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IIED

INTERNATIONAL INSTITUTE FOR
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EPM

ENVIRONMENTAL PLANNING
AND MANAGEMENT PROJECT

CHARACTERIZING MAP SIMILARITY:

EXTENDING THE SPATIAL ANALYSIS CAPABILITIES OF THE IIED DEVELOPMENT PLANNING MODEL

Joseph K. Berry
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International Institute for Environment and Development
1717 Massachusetts Ave. NW, Suite 302
Washington, DC 20036
(202) 462-0900

PROJECT ABSTRACT

The International Institute for Environment and Development (IIED) recently developed a planning model for assessing the implications of agriculture and related enterprises within developing countries. This report describes and demonstrates several software routines specially designed to extend the spatial data handling and analysis capabilities of the current model.

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1.0 PROJECT SCOPE

The IIED Planning Model uses a Geographic Information System (GIS) originally developed for mainframe computers. This general purpose package, co-developed with this consultant, is widely distributed and is used by numerous organizations for spatial data handling and analysis. A personal computer implementation of this software, trade-named pMAP, has been recently developed. It is anticipated that pMAP will be interfaced to the IIED Planning Model, as well as support other activities, such as training. A series of phased activities may be undertaken to achieve these goals.

The activities reported in this document represent the first phase of activities. The project was designed to extend the pMAP capabilities to take advantage of the simplified data encoding and display devices of microcomputers and develop a sub-system for assessing similarity among spatial features considering a variety of mappable attributes. The project included three major activities:

- Development of computer routines for extending the data handling capabilities of the

Professional Map Analysis Package (pMAP) system used in analysis and display of spatial data for the IIED Planning Model.

- Demonstrate the application of similarity measures to characterizing areas of similar thematic descriptors.

- Presentation of results and discussion of general applications of GIS technology to IIED and invited persons.

The presentation was made February 7, 1986 at the USAID Annex in Alexandria, Virgina. Several deliverables are included with this report. All of the software and data base developed under this contract are appended. Each program is delivered in source and some programs are also in run-time code (see diskette marked "UTILITIES"). A brief on-line "documentation" file for major programs are included on the Utilitis Disk and appended to this document in typed form. All programs are interactive and provide self-explanatory prompts for user responses. A complete set of demonstration maps, in pMAP Version 2.00 format, is contained on a second disk (see diskette marked "WORLD").

The material presented in this report assumes a basic understanding of the IBM PC operating environment and

familiarity with the Professional Map Analysis Package (pMAP) and Golden Software Graphics package. The various manuals and tutorials serve as primary references.

1.0 DATA CAPTURE ROUTINES

The data capture routines include DIGITIZE and P-G. The program DIGITIZE captures digitizer data and converts the raw data into the pMAP system format. The data files may then be read into the pMAP system using the TRACE or POINT commands. An on-line demonstration of DIGITIZE, which uses special files CREATE.DGZ and APPEND.DGZ, may be accessed by inserting DOS in the A> drive and the Utilities Disk in the B> drive, and entering

```
A>basica B:digitize
```

Select the appropriate options from the various menus to invoik the demonstration. The DIGITIZE program is currently configured for an IBM PC (or compatible) with an RS232 communications port connected to a Summagraphics Bit Pad Digitizer. A more detailed listing of technical information is available as one of the options in the main menu. Comments within the code identify lines which might require changing for different hardware.

The program P-G converts data between the pMAP system and the Golden Software Graphics package. A copy of the Golden system was purchased through this project and delivered in March, 1986. The P-G conversion capability allows maps from pMAP to be displayed within Golden Software as planimetric contour plots or as 3-dimensional surfaces on a dot matrix printer or pen plotter. The reverse conversion is also useful. Golden Software's spatially interpolated point data (i.e. continuous statistical distributions) may be transfered using P-G to create a data file for direct input into the pMAP system (READ command).

The P-G program is provided as both source code (P-G.BAS) and run-time code (P-G.EXE). To generate a Golden Software compatible data file from pMAP, a standard file is first generated using the command DUMP. For example, while in the pMAP system, enter

CMD: dump elevation onto B:elev.dmp bare

to create a file named ELEV.DMP on the floppy disk in your B: drive. Note the number of rows and columns of the data base (INFORM command) and then exit the pMAP system (QUIT

command). Place the Utilities Disk in the A: drive, then enter,

A> P-G

to begin the conversion routine. Follow the instructions contained in each of the menus. A demonstration set of files (ELEV.DMP and ELEV.GRD) from the pMAP Tutorial data base (25 rows by 25 columns) is provided.

3. DATA DISPLAY ROUTINES

Program SQPRINT allows a user to set font size and line spacing for IBM and Epson printers or their compatibles (files SQPRINT.BAS and SQPRINT.EXE). The SQPRINT routine is executed before entering pMAP by entering,

A> SQPRINT

Respond to the program's queries by entering the appropriate mode factor (font size) and line spacing (in 1/72th of an inch). A sample of printer output using the selected factors is generated. This setting will remain in effect until the printer is turned off or the system "rebooted" with DOS. Perfectly square maps can be generated by entering 0 for the mode and 21 for the spacing. However, this causes the characters to be printed with distracting

overlap. Combination 0 and 25 is most frequently used. Appended is a set of printer output for several different combinations.

Program COLOR generates a color display of maps DUMPed from pMAP (file COLOR.BAS). Currently only three colors (i.e. map categories) can be displayed with normal IBM Color Graphics boards. Through activities outside this project, a sixteen level version utilizing special graphics handling software is being developed. Once completed, the updated version will be forwarded to IIED without charge.

To generate a map display using COLOR, first create a standard data file of a map (DUMP command), then exit the pMAP system. Place a copy of DOS in the A: drive and enter,

```
A> basica
```

Once the BASICA interpreter is accessed, remove the DOS disk and place the Utilities Disk in the A: drive. Enter,

```
LOAD"B:color
```

to execute the program. Respond to the program prompts for file name (remember B:filename.dmp), number of rows and columns, enlargement factor, and title. The display limits

of COLOR are 200 by 200 pixels with the right portion of the screen reserved for the title. Determination of the legal enlargement factors are automatically computed (e.g. 1X,2X for maps of 100 rows by 100 columns; 1X,2X,3X,4X for 50 by 50).

4. SIMILARITY INDEX

The MAPSIM routine generates a map of similarity, expressed as an index of 1 to 100 ("percent" similar), of all locations in a study area as compared to a user defined set of characteristics. The on-line and appended documentation of the program contains an extensive explanation of the concepts and specific algorithms, as well as the procedures for using the routine. The figure on the next page shows the approach used in computing the index.

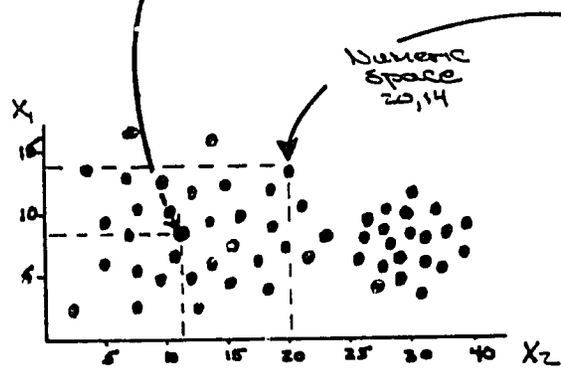
5. DEMONSTRATION OF SIMILARITY MEASURES

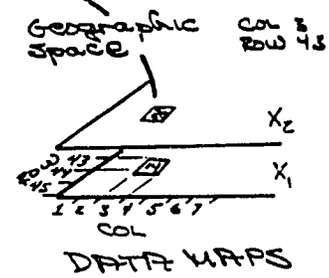
5.1 Data Base Encoding

As a means to demonstrate the various techniques for generating maps of similarity among locations, a data base of several themes were encoded from generally available world maps. The maps are based on "Winkel's Tripel

MINIMUM DISTANCE SIMILARITY MEASURE

USER DEFINED VECTOR:
$\bar{u} = [X_1 = 8, X_2 = 11]$
for comparisons





$$d_{max} = \sqrt{(X_{1max})^2 + (X_{2max})^2}$$

$$d = \sqrt{(u_1 - X_1)^2 + (u_2 - X_2)^2}$$

$$\text{Index} = 100 - \left[\left(\frac{d}{d_{max}}\right) * 100\right]$$

PROCEDURE:

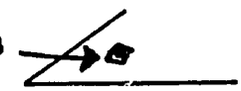
+ The user specifies "model" response vector for comparison (e.g. $\underline{U}$ = [8, 11]).

+ Maximum possible statistical distance within data set is determined.

+ Axes are scaled using user defined weights of data planes, if specified.

Loop:
- + Compute distance from comparison response vector to vector of first map location;
- + calculate index;
- + assign index value to the sample location on the final similarity map;
- + loop until all sample locations are assigned a similarity index.

$$100 - \left[\frac{10.8}{29.4} * 100\right] = 63$$



SIMILARITY MAP

Projection which is most often used in the Times Concise Atlas of the World. Although the meridians (lines of longitude) would be curved, it is not a "true" equal area projection. The maps encoded include

- o WORLDLAND - land masses and oceans
- o GEOPOLITICAL - geopolitical regions
- o GNP - gross national product per capita
- o POPULATION - population density
- o VEGETATION - vegetation and/or landuse
- o PROTEIN - animal protein consumption per capita
- o RELIGION - major religion

Appended are printer displays of each of the maps. These maps represent a variety of data types as summarized below.

- o Thematic Attribute:
  - Nominal- GEOPOLITICAL, VEGETATION, RELIGION
  - Ordinal- GNP, POPULATION, PROTEIN
  - Interval- none
  - Ratio- none
  - Dicotomous- WORLDLAND
- o Spatial Attribute:
  - Cloropleth- all maps
  - Isopleth- none

Consideration of the data types are extremely important when dealing with maps in a quantitative fashion. A complete treatise of the fundamental concepts of spatial statistics is beyond the scope of this report. However, consideration of data types is briefly discussed within the context of the demonstration (Section 5.0).

The large continental land masses were digitized and entered into pMAP through the TRACE command. Relatively small features and minor editing were entered as points (POINT command). Using this WORLDLAND map as a base, the boundaries of the categories for several themes were, in turn, digitized and entered in a similar fashion. Within pMAP, the thematic boundaries for each map were overlaid onto the background of land boundaries. Each composite map was edited for minor boundary inconsistencies. The use of a persistent land/water boundary map created consistency in registration and minimized digitizing. The actual digitizing was completed in approximately 50 hours. The individual doing the map encoding had no prior experience, therefore a portion of this time was self-training. Current estimates are about two hours per typical WORLD map, once experience has been gained.

The data base is contained on the second disk marked WORLD.* (files WORLD.* where the .* extensions indicate standard pMAP files). The data base configuration is 100 columns by 55 rows, 400 km per cell, and limited to 15 map

spaces so it may be used with floppy drives. To access the data base, place the pMAP System disk (Version 2.00) in the A: drive and the WORLD disk in the B: drive. Enter

```
A> pmap
        ... banner will scroll ....
Enter MAP database name (without extension): world
Specify drive letter containing database: b
ALL FILES ARE OPEN
ALL TABLES ARE INITIALIZED
CMD:
```

At this point you have accessed the WORLD data base and can begin displaying and analyzing maps.

5.2 Descrete Similarity Measures

The results of the demonstration of similarity measures using pMAP and the MAPSIM sub-system are appended. The example analysis compares the northwest portion of Nigeria (location column 48 and row 31) with all other areas of the world. One approach creates "dicotomous maps" showing all locations having the same value (thematic characteristic) as that portion of Nigeria. These maps were created by simply displaying those areas with the same value using the symbol

" 0 ", non-land areas as " "and all other values as a blank. For example, the following command sequence was used to create the NIGERIA-GNP map:

```
CMD: define 3
  >> 0
  >> 1 0
  >> 2
  >> 3
  >> 4
  >> 5
  >> 6
  >> 7
  >> 8
  >> -1
CMD: Display gnp using 3 width 50
```

To pause the screen as a map is displayed, simultaneously press the keys Ctrl/S; press Ctrl/S again to continue scrolling. To generate a square printer copy, run the SQPRINT routine before entering pMAP. Just before DISPLAYing a map, you may "slave" the printer by simultaneously the pressing Cntrl/PrtSc keys and the map will be displayed to both the screen and the printer (press Cntrl/PrtSc keys again to stop printer copy). These maps can be taped together and photocopied onto transparencies for "McHargian" overlay on an overhead projector. Darker locations on the projected image represent areas with greater similarity.

A more quantitative approach to the same analysis is accomplished by RENUMBERing each thematic map to a "binary" map with 1 assigned to Nigeria's value and 0 to all other locations and then COMPUTing the sum of the maps. For example,

```
CMD: renumber gnp for binary-gnp /
  >>   assigning 0 to 1 thru 8
  >>   assigning 1 to 1
       ... 0 and 1 (same) for other 4 maps ...
CMD: compute binary-gnp plus binary-pop plus .... /
       for binarysum-map
```

For this demonstration data base, the BINARYSUM-MAP values vary from 0 (no similarity; i.e. clear areas on projected image) to 5 (identical; i.e. darkest areas).

The simple binary sum indicates the number of data planes having similar responses, but does not indicate which planes these are. This more detailed characterization can be accomplished by assigning a binary progression (e.g. 1,2,4,8,16,...) of values to the similar values on each data plane before COMPUTing the sum. For example,

```
CMD: renumber gnp for bprog-gnp /
  >>   assigning 0 to 1 thru 8 /
  >>   assigning 1 to 1
         ... 0 and 2,4,8,16 for other 4 maps ...
CMD: compute bprog-gnp plus bprog-pop .... /
       for bprogsum-map
```

In this instance the BPROGSUM-MAP values would range from 0 (no similarity) to 31 (identical; 1+2+4+8+16=31). A value of 10 would indicate similar responses on the second (2) and fourth (8) data planes. Note that no consistent interpretation of the range of values (continuum) can be made (e.g. 8 is not "more" than 5, just different combination of similar data planes).

Another dictomous procedure for assessing similarity uses binary multiplication to quickly locate areas with identical characteristics to a user-defined pattern. Maps are RENUMBERed with 1 indicating similar areas and 0 nonsimilar areas, and a map of their product is COMPUTed. Within the final map, the areas having identical characteristics to the "model" pattern are assigned the product value 1; those having at least one different response equal 0. Note that the locations assigned 1 (identical) should be the same as those having the largest possible simple binary and binary progression sums (5 and 31 respectively for the demonstration data base).

5.3 Continuous Similarity Measures

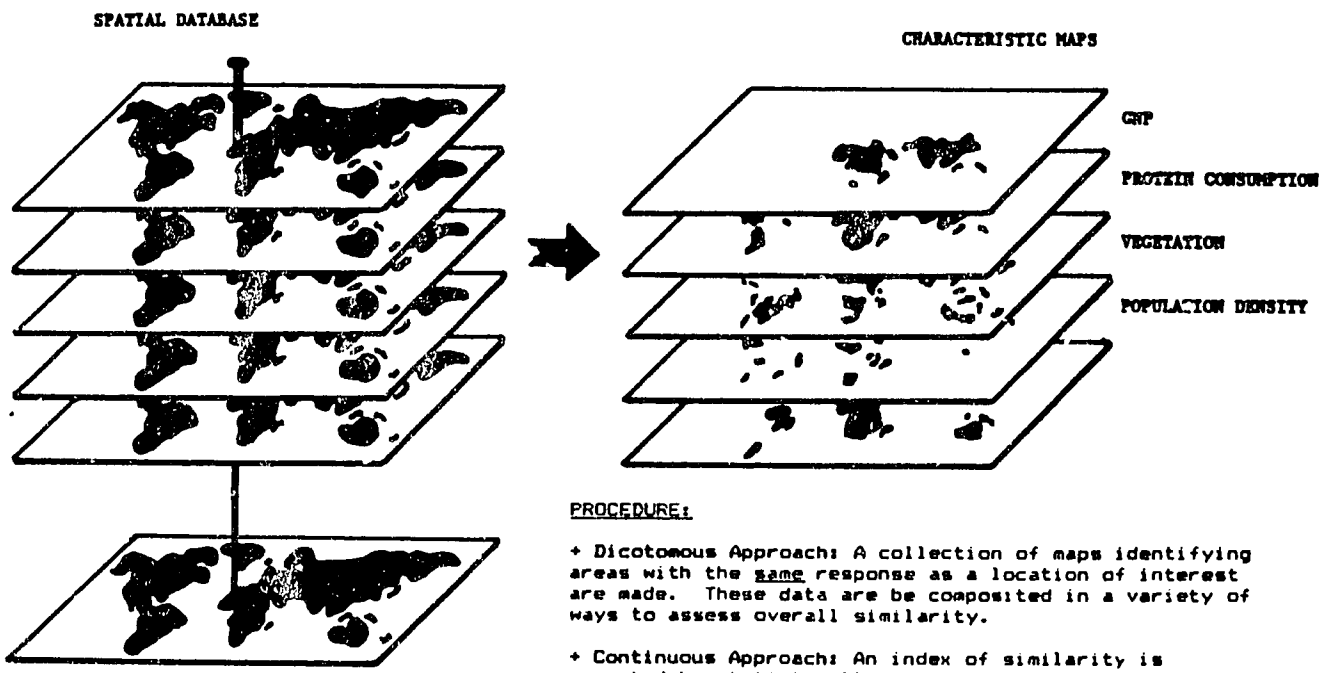
The "descrete" approaches all treat similarity as an all or nothing comparison. In each case, the dicotomous maps identify just the locations with the same characteristic. If the legends of a map can be expressed in relative terms, then a gradient of similarity can be established and mapped. For example, on the GNP map, locations with value 2 ($200-$500) are more similar to Nigeria's GNP (1- <$200) than level 8 (>$4000). The minimum distance measure statistically compares the relative similarity of each location's characteristic pattern to that of the one of interest. For example, each of the WORLD maps were DUMPed from pMAP as standard matrix. The Utilities Disk was inserted into the A: drive and the MAPSIM sub-system was accessed by entering

A> mapsim

In response to the queries, the files containing the map data were specified with no preferential weighting. The "modal" feature vector for northwestern Nigeria was specified (GNP- 1; POPULATION- 3; VEGETATION- 5; PROTEIN- 1; RELIGION- 5). The program then computed an index of similarity (0-100% similar) for the feature vectors at each

CHARACTERIZING MAP SIMILARITY

Descrete Similarity Measures



PROCEDURE:

+ Dicotomous Approach: A collection of maps identifying areas with the same response as a location of interest are made. These data are be composited in a variety of ways to assess overall similarity.

+ Continuous Approach: An index of similarity is computed by statistically comparing the characteristics of a location of interest to the characteristics of all of the other locations on the mapped area.

Continuous Similarity Measures

map location. This data was automatically stored in a data file ready for READing into the pMAP system. Note that the areas having 100% index values on the NIGERIA-SIMILAR map are the same as those identified as identical by the descrete procedures (simple binary sum= 5; binary progression sum= 31; simple binary product= 1). The MAPSIM measure has the additional advantages of defining the relative degree of similarity, and allowing for weighting of some data planes over others in the calculation.

5.4 Generalizing Similarity Maps

Both the descrete and continuous measures of similarity often yield estimates with sharp data changes ("plateaus" and "salt and pepper"). A generalized map showing the typical regional trends can be created by smoothing the data. This is accomplished within pMAP by SCANing the data for the average (ignoring the ocean background) within a certain radius. For example, enter

```
CMD: scan nigeria-similarity average for smooth /
  >>   around nigeria-similarity /
  >>   within 1 /
  >>   ignoring 0
```

This will create a smoothed version of the similarity index values as a function of the average of all the values in a

nine cell window about each land area.

6.0 ADDITIONAL RESEARCH

Several follow-on research activities are warranted. The WORLD data base should be expanded to include such factors as calorie consumption per capita, water availability per capita, and life expectancy. A more comprehensive analysis of the data base would be useful in simulating socio- and bio-regionalism concepts. A "clustering" similarity measure (responsive to inherent patterns in the data, rather than user defined ones) should be developed. Other ways in which pMAP could assist the IIED Planning Model, such as model parameter definition and spatially characterizing model results, should be investigated.

PROGRAMS RESIDING OUTSIDE OF PMAP

----- MAPSIM -----

MAPSIM allows you to create a similarity map -- a new map overlay where each cell contains information about how closely that map location resembles some model set of attributes, based on a selected set of overlays. Thus, the similarity of all map locations to a selected set of conditions (eg. topography, soil, vegetation, rainfall) can be calculated.

CONCEPT

The calculation of this similarity is based on a distance measurement made in an N-dimensional feature space, where N is the number of overlays, or feature conditions, that are being used to describe the relationships between map locations and the model conditions (see discussion of a minimum distance classifier in Tou and Gonzales 1974 - Pattern Recognition Principles, Addison-Wesley, p. 76-86). An option to weight similarity to specific conditions (ie. overlays) is provided for, thus allowing for example, the distance to vegetation type to be more strongly considered in establishing similarity than topography.

TECHNICAL

The MAPSIM program calculates similarities between the model conditions and each cell in the working map by creating an N-dimensional orthogonal space in which distances are evaluated. Each overlay characteristic is established as an axis in that N-dimensional feature space. Thus the model conditions (a vector provided by the user of length N) represents one point in the space. In a like manner, each map location is described by a vector that can also be represented as a single point in the N-dimensional space.

The calculated similarity is a function of the distance in space between a map location and the model conditions. This similarity sets the farthest point as zero and a point identical to model conditions as 100. Because the overlay values are simply a function of the units they are expressed in (eg. cm, m, km, etc.), they must be first scaled so that values between overlays are comparable. As a default setting, all overlays are scaled to the same range, ie. the distance in scaled units between the minimum and maximum value is the same. An option for variable scaling is provided for, which essentially allows each overlay condition to be weighted in the overall calculation of similarity.

The function to calculate distances is based on orthogonal axes (square root of the sums of squares). After all distances (map location to the model conditions) have been calculated, the maximum distance is rescaled to zero similarity and a lcation with conditions identical to the model would be scaled to 100. Weighting is achieved by scaling each overlay differently before calculating similarity. A weighting of 100 for a particular overlay would scale the range of observations for that map with the maximum range (0 to 255). A weighting of 50 would scale observations in a range from 0 to 127. Thus, differences in values for the 100-scaled data would carry more weight in separating points in the N-dimensional feature space.

PROGRAM OPERATION

1) The MAPSIM program requires an ASCII file of numbers for each overlay desired for the analysis. These files are easily created using the DUMP command in PMAP.

These files must have the same number of values, and the total for each map must be equal to (rows times columns). If using DUMP to create the files, these requirements will be automatically dealt with. MAPSIM will not function without the proper number of values.

2) For convenience, before starting MAPSIM, you can create a file which contains the list of map files (in ASCII) that you wish to use to generate the similarity map. The list can be generated using any ASCII editor or by using DOS. For example:

```
==========================

A> copy con: map.lst
water
cover
elevat
slope
^Z        (press F6 to display ^Z on the screen)
<Return>

==========================
```

These files should reside on the default disk device, or otherwise specify a DOS PATH in the name list. For example:

```
C:\MAP\covertyp
C:\MAP\water
.
.          (note: names can have up to 8 letters)
.
C:\MAP\elevatio
```

Map names can also be entered into MAPSIM one at a time.

3) To start MAPSIM, type MAPSIM at the DOS prompt from the disk or volume sub-directory containing the program MAPSIM.COM.

```
A> MAPSIM
```

All input files can be found by MAPSIM by specifying a DOS PATH if necessary.

The program has three "windows". The large upper window is the program output window. It displays any calculated results from the program that might be of interest to you. The lower left window is the program communication window. Information about the program or input required by the program are displayed here. The small window in the lower right is the status window.

```
-----------------------------------
|                                 |
|                                 |
|   Program Output Window         |
|                                 |
|                                 |
|                                 |
|                                 |
|                                 |
|=================================|
|                   |             |
|   Communication   | Status      |
|                   |             |
|                   |             |
-----------------------------------
```

The program fist displays information about the program. Information is displayed for 4 seconds, press the <return> key to go on without waiting.

4) The first piece of information needed is the size of the maps being read in the the number of overlays to be used.

```
=====================================

Enter number of rows, columns and overlays to read
   (separate the three integers with spaces)
            ==> 25 25 5

=====================================
```

The above would indicate a map size of 25 rows by 25 columns for 5 overlays. The program will stop if the wrong number of values or overlays is contained in the number files or map list.

5) The next information the program needs is map names. You are given the option of typing each map name in one by one. You if do not want this option, then type the name of of the file containing the list of map names (eg. MAP.LST).

6) Then the values for the model conditions are requested. The number of values needed is equal to the number of overlays (above example is 5). For example:

```
=====================================

Enter ideal for overlay number 1  Value:  300.02
Enter ideal for overlay number 2  Value:  22
(etc.)

=====================================
```

Each ideal value should be within the range of observed values for the corresponding map. If not the program will scale the value to 0 or 100 as the case may be.

7) After the last value is entered the program will ask if weighting is desired. If you answer Y(es), the program will prompt you for a weighting factor from 10 to 100 for each overlay. A value of 100 requests maximum weighting (ie. maximum emphasis on the overlay variables), and a value of 10 gives an overlay variable the minimum weighting. If less than 10 is desired, it is probably better to leave the overlay variable out of the analysis.

8) The program will then continue to completion, only stopping to request an output filename to store the map. This name should not have an extension (ie. OUTPUT, not OUTPUT.MAP) as the extension .SIM will be automatically added.

9) Use READ in PMAP to read in the new map and VIEW it within the PMAP environment. The headers and completion line needed by the READ command will already be in the file. Delete this information if the similarity map is to be used in MAPSIM.

```
=====================================

> READ OUTPUT.SIM

=====================================
```

OPERATIONAL NOTES

The program has two versions, one for the 8088 IBM-PC compatible and 80286 IBM-AT compatible computers (MAPSIM) and one for computers with the 8087 or 80287 numeric coprocessor (MAPSIM87). MAPSIM87 is faster.

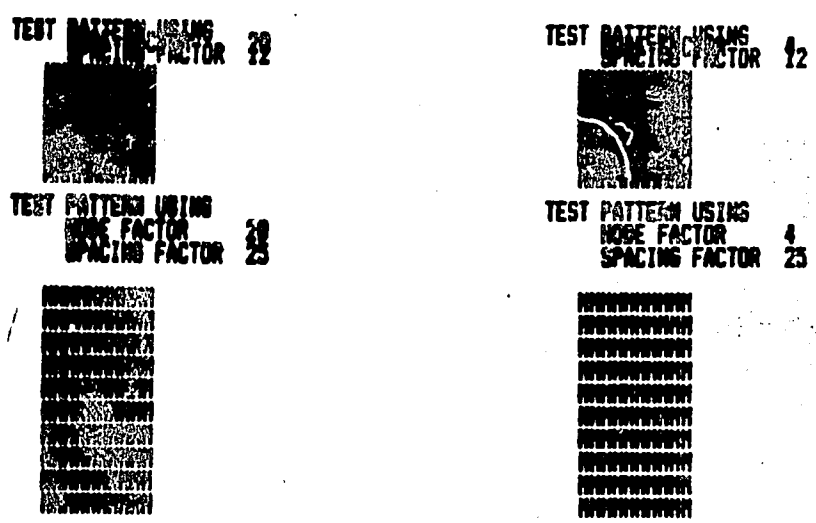
The size of the maps and the number of overlays that can be read in is determined by available memory. In a 256K RAM machine with no memory resident programs like RAM disks, print spoolers, desktop accessories, etc.; about 8 map overlays of 100 by 100 can be read in. Larger machines can use more memory (up to the 640K DOS limit). The program checks for adequate memory. Approximate computer memory needed is calculated by

(map size X number of overlays) + 100K

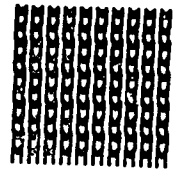
You can probably squeeze more maps in if you keep trying (until memory error is generated).

The program is set up for a color graphics adapter. Windows do not show on a monochrome system, but the program will function properly.

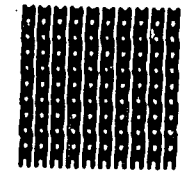
```
1   REM ... PROGRAM BY JOSEPH K. BERRY - ALL RIGHTS RESERVED
2   REM                    DECEMBER, 1985
3   REM
10  REM ... SET PRINTER FORMAT FOR IBM/EPSON (FX-80) OR COMPATIBLE PRINTERS
20  PRINT
30  PRINT "EXECUTING PROGRAM TO SET IBM/EPSON FX-80 PRINTER FORMAT"
40  INPUT "  PRINT MODE FACTOR (0- NORMAL; OTHER MODES 1-63)";C
50  LPRINT CHR$(27);"!";CHR$(C)
60  PRINT "  LINE SPACING FACTOR IN 1/72THS OF AN INCH..."
70  INPUT "      (SQUARE -- 21 FOR NORMAL)";S
80  REM ... IBM/EPSON FX-80 PRINTERS
90  LPRINT CHR$(27);"3";CHR$(S);"    TEST PATTERN USING"
100 LPRINT "          MODE FACTOR    ";C
110 LPRINT "          SPACING FACTOR ";S
120 LPRINT
130 FOR I=1 TO 10
140 LPRINT "        MMMMMMMMMM"
150 NEXT
160 LPRINT
170 PRINT
180 PRINT "...OK, PRINTER CONFIGURED"
190 PRINT
210 END
```



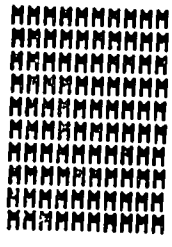
TEST PATTERN USING
MODE FACTOR 1
SPACING FACTOR 17



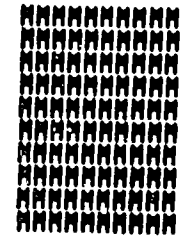
TEST PATTERN USING
MODE FACTOR 17
SPACING FACTOR 17



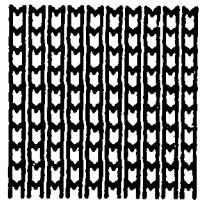
TEST PATTERN USING
MODE FACTOR 1
SPACING FACTOR 25



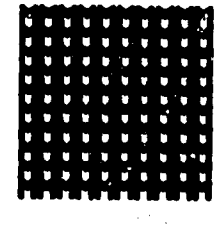
TEST PATTERN USING
MODE FACTOR 17
SPACING FACTOR 25



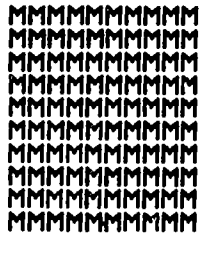
TEST PATTERN USING
MODE FACTOR 0
SPACING FACTOR 21



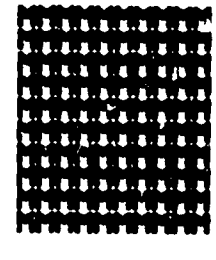
TEST PATTERN USING
MODE FACTOR 24
SPACING FACTOR 21



TEST PATTERN USING
MODE FACTOR 0
SPACING FACTOR 25



TEST PATTERN USING
MODE FACTOR 24
SPACING FACTOR 25



```
TEST  PATTERN USING
      MODE FACTOR        33
      SPACING FACTOR     36

    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
```

```
TEST  PATTERN USING
      MODE FACTOR        37
      SPACING FACTOR     36

    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
```

```
TEST  PATTERN USING
      MODE FACTOR        51
      SPACING FACTOR     36

    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
    MMMMMMMMMMM
```

```
TEST  PATTERN USING
      MODE FACTOR          32
      SPACING FACTOR       50

     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM

TEST  PATTERN USING
      MODE FACTOR          40
      SPACING FACTOR       50

     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM

TEST  PATTERN USING
      MODE FACTOR          56
      SPACING FACTOR       50

     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
     MMMMMMMMMMM
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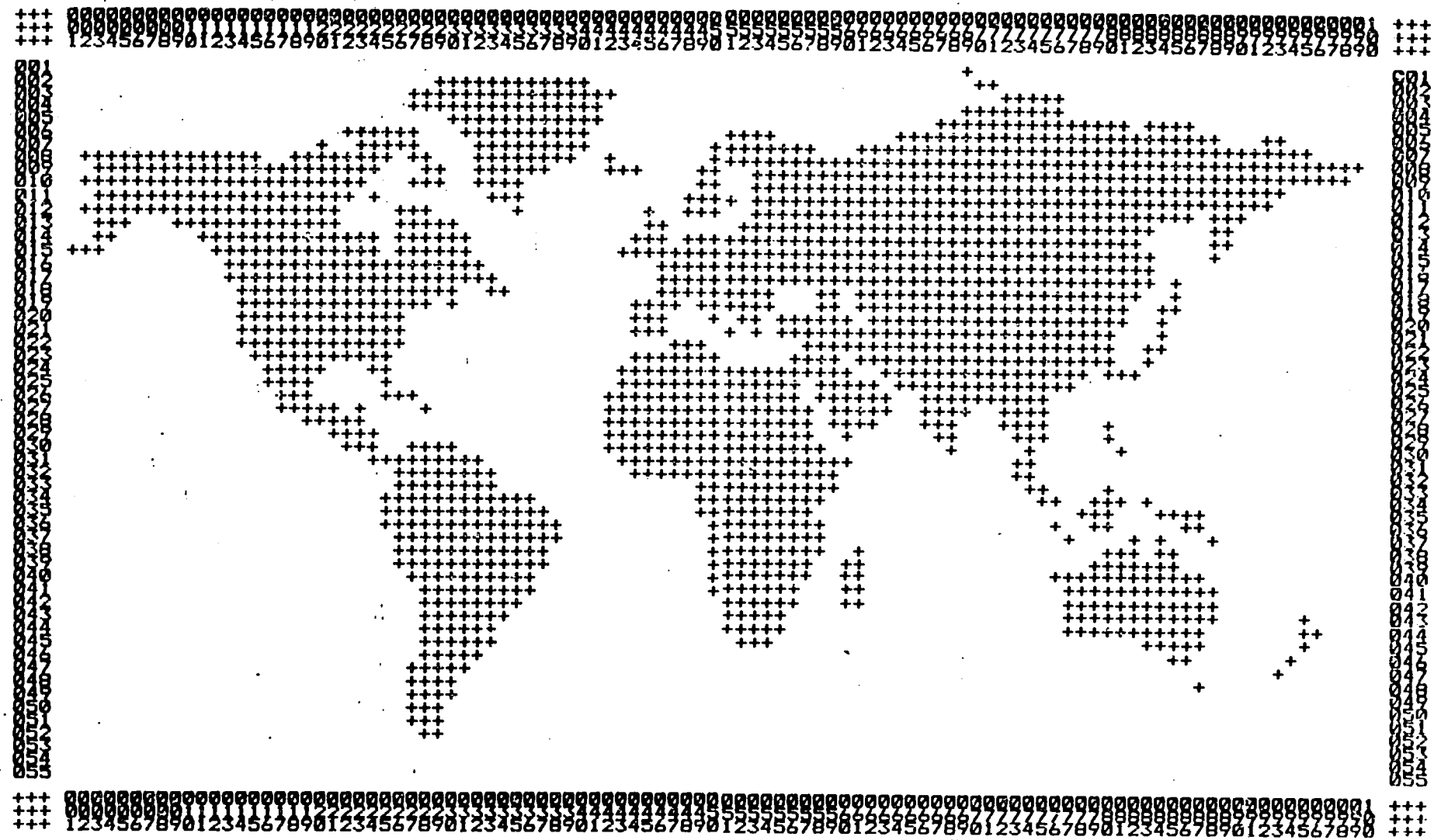

BASELAND
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0	OCEAN-SEA	3684	66.98
++++++++++	1	LANDMASS	1816	33.02
	TOTAL NO. OF CELLS =	5500		

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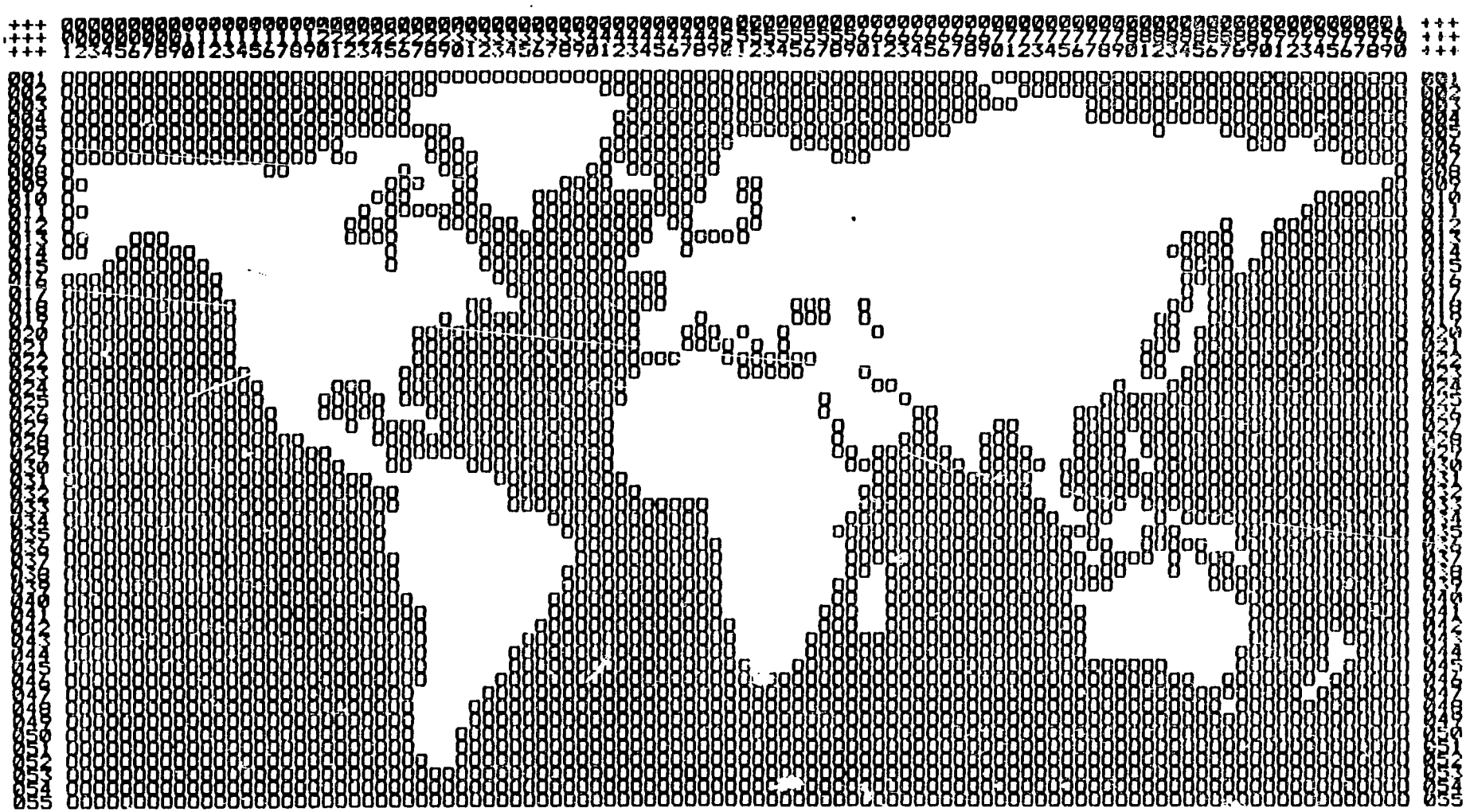

BASEOCEAN
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0	LAND MASS	1816	33.02
0000000000	1	OCEAN-SEA	3684	66.98
	TOTAL NO. OF CELLS =	5500		

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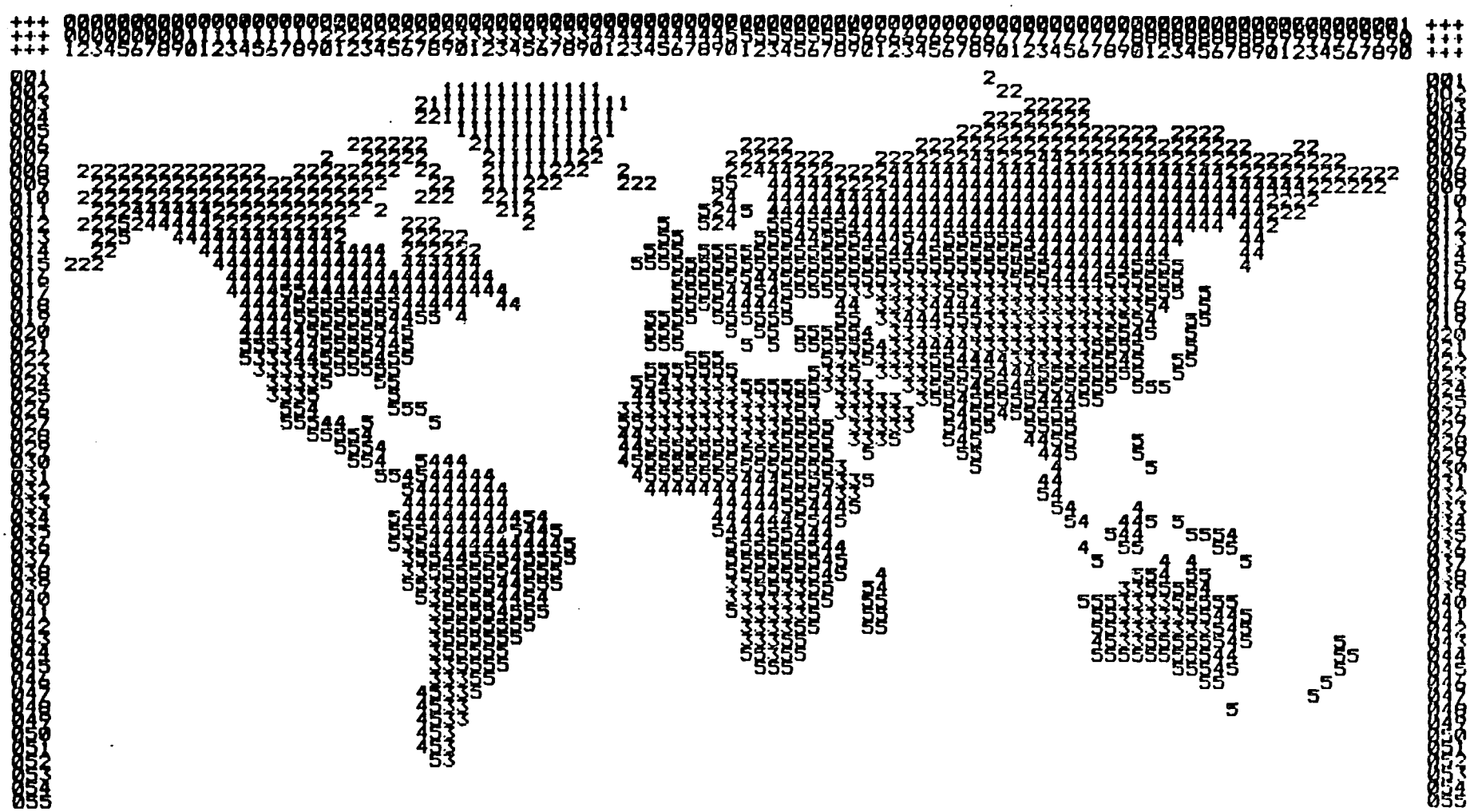

VEGETATION
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0		3684	66.98
1111111111	1	ICECAP	74	1.35
2222222222	2	ARTIC TUNDRA	310	5.64
3333333333	3	DESERT-WASTELAND	264	4.80
4444444444	4	FOREST	546	9.93
5555555555	5	FARMLAND-PRARRIE	622	11.31
	TOTAL NO. OF CELLS =	5500		

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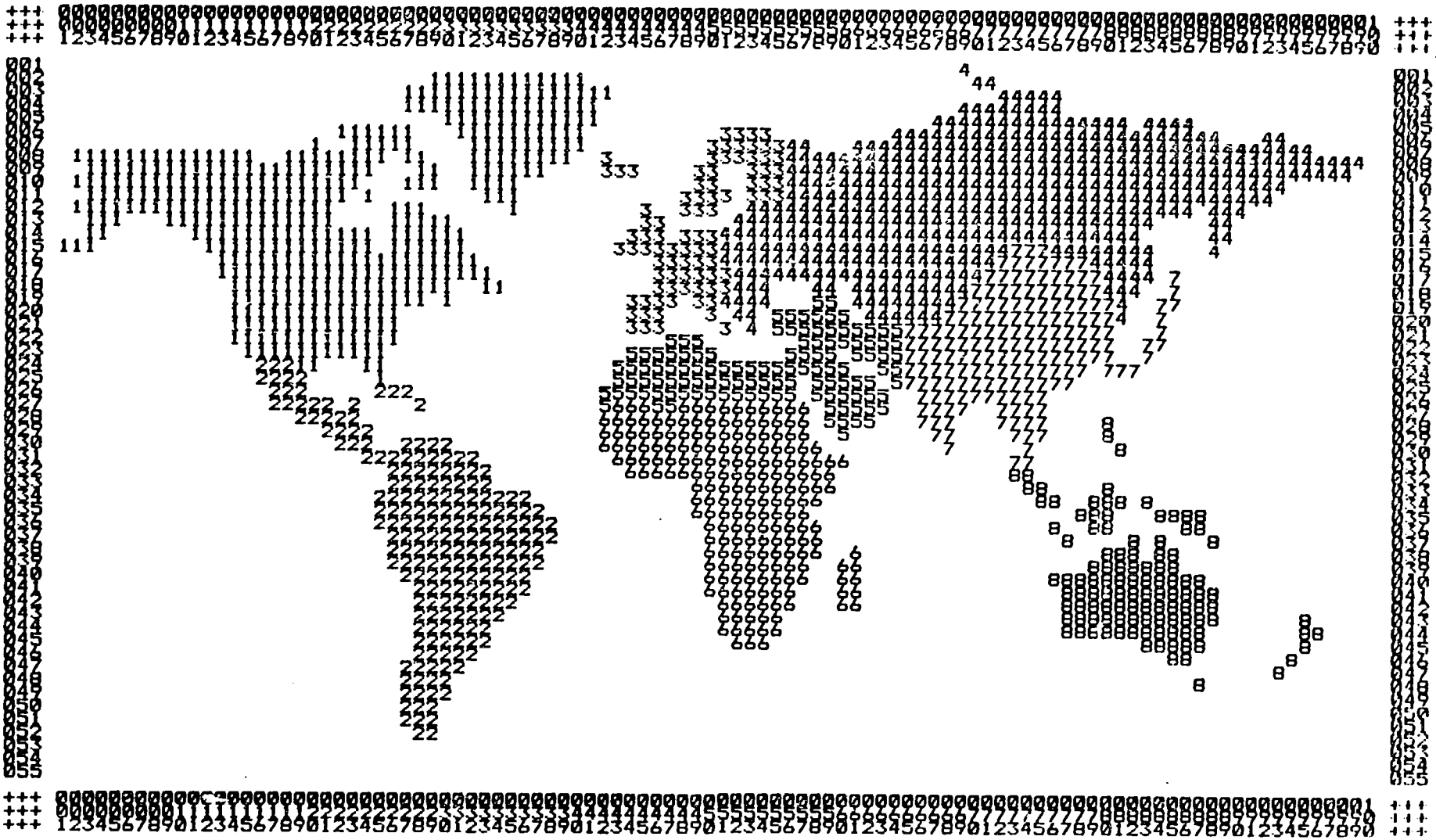

GEOPOLITICAL
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0		3684	66.98
1111111111	1	N. AMERICA - GREENLAND	421	7.65
2222222222	2	LATIN AMERICA	209	3.80
3333333333	3	WESTERN EUROPE	88	1.60
4444444444	4	E. EUROPE - USSR	486	8.84
5555555555	5	N. AFRICA - MIDDLE EAST	118	2.15
6666666666	6	CENTRAL-SOUTHERN AFRICA	204	3.71
7777777777	7	CENTRAL-SOUTHERN ASIA	175	3.18
8888888888	8	AUSTRALIA - OCEANA	115	2.09
	TOTAL NO. OF CELLS =	5500		

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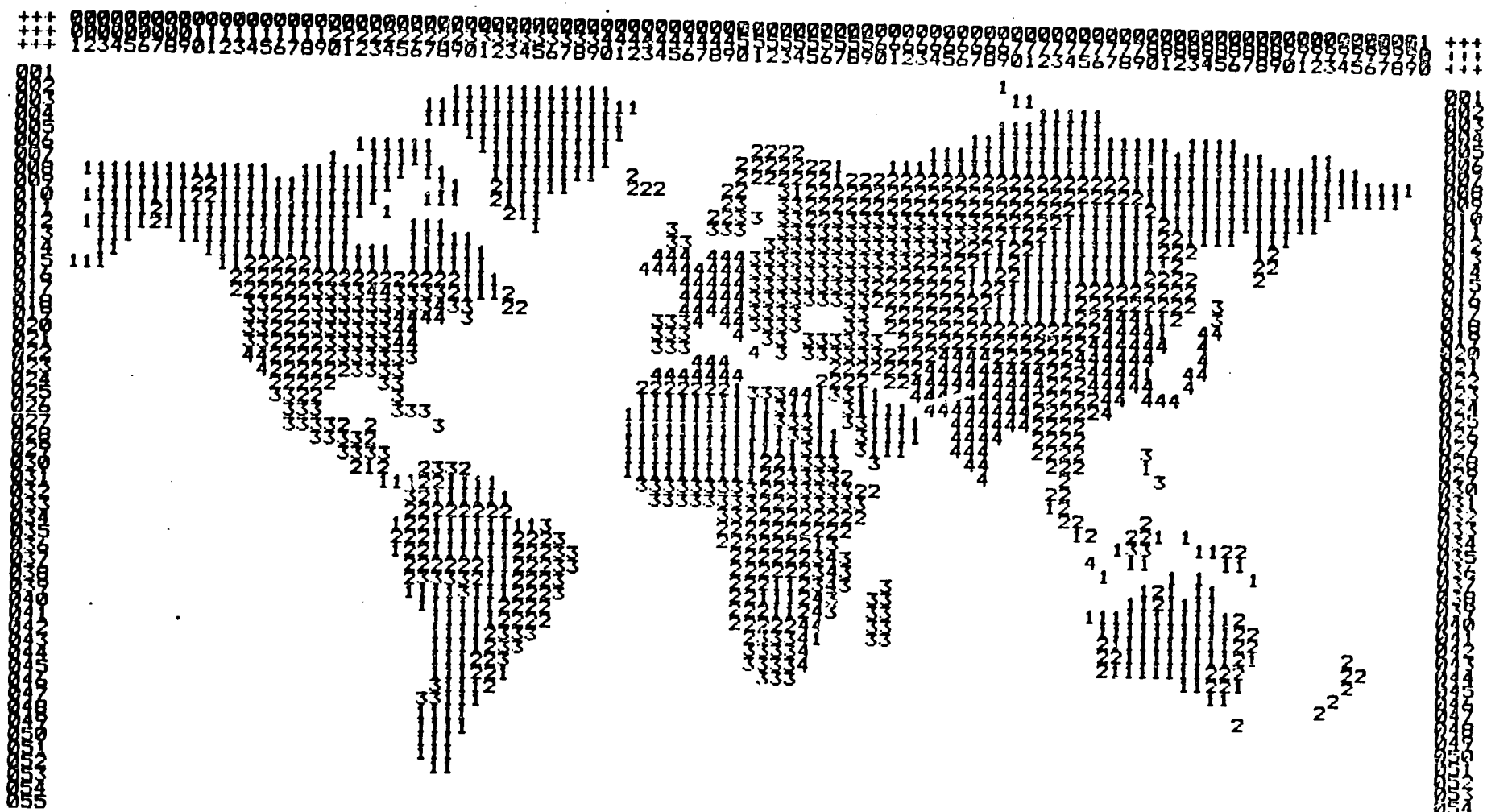

POPULATION
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0		3684	66.98
1111111111	1	<1 PERS PER SQ MI	807	14.67
2222222222	2	1-10 PERS PER SQ MI	515	9.36
3333333333	3	10-100 PERS PER SQ MI	326	5.93
4444444444	4	>100 PERS PER SQ MI	168	3.05
	TOTAL NO. OF CELLS =	5500		

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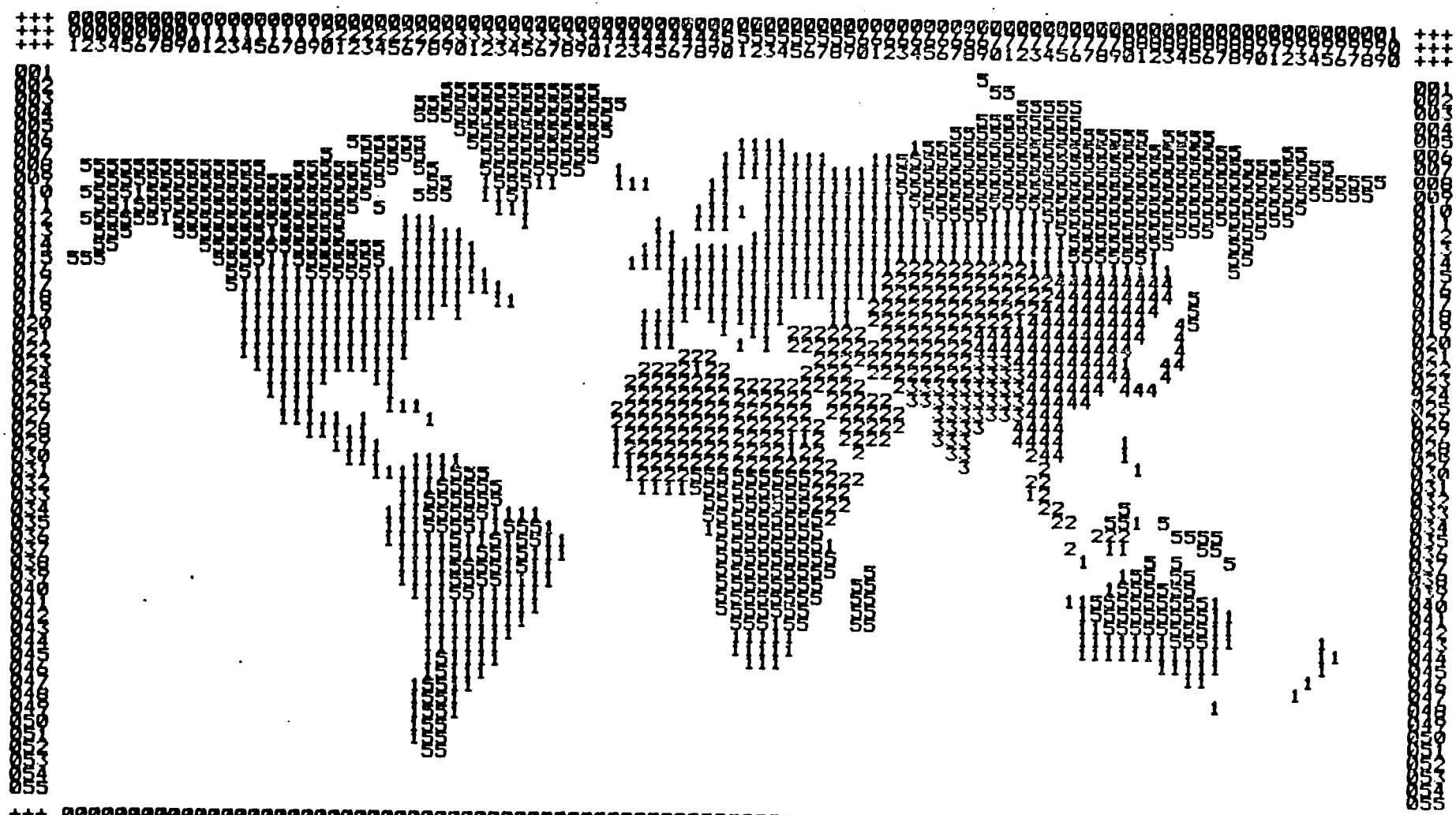

RELIGION
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0		3684	66.98
1111111111	1	CHRISTIAN	652	11.85
2222222222	2	MUSLIM	275	5.00
3333333333	3	HINDU	42	.76
4444444444	4	BUDDIST	110	2.00
5555555555	5	LOCAL-ANIMIST	737	13.40
	TOTAL NO. OF CELLS =	5500		

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GNP
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL		NO.OF CELLS	PCT. OF MAP
	0			3684	66.98
1111111111	1	<$200	PER YEAR	314	5.71
2222222222	2	$200-500	"	251	4.56
3333333333	3	$500-1000	"	174	3.16
4444444444	4	$1000-1500	"	562	10.22
5555555555	5	$1500-2000	"	96	1.75
6666666666	6	$2000-2500	"	91	1.65
7777777777	7	$2500-4000	"	184	3.35
8888888888	8	>$4000	"	144	2.62
	TOTAL NO. OF CELLS =			5500	

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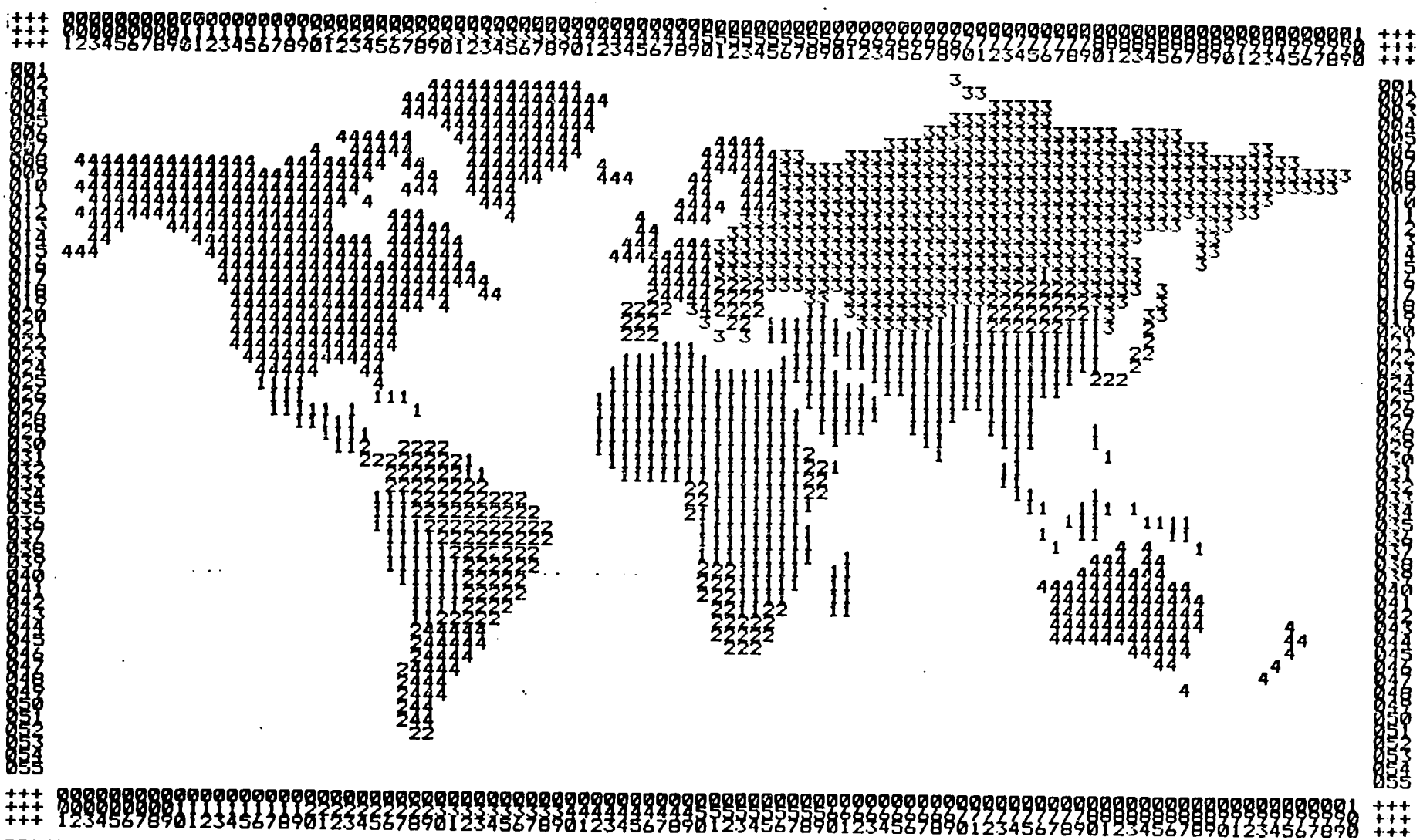

PROTEIN
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0		3684	66.98
1111111111	1	<20 GRAMS PER DAY	504	9.16
2222222222	2	20-35 GRAMS PER DAY	205	3.73
3333333333	3	35-50 GRAMS PER DAY	496	9.02
4444444444	4	>50 GRAMS PER DAY	611	11.11
	TOTAL NO. OF CELLS =		5500	

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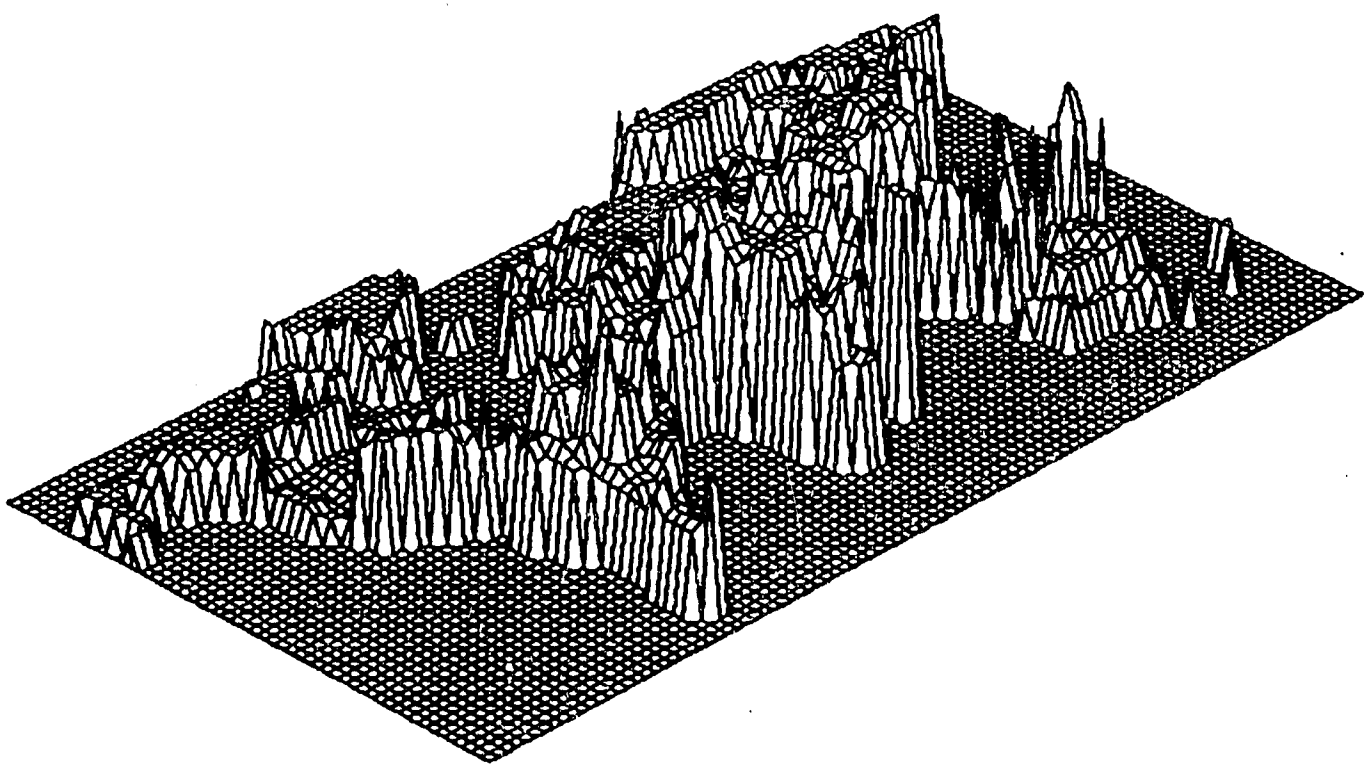
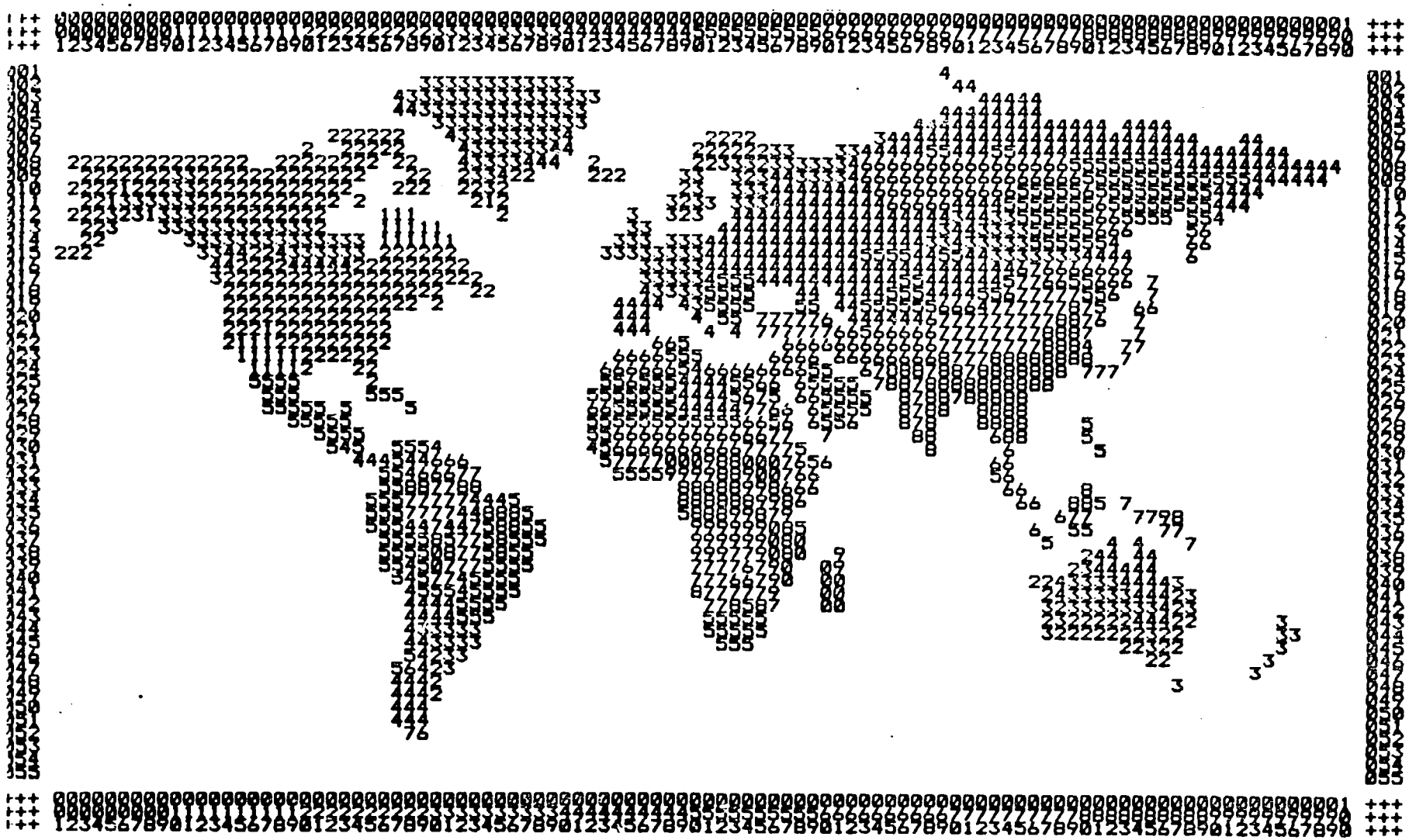


Nigeria Similarity



NIGERIA-SIMILAR
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0		3684	66.98
1111111111	1	1-10% (LEAST SIMILAR)	31	.56
2222222222	2	11-20%	303	5.51
3333333333	3	21-30%	255	4.64
4444444444	4	31-40%	405	7.36
5555555555	5	41-50%	303	5.51
6666666666	6	51-60%	204	3.71
7777777777	7	61-70%	144	2.62
8888888888	8	71-80%	112	2.04
9999999999	9	81-90%	35	.64
[illegible]	10	91-100% (MOST SIMILAR)	24	.44
	TOTAL NO. OF CELLS =	5500		

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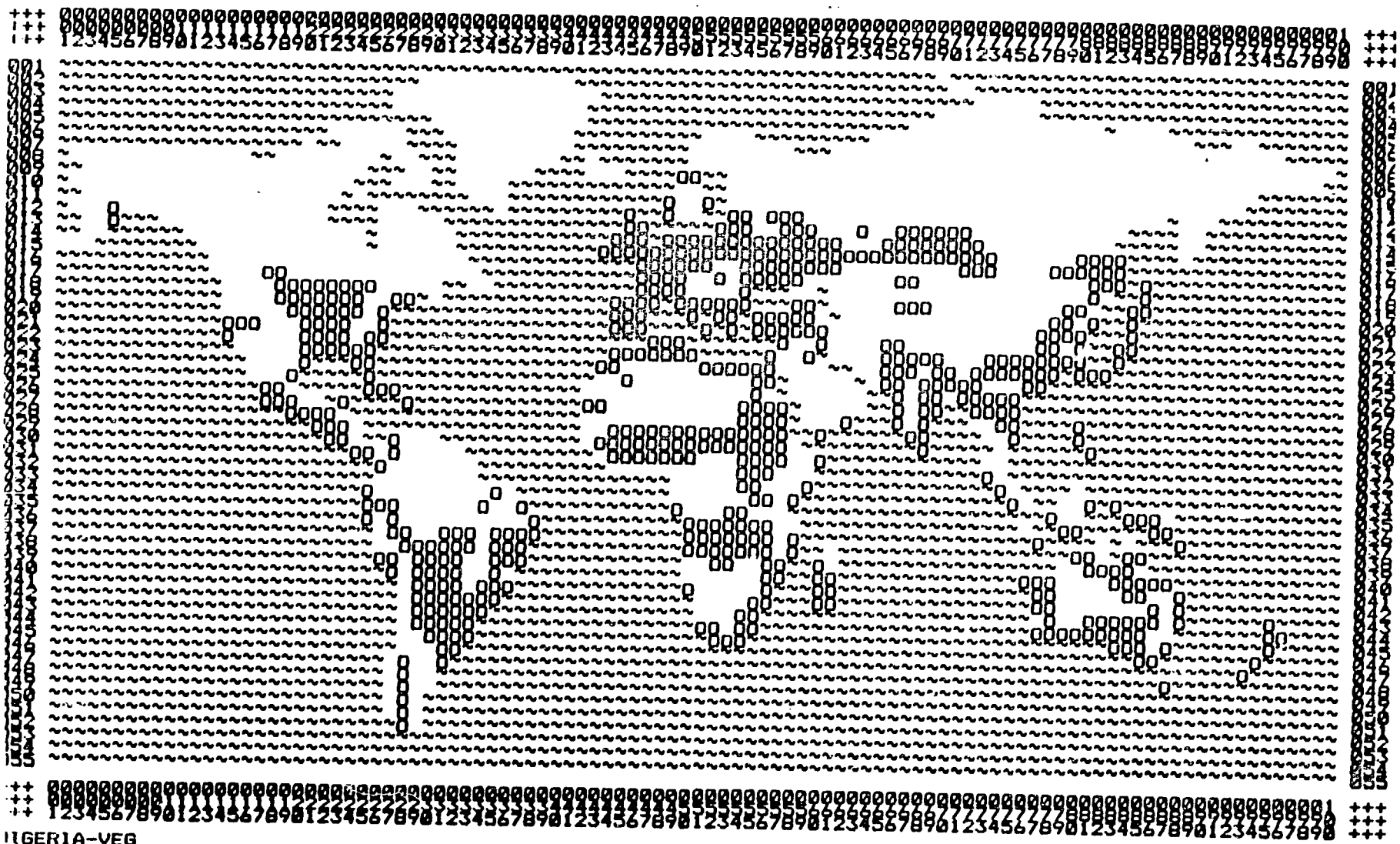

NIGERIA-VEG
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT. OF MAP
~~	0		3684	66.98
	1	ICECAP	74	1.35
	2	ARTIC TUNDRA	310	5.64
	3	DESERT-WASTELAND	264	4.80
	4	FOREST	546	9.93
0000000000	5	FARMLAND-PRARRIE	622	11.31
	TOTAL NO. OF CELLS =		5500	

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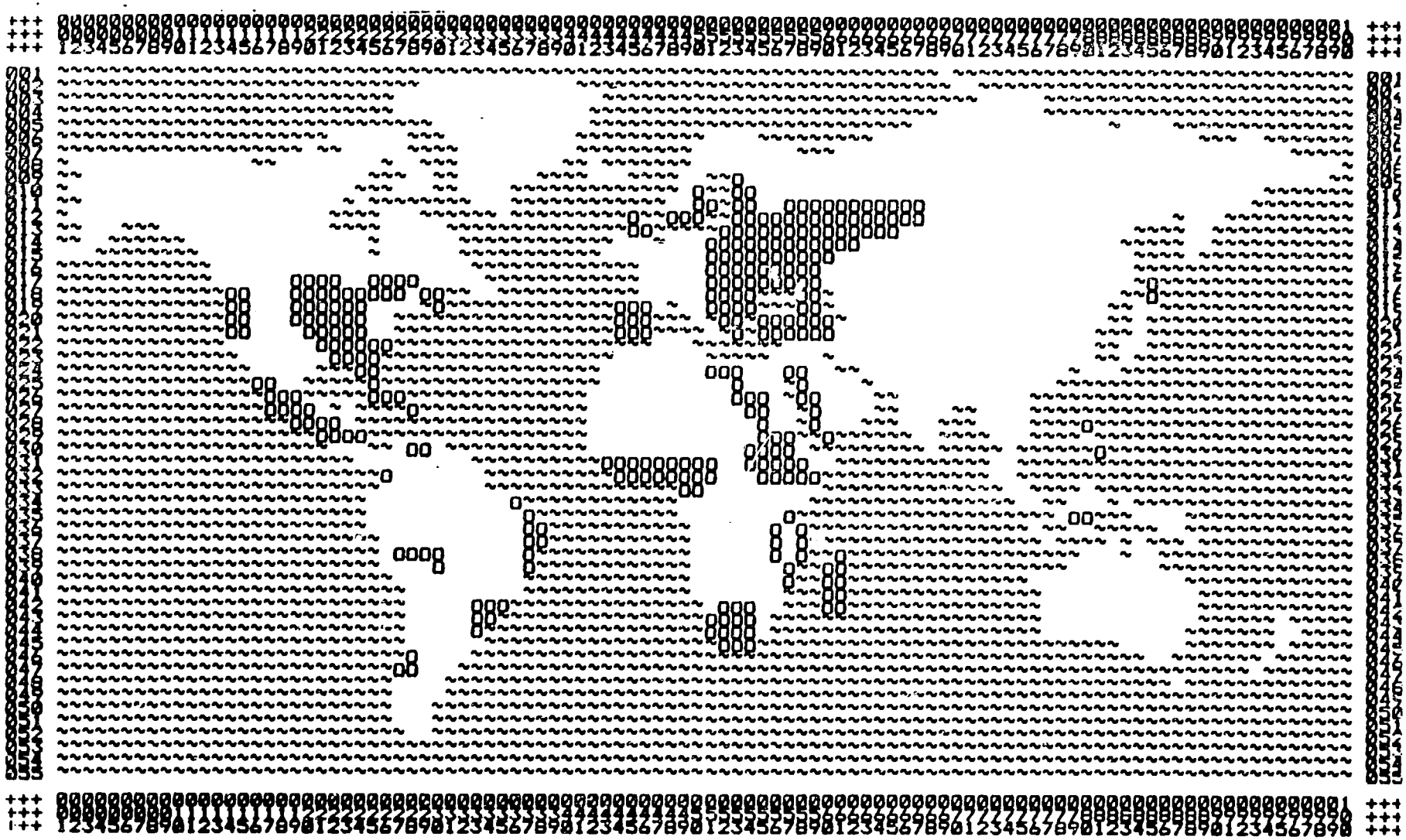

NIGERIA-POP
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
~~	0		3684	66.98
	1	<1 PERS PER SQ MI	807	14.67
	2	1-10 PERS PER SQ MI	515	9.36
0000000000	3	10-100 PERS PER SQ MI	326	5.93
	4	>100 PERS PER SQ MI	168	3.05
	TOTAL NO. OF CELLS =		5500	

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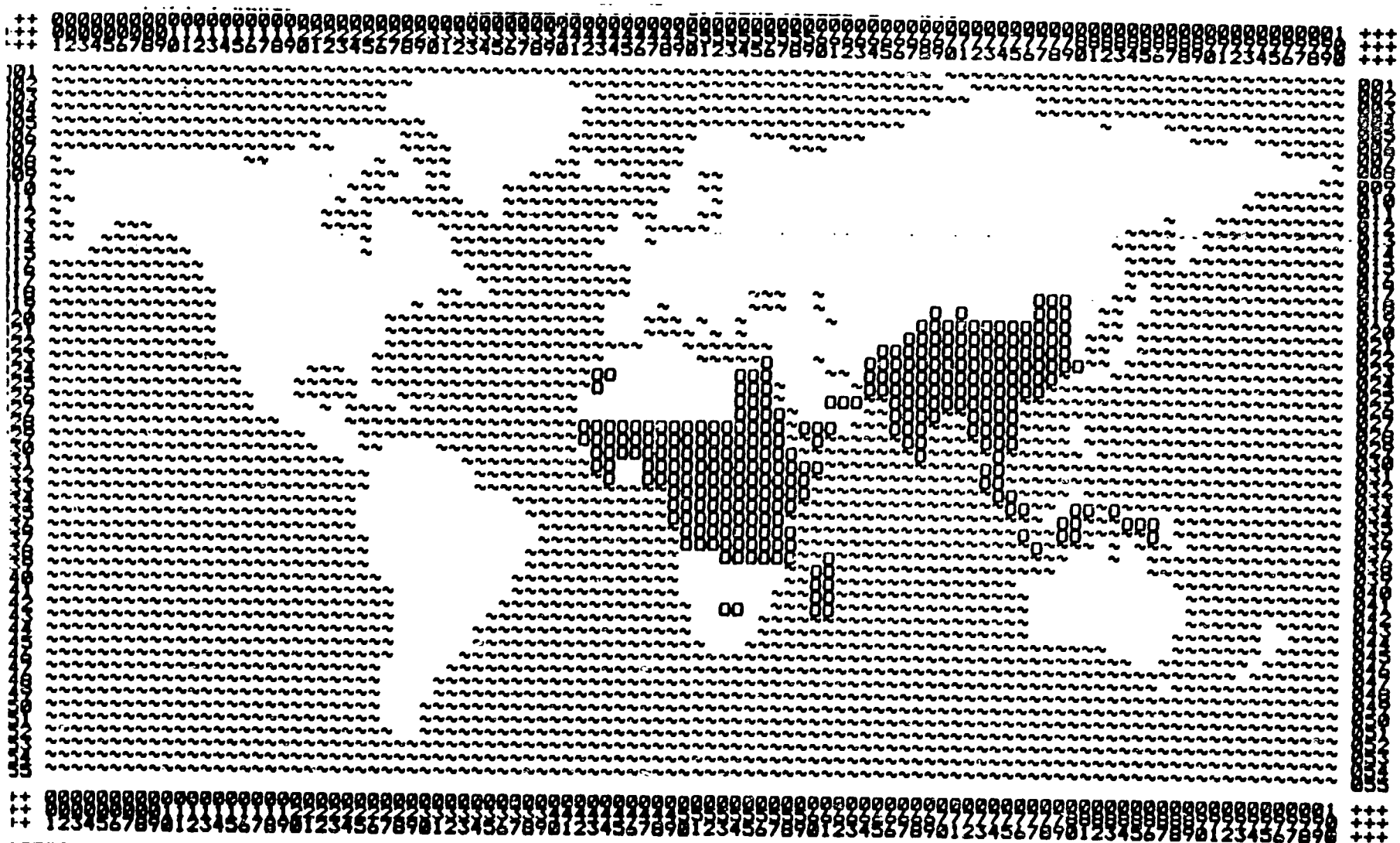

LGERIA-GNP
CALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL		NO.OF CELLS	PCT. OF MAP
~~	0			3684	66.98
0000000000	1	<$200	PER YEAR	314	5.71
	2	$200-500	"	251	4.56
	3	$500-1000	"	174	3.16
	4	$1000-1500	"	562	10.22
	5	$1500-2000	"	96	1.75
	6	$2000-2500	"	91	1.65
	7	$2500-4000	"	184	3.35
	8	>$4000	"	144	2.62

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NIGERIA-PROTEIN
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
	0		3684	66.98
0000000000	1	<20 GRAMS PER DAY	504	9.16
	2	20-35 GRAMS PER DAY	205	3.73
	3	35-50 GRAMS PER DAY	496	9.02
	4	>50 GRAMS PER DAY	611	11.11
	TOTAL NO. OF CELLS =		5500	

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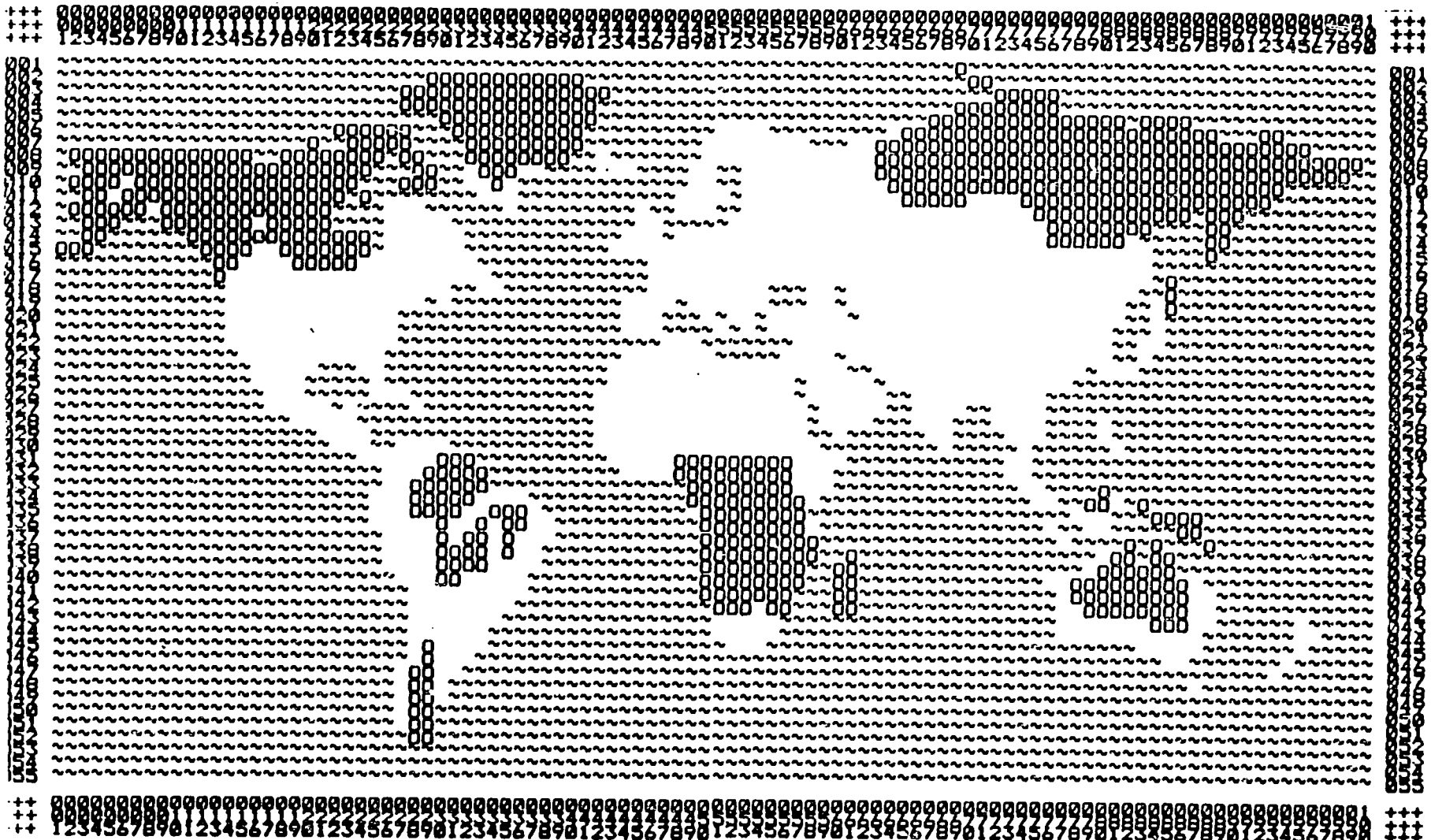

NIGERIA-RELIGION
SCALE: 400.0 km PER CELL

SYMBOL	VALUE	LABEL	NO.OF CELLS	PCT. OF MAP
~~	0		3684	66.98
	1	CHRISTIAN	652	11.85
	2	MUSLIM	275	5.00
	3	HINDU	42	.76
	4	BUDDIST	110	2.00
0000000000	5	LOCAL-ANIMIST	737	13.40
	TOTAL NO. OF CELLS =		5500	

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