points in the pictogram is dependent on the number and arrangement of the sample plots or points on the study area and on the proportions and size of the pictogram desired. Values for the locations in the matrix between the real data points are obtained by the program by linear interpolation between the real points. In the example given above, the real data are in locations 1, 22, 43, etc. The program calculates values for locations 2, 3, 4 . . . 21; 23, 24, . . . 42, etc. based on a linear interpolation between the data in location 1 and 22, 22 and 43, etc.

The computer then sets up a line of alphanumeric type characters (you are reading alphanumeric type characters) to represent the range class of each value in the first row of the matrix. For example, if the data were cover percentages from herb plots ranging from 1% to 100%, the user would establish 10 range classes (i.e., 1–10, 11–20, . . . 91–100; range classes, however, need not be of equal size) and select a set of alphanumeric characters to represent them. In the illustrations given in this paper, these type characters are b.- ='/0*$NM (where b is to be read as meaning a blank, i.e., space). Thus a "." would represent the lowest range class, a "-" the next larger range class, etc.

The line of assigned-type characters are printed. Then without skipping to a new line on the printer, the computer scans the row of type characters assigned on the first printing and assigns to each the type character of the next lower range class. This line is then printed superimposed over the preceding printing. This process is repeated 10 times for each line of the matrix before the printer starts a new line for the next row of the matrix.

Values which are initially large (i.e., fall in higher range classes) will be overprinted by many more characters before the blank is reached. An initial value which falls in the lowest range class will have a blank assigned on all overprintings after the first. Areas of values in the lowest range class will be represented by a ".", whereas areas of larger values will be overprinted more times with nonblank characters and will show up as progressively darker areas on the final pictogram. If the sampled parameter is differentially distributed on the study area and if the real sampling intensity is sufficient to include this, then the differential distribution will be obvious as darker or lighter areas of overprinting on the pictogram.

The programs are designed for data from systematic rectangular grid sampling systems (although the study area does not have to be rectangular) and are not readily usable for illustrating data from a random sampling. Three examples of uses to which the main program has been put and several modifications are illustrated in Fig. 1–3.

Figure 1 illustrates the use of the program for showing height of land by using tone density and contour lines. This example is based on a survey of

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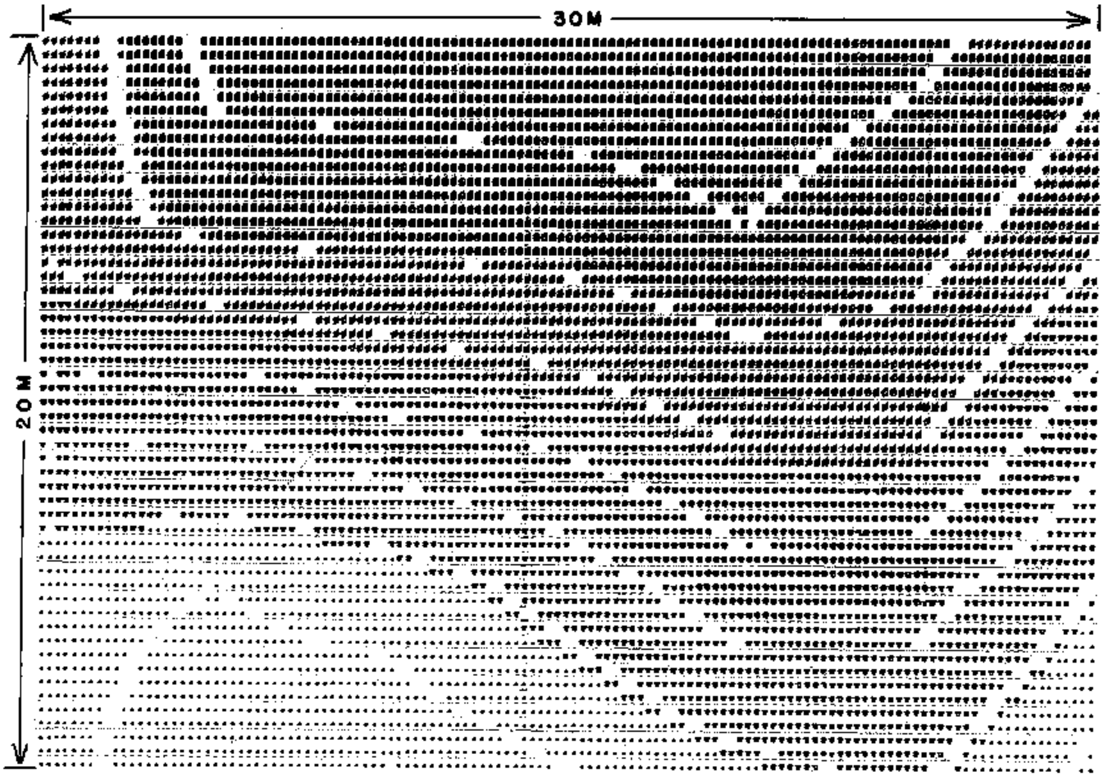

FIG. 1. A contour map of a 20- by 30-m section of *Ilex*-dominated forest behind the secondary dune on a barrier beach. The darkest areas represent a height of 5.3 m above mean high tide and the lightest areas 1.7 m above mean high tide. Contour lines are at 0.5-m intervals. The area without contour lines on the lower right is due to the flat nature of the land in that area, and the contour runs between the lines of printing. This is a problem of limit of resolution of the technique at the scale used. (Data from Henry Art).

the Sunken Forest on Fire Island, New York, an *Ilex*-dominated forest behind the secondary dune on a barrier beach. The darker areas of the pictogram are the higher land. There is a large amount of quantitative data on vegetation, precipitation, biomass, and nutrient cycling collected from systematically placed plots in this area. The pictogram program will allow rapid visual evaluation of the distribution of these characteristics in the study area.

Figure 2 illustrates the spatial and temporal change in cover percentage of old-field species during a period of 12 years following abandonment. The field is 100 m long and 50 m wide. Hutcheson Memorial Forest, an oak-dominated old-age forest, is adjacent to the upper edge of the field in all the pictograms. Data for this pictogram were obtained from 48 permanent plots (40 in the first 3 years). Eight plots adjacent to the forest edge were not established until the fourth sampling. The last two plots in this row were never established. These two omissions account for the blank areas at the top of the first three *Plantago Rugelii* pictograms and the rectangular blank at the upper right corner on the other pictograms. The pictograms of the individual years have been greatly reduced in reproduction in the text, actually each year is printed out on one full-size computer-paper page (i.e., 11 by 15 inches).

Both successional trends and site preferences are shown in the three species sequences. *Plantago Rugelii*, an early invader, colonized the whole field and was all but gone after 8–9 years. There is no readily recognized site preference of this species in the pictograms. *Prunella vulgaris* appears to be quite site specific, at least in the early years, occurring with greatest cover percentage near the edge of the forest. *Fragaria virginiana* did not occur in any of the plots until the fourth year after abandonment and then progressively increased in total cover and spread over the whole field by the twelfth year. *Fragaria virginiana* first appeared in the row of plots farthest from the forest edge.

Figure 3 illustrates the distribution of sugar maple seedlings (stems ≤ 0.5 m tall) on a 13-ha forested watershed in New Hampshire. The data for this pictogram consisted of density counts on four quadrats (1 by 1 m) on each of 208 10- by 10-m tree-sampling plots located within a systematic grid system of 25- by 25-m units. Within these latter units, the plots were random. The darkest portions indicate ca. 800 stems per 4 m^2. The pictogram clearly shows a defi-

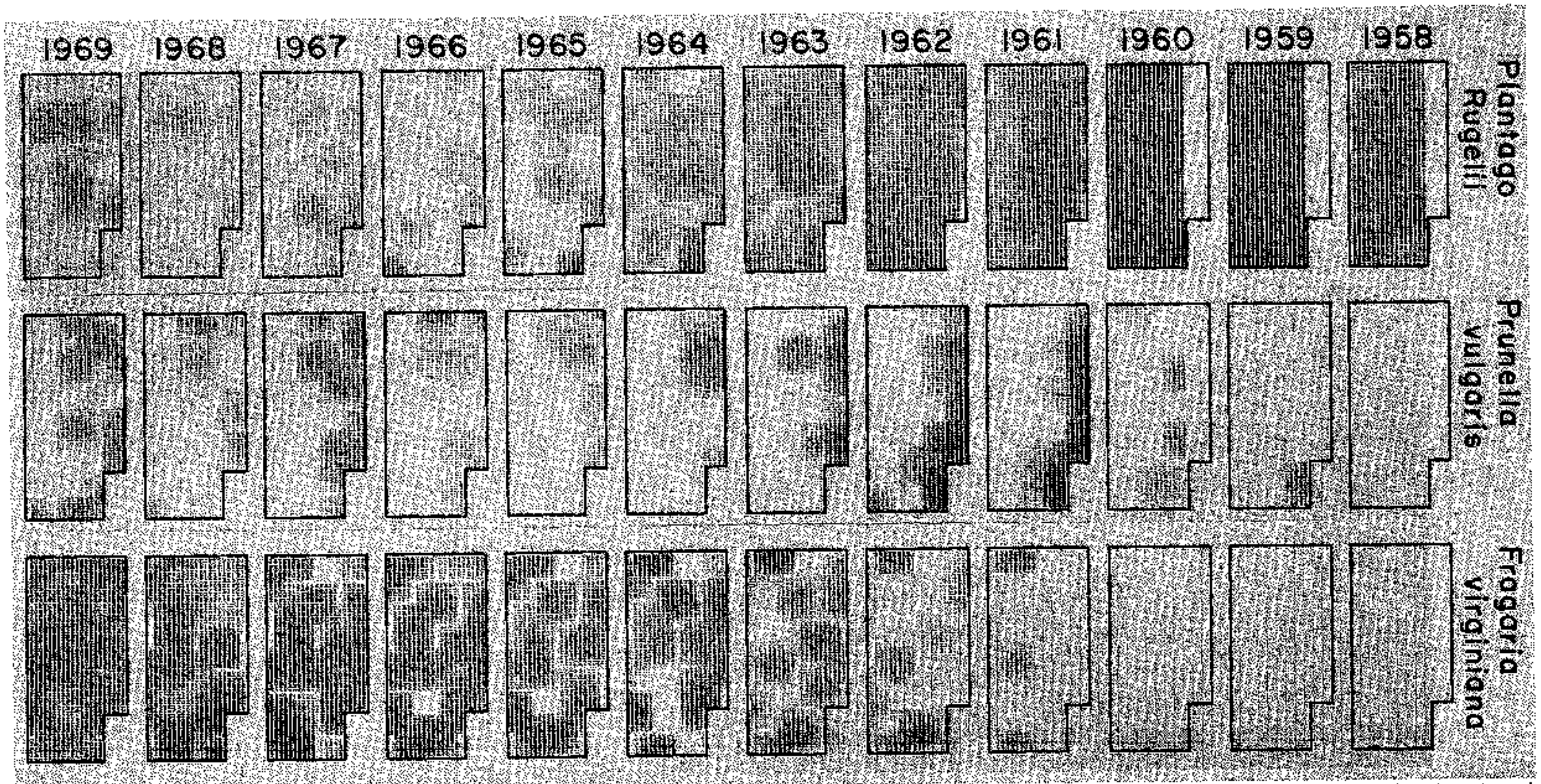

FIG. 2. Spatial and temporal distribution of cover of *Plantago Rugelii*, *Prunella vulgaris*, and *Fragaria virginiana* on a 50- by 100-m abandoned agricultural field adjacent to Hutcheson Memorial Forest in Franklin Township, N. J. The field was abandoned in 1957 and sampled by forty-eight 1- by 1-m permanent plots (except for the first 3 years when only 40 plots were established). The forest is adjacent to the upper edge of each pictogram. The lines outlining the fields were drawn by hand. (Data from M. F. Buell, H. F. Buell, and J. D. Small).

FIG. 3. Spatial distribution of sugar maple seedlings (≤0.5 m tall) on watershed 6 at the Hubbard Brook Experimental Forest in New Hampshire. The figure represents a 13-ha area of mature uneven-aged northern hardwood forest with a strong altitudinal gradient. Elevation rises 240 m from the weir (bottom of pictogram) to the ridge (top of pictogram).

nite decreasing trend in seedling density from lower to upper watershed.

The value of this technique is not in making a single pictogram; rather in the same run the computer can make dozens of pictograms. Cover percentages of each species separately, biomass, tree basal area, species diversity, soil moisture, or other measured features can be pictured in an array of pictograms. By viewing pictograms, relationships or trends become apparent and form the bases for more exacting numerical investigations. The use of the technique for representing the repeated sampling of permanent plots is especially dramatic in expressing the changes in time and space. The patterns of distribution shown by this technique may be more understandable than tabular or mathematical representation of the same data.

Details of the computer technology used in the program are inappropriate to discuss in this report. Those readers with knowledge in using "canned" computer programs will have no difficulty in using the square or rectangular pictogram program (the basic program) by following the directions available with the program.[2] Those lacking such knowledge will require assistance from a computer programmer. The programs which produce pictograms for irregularly shaped study areas require a modest amount of Fortran IV programming knowledge and can be adapted to almost any shape. A pictogram may be several pages wide or several pages long. The use of these options or other modifications depends on the computer facilities available to the user.

The basic computer requirements of the simple square or rectangle program are a core storage of about 20,000 locations and a printer which responds to carriage control to suppress line skip (and page skip if it is desired to extend the pictogram to more than one page). Most second- and third-generation computers and printers have these capabilities. All the programs are written in Fortran IV and have been run on the IBM 7040–7094 direct couple system computer at Yale University. The old-field program has also been run on the IBM 360 at Rutgers University, and the basic program has been run on the IBM 360–M40 at the University of Vermont.

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[2] Listings of the programs used in making the illustrations for this report are available from the author. The program used for Fig. 1 is most versatile and easiest to use.

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