This is to certify that the

thesis entitled

THEMATIC MAP LEGEND DESIGN FEATURES
AND AUTOMATED CARTOGRAPHY

presented by

Robert Michael Conley

has been accepted towards fulfillment
of the requirements for

M.A. degree in Geography

Richard Groop
Major professor

Date May 11, 1994

DATE DUE	DATE DUE	DATE DUE
JUN 0 1		

THEMATIC MAP LEGEND DESIGN FEATURES AND AUTOMATED CARTOGRAPHY

By

Robert Michael Conley

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Geography

1994

ABSTRACT

THEMATIC MAP LEGEND DESIGN FEATURES AND AUTOMATED CARTOGRAPHY

By

Robert Michael Conley

A thematic map legend design is crucial to the understanding of an intended map message. This study investigates the importance of various thematic map legend design features and then looks at how well computer mapping software packages manipulate those features when designing a legend. Fifteen legend design features were identified. A questionnaire was distributed to forty professional cartographers and geographers asking their opinions about relative importance of the fifteen features. Twelve computer mapping software packages were evaluated on their ability to design a thematic map legend by manipulating the same fifteen features. This study resulted in the ranking of the features according to their judged importance and the twelve computer mapping software packages according to their legend design performances.

I dedicate this thesis to my loving family who gave me their full support and encouragement.

ACKNOWLEDGMENTS

I would like to acknowledge Dr. Richard E. Groop for assisting me with my thesis topic and for lending support when I needed it the most. Dr. Groop gave up several hours of his personal time for meetings and was always open to my ideas. I would like to thank Dr. Judy M. Olson for her thoughtful edits and input on my survey booklet design, and Bill Enslin at the Center for Remote Sensing for allowing me to use the CMAP GIS software and hardware. Finally, I would like to thank Nancy Yattaw and Jim Wilfong for their assistance in testing the graphics design for my survey booklet.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THEMATIC MAP LEGEND DESIGN ISSUES

Over the past 30 years, cartographers have actively conducted research on how to improve the quality of thematic maps or the techniques used to design them. An exhaustive amount of research has been conducted on an array of map symbol types, symbol positions on a map, and symbol perception by map readers. The goal of this type of research has been to understand better how people read thematic maps and whether the intended map message is received by the map reader. Thematic map legend designs must also be crucial to understanding map messages since legends explain map symbols.

A thematic map is unlike a general purpose reference map, which shows graphically, a real world representation of the individual features in a given area and may include terrain, vegetation type, buildings, roads and so on. If a legend is used on a general purpose map, it usually indicates a poorly designed and constructed map (Shelton, 1985). A thematic map, however, needs a legend to explain the different symbols because they are generally far more abstract. It is an unwritten but cardinal rule of the cartographer that any symbol that is not self explanatory must be identified in a legend. Furthermore, any symbol in the legend should appear exactly as it does on the map, drawn in precisely the same size, manner and complexity (Robinson, 1984).

Legend Design Variables

Traditionally, the size, shape, and placement of a map legend has depended on the entire map layout design based on some general and vaguely-defined principles of visual balance, size relationship, and aesthetic quality (Dent, 1972). Beyond these principles, the cartographer has a large number of variables and design decisions to deal with when

creating a thematic map legend. Some variables, such as location on the page and size, are general to all maps and others, such as the arrangement of features, are specific to particular types of thematic representations. The section below describes some of the more important legend variables.

An important design consideration for choropleth legends is the arrangement of the boxes and their associated values. The typical choropleth legend box has a 3:5 ratio and is stacked vertically with the value description to the right of the box (Figure 1A). This arrangement is the best solution for placing labels with each box (Cuff, 1982). A horizontal arrangement, however, is sometimes necessary because of space restrictions, map configurations, or simply as a preferred arrangement by the designer. Three alternative horizontal designs illustrate how labeling can be confusing (Figure 1B), how one can use extravagant amounts of space (Figure 1C), and how labels above or below can result in a more compact layout (Figure 1D).

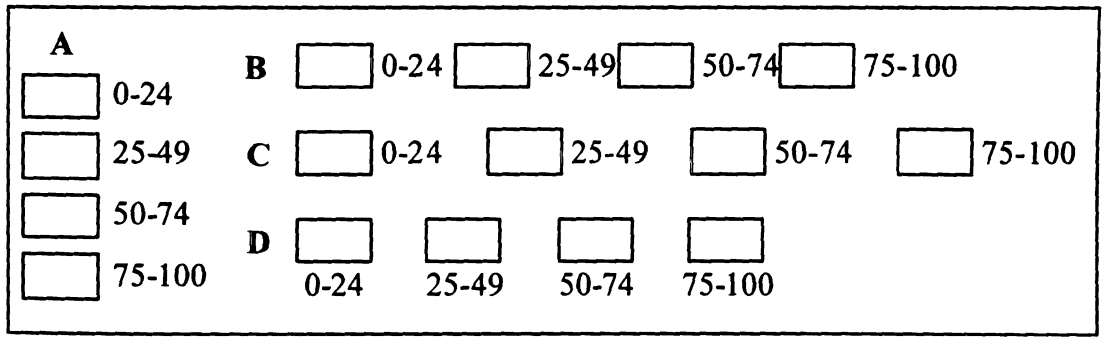


Figure 1. Legend box arrangements.

Another consideration is the location of larger and smaller values: should the largest value be at the top or bottom with a vertically stacked legend design, and on the left or right with a horizontally arranged legend design? Some individuals may associate the largest value and darkest color as being "heavier" and prefer to see it at the bottom. Other individuals may see the largest value and darkest color as "higher" and prefer to see it as the top legend box. There may also be conflicting preferences with respect to a horizontal

arrangement. Likewise there may be preferences associated with alternative diagonal arrangements or "natural" legend designs where either a part of the actual map is duplicated or a representative arrangement is drawn up with the appropriate labels and title attached.

Questions to reveal similar preferences can be asked of a graduated symbol legend: should the symbols be vertically or horizontally arranged and in what order? Both arrangements have traditionally been acceptable on thematic maps, with the horizontal (Figure 2A) more common than vertically arranged symbols (Figures 2B). When legend space on a map is restricted, or as a matter of personal preference, a nested circle legend can be used as a third design (Figure 2C). The decision is affected by the map size, configuration, legend placement space, preferences of the cartographer, and results of research that suggest that nested symbols are associated with greater difficulty in value estimation.

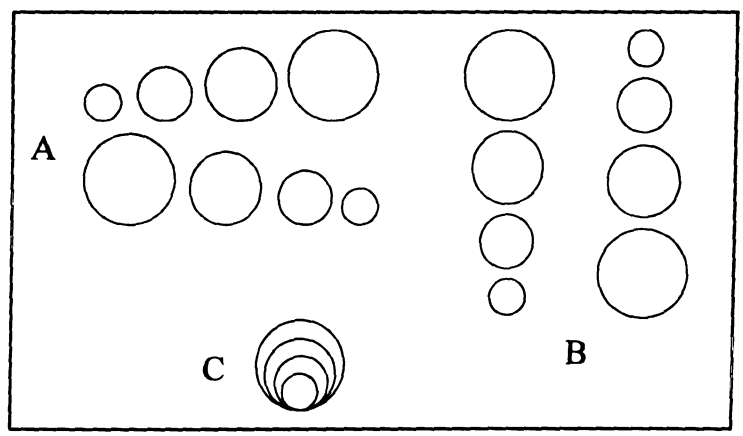


Figure 2. Graduated circle arrangements.

Isoline legends are traditionally a very simple verbal statement of the isoline interval: "Each contour line equals 10 feet". However, some designers have recently advocated the inclusion of a "natural" legend (Figure 3) that more graphically describes the line and (sometimes included) shading symbols (Delucia and Hiller, 1982). The design of these

legends offer many choices since there are few traditional rules governing them.

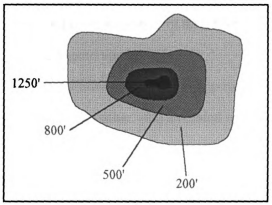


Figure 3. "Natural" isoline legend.

Dot map legends are very similar to those of isoline maps. Traditionally, a point symbol with a verbal description of it's value required few design decisions. But with the advent of "natural" dot legends and the use of variable scaling for eliciting more accurate judgements of values (Olson, 1977), legends were used to show various densities (Figure 4) and new considerations and variables are added.

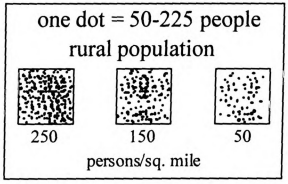


Figure 4. "Natural" dot legend.

Other kinds of thematic representations such as flow maps (graduated line symbols), cartograms, three-dimensional illustrations, or nominal data maps have equally diverse legend design considerations.

As noted earlier, some legend variables apply to all kinds of maps. These include the legend size relative to the map and page size, location on the page relative to other map elements, wording of headings and other explanatory text, font size, font style, and the internal arrangement of differing legend elements.

Taken together, legend design variables for specific map types and those that apply generally to all maps present the cartographer with a myriad of design decisions. Undoubtedly, some decisions are made carefully and some are made without much thought; most are decided according to convention and subjective taste; and certainly, few are made on the basis of objective research results.

Legend Design Research

Surprisingly little cartographic research has focused on thematic map legends and few "rules" have evolved concerning their design. In The Look of Maps, Robinson (1980) recognized the importance of legend design: "the legend is a map component and is capable of being varied according to the principles of contrast. Assigning visual importance is a problem that continuously faces cartographic technique. Components such as the legend boxes are not always of equal importance to a particular map or among similar types of maps. The legends of many maps are of little importance particularly when the symbols used are well known or self explanatory, however, in other cases, the legend box may hold the key that makes the map intelligible." However, Elements of Cartography (Robinson, 1978), after 30 years as the leading textbook on cartographic practice in the U.S. and in its fourth edition, devotes only two paragraphs out of 448 pages to legend design issues.

A book written by Cuff and Mattson (1982), Thematic Maps: Their Design and Production, addresses legends in some detail. They discuss the arrangement of legend symbols, especially graduated circles; choosing a legend heading; and they describe the positioning and size of legends on a map. While the book offers a more complete and thorough treatment of the thematic map legend, they base their design recommendations

on convention and tradition, not experimental research conclusions.

Over the past four decades, extensive and thorough research has been conducted on map communication, design, production, and use, and in particular, the perception qualities of thematic symbols. From these studies, many principles of map design, however tentative, have emerged. Few of these studies or resulting principles have dealt with legend design. And considering the importance of thematic map legends to their understanding, this seems unusual. The majority of the research literature that directly examines thematic map legends can be classified into four major categories: (1) natural legend designs, (2) bivariate classed and unclassed choropleth map legends, (3) color organization on two-variable maps, and (4) specific symbol perception studies.

Delucia and Hiller (1982), conducted research on the potential of natural legend designs for a map as a more efficient means of communicating information. They remarked "the legend of a thematic map is crucial to the map interpretation processes because the reader depends upon it to decode and comprehend the map symbols used. The symbol dimensions and patterns in the legend should be as identical as possible with those used on the map to avoid confusion and reduce inefficiency in the information communication process" (Delucia and Hiller, 1982, p. 46). Their findings indicated that a natural legend format (with layered tint maps) facilitated the reader's ability to perform certain map reading tasks more efficiently and that overall map reading accuracy was measurably improved when a natural legend design was used. Fontanella (1989) studied the use of natural legends on battlefield maps. He noted that a natural legend depicts map symbols in a context more closely resembling actual situations within the body of a map, whereas a conventional legend catalogues them. He found this to be particularly applicable to battlefield symbols that are complex and highly abstract requiring a detailed legend and sophistication of the user. Neither of these studies tested design variables in the construction of natural legends, only the desirability of such legends over the conventional.

Bivariate choropleth maps display, in overlay fashion, two distinct geographic variables using enumeration unit data. These maps are both visually and intellectually complex and the assumption is that users must rely heavily on legends to correctly interpret them. Aspass and Lavin (1989) viewed unclassed bivariate choropleth legends as having the potential to communicate both data-specific and thematic information and that design of these legends may have an effect on reader's ability to acquire this information. After testing four legend designs using unclassed line symbols, they found that the presence or absence of a legend had little effect on map readers' abilities to identify regional trends. Brassel and Utano (1979) combined traditional discrete legend boxes (each designating a particular value) and Tobler's (1971) continuous grey-scale legend which portrays the continuous character of unclassed choropleth symbols. They found that map readers were able to make numerical estimates from any map symbol despite the minimal information presented in the legend; however, "estimation accuracy has not yet been examined through empirical research" (Brassel and Utano, 1979, p. 41). Carstensen (1986) also examined bivariate choropleth map legend designs by using various methods of scaling the axes of the legends using continuous shading to represent two variables. The overall question posed by Carstensen concerned the relationship of the diagonals of the legend and the statistical trends in the data. After examining a sample of nine maps, he concluded that the axis scaling strategy had a distinct quantifiable impact on the effectiveness of the map.

A number of other legend designs have been suggested for bivariate choropleth maps but their ability to assist map users in actual map use have not been tested. Lavin and Archer (1984) suggested using two separate legends, one for each variable and Smith (1977) designed a matrix legend that shows the bivariate relationship among three data classes for each variable using a combination of gray tone gradations and patterns.

A third area of study involved the use of color on two-variable maps. The U.S. Bureau of Census generated and published several two-variable choropleth maps in the early

1970's. A paper by Olson (1975) detailed some considerations in the development of these color schemes. Olson suggested that: (1) colors must be distinguishable in the legend and map, (2) the color on a map must be matchable with the corresponding legend boxes, (3) the legend boxes must be distinguishable from each other and the color should progress smoothly and be visually coherent but separable, (4) a 4 X 4 legend might be visually subdivided into smaller categories (2 X 2), and (5) since readers associate darker colors with higher values, tones should progress from lighter to darker where the lightest tone should be at the lower left and the darkest the upper right. Olson (1981) conducted four experiments with human subjects to examine the efficacy of the census-style color two-variable legend. She concluded that: (1) subjects could not spontaneously order the colors into the legend arrangement used on the maps but they could recognize order in the arrangement; and (2) the legends on the maps were necessary to convey the relative values represented by the symbols.

The fourth category of legend design research involves specific symbols. Dobson (1974) examined proportional circles and concluded that "the unwise selection of legend values may inhibit the transformation of information and render the map ineffective as a graphic display. In order to render the proportional circle map effective as an areal table, it is necessary to provide a series of circles in a legend that gives the reader an anchoring stimulus and assists him in estimating the magnitudes represented by the various sizes of circles on the map" (Dobson, 1984, p. 45). He defined the legend problem for a proportional circle map as how to provide the reader with a limited number of circles that can best define the values in the map body.

The importance of thematic map legends was measured in an eye movement study by Antes, Chang, and Mullis (1985) where it was suggested that overall map design will influence the manner in which a map is initially viewed, which in turn, will influence the kind of information it communicates. They used a set of balanced and unbalanced graduated circle maps where both contained a legend and other components that were logically

and illogically placed. Their findings revealed that complex maps attracted more early attention to the legend than did simple maps. The longer the subjects viewed the maps, however, the less time they spent returning to the legends. The subjects also fixated longest on the subtitle (which revealed the thematic content) and second longest on the legend. It was concluded that map balance affects the distribution of attention only during early viewing, and that good map balance leads the eye to fixate readily on informative map components like the legend.

Computer Mapping and Map Legends

Cartography today is rapidly and progressively becoming computerized. Computerization began with large mainframes but in recent years minicomputers and microcomputers have come to dominate automated mapping. Mapping software has reflected this trend moving from large special purpose mapping programs to small, general purpose programs. Many automated mapping systems are parts of much larger systems such as statistical analysis or surveying systems. In addition, the growth of geographic information systems (GIS) has resulted in the development of integrated systems for the management and analysis of spatial data with computer mapping capabilities. Combinations of hardware and software now available for mapping often provide greater flexibility in compilation, design and symbolization than with traditional procedures.

As these technologies have grown, more and more people are able to produce thematic maps, be they professional cartographers, GIS specialists, planners, or other public and private people working with spatial data. This means that the majority of the users of these products may have little or no cartographic training. It should be the responsibility of professional cartographers to monitor the quality of the maps produced and to attempt to influence the specifications of the hardware and software that produce them (Noronha 1987).

As hardware and software systems for thematic map production have improved in recent years, design capabilities within these systems has also improved. Map makers

can now choose colors, select type size and fonts, arrange map elements on the page, select line weights, and make other types of design choices to enhance the map product. However, just as cartographic researchers have generally ignored thematic map legend design, mapping software developers often fail to include design flexibility in the creation of legends. While it is true that most computer-generated cartographic products do have legends, they are often very crude, hard to read and understand, and have poor visual esthetics, especially those from GIS software. The cartographer or GIS operator may meticulously design a map to his or her satisfaction and then, often as an afterthought, create a poor legend, sometimes because the software does not allow many design options.

Given the cartographic research record on thematic map legends and the proliferation of the software needed to produce legends for those maps, two questions arise: (1) what are the important legend design characteristics and (2) which mapping systems include legend design options and how well do they serve in the creation of good legends?

Study Objectives

This study focuses on specific thematic map legend design features and the ability of computer mapping software packages to manipulate these features when designing a legend. Included are the following two objectives: (1) To categorize essential thematic map legend design features and to determine the importance of these categories; and (2) using these results, to establish a set of criteria for judging legend design capabilities and to apply these criteria to computer mapping software packages. Results of the study will be a ranking of the importance of legend design features and of the goodness of software packages for designing legends.

CHAPTER II

EVALUATING THE IMPORTANCE OF THEMATIC MAP LEGEND FEATURES AND PERFORMANCE OF SOFTWARE LEGEND CAPABILITIES

Establishing the Importance of Legend Design Features

The first objective of this study was to categorize and determine the importance of the thematic map legend design features. After an extensive literature review of the text-books that discussed map legends and map design variables, a categorization scheme was developed that included two major categories: legend layout and legend text. These were subdivided into fifteen categories as shown in Table 1 below.

Table 1
Categorized Legend Design Features

Legend Layout	**Legend Text**
Legend size	Clarity of all legend wording
Legend shape	Conciseness of all legend wording
Legend location	Type face
Inclusion of a legend neatline	Type style
Visual proximity of legend features	Type size
Sequencing of legend features	Text angle
Arrangement of legend features	Text location
	Text spacing

These variables were subjectively determined, and an effort was made to include all design features discussed in the cartographic literature and textbooks. These features were then used to develop a questionnaire to determine their relative importance.

Each of the features in each category was paired with all other features in that category (Table 2). This was done so that the importance of one feature could be equally weighed against the importance of all of the others. The layout category with seven features yielded 21 total pairings and the text category with 8 features yielded 28 total pairings.

Table 2
Legend Design Feature Pairings

LAYOUT FEATURE PAIRINGS

size shape	shape location	location neatline	neatline proximity	proximity sequencing	sequencing arrangement	arrangement
size location	shape neatline	location proximity	neatline sequencing	proximity arrangement		
size neatline	shape proximity	location sequencing	neatline arrangement			
size proximity	shape sequencing	location arrangement				
size sequencing	shape arrangement					
size arrangement						

TEXT FEATURE PAIRINGS

clarity conciseness	conciseness type face	type face type style	type style type size	type size angle	angle location	location spacing	spacing
clarity type face	conciseness type style	type face type size	type style angle	type size location	angle spacing		
clarity type style	conciseness type size	type face angle	type style location	type size spacing			
clarity type size	conciseness angle	type face location	type style spacing				
clarity angle	conciseness location	type face spacing					
clarity location	conciseness spacing						
clarity spacing							

Next, several thematic map legends were constructed for use as illustrations in the questionnaire booklet (Figure 5). These legends are the ones commonly used on the major types of thematic maps. They included: (1) natural legends for choropleth and isoline maps; (2) horizontally and vertically arranged conventional choropleth; (3) dot density; (4) graduated symbol; and (5) flow lines.

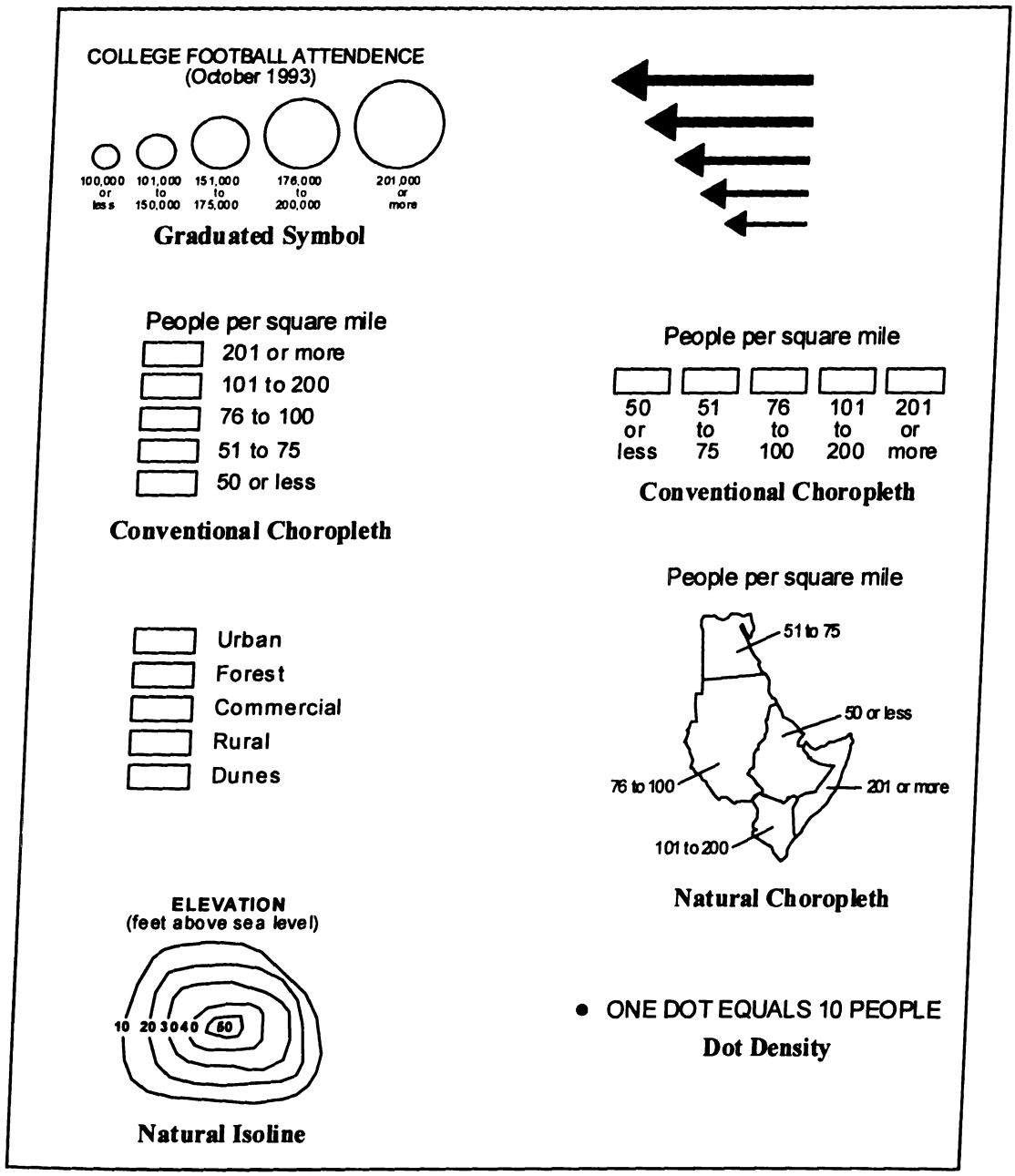


Figure 5. Examples of thematic map legend types.

These legends were chosen because they represented common legend types and because they provided considerable variety in appearance. They were alternatively attached to five different base maps (Figure 6) in a variety of positions and with different headings. The map-legend combinations were coded (Table 3), and the codes were

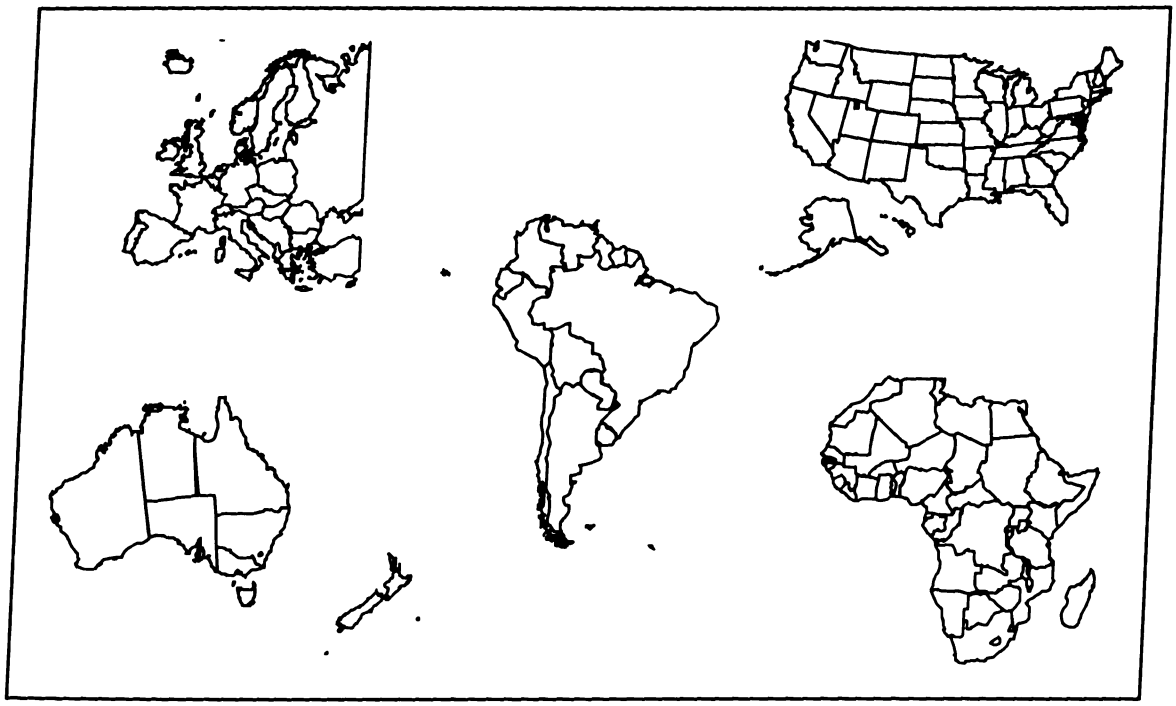


Figure 6. Base maps.

Table 3

Coding Scheme For Questionnaire Booklet

BASE MAPS USED (code assignment):	**LEGEND TYPES USED (code assignment):**
1. United States (A1)	1. Natural (B1)
2. Europe (A2)	2. Nominal [vertical] (B2a)
3. Australia (A3)	3. Nominal [horizontal] (B2b)
4. South America (A4)	4. Dot Density (B3)
5. Africa (A5)	5. Isoline (B4)
	6. Choropleth [vertical] (B5a)
	7. Choropleth [horizontal] (B5b)
	8. Graduated Circle [vertical] (B6a)
	9. Graduated Circle [horizontal] (B6b)
	10. Flow Line (B7)
	11. Shape Outline (B8)

randomly assigned to all of the variables. Booklets were assembled with the constraint that the same base maps, legend types, or word sets did not appear on adjacent pages in the booklet. Two map-legend combinations were assigned to each booklet page such that a legend feature alternated between top and bottom (see sample booklet inside back cover). The random scheme reduced the possibility of learned responses and boredom.

For the layout category, each feature was displayed in the booklet 6 times and for the text category each feature was displayed in the booklet 7 times. Thus, a person selecting "legend size" as the important feature four times in the booklet would be choosing the legend size feature four out of a possible 6 occurrences. The questionnaire booklet had 52 pages at a size of 8.25" X 5.5" (see sample booklet inside back cover). A page of instructions briefly explained the purpose of thematic map legends and how to assess feature importance. Each page had one feature pairing from the seven features of the layout category and eight features from the text category. At the bottom of each page, a place was provided to place an X or check mark for those repondants who could not decide between the two displayed features.

Forty people were selected to fill out the questionnaire booklets. The people chosen were Michigan State University Geography Department faculty, staff, and graduate students, employees selected from the Center for Remote Sensing, and employees from the State of Michigan Land and Water Management's MiRIS program. All were well qualified as map designers and in the application of cartography to computer mapping, remote sensing and GIS projects. Thus, participants were an "expert" set. Thirty-two response booklets were collected. The feature pairing responses were entered into response occurrence spreadsheets and resulting frequencies tallied. From these frequencies, the importance of each legend design feature was determined. Results are presented in the next chapter.

Computer Mapping Software Package Evaluation

To evaluate legend design capabilities of mapping routines, a survey was conducted of computer software for thematic mapping. From this survey, twelve packages were

selected for evaluation (Table 4). They were chosen on the basis of several qualities: (1) availability and accessibility; (2) representation of different mapping tasks such as GIS applications, computer aided design, computer mapping, and presentation graphics; and (3) ease of use on a PC-type platform. In addition, the twelve programs represented a range of cost and sophistication. As such, these programs form a representative set of computer mapping systems most commonly used in business, public sectors, and academic realms.

Table 4

Thematic Mapping Software

Software	Version/Platform	Price	Manufacturer
MapViewer	1.1/Windows	$ 249.00	Golden Software, Inc.
PC Globe	2.0/DOS	$ 99.00	PC Globe, Inc.
Atlas*GIS	1.1/DOS	$ 2495.00	Strategic Mapping, Inc.
CMAP	2.Beta/DOS	$ 750.00	Michigan State University
IDRISI	4.0/DOS	$ 100.00/student	Clark University
MapInfo	2.0.1/Windows	$ 995.00	MapInfo Corp.
Microstation PC	4.0/DOS	$ 200.00/student	Intergraph Corp.
AutoCad	11.0/DOS	$ 495.00/student	Autodesk, Inc.
FreeHand	3.1/Windows	$ 395.00	Aldus Corp.
CorelDraw	3.0/Windows	$ 395.00	Corel Systems Corp.
Harvard Graphics	1.01/Windows	$ 125.00	Software Publishing Corp.
PowerPoint	2.0/Windows	$ 295.00	Microsoft Corp.

Each software package was run on a 486-33MHz machine using Windows 3.1 and PC Tools on Top for Windows as the desktop. The images were generated by using Hijaak 2.0 for Windows and DOS to capture the entire monitor screen from each software package after a map and legend was made. This method allowed the software map

making environment to be displayed. The images were then saved in a Tiff file format and placed in Aldus Page Maker 5.0 for Windows. Following is a brief description of each program along with a sample thematic map and legend produced on each.

MapViewer is a thematic mapping package that runs under Microsoft Windows. The software package comes with, sample base maps and data, and a 483-page manual. MapViewer is capable of producing several thematic maps including choropleth, graduated symbol, and dot density (Figure 7). A default legend can be selected and then modified freely, or a custom legend can be created with various drawing tools. MapViewer is easy to learn and use and has text and line editing functions.

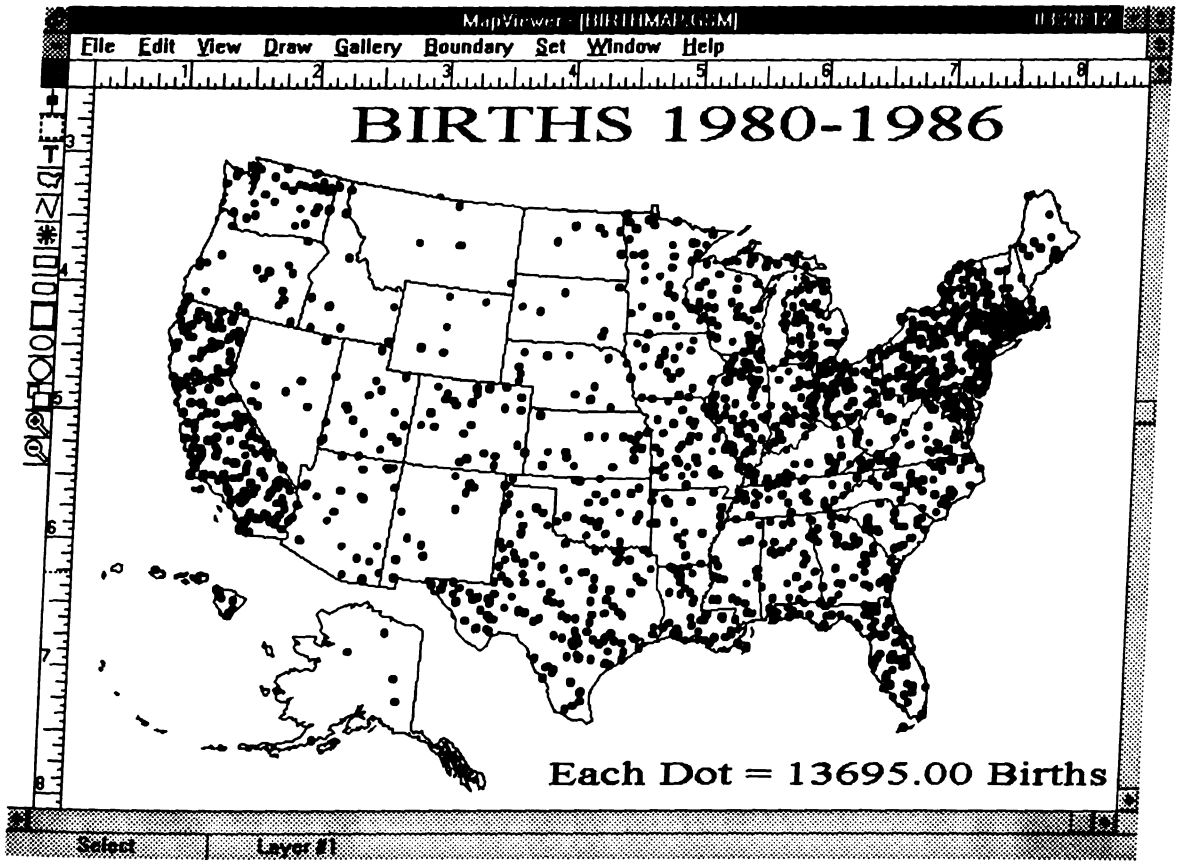


Figure 7. A dot map produced with MapViewer.

PC Globe is a DOS platform choropleth mapping software package (Figure 8) designed primarily for educational settings. PC Globe has a large data base and several base maps to choose from. This software uses only a default legend which cannot be edited.

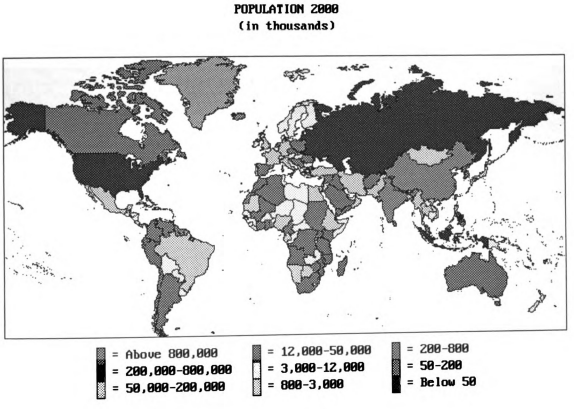


Figure 8. PC Globe choropleth map.

Atlas*GIS is a vector GIS package that includes many complex mapping, editing, and data handling routines and comes with sample base maps and data sets. Most maps have two default legend spaces allocated (not shown in Figure 9) on the right side of the map area and these legends can be edited to an extent. Atlas*GIS offers a freehand drawing system which was used in the example. This software is mouse driven but has a steep learning curve and requires several steps to perform almost all functions.

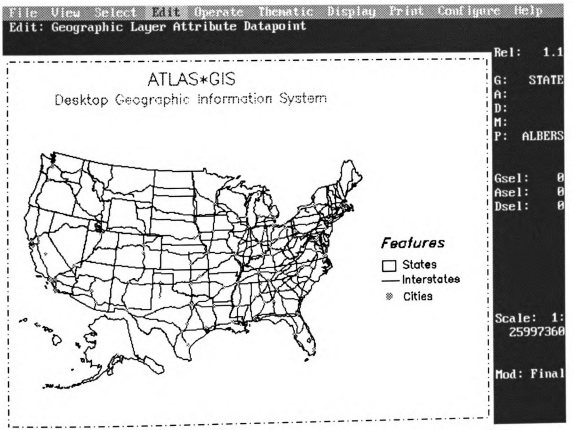


Figure 9. Atlas*GIS feature map.

CMAP, is a university-developed vector GIS software package that has extremely strong data conversion programs and utilities and modest mapping capabilities (Figure 10). CMAP uses a default legend; however, a "key" file must be created first. The key file contains the legend symbol descriptions and codes for the symbols and patterns to be used. After the key file is created, the map and legend can be displayed and a legend title created through a series of complex steps. CMAP also allows freehand functions. Approximately one half of the commands and modules are mouse driven.

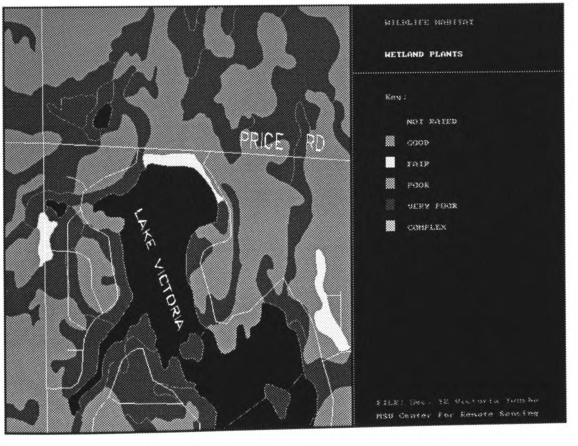


Figure 10. CMAP shaded areal patterns.

IDRISI is a raster based GIS software package (Figure 11). Also a university developed product, it offers only a default legend with editing limited to the symbol descriptions. This is done through a text editor provided in the software or through an external text editor. IDRISI is mouse or keyboard driven and requires several complex steps to operate.

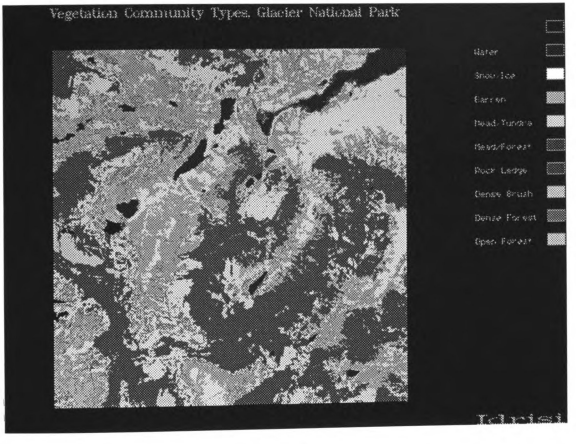


Figure 11. IDRISI areal shading patterns.

MapInfo is a GIS software package that has extensive mapping capabilities and runs under Microsoft Windows (Figure 12). This software includes a database, sample base maps, address matching, and point and boundary analysis. It offers several thematic mapping capabilities. It has a default legend (Figure 12A) with limited editing capabilities and some drawing tools for customizing legends (Figure 12B) and it is mouse driven.

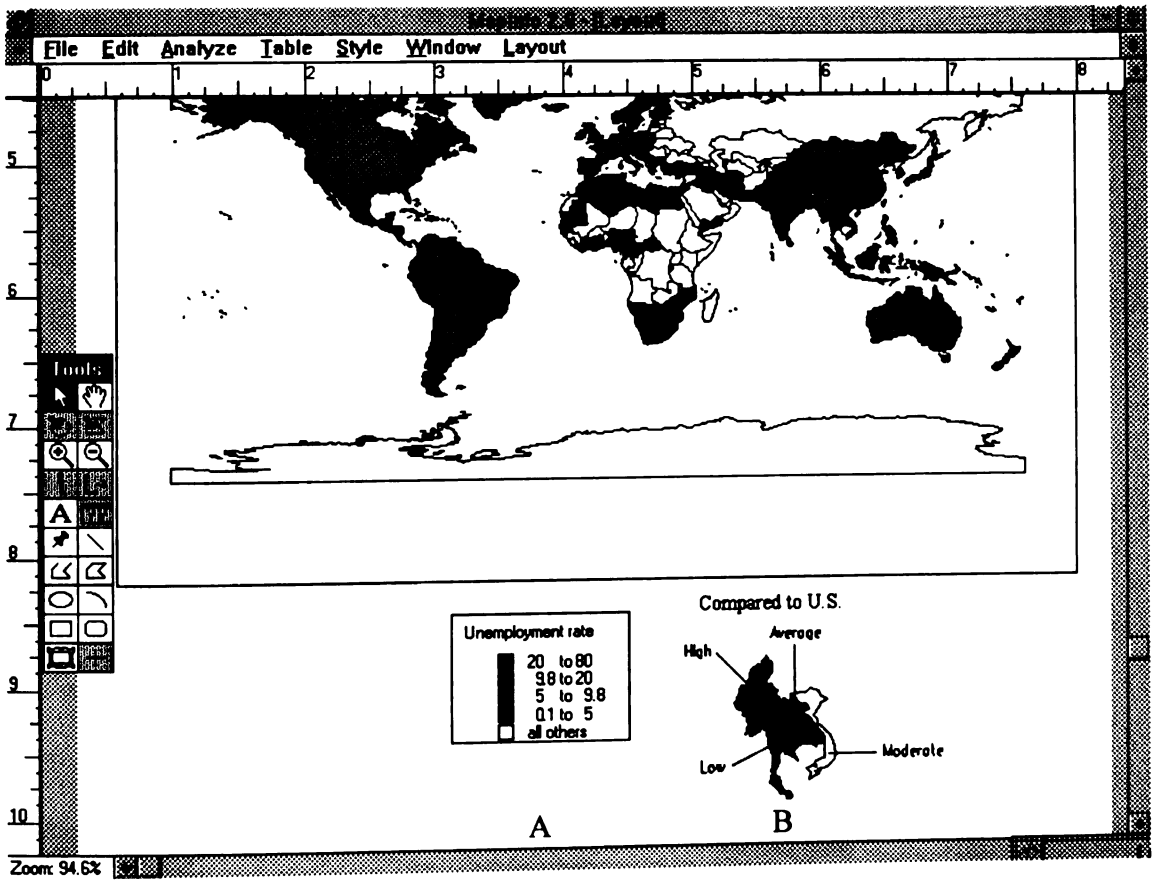


Figure 12. MapInfo choropleth map.

Microstation PC is a highly sophisticated CAD and mapping package for the PC-based workstation (Figure 13). Microstation offers a wide range of freehand tools and menu interfaces but no sample data or base maps. The software is mouse and button cursor driven but is difficult to learn even with the various manuals and menu interfaces. Once learned, however, it is extremely versatile in designing map features including thematic legends.

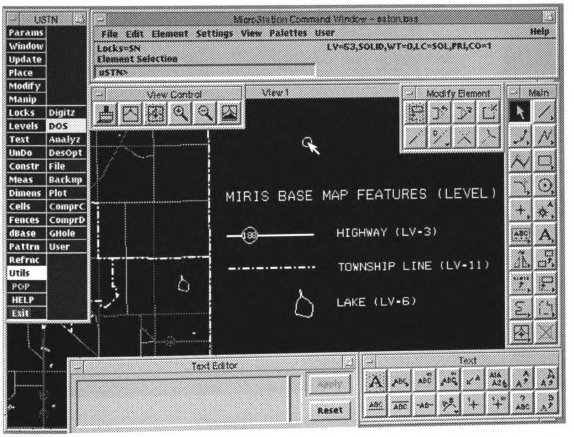


Figure 13. Microstation PC feature map legend.

AutoCad is one of the most popular and widely used CAD software packages and it has some mapping applications. The package has unlimited freehand tools and functions and even though it is mouse and button cursor driven it is difficult to learn, awkward to use, and time-consuming for mapping. Figure 14 below shows only a legend, not a complete map.

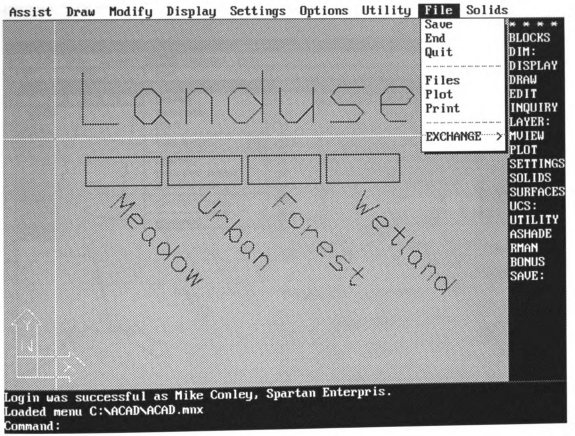


Figure 14. AutoCad legend.

Freehand is a graphics program that is extensively used for map drawing or finishing (Figure 15). Freehand comes with clip art maps and symbols. It has good import and export options, good text and line editing functions and capabilities, and it is mouse driven. Freehand offers no default legends but allows any type to be custom-made easily. This software is easy to learn and it offers several menu interfaces allowing the entire package to be used effectively.

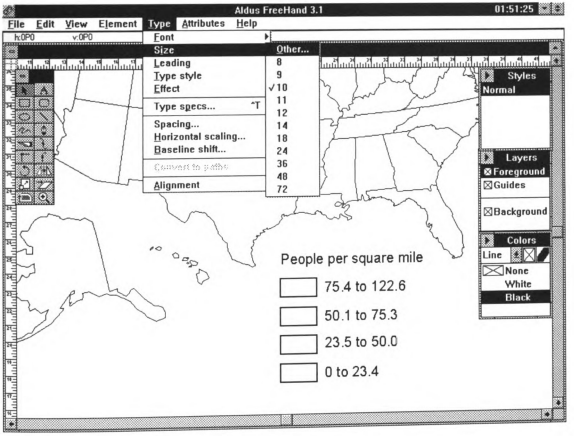


Figure 15. FreeHand thematic map.

CorelDraw is a graphics program with editable previews, 3-D graphics, charting, painting, photo editing, presentation capabilities, and is extensively used for map drawing or finishing (Figure 16). It comes with clip art maps, symbols, and text and line editing capabilities. It is mouse driven and has several menu interfaces including an editable color palette displayed on the bottom of the screen.

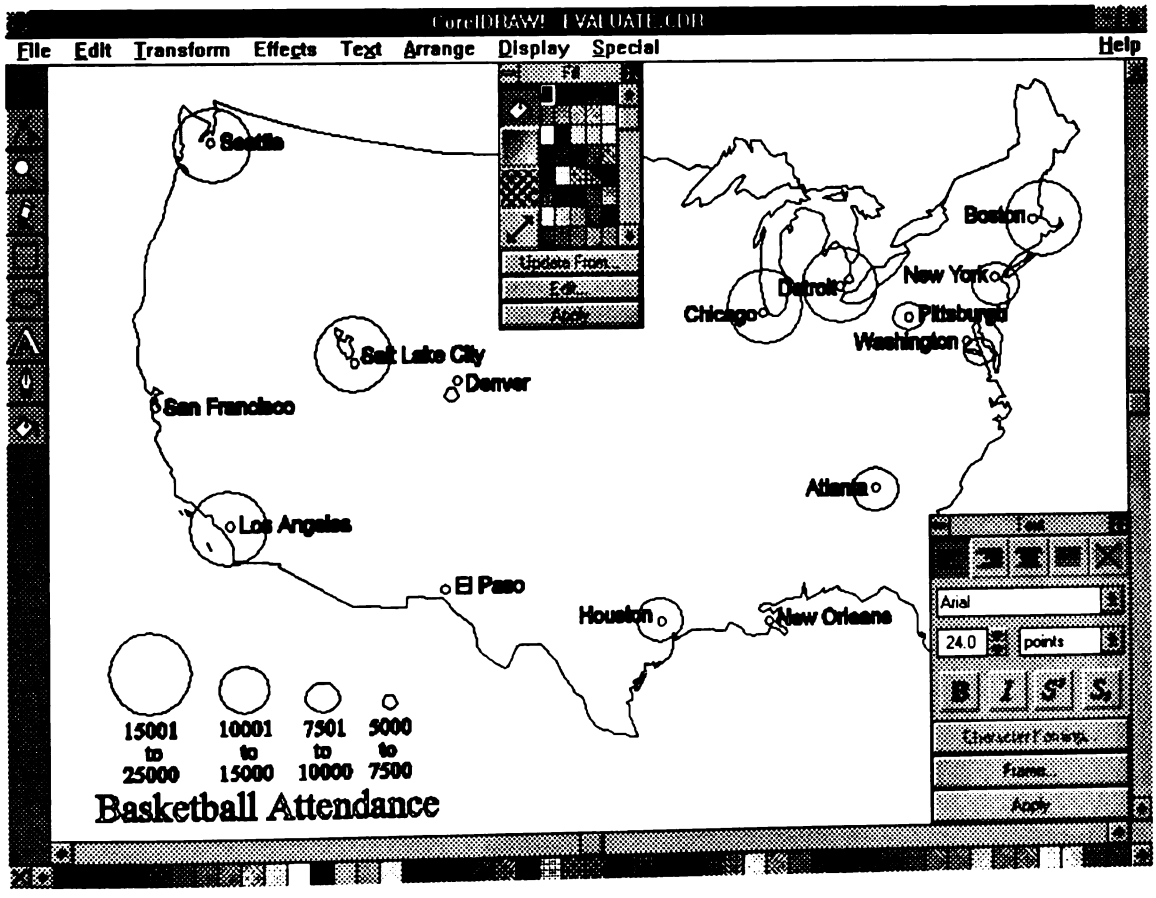


Figure 16. CorelDraw graduated symbol map.

Harvard Graphics is a presentation creation software package that has extensive drawing tools and capabilities (Figure 17). It comes with an extensive clip art gallery that includes a map section, and it has text and line editing capabilities. The program is mouse driven and is easy to learn and use.

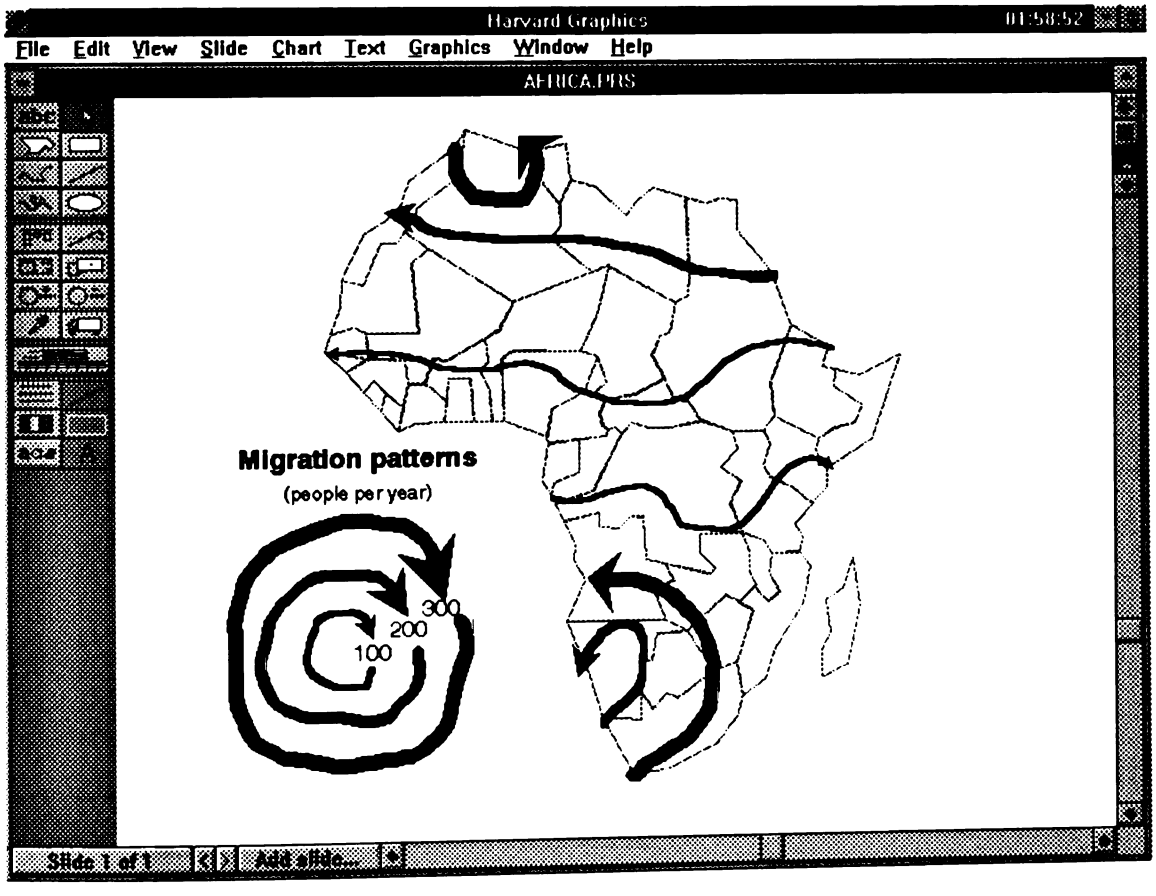


Figure 17. Harvard Graphics flow map.

PowerPoint (Figure 18) is presentation creation software similar to Harvard Graphics. It comes with clip art, is mouse driven, offers good text and line editing capabilities, and has extensive freehand tool functions.

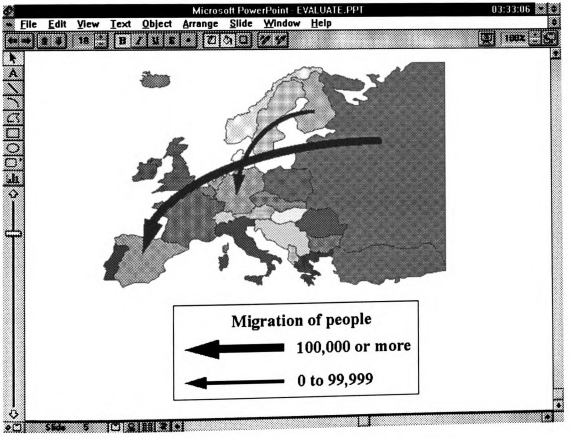


Figure 18. PowerPoint flow map.

Performance Rating Scale Development

To evaluate the legend design capabilities of the twelve software packages, a simple rating scale was developed to apply to the layout and text features identified above. The scale is outlined in Table 5.

Table 5

Software Evaluation Rating Scale

PERFORMANCE RATING SCALE:	
0 - Cannot manipulate the features when designing a legend	
1 - Difficult to manipulate the features when designing a legend	
2 - Easy to manipulate the features when designing a legend	
EASY AND VERSATILE:	**DIFFICULT AND INFLEXIBLE:**
-obvious functions and drawing tools	-no obvious functions and drawing tools
-few steps involved	-several steps involved
-several manipulations allowed	-few manipulations allowed
-default legend templates used	-no default legend templates used
-tool bars displayed	-no tool bars displayed
-button cursor or mouse driven	-keyboard use only
-freehand editing allowed	-no freehand editing allowed
-online help or tutorials	-no/limited online help or tutorials
-good reference materials	-poor/limited reference materials

An evaluation scale was applied to each of the twelve mapping packages. A variety of maps were constructed in each package and a subjective evaluation was conducted based on previous experience in producing these maps. A preexisting base map, usually clip art, was used when possible. Each of the 15 features was manipulated in some fashion with the various drawing tools and available commands. A number was then

assigned from the rating scale for performance with that feature. Resulting ratings were used in conjunction with the design feature importance survey results to produce an overall rating index. The results of the software rating and the survey results are presented in the next chapter.

CHAPTER 3

ANALYSIS AND RESULTS

Feature Importance Survey

Questionnaire response data from the 32 returned questionnaire booklets was tabulated in the manner shown in Appendix A. Rows represent feature pairing combinations and each column is the chosen response to that particular combination. Each of the two categories (layout and text) had different potential response occurrences. In the layout category, every feature was paired a total of 6 times. In the text category, every feature was paired a total of 7 times. These responses were then tabulated as frequencies (the number of times a respondant selected a feature) for each of the 32 booklets (Table 6). The "neither" response was ignored during the ranking process and was analyzed separately.

To obtain an overall importance ranking for each legend design feature, mean response rates were calculated. Because the two categories had different possible total occurrences (layout-6; text-7), the features in each category were ranked within that category. Figure 19 shows the mean responses (excluding "neither" responses) for each feature in each of the two categories.

An analysis of variance (ANOVA) was performed to test for a difference between the means. It was applied to each of the two categories and results are shown in Table 7. In each of the two categories, the critical F statistic from the ANOVA was less than the calculated F statistic, resulting in the rejection of the null hypothesis. In other words, the means in each category were statistically significantly different.

Table 6
Legend Layout and Text Response Data

Frequency of Responses

Legend Size	Legend Shape	Legend Location	Legend Neatline	Visual Proximity	Sequencing	Arrangement
4	1	2	0	4	6	4
3	1	3	0	6	3	4
1	2	3	3	5	3	4
2	0	3	0	4	5	4
3	3	5	0	4	0	3
2	1	5	0	3	4	5
6	4	3	2	1	1	2
6	0	2	1	5	4	3
3	1	2	0	5	5	5
4	0	3	0	4	4	2
1	0	2	0	4	4	4
5	1	4	0	3	2	4
2	1	5	0	5	3	4
2	1	4	0	6	2	5
4	3	5	0	3	1	3
4	0	2	1	4	4	5
4	1	2	1	6	1	3
5	1	3	2	6	0	4
1	2	4	1	5	4	4
2	4	3	0	4	4	4
2	3	2	1	3	4	4
2	1	2	0	3	5	5
0	1	3	0	1	2	2
2	0	6	0	4	3	4
4	2	3	5	4	0	3
5	3	3	1	1	1	4
2	0	3	1	4	5	6
4	3	5	0	5	0	2
2	2	3	1	5	1	4
2	1	4	0	3	5	5
3	1	2	0	5	3	5
0	3	4	2	5	2	3

Legend Layout Design Features

Frequency of Responses

Text Angle	Type Size	Type Style	Text Spacing	Type Face	Text Location	Clarity	Conciseness
4	3	0	2	0	4	6	7
3	2	0	3	0	6	7	5
5	4	1	3	1	5	7	2
2	4	0	3	0	5	6	6
1	4	0	2	0	5	7	5
4	4	0	2	0	4	7	6
5	4	0	2	0	4	7	2
3	6	0	3	1	4	6	4
0	3	2	4	1	5	7	5
4	5	1	2	1	1	6	3
1	3	0	2	1	4	5	5
0	2	0	1	1	2	5	4
3	3	0	2	0	4	7	4
3	0	2	2	0	6	7	5
2	4	1	2	0	3	5	6
4	5	1	1	3	4	6	2
3	4	1	3	1	5	4	6
7	3	0	1	0	4	4	6
5	3	1	4	1	4	4	6
7	3	0	2	0	5	6	4
6	1	0	3	2	5	5	4
1	3	1	4	1	4	7	5
0	1	0	1	0	5	5	4
2	2	3	3	5	4	2	4
2	2	2	4	0	6	7	5
3	4	0	2	2	3	6	7
2	4	1	3	3	4	5	6
1	4	0	2	0	5	7	5
2	2	1	1	3	6	6	6
3	2	0	6	0	4	6	4
0	7	1	3	2	5	4	4
4	5	3	1	4	4	6	1

Legend Text Design Features

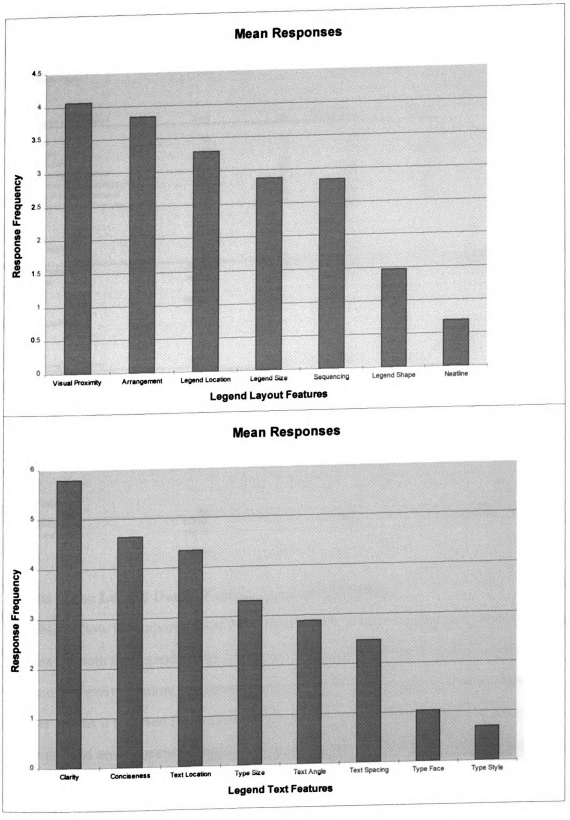


Figure 19. Response means for legend design features.

Table 7
ANOVA Using Legend Design Importance Response Data

Anova: Single-Factor

Summary

Legend Layout Features	*Count*	*Sum*	*Mean Response*	*Variance*
Legend Size	32	92	2.88	2.5
Legend Shape	32	47	1.47	1.48
Legend Location	32	105	3.29	1.31
Inclusion of a legend Neatline	32	22	0.69	1.25
Visual Proximity of Legend Features	32	130	4.06	1.87
Sequencing of Legend Features	32	91	2.84	3.1
Arrangement of Legend Features	32	123	3.84	1.04

ANOVA

Source of Variation

	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	291.71	6	48.62	27.11	4.96001E-24	2.14
Within Groups	389.13	217	1.79			
Total	680.84	223				

Anova: Single-Factor

Summary

Legend Text Features	*Count*	*Sum*	*Mean Response*	*Variance*
Legend Text Angle	32	92	2.88	3.73
Legend Type Size	32	106	3.31	2.16
Legend Type Style	32	22	0.69	0.8
Legend Text Spacing	32	79	2.47	1.29
Legend Type Face	32	33	1.03	1.77
Legend Text Location	32	139	4.34	1.2
Clarity of Legend Wording	32	185	5.78	1.53
Conciseness of Legend Wording	32	148	4.63	2.18

ANOVA

Source of Variation

	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	692.56	7	98.94	54	2.09721E-46	2.05
Within Groups	454.38	248	1.83			
Total	1146.94	255				

Results of the Legend Design Feature Importance Ranking

Table 8 show the importance of the legend design features ranked by the mean responses for both the legend layout and legend text categories. The higher number means that feature received "more important" responses in the feature pairings and the lower number means it received fewer responses by the 32 people. The similar ranking of the proximity and arrangement of legend features is logical in that they are both related to the placement of features in a legend. The lower ranking of legend shape probably indicates that the shape is a result of the influence that other features have on it. In other words, manipulating the other legend design features might determine the shape. Finally, the

legend neatline is ranked last, probably because it might not be viewed as a necessary legend design feature but rather as an artistic addition.

Table 8

Legend Design Features Ranked by Mean Responses

Legend Layout	**Mean Response**
1. Visual Proximity of Legend Features	4.06
2. Arrangement of Legend Features	3.84
3. Legend Location	3.29
4. Legend Size	2.88
5. Sequencing of Legend Features	2.84
6. Legend Shape	1.47
7. Inclusion of a Legend Neatline	0.69
Legend Text	**Mean Response**
1. Clarity of Legend Wording	5.78
2. Conciseness of Legend Wording	4.63
3. Text Location	4.34
4. Type Size	3.31
5. Text Angle	2.88
6. Text Spacing	2.47
7. Type Face	1.03
8. Type Style	0.69

With text features, clarity and conciseness are both ranked highly and are probably seen as being interrelated. The two features type face and type style, ranking last, were the two least important features and could be veiwed as a non-functional aspect of the legend design.

"Neither " Responses

The "neither" responses were not used in the initial feature response analysis. However, it is important to understand why these responses were given and whether the results can be used in some meaningful way.

Almost all feature pairings had low "neither" response rates (5 out of 32). Only four pairings had higher "neither" response rates than this norm. These are shown in Table 9.

Table 9
"Neither" Responses

Feature Pairing	**Response Percentage**
clarity-conciseness of wording	15
text location-angle	7
type style-type face	6
text angle-spacing	6

These responses may be the result of two possible explanations: (1) Either respondents were not able to differentiate the features (i.e., the difference between type style and type face), (2) the features are so interrelated that respondents could not decide on which was most important, or (3) the features are equally important.

Mapping Software Performance Ranking

The legend design capabilities of each software package were subjectively evaluated using the performance rating described in Table 5. The results are presented in Table 10. There was considerable variation among software packages in the flexibility allowed for legend design. In general "graphics" and "presentation" software allowed the most

Table 11 presents the combination of performance ratings and design feature importance rankings. The ranking of each feature was multiplied by the performance rating to create a score for each software package in each category. These were then summed for the software to provide a composite rating. Table 12 lists the packages in order of composite rating.

design choices while "GIS" and "CAD" packages had more flexibility. Overall, the twelve software packages used here seemed to provide a full range of capabilities.

Table 10
Software Evaluation Scores

Software Package: / *Software Type:*	MapViewer 1.1 Thematic Cartography	PC Globe Thematic Cartography	Atlas*GIS 1.1 GIS	C-MAP 2.Beta GIS	IDRISI 4.0 GIS
Legend Design Features: LAYOUT					
Legend Size	2	0	1	1	0
Legend Shape	2	0	1	1	0
Legend Location	2	0	1	1	0
Inclusion of a Neatline	2	0	1	1	0
Visual Proximity of Features	2	0	1	2	0
Sequencing of Features	1	0	1	2	0
Arrangement of Features	2	0	1	2	0
TEXT					
Text Angle	0	0	2	2	0
Type Size	2	0	2	2	0
Type Style	2	0	2	0	0
Text Spacing	2	0	1	1	1
Type Face	2	0	1	0	0
Text Location	2	0	1	2	0
Clarity of (all) Wording	2	0	2	2	1
Conciseness of (all) Wording	2	0	2	2	1

Software Package: / *Software Type:*	MapInfo 2.0.1 GIS	Microstation 4.0 CAD	AutoCad 11.0 CAD	FreeHand 3.1 Graphics	CorelDraw 3.0 Graphics
Legend Design Features: LAYOUT					
Legend Size	1	1	2	2	2
Legend Shape	1	2	1	2	2
Legend Location	2	2	1	2	2
Inclusion of a Neatline	1	2	2	2	2
Visual Proximity of Features	1	2	1	2	2
Sequencing of Features	1	2	1	2	2
Arrangement of Features	1	2	1	2	2
TEXT					
Text Angle	0	2	2	1	2
Type Size	2	1	2	2	2
Type Style	2	1	1	2	2
Text Spacing	1	2	1	2	2
Type Face	2	1	2	2	2
Text Location	2	2	1	2	2
Clarity of (all) Wording	2	2	2	2	2
Conciseness of (all) Wording	2	2	2	2	2

Software Package: / *Software Type:*	Harvard Graphics 1.01 Presentation	PowerPoint 3.0 Presentation
Legend Design Features LAYOUT		
Legend Size	2	2
Legend Shape	2	2
Legend Location	2	2
Inclusion of a Neatline	2	2
Visual Proximity of Features	2	2
Sequencing of Features	2	2
Arrangement of Features	2	2
TEXT		
Text Angle	2	0
Type Size	2	2
Type Style	2	2
Text Spacing	2	2
Type Face	2	2
Text Location	2	2
Clarity of (all) Wording	2	2
Conciseness of (all) Wording	2	2

Performance Rating:
0 - Cannot manipulate the features to design a legend
1 - Difficult to manipulate the features to design a legend
2 - Easy to manipulate the features to design a legend

Table 11
Software Performance Scores

LEGEND DESIGN FEATURE	RANKING	MapViewer		PC Globe		Atlas*GIS		C-MAP	
		RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE
LAYOUT									
Legend Size	4	2	8	0	0	1	4	1	4
Legend Shape	6	2	12	0	0	1	6	1	6
Legend Location	3	2	6	0	0	1	3	1	3
Inclusion of a Neatline	7	2	14	0	0	1	7	1	7
Visual Proximity of Features	1	2	2	0	0	1	1	2	2
Sequencing of Features	5	1	5	0	0	1	5	2	10
Arrangement of Features	2	2	4	0	0	1	2	2	4
TEXT									
Text Angle	5	0	0	0	0	2	10	2	10
Type Size	4	2	8	0	0	2	8	2	8
Type Style	8	2	16	0	0	2	16	0	0
Text Spacing	6	2	12	0	0	1	6	1	6
Type Face	7	2	14	0	0	1	7	0	0
Text Location	3	2	6	0	0	1	3	2	6
Clarity of Wording	1	2	2	0	0	2	2	2	2
Conciseness of Wording	2	2	4	0	0	2	4	2	4
TOTAL			**118**		**0**		**84**		**72**

LEGEND DESIGN FEATURE	RANKING	IDRISI		MapInfo		Microstation		AutoCad	
		RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE
LAYOUT									
Legend Size	4	0	0	1	4	1	4	2	8
Legend Shape	6	0	0	1	6	2	12	1	6
Legend Location	3	0	0	2	6	2	6	1	3
Inclusion of a Neatline	7	0	0	1	7	2	14	2	14
Visual Proximity of Features	1	0	0	1	1	2	2	1	1
Sequencing of Features	5	0	0	1	5	2	10	1	5
Arrangement of Features	2	0	0	1	2	2	4	1	2
TEXT									
Text Angle	5	0	0	0	0	2	10	2	10
Type Size	4	0	0	2	8	1	4	2	8
Type Style	8	0	0	2	16	1	8	1	8
Text Spacing	6	1	6	1	6	2	12	1	6
Type Face	7	0	0	2	14	1	7	2	14
Text Location	3	0	0	2	6	2	6	1	3
Clarity of Wording	1	1	1	2	2	2	2	2	2
Conciseness of Wording	2	1	2	2	4	2	4	2	4
TOTAL			**9**		**87**		**109**		**94**

LEGEND DESIGN FEATURE	RANKING	FreeHand		CorelDraw		Harvard Graphics		PowerPoint	
		RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE
LAYOUT									
Legend Size	4	2	8	2	8	2	8	2	8
Legend Shape	6	2	12	2	12	2	12	2	12
Legend Location	3	2	6	2	6	2	6	2	6
Inclusion of a Neatline	7	2	14	2	14	2	14	2	14
Visual Proximity of Features	1	2	2	2	2	2	2	2	2
Sequencing of Features	5	2	10	2	10	2	10	2	10
Arrangement of Features	2	2	4	2	4	2	4	2	4
TEXT									
Text Angle	5	1	5	2	10	2	10	0	0
Type Size	4	2	8	2	8	2	8	2	8
Type Style	8	2	16	2	16	2	16	2	16
Text Spacing	6	2	12	2	12	2	12	2	12
Type Face	7	2	14	2	14	2	14	2	14
Text Location	3	2	6	2	6	2	6	2	6
Clarity of Wording	1	2	2	2	2	2	2	2	2
Conciseness of Wording	2	2	4	2	4	2	4	2	4
TOTAL			**123**		**128**		**128**		**118**

The highest number is the best overall software package allowing the most flexibility when manipulating the individual legend design features and the lowest number offers the least. Harvard Graphics and Corel Draw received the highest scores, both at 128 points. FreeHand ranked next with 123 points and PowerPoint and Map Viewer both

scored 118 points. A summary of software legend design difficulties appears in Table 13.

Table 12
Software Ranking by Performance Evaluation Scores

Software Ranking By Performance Scores	
Harvard Graphics	128
Corel Draw	128
FreeHand	123
MapViewer	118
PowerPoint	118
Microstation	109
AutoCad	94
MapInfo	87
Atlas*GIS	84
CMAP	72
IDRISI	9
PC Globe	0

Table 13
Software Evaluation Difficulties

Software Package	Layout Difficulties	Text Difficulties
Harvard Graphics	none	none
CorelDraw	none	none
FreeHand	none	none
MapViewer	none	cannot manipulate text angle
PowerPoint	none	cannot manipulate text angle
MicroStation	steep learning curve	manipulating type style
AutoCad	steep learning curve	manipulating type style and face
MapInfo	none	cannot manipulate text angle
Atlas*GIS	steep learning curve	steep learning curve
CMAP	awkward manipulations/steps	manipulating type style and face
IDRISI	no manipulations allowed	limited text editing
PC Globe	no manipulations allowed	no manipulations allowed

Both of these tables can provide a usable guide (or a basis for recommendation of appropriate software) for the users of software who are concerned with thematic map legend design flexibility.

In general, software that uses the windows environment, especially those with graphics capabilities, ranked higher than those in the DOS environment with command driven menus and interfaces. The Graphics, CAD, and Presentation packages have the best overall performance. The two operating systems themselves, DOS and Windows, do not seem to be a direct influence on the ratings, however; as long as the package offers some sort of graphics capabilities it ranks more highly. MapInfo is the exception; there is graphics capability, but it is limited in the types of manipulations allowed. Finally, locally developed university software such as CMAP and IDRISI have low legend design capabilities. PC Globe, on the other hand, is a commercial package and has no legend design capabilities.

CHAPTER 4

LEGEND DESIGN CONCLUSIONS AND RECOMMENDATIONS

Good map design has long been a major research field in cartography. Most of the emphasis has been on individual map components. Since then, cartographic research has moved in the direction of visualization, understanding geographic patterns "the whole map picture" and other research arenas. During the same time period, cartography has been revolutionized by automation which has brought about a need for evaluating and investigating automated designs in terms of their cartographic quality.

This thesis evaluates the legend designs produced by computers by identifying the design features important to professionals to aid the user in designing automated maps. Computer mapping software products are designed by programmers with little back-ground in cartography. Thus, their software designs for map making vary in flexibility in terms of a users ability to manipulate legend design features. One cannot overlook the fact, however, that even the most flexible software cannot produce a good map design unless users themselves have the knowledge or guidance to produce an appropriate map design. This thesis has produced a thematic mapping software selection list (based on flexibilty) and a ranking of 15 legend design features based on importance that can be used by the map maker.

Legend Design Features

This study has shown that some legend features are more important than others. The results of the questionnaire on legend design features has indicated the relative importance of these features and has revealed that some of these features are more important than others. Table 9 can be used as a guide when designing a thematic map legend

regardless of the type of legend being made. It shows that the visual proximity and the arrangement of legend design features are particularly crucial and should be included on all legend designs while the inclusion of a legend neatline can be considered less important (according to the experts questioned in this study) and the designer can choose whether or not to include one around a legend.

Future Legend Design Research

The input in this study has been provided by relative experts in cartography who completed a questionnaire. The results provide food for thought concerning further research. Work should be done by developing a series of testing instruments and to use these instruments to test map users on the importance of thematic map legend design features in hopes that maps can be read in a more efficient and meaningful manner. Research questions could center on the arrangement and the sequencing of legend design features (particularly with choropleth and graduated circle map legends); horizontal vs vertical legend arrangements; whether or not there is a preferred sequencing of the choropleth legend boxes and graduated circles; and whether map users prefer the larger value and darker colors to be on the top with vertically arranged choropleth legend boxes and graduated circles, and on the right with horizontally arranged boxes and graduated circles. The results of these studies combined with Table 9, could more definitively guide thematic map legend designers.

Computer Mapping Software

This study has shown that there is considerable variability in the ability of computer mapping software to handle thematic map legend design needs. In general, the CAD and freehand graphics software packages performed better than the GIS and presentation software. On another dimension, the common commercial software, as was expected, performed better than the packages that were University developed (Table 13). The difficulties in the different packages varied considerably (Table 14).

Future Computer Mapping Software Research

The twelve software packages evaluated for this study were used on a PC computer in the DOS or Windows environment. The same or similar software packages should be evaluated in a UNIX and Macintosh environment as well. Some examples of software for the UNIX environment would be Intergraph's MGE/MGA, Grass, and Arc/Info. For the Macintosh environment, Map II, Illustrator, and Map Grafix could be evaluated. Other software for the PC DOS environment that could be evaluated includes ERDAS, Surfer, and Arc/Info.

A more stringent and standardized set of evaluation criteria could be developed and applied when evaluating software in any environment. This criteria could include the flexibility of the import and export functions offered by the software, output capabilities such as laser printing and pen plotting, and default legends (if any). Finally, a set of software purchase or use criteria could be developed as a result of platform and operating environment comparisons for thematic map legend design.

APPENDIX A

APPENDIX A

Booklet Response Data

PAGE # and FEATURE PAIRINGS:	Respondent 1	Respondent 2	Respondent 3	Respondent 4
1 legend size-shape	size	size	size	size
2 type size-conciseness of wording	conciseness	conciseness	type size	conciseness
3 text location-spacing	txt location	txt location	txt location	txt location
4 legend size-arrangement of features	size	neither	arrangement	arrangement
5 legend sequencing-size	sequencing	sequencing	sequencing	sequencing
6 conciseness of wording-text spacing	conciseness	conciseness	txt spacing	conciseness
7 legend nestline-proximity of features	proximity	proximity	proximity	proximity
8 text location-conciseness of wording	conciseness	txt location	conciseness	conciseness
9 clarity of wording-text location	clarity	clarity	clarity	clarity
10 conciseness of wording-typeface	conciseness	conciseness	typeface	conciseness
11 arrangement of features-legend location	arrangement	arrangement	location	arrangement
12 legend nestline-sequencing of features	sequencing	sequencing	sequencing	sequencing
13 arrangement of features-legend nestline	arrangement	arrangement	arrangement	arrangement
14 legend nestline-size	size	size	neatline	size
15 clarity of wording-text spacing	clarity	clarity	clarity	clarity
16 proximity of features-legend size	proximity	proximity	proximity	proximity
17 sequencing-proximity of features	sequencing	proximity	sequencing	sequencing
18 clarity-conciseness of wording	conciseness	clarity	clarity	neither
19 text location-angle	neither	txt location	txt location	txt location
20 type style-clarity of wording	clarity	clarity	clarity	clarity
21 text spacing-type style	txt spacing	txt spacing	txt spacing	txt spacing
22 legend nestline-location	location	location	neatline	location
23 legend size-location	size	size	location	neither
24 legend sequencing-shape	sequencing	sequencing	shape	sequencing
25 text angle-clarity of wording	clarity	clarity	clarity	clarity
26 legend shape-proximity of features	proximity	proximity	proximity	proximity
27 text spacing-typeface	txt spacing	txt spacing	txt spacing	txt spacing
28 text location-type size	txt location	txt location	txt location	txt location
29 typeface-text angle	angle	angle	angle	angle
30 legend shape-arrangement of features	arrangement	arrangement	arrangement	arrangement
31 proximity-arrangement of features	arrangement	proximity	proximity	proximity
32 legend shape-nestline	shape	shape	neatline	neither
33 conciseness of wording-text angle	conciseness	conciseness	angle	conciseness
34 legend location-shape	location	location	shape	location
35 sequencing-arrangement of features	sequencing	arrangement	arrangement	neither
36 legend location-sequencing of features	sequencing	location	location	sequencing
37 type size-typeface	type size	type size	type size	type size
38 text location-type style	txt location	txt location	txt location	txt location
39 type style-type size	type size	type size	type size	type size
40 clarity of wording-type size	clarity	clarity	clarity	clarity
41 type style-typeface	neither	neither	type style	neither
42 type size-text angle	angle	angle	angle	type size
43 text angle-spacing	angle	neither	angle	txt spacing
44 typeface-clarity of wording	clarity	clarity	clarity	clarity
45 legend location-proximity	proximity	proximity	proximity	location
46 typeface-text location	txt location	txt location	txt location	txt location
47 type size-text spacing	type size	txt spacing	type size	type size
48 type style-text angle	angle	angle	angle	angle
49 type style-conciseness of wording	conciseness	conciseness	conciseness	conciseness

PAGE # and FEATURE PAIRINGS:	Respondent 5	Respondent 6	Respondent 7	Respondent 8
1 legend size-shape	size	size	size	size
2 type size-conciseness of wording	type size	conciseness	type size	type size
3 text location-spacing	txt location	txt location	location	txt location
4 legend size-arrangement of features	arrangement	arrangement	size	size
5 legend sequencing-size	size	sequencing	size	size
6 conciseness of wording-text spacing	conciseness	conciseness	conciseness	txt spacing
7 legend neatline-proximity of features	neither	proximity	neatline	proximity
8 text location-conciseness of wording	conciseness	conciseness	neither	conciseness
9 clarity of wording-text location	clarity	clarity	clarity	clarity
10 conciseness of wording-typeface	conciseness	conciseness	conciseness	conciseness
11 arrangement of features-legend location	location	arrangement	neither	arrangement
12 legend neatline-sequencing of features	neither	sequencing	neatline	sequencing
13 arrangement of features-legend neatline	arrangement	arrangement	neither	arrangement
14 legend neatline-size	size	size	size	size
15 clarity of wording-text spacing	clarity	clarity	clarity	clarity
16 proximity of features-legend size	proximity	proximity	size	size
17 sequencing-proximity of features	proximity	sequencing	proximity	proximity
18 clarity-conciseness of wording	clarity	clarity	clarity	clarity
19 text location-angle	txt location	angle	txt location	txt location
20 type style-clarity of wording	clarity	clarity	clarity	clarity
21 text spacing-type style	txt spacing	txt spacing	txt spacing	txt spacing
22 legend neatline-location	location	location	location	location
23 legend size-location	location	location	size	size
24 legend sequencing-shape	shape	sequencing	shape	sequencing
25 text angle-clarity of wording	clarity	clarity	clarity	clarity
26 legend shape-proximity of features	proximity	neither	shape	proximity
27 text spacing-typeface	txt spacing	txt spacing	txt spacing	txt spacing
28 text location-type size	txt location	txt location	txt location	type size
29 typeface-text angle	angle	angle	angle	angle
30 legend shape-arrangement of features	shape	arrangement	shape	arrangement
31 proximity-arrangement of features	proximity	proximity	arrangement	proximity
32 legend shape-neatline	shape	shape	shape	neatline
33 conciseness of wording-text angle	conciseness	conciseness	angle	conciseness
34 legend location-shape	location	location	neither	location
35 sequencing-arrangement of features	arrangement	arrangement	arrangement	sequencing
36 legend location-sequencing of features	location	location	sequencing	sequencing
37 type size-typeface	type size	type size	type size	type size
38 text location-type style	txt location	txt location	txt location	txt location
39 type style-type size	type size	type size	type size	type size
40 clarity of wording-type size	clarity	clarity	clarity	neither
41 type style-typeface	neither	neither	neither	typeface
42 type size-text angle	type size	type size	angle	type size
43 text angle-spacing	neither	angle	angle	angle
44 typeface-clarity of wording	clarity	clarity	clarity	clarity
45 legend location-proximity	neither	location	location	proximity
46 typeface-text location	txt location	txt location	txt location	txt location
47 type size-text spacing	neither	type size	type size	type size
48 type style-text angle	neither	angle	angle	angle
49 type style-conciseness of wording	conciseness	conciseness	neither	conciseness

PAGE # and FEATURE PAIRINGS:	Respondent 9	Respondent 10	Respondent 11	Respondent 12
1 legend size-shape	size	size	neither	size
2 type size-conciseness of wording	conciseness	neither	conciseness	type size
3 text location-spacing	txt location	neither	txt location	neither
4 legend size-arrangement of features	arrangement	neither	arrangement	size
5 legend sequencing-size	sequencing	neither	sequencing	size
6 conciseness of wording-text spacing	conciseness	neither	conciseness	neither
7 legend nestline-proximity of features	proximity	proximity	proximity	proximity
8 text location-conciseness of wording	txt location	conciseness	conciseness	conciseness
9 clarity of wording-text location	clarity	neither	clarity	clarity
10 conciseness of wording-typeface	conciseness	conciseness	conciseness	conciseness
11 arrangement of features-legend location	arrangement	location	arrangement	neither
12 legend nestline-sequencing of features	sequencing	sequencing	sequencing	sequencing
13 arrangement of features-legend nestline	arrangement	arrangement	arrangement	arrangement
14 legend nestline-size	size	size	size	size
15 clarity of wording-text spacing	clarity	clarity	clarity	clarity
16 proximity of features-legend size	proximity	size	proximity	proximity
17 sequencing-proximity of features	sequencing	neither	neither	neither
18 clarity-conciseness of wording	clarity	clarity	neither	neither
19 text location-angle	neither	neither	txt location	txt location
20 type style-clarity of wording	clarity	clarity	clarity	clarity
21 text spacing-type style	txt spacing	txt spacing	txt spacing	neither
22 legend nestline-location	location	location	location	location
23 legend size-location	size	size	location	size
24 legend sequencing-shape	sequencing	sequencing	sequencing	sequencing
25 text angle-clarity of wording	clarity	clarity	neither	clarity
26 legend shape-proximity of features	proximity	proximity	proximity	proximity
27 text spacing-typeface	txt spacing	txt spacing	txt spacing	neither
28 text location-type size	txt location	type size	neither	neither
29 typeface-text angle	typeface	angle	neither	neither
30 legend shape-arrangement of features	arrangement	arrangement	arrangement	arrangement
31 proximity-arrangement of features	proximity	proximity	neither	arrangement
32 legend shape-nestline	shape	neither	neither	shape
33 conciseness of wording-text angle	conciseness	angle	neither	conciseness
34 legend location-shape	location	location	neither	location
35 sequencing-arrangement of features	arrangement	sequencing	neither	arrangement
36 legend location-sequencing of features	sequencing	sequencing	sequencing	location
37 type size-typeface	type size	type size	type size	neither
38 text location-type style	txt location	type style	txt location	neither
39 type style-type size	type size	type size	type size	neither
40 clarity of wording-type size	clarity	clarity	clarity	neither
41 type style-typeface	type style	typeface	typeface	typeface
42 type size-text angle	type size	type size	neither	type size
43 text angle-spacing	txt spacing	angle	neither	txt spacing
44 typeface-clarity of wording	clarity	clarity	clarity	clarity
45 legend location-proximity	proximity	proximity	proximity	location
46 typeface-text location	txt location	txt location	txt location	txt location
47 type size-text spacing	txt spacing	type size	type size	neither
48 type style-text angle	type style	angle	angle	neither
49 type style-conciseness of wording	conciseness	conciseness	conciseness	conciseness

PAGE # and FEATURE PAIRINGS:	Respondent 13	Respondent 14	Respondent 15	Respondent 16
1 legend size-shape	size	neither	size	size
2 type size-conciseness of wording	conciseness	conciseness	conciseness	type size
3 text location-spacing	txt location	txt location	txt location	txt location
4 legend size-arrangement of features	arrangement	arrangement	size	size
5 legend sequencing-size	sequencing	size	size	sequencing
6 conciseness of wording-text spacing	conciseness	conciseness	conciseness	conciseness
7 legend neatline-proximity of features	proximity	proximity	proximity	proximity
8 text location-conciseness of wording	txt location	txt location	conciseness	conciseness
9 clarity of wording-text location	clarity	clarity	clarity	clarity
10 conciseness of wording-typeface	conciseness	conciseness	conciseness	typeface
11 arrangement of features-legend location	neither	arrangement	arrangement	arrangement
12 legend neatline-sequencing of features	sequencing	sequencing	sequencing	sequencing
13 arrangement of features-legend neatline	arrangement	arrangement	arrangement	arrangement
14 legend neatline-size	size	size	size	size
15 clarity of wording-text spacing	clarity	clarity	clarity	clarity
16 proximity of features-legend size	proximity	proximity	neither	proximity
17 sequencing-proximity of features	proximity	proximity	proximity	sequencing
18 clarity-conciseness of wording	clarity	clarity	neither	neither
19 text location-angle	neither	txt location	txt location	txt location
20 type style-clarity of wording	clarity	clarity	clarity	clarity
21 text spacing-type style	txt spacing	type style	txt spacing	txt spacing
22 legend neatline-location	location	location	location	neither
23 legend size-location	location	location	location	size
24 legend sequencing-shape	sequencing	sequencing	shape	sequencing
25 text angle-clarity of wording	clarity	clarity	clarity	clarity
26 legend shape-proximity of features	proximity	proximity	neither	proximity
27 text spacing-typeface	txt spacing	txt spacing	txt spacing	typeface
28 text location-type size	location	txt location	neither	type size
29 typeface-text angle	angle	angle	angle	angle
30 legend shape-arrangement of features	arrangement	arrangement	shape	arrangement
31 proximity-arrangement of features	neither	proximity	proximity	arrangement
32 legend shape-neatline	shape	shape	shape	neatline
33 conciseness of wording-text angle	neither	conciseness	conciseness	angle
34 legend location-shape	location	location	location	location
35 sequencing-arrangement of features	arrangement	arrangement	arrangement	arrangement
36 legend location-sequencing of features	location	location	location	location
37 type size-typeface	type size	neither	type size	type size
38 text location-type style	txt location	txt location	neither	txt location
39 type style-type size	type size	type style	type size	type size
40 clarity of wording-type size	clarity	clarity	neither	clarity
41 type style-typeface	neither	neither	type style	typeface
42 type size-text angle	neither	angle	type size	type size
43 text angle-spacing	angle	neither	neither	angle
44 typeface-clarity of wording	clarity	clarity	clarity	clarity
45 legend location-proximity	proximity	proximity	location	proximity
46 typeface-text location	txt location	txt location	txt location	txt location
47 type size-text spacing	type size	txt spacing	type size	neither
48 type style-text angle	angle	angle	angle	angle
49 type style-conciseness of wording	conciseness	conciseness	conciseness	type style

PAGE # and FEATURE PAIRINGS:	Respondent 17	Respondent 18	Respondent 19	Respondent 20
1 legend size-shape	size	size	size	size
2 type size-conciseness of wording	conciseness	conciseness	conciseness	conciseness
3 text location-spacing	txt location	txt location	txt location	txt location
4 legend size-arrangement of features	size	size	arrangement	arrangement
5 legend sequencing-size	neither	size	sequencing	sequencing
6 conciseness of wording-text spacing	conciseness	conciseness	conciseness	conciseness
7 legend nestline-proximity of features	proximity	proximity	proximity	proximity
8 text location-conciseness of wording	conciseness	conciseness	txt location	txt location
9 clarity of wording-text location	clarity	clarity	clarity	clarity
10 conciseness of wording-typeface	conciseness	conciseness	conciseness	conciseness
11 arrangement of features-legend location	arrangement	arrangement	location	arrangement
12 legend nestline-sequencing of features	sequencing	neatline	sequencing	sequencing
13 arrangement of features-legend nestline	arrangement	arrangement	arrangement	arrangement
14 legend nestline-size	size	size	neatline	size
15 clarity of wording-text spacing	txt spacing	clarity	clarity	clarity
16 proximity of features-legend size	proximity	proximity	proximity	proximity
17 sequencing-proximity of features	proximity	proximity	proximity	proximity
18 clarity-conciseness of wording	conciseness	conciseness	conciseness	clarity
19 text location-angle	txt location	angle	angle	angle
20 type style-clarity of wording	clarity	clarity	type style	clarity
21 text spacing-type style	type style	neither	txt spacing	txt spacing
22 legend nestline-location	location	location	location	location
23 legend size-location	size	size	location	location
24 legend sequencing-shape	neither	shape	sequencing	sequencing
25 text angle-clarity of wording	clarity	angle	angle	angle
26 legend shape-proximity of features	proximity	proximity	proximity	shape
27 text spacing-typeface	txt spacing	txt spacing	txt spacing	txt spacing
28 text location-type size	txt location	txt location	type size	txt location
29 typeface-text angle	angle	angle	angle	angle
30 legend shape-arrangement of features	shape	arrangement	shape	shape
31 proximity-arrangement of features	proximity	proximity	arrangement	arrangement
32 legend shape-nestline	neatline	neatline	shape	shape
33 conciseness of wording-text angle	angle	angle	conciseness	angle
34 legend location-shape	neither	location	location	shape
35 sequencing-arrangement of features	arrangement	arrangement	arrangement	sequencing
36 legend location-sequencing of features	location	location	sequencing	location
37 type size-typeface	type size	type size	type size	type size
38 text location-type style	txt location	txt location	txt location	txt location
39 type style-type size	type size	type size	type size	type size
40 clarity of wording-type size	type size	clarity	clarity	clarity
41 type style-typeface	type face	neither	typeface	neither
42 type size-text angle	type size	angle	angle	angle
43 text angle-spacing	txt spacing	angle	txt spacing	angle
44 typeface-clarity of wording	clarity	neither	clarity	clarity
45 legend location-proximity	proximity	proximity	proximity	proximity
46 typeface-text location	txt location	txt location	txt location	txt location
47 type size-text spacing	neither	type size	txt spacing	type size
48 type style-text angle	angle	angle	angle	angle
49 type style-conciseness of wording	conciseness	conciseness	conciseness	conciseness

PAGE # and FEATURE PAIRINGS:	Respondent 21	Respondent 22	Respondent 23	Respondent 24
1 legend size-shape	size	size	neither	size
2 type size-conciseness of wording	conciseness	neither	conciseness	type size
3 text location-spacing	txt location	txt location	txt location	neither
4 legend size-arrangement of features	arrangement	arrangement	neither	arrangement
5 legend sequencing-size	size	sequencing	sequencing	sequencing
6 conciseness of wording-text spacing	conciseness	conciseness	conciseness	conciseness
7 legend neatline-proximity of features	proximity	proximity	proximity	proximity
8 text location-conciseness of wording	txt location	conciseness	neither	txt location
9 clarity of wording-text location	neither	clarity	neither	txt location
10 conciseness of wording-typeface	conciseness	conciseness	conciseness	conciseness
11 arrangement of features-legend location	arrangement	arrangement	location	location
12 legend neatline-sequencing of features	sequencing	sequencing	sequencing	sequencing
13 arrangement of features-legend neatline	arrangement	arrangement	arrangement	arrangement
14 legend neatline-size	neatline	size	neither	size
15 clarity of wording-text spacing	clarity	clarity	clarity	txt spacing
16 proximity of features-legend size	proximity	proximity	neither	neither
17 sequencing-proximity of features	sequencing	sequencing	neither	proximity
18 clarity-conciseness of wording	clarity	clarity	neither	conciseness
19 text location-angle	neither	txt location	txt location	txt location
20 type style-clarity of wording	clarity	clarity	clarity	clarity
21 text spacing-type style	txt spacing	txt spacing	neither	type style
22 legend neatline-location	location	location	location	location
23 legend size-location	location	neither	neither	location
24 legend sequencing-shape	sequencing	sequencing	neither	sequencing
25 text angle-clarity of wording	angle	clarity	clarity	angle
26 legend shape-proximity of features	proximity	proximity	neither	proximity
27 text spacing-typeface	txt spacing	txt spacing	neither	typeface
28 text location-type size	txt location	neither	txt location	txt location
29 typeface-text angle	angle	angle	neither	typeface
30 legend shape-arrangement of features	shape	arrangement	shape	arrangement
31 proximity-arrangement of features	arrangement	neither	arrangement	proximity
32 legend shape-neatline	shape	shape	neither	neither
33 conciseness of wording-text angle	angle	conciseness	conciseness	angle
34 legend location-shape	shape	location	neither	location
35 sequencing-arrangement of features	neither	arrangement	neither	arrangement
36 legend location-sequencing of features	sequencing	sequencing	location	location
37 type size-typeface	typeface	type size	type size	typeface
38 text location-type style	txt location	txt location	txt location	type style
39 type style-type size	type size	type size	neither	neither
40 clarity of wording-type size	clarity	clarity	clarity	clarity
41 type style-typeface	typeface	typeface	neither	neither
42 type size-text angle	angle	type size	neither	type size
43 text angle-spacing	angle	txt spacing	txt spacing	txt spacing
44 typeface-clarity of wording	clarity	clarity	clarity	typeface
45 legend location-proximity	neither	neither	neither	location
46 typeface-text location	txt location	txt location	txt location	typeface
47 type size-text spacing	txt spacing	txt spacing	neither	txt spacing
48 type style-text angle	angle	type style	neither	type style
49 type style-conciseness of wording	conciseness	conciseness	neither	conciseness

PAGE # and FEATURE PAIRINGS:	Respondent 25	Respondent 26	Respondent 27	Respondent 28
1 legend size-shape	size	size	size	size
2 type size-conciseness of wording	conciseness	conciseness	conciseness	neither
3 text location-spacing	txt location	txt location	txt location	txt location
4 legend size-arrangement of features	arrangement	arrangement	arrangement	size
5 legend sequencing-size	size	size	sequencing	size
6 conciseness of wording-text spacing	conciseness	conciseness	conciseness	conciseness
7 legend neatline-proximity of features	neatline	neither	proximity	proximity
8 text location-conciseness of wording	txt location	conciseness	txt location	conciseness
9 clarity of wording-text location	clarity	clarity	clarity	clarity
10 conciseness of wording-typeface	conciseness	conciseness	conciseness	conciseness
11 arrangement of features-legend location	arrangement	arrangement	arrangement	location
12 legend neatline-sequencing of features	neatline	neither	sequencing	neither
13 arrangement of features-legend neatline	neatline	neither	arrangement	arrangement
14 legend neatline-size	neatline	size	size	size
15 clarity of wording-text spacing	clarity	clarity	clarity	clarity
16 proximity of features-legend size	size	size	proximity	proximity
17 sequencing-proximity of features	proximity	proximity	sequencing	proximity
18 clarity-conciseness of wording	clarity	conciseness	conciseness	clarity
19 text location-angle	txt location	angle	angle	txt location
20 type style-clarity of wording	clarity	clarity	clarity	clarity
21 text spacing-type style	txt spacing	txt spacing	txt spacing	txt spacing
22 legend neatline-location	location	location	location	location
23 legend size-location	size	size	location	location
24 legend sequencing-shape	shape	sequencing	sequencing	shape
25 text angle-clarity of wording	clarity	clarity	angle	clarity
26 legend shape-proximity of features	proximity	shape	proximity	proximity
27 text spacing-typeface	txt spacing	typeface	typeface	txt spacing
28 text location-type size	txt location	type size	type size	txt location
29 typeface-text angle	angle	typeface	typeface	angle
30 legend shape-arrangement of features	shape	shape	arrangement	shape
31 proximity-arrangement of features	proximity	arrangement	arrangement	proximity
32 legend shape-neatline	neatline	neatline	neatline	shape
33 conciseness of wording-text angle	conciseness	conciseness	conciseness	conciseness
34 legend location-shape	location	shape	location	location
35 sequencing-arrangement of features	arrangement	arrangement	arrangement	arrangement
36 legend location-sequencing of features	location	location	sequencing	location
37 type size-typeface	type size	type size	type size	type size
38 text location-type style	txt location	txt location	txt location	txt location
39 type style-type size	type size	type size	type size	type size
40 clarity of wording-type size	clarity	clarity	clarity	clarity
41 type style-typeface	type style	neither	typeface	neither
42 type size-text angle	angle	type size	type size	type size
43 text angle-spacing	txt spacing	angle	txt spacing	neither
44 typeface-clarity of wording	clarity	clarity	clarity	clarity
45 legend location-proximity	proximity	location	proximity	neither
46 typeface-text location	txt location	txt location	txt location	txt location
47 type size-text spacing	txt spacing	txt spacing	txt spacing	type size
48 type style-text angle	type style	angle	type style	neither
49 type style-conciseness of wording	conciseness	conciseness	conciseness	conciseness

PAGE # and FEATURE PAIRINGS:	Respondent 29	Respondent 30	Respondent 31	Respondent 32
1 legend size-shape	size	neither	size	shape
2 type size-conciseness of wording	conciseness	conciseness	type size	type size
3 text location-spacing	txt location	txt location	txt location	txt location
4 legend size-arrangement of features	arrangement	arrangement	arrangement	arrangement
5 legend sequencing-size	sequencing	sequencing	sequencing	sequencing
6 conciseness of wording-text spacing	conciseness	txt spacing	conciseness	conciseness
7 legend neatline-proximity of features	proximity	proximity	proximity	neither
8 text location-conciseness of wording	txt location	txt location	txt location	txt location
9 clarity of wording-text location	clarity	clarity	neither	clarity
10 conciseness of wording-typeface	conciseness	conciseness	conciseness	typeface
11 arrangement of features-legend location	neither	arrangement	arrangement	arrangement
12 legend neatline-sequencing of features	neither	sequencing	sequencing	sequencing
13 arrangement of features-legend neatline	arrangement	arrangement	arrangement	arrangement
14 legend neatline-size	size	size	size	neatline
15 clarity of wording-text spacing	clarity	txt spacing	clarity	txt spacing
16 proximity of features-legend size	proximity	size	neither	proximity
17 sequencing-proximity of features	proximity	sequencing	proximity	proximity
18 clarity-conciseness of wording	conciseness	clarity	neither	clarity
19 text location-angle	txt location	neither	txt location	angle
20 type style-clarity of wording	clarity	clarity	clarity	clarity
21 text spacing-type style	type style	txt spacing	txt spacing	type style
22 legend neatline-location	neatline	location	location	location
23 legend size-location	location	location	size	location
24 legend sequencing-shape	shape	sequencing	sequencing	shape
25 text angle-clarity of wording	clarity	clarity	clarity	clarity
26 legend shape-proximity of features	proximity	proximity	proximity	proximity
27 text spacing-typeface	typeface	txt spacing	txt spacing	typeface
28 text location-type size	txt location	neither	type size	txt location
29 typeface-text angle	typeface	angle	typeface	typeface
30 legend shape-arrangement of features	shape	arrangement	arrangement	shape
31 proximity-arrangement of features	arrangement	arrangement	proximity	proximity
32 legend shape-neatline	neither	shape	shape	neatline
33 conciseness of wording-text angle	conciseness	conciseness	conciseness	angle
34 legend location-shape	location	location	neither	location
35 sequencing-arrangement of features	arrangement	sequencing	arrangement	neither
36 legend location-sequencing of features	location	location	location	location
37 type size-typeface	type size	type size	type size	type size
38 text location-type style	txt location	txt location	txt location	txt location
39 type style-type size	neither	type size	type size	type size
40 clarity of wording-type size	clarity	clarity	type size	clarity
41 type style-typeface	typeface	neither	typeface	type style
42 type size-text angle	angle	angle	type size	type size
43 text angle-spacing	txt spacing	txt spacing	txt spacing	angle
44 typeface-clarity of wording	clarity	clarity	clarity	clarity
45 legend location-proximity	proximity	proximity	proximity	proximity
46 typeface-text location	txt location	txt location	txt location	typeface
47 type size-text spacing	type size	txt spacing	type size	type size
48 type style-text angle	angle	angle	type style	angle
49 type style-conciseness of wording	conciseness	conciseness	conciseness	type style

LIST OF REFERENCES

LIST OF REFERENCES

Antes, James R., Chang, Kang-tsung, and Mullis, Chad. 1985. "The Visual Effect of Map Design: An Eye-Movement Analysis." *The American Cartographer*, vol.12, no.2, pp. 143-155.

Aspaas, Helen Ruth and Stephen J. Lavin. 1989. "Legend Designs for Unclassed Bivariate Choropleth Maps." *The American Cartographer*, vol. 16, no. 4, pp. 257- 268.

Carstensen, Laurence W. 1986. "Bivariate Choropleth Mapping: The Effects of Axis Scaling." *The American Cartographer*, vol. 13, no. 1, pp. 27-42.

Clark, W.A.V. and Hosking, P.L. 1986. *Statistical Methods for Geographers*. John Wiley & Sons, Inc., New York, NY., 518.

Clarke, Keith C., 1990. *Analytical and Computer Cartography*. Prentice Hall, New Jersey, 290.

Cuff, David J. and Mark T. Mattson. 1982. *Thematic Maps: Their Design and Production*. Methuen & Co., New York, NY., 169.

DeLucia, A.A. and D.W. Hiller. 1982. "Natural Legend Design for Thematic Maps." *The Cartographic Journal*, vol. 19, no. 1, pp. 46-52.

Dent, Borden D. 1972. "Visual Organization and Thematic Map Communication." *The American Cartographer*, vol. 2, no. 2, pp. 79-93.

Dobson, Michael W. 1974. "Refining Legend Values for Proportional Circle Maps." *The Canadian Cartographer*, vol. 11, no. 11, pp. 45-53.

Fontanella, Joseph F. 1988. *Assessment of the Effectiveness of Battlefield Maps*. East Lansing: M.S.U., (Masters Thesis).

Gilmartin, Patricia P. 1978. "Evaluation of Thematic Maps Using the Semantic Differential Test." *The American Cartographer*, vol. 5, no. 2, pp. 133-139.

International Paper Co. 1989. *Pocket Pal: A Graphic Arts Production Handbook.* International Paper Co., Memphis, Tn., 220.

Keates, John. 1973. *Cartographic Design and Production.* Second Edition, John Wiley & Sons, Inc., New York, NY., 240.

MacEachren, Alan M. 1987. "The Evolution of Computer Mapping and its Implications for Geography." *Journal of Geography,* May/June, pp. 100-107.

Marble, Duane F. 1987. "The Computer and Cartography." *The American Cartographer,* vol. 14, no. 2, pp. 101-103.

Michigan State University. 1993. *The Graduate School Guide To The Preparation Of Master's Theses And Doctoral Dissertations.* East Lansing, Michigan, 32.

Monmonier, Mark S. 1982. *Computer-Assisted Cartography: Principles and Prospects.* Prentice Hall, New Jersey, 214.

Muehrcke, Phillip. C. 1972. "Thematic Cartography." *Association of American Geographers*, (resource paper no. 19), 66.

Muehrcke, Phillip C. 1990. "Cartography and Geographic Information Systems." *Cartography and Geographic Information Systems,* vol. 17, no. 1, pp. 7-15.

Noronha, Valerian T. 1987. "Choropleth Mapping in a Microcomputer Environment: A Critical Evaluation of Some Commercial Implementations." *The American Cartographer,* vol. 14, no. 2, pp. 139-154.

Olson, Judy M. 1975. "The Organization of Color on Two-Variable Maps." Auto Carto II Proceedings, pp. 289-294.

Olson, Judy M. 1977. "Rescaling Dot Maps For Pattern Enhancement." *The International Yearbook of Cartography*, vol 17, pp. 125-137.

Olson, Judy M. 1981. "Spectrally Encoded Two-Variable Maps." *Annals of the Association of American Geographers,* vol. 71, no. 2, pp. 259-276.

Paslawski, J. 1983. "Natural Legend Design for Thematic Maps." *The Cartographic Journal*, vol. 20, no. 1, pp. 36-37.

Petchenik, Barbara Bartz. 1974. "A Verbal Approach to Characterizing the Look of Maps." *The American Cartographer*, vol. 1, no. 1, pp. 63-71.

Robinson, Aurther H. 1980. *The Look of Maps: An examination of Cartographic Design.* The University of Wisconsin Press. Madison, Wisconsin, 105.

Robinson, Aurther H. and Randall Sale. 1978. *Elements of Cartography.* Fourth Edition, John Wiley & Sons, Inc., New York, NY., 270.

Turabian, Kate L. 1987. *A Manual for Writers of Term Papers, Theses, and Dissertations.* Fourth Edition. The University of Chicago Press. Chicago, Illinois, 300.

Shelton, Hal. 1985. Video Tape. Map Division, Library of Congress. Strunk, William and White, E.B. 1979. *The Elements of Style.* Third Edition. MacMillan Publishing Co., Inc. New York, New York, 92.

Werner, Robert and Young, James. 1991. "A Checklist to Evaluate Mapping Software" *Journal of Geography*, May/June, pp. 118-119.

Thematic Map Legend Design Questionnaire

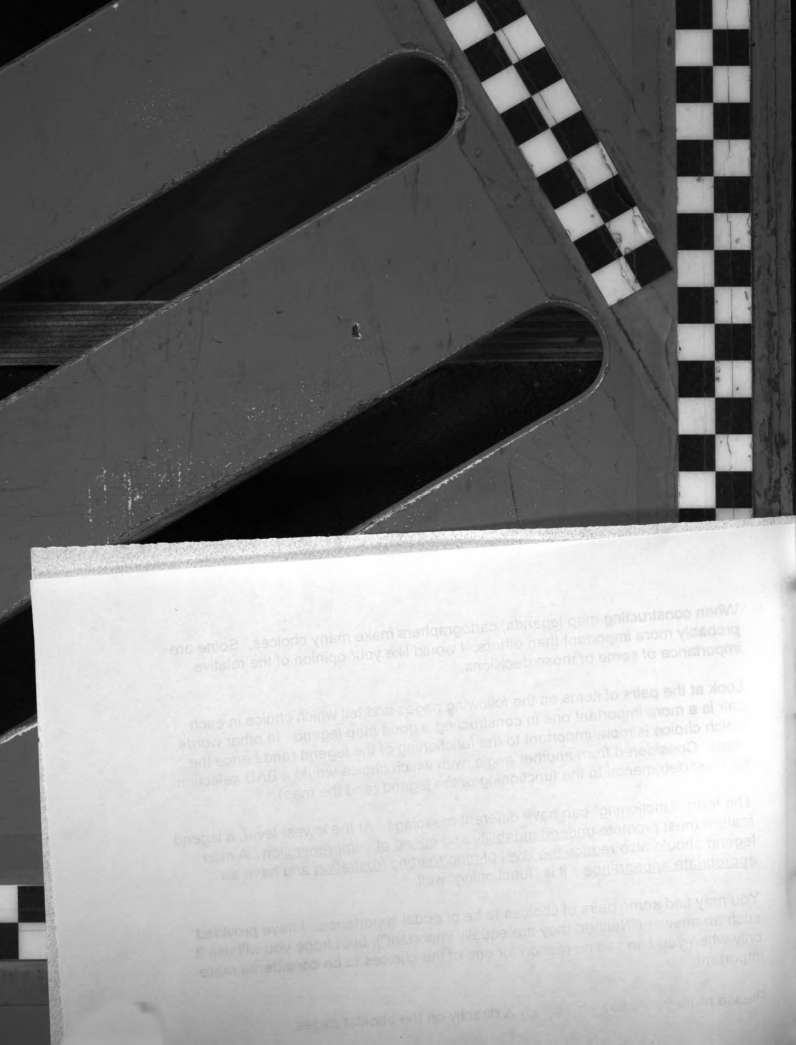
When constructing map legends, cartographers make many choices. Some are probably more important than others. I would like your opinion of the relative importance of some of those decisions.

Look at the pairs of items on the following pages and tell which choice in each pair is a more important one in constructing a good map legend. In other words, which choice is more important to the functioning of the legend (and hence the map). Considered from another angle, with which choice would a BAD selection be most detrimental to the functioning of the legend (and the map).

The term "functioning" can have different meanings. At the lowest level, a legend feature must promote understandability and speed of comprehension. A map legend should also reduce the level of map reading frustration and have an appropriate appearance if it is "functioning" well.

You may find some pairs of choices to be of equal importance. I have provided such an answer ("Neither; they are equally important"), but I hope you will use it only when you can see no reason for one of the choices to be considered more important.

Please mark your answers with an **X** directly on the booklet pages.



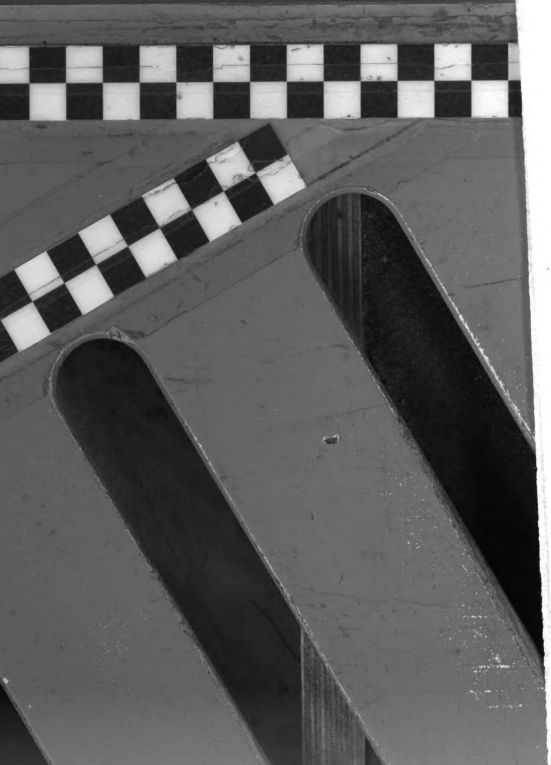
Which is more important?

Legend Size

OR

Legend Shape

Neither; they are equally important



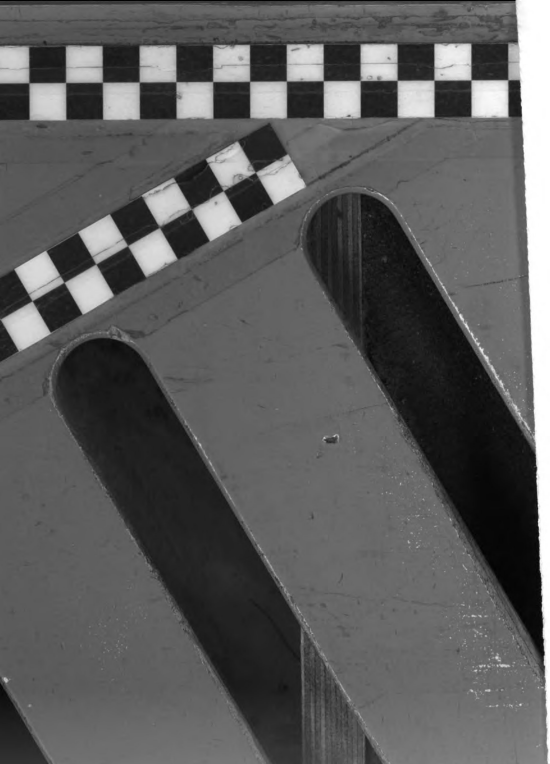
Which is more important?

— Type Size

OR

— Conciseness of (all) Legend Wording

— Neither; they are equally important



Which is more important?

Text Location

Land Use/Cover
☐ Urban
☐ Forest
☐ Commercial
☐ Rural
☐ Dunes

☐ Urban
Forest ☐
☐ Commercial
Rural ☐
☐ Dunes
Land Use/Cover

Land Use/Cover
Urban ☐
Forest ☐
Commercial ☐
Rural ☐
Dunes ☐

OR

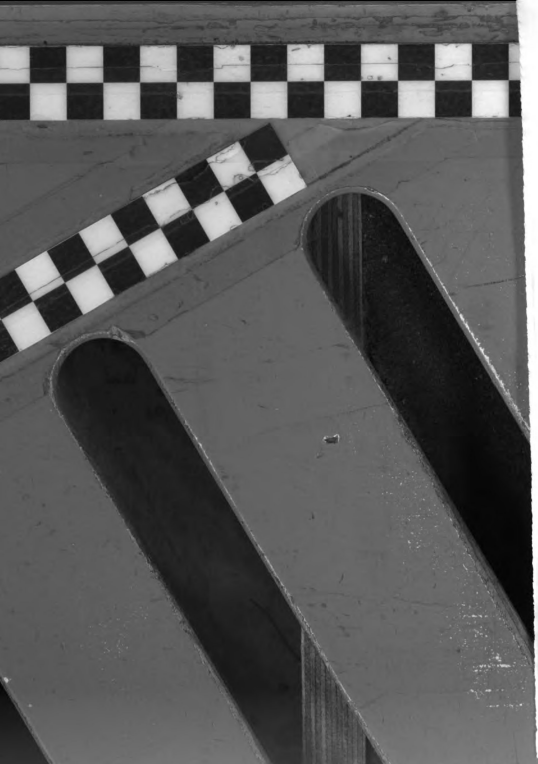
Text Spacing

Urban
Forest
Commercial
Rural
Dunes

Urban
Forest
Commercial
Rural
Dunes

Urban
Forest
Commercial
Rural
Dunes

Neither; they are equally important



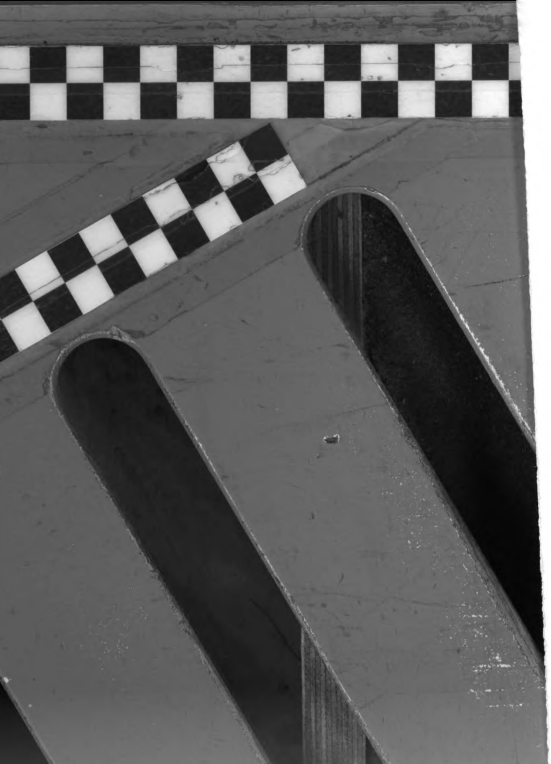
Which is more important?

Legend Size

OR

Arrangement of Legend Features

Neither; they are equally important



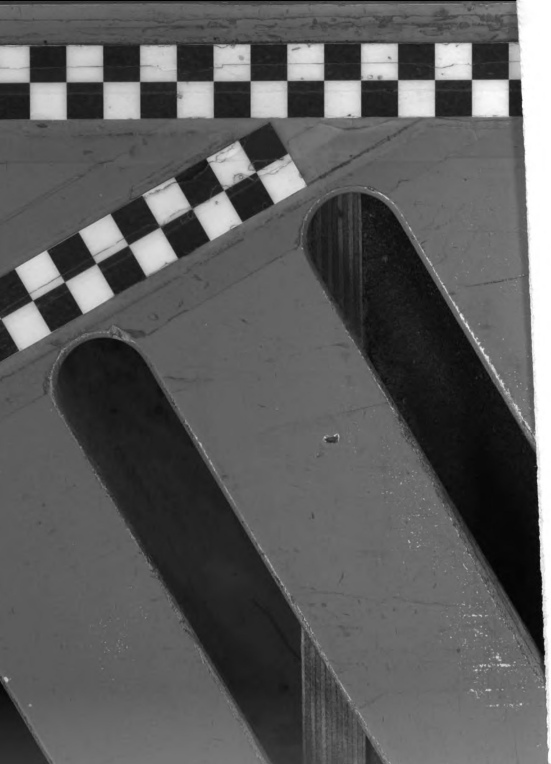
Which is more important?

X **Sequencing of Legend Features**

OR

Legend Size

Neither; they are equally important



Which is more important?

Conciseness of (all) Legend Wording

OR

Text Spacing

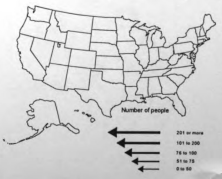
Neither; they are equally important

Which is more important?

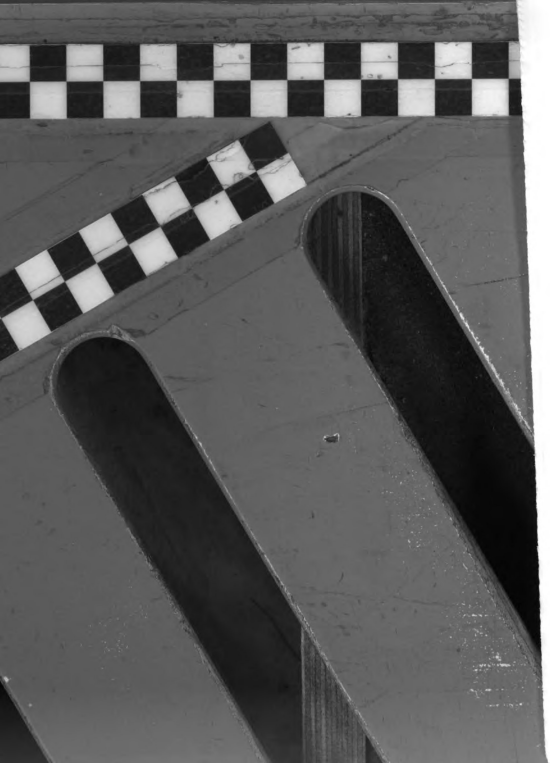
Inclusion of a Legend Neatline

OR

X Visual Proximity of Legend Features (how close the symbols, descriptions, and title are to each other)

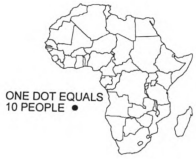


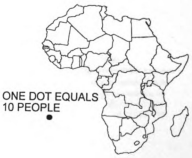
Neither; they are equally important



Which is more important?

__ **Text Location**

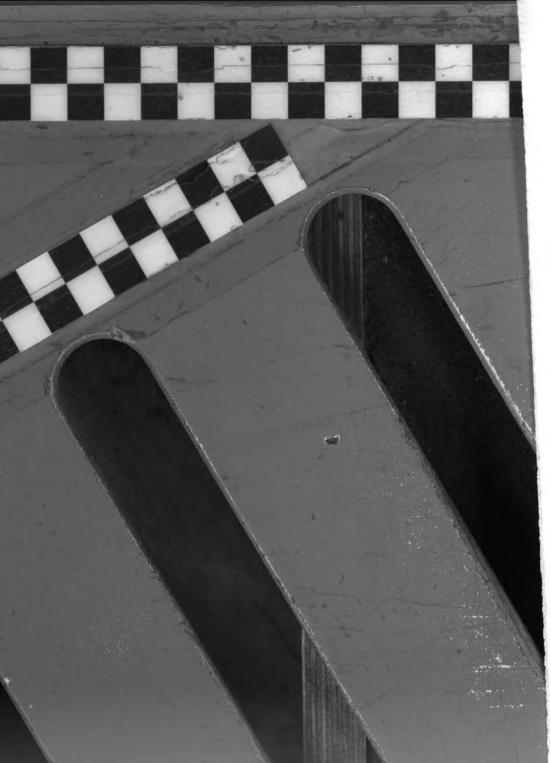




OR

__ **Conciseness of (all) Legend Wording**

__ **Neither; they are equally important**



Which is more important?

Clarity of (all) Legend Wording

OR

Legend Location

Neither; they are equally important

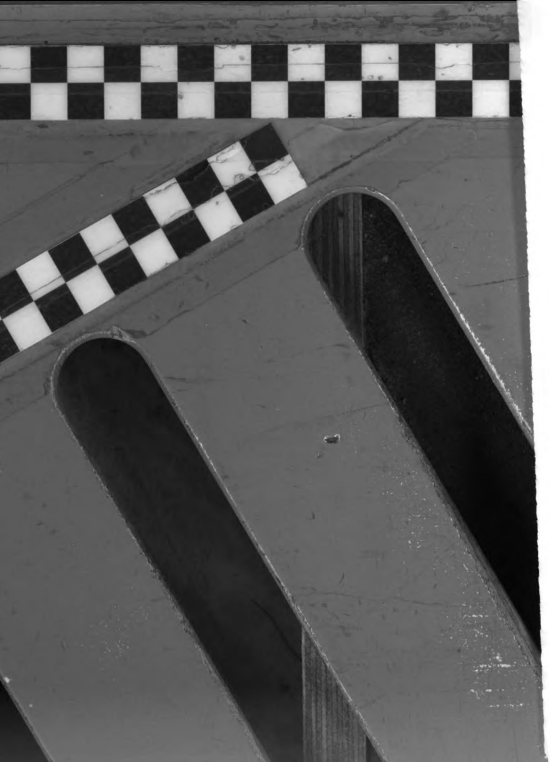
Which is more important?

X Conciseness of (all) Legend Wording

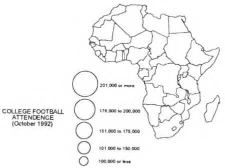
OR

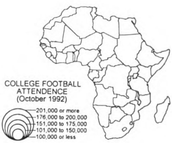
__ Typeface

__ Neither; they are equally important



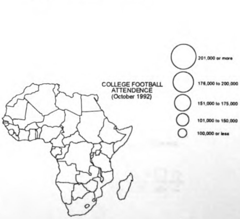
Which is more important?





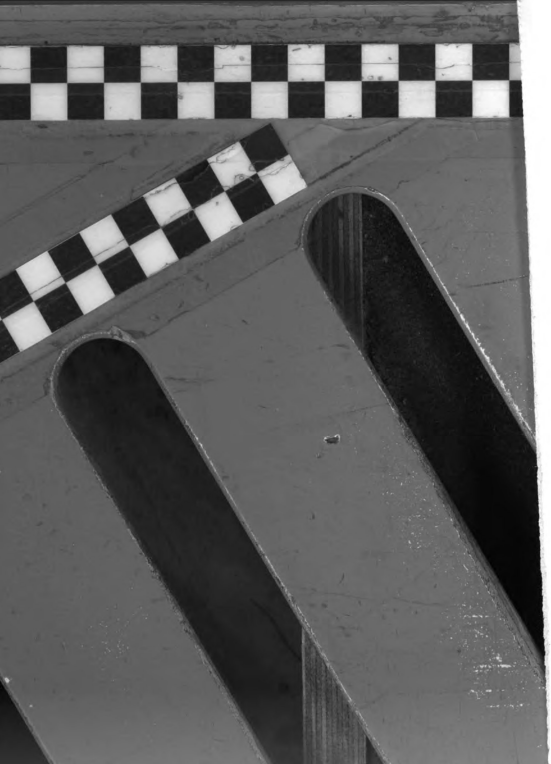
___ **Arrangement of Legend Features**

OR



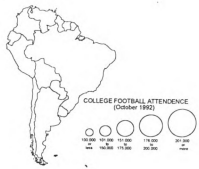
___ **Legend Location**

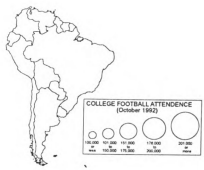
___ **Neither; they are equally important**



Which is more important?

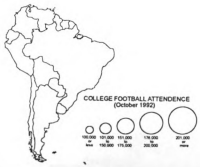
— Inclusion of a Legend Neatline

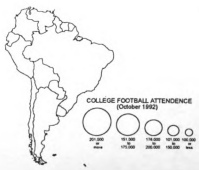




OR

X — Sequencing of Legend Features





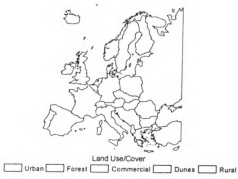
— Neither; they are equally important

Which is more important?

X Arrangement of Legend Features

OR

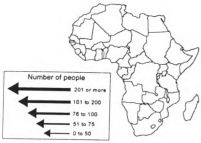
Inclusion of a Legend Neatline



Neither; they are equally important

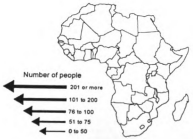
Which is more important?

— Inclusion of a Legend Neatline



OR

X — Legend Size



— Neither; they are equally important

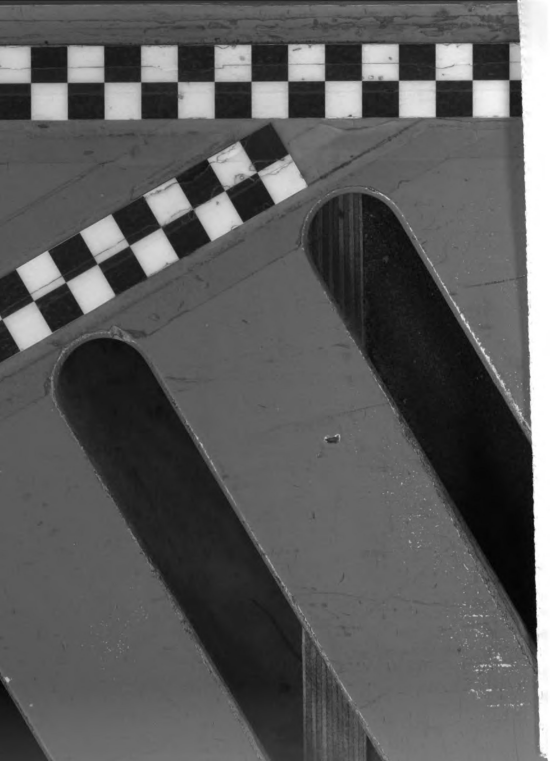
Which is more important?

X Clarity of (all) Legend Wording

OR

— Text Spacing

— Neither; they are equally important



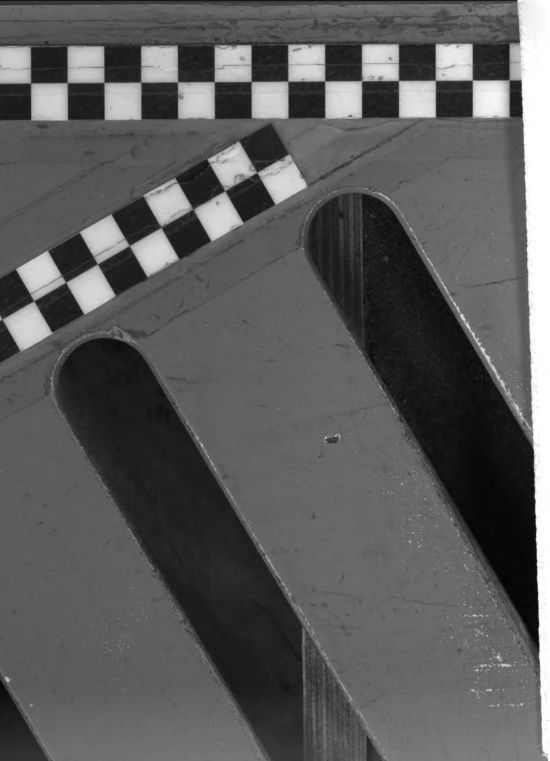
Which is more important?

Visual Proximity of Legend Features (how close the symbols, descriptions, and title are to each other)

OR

Legend Size

Neither; they are equally important

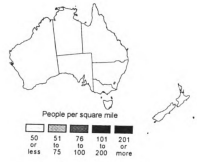


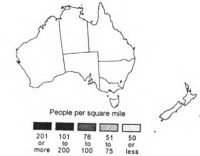
Which is more important?

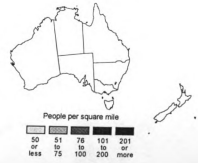
— **Sequencing of Legend Features**

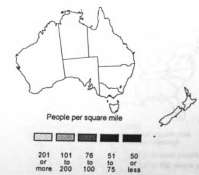
OR

— **Visual Proximity of Legend Features (how close the symbols, descriptions, and title are to each other)**









X — **Neither; they are equally important**

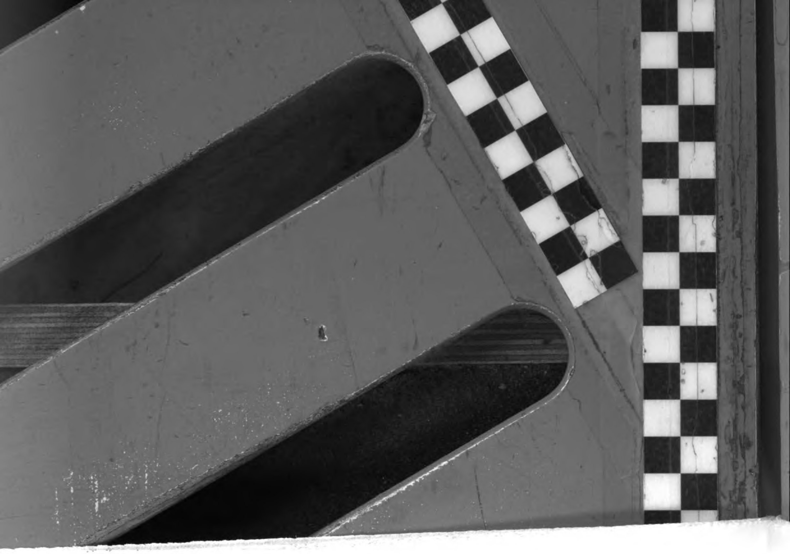
Which is more important?

Clarity of (all) Legend Wording

OR

Conciseness of (all) Legend Wording

Neither; they are equally important



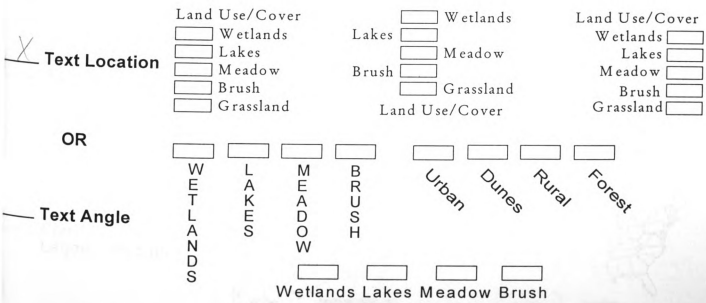
ch is r

Tex

Te

N

Which is more important?



Neither; they are equally important

Which is more important?

—— Type Style

OR

—X— Clarity of (all) Legend Wording

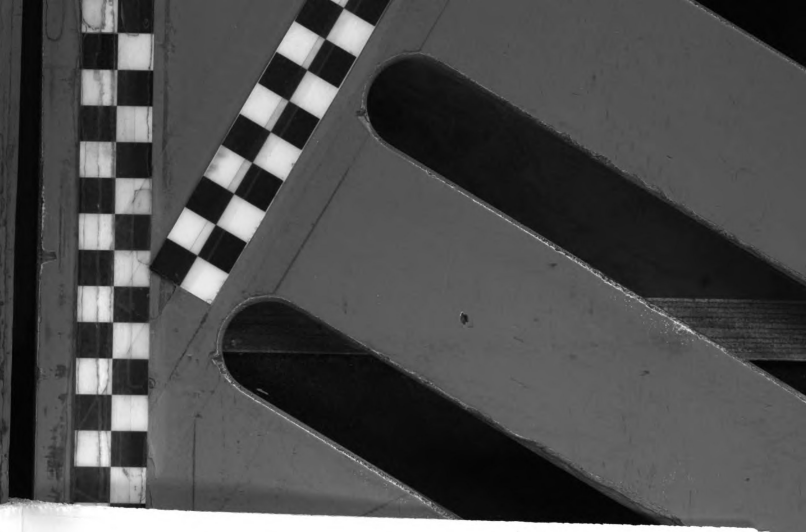
—— Neither; they are equally important

ch is

Te

Ty

Ne



Which is more important?

X **Text Spacing**	Wetlands Lakes Meadow Brush Grassland	Wetlands Lakes Meadow Brush Grassland	Wetlands Lakes Meadow Brush Grassland	
OR				
___ **Type Style**	**Wetlands** **Lakes** **Meadow** **Brush** **Grassland**	*Wetlands* *Lakes* *Meadow* *Brush* *Grassland*	***Wetlands*** ***Lakes*** ***Meadow*** ***Brush*** ***Grassland***	*Wetlands* *Lakes* *Meadow* *Brush* *Grassland*

___ **Neither; they are equally important**

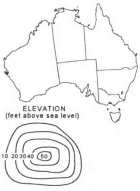
is m

incl
Leg

Le

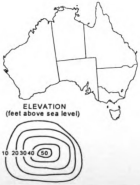
M

Which is more important?



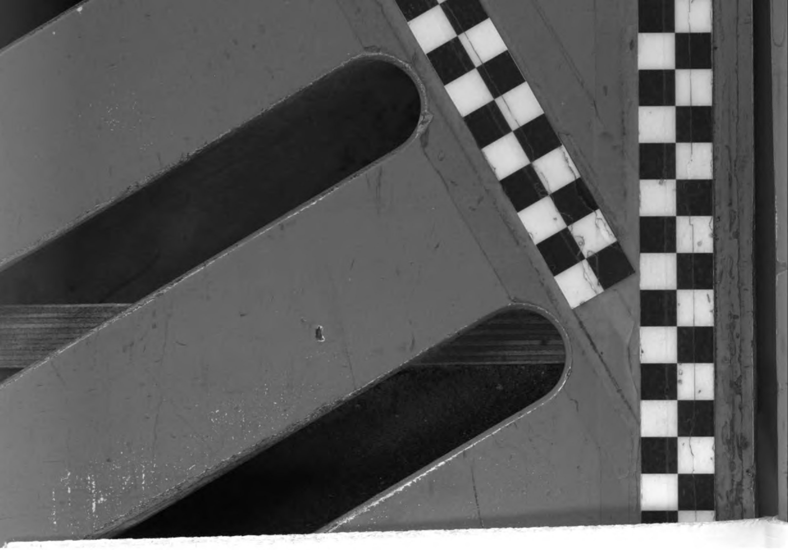
__ Inclusion of a Legend Neatline

OR



X Legend Location

__ Neither; they are equally important



ich is n

Leg

Le

N

Which is more important?

__ Legend Size

OR

X Legend Location

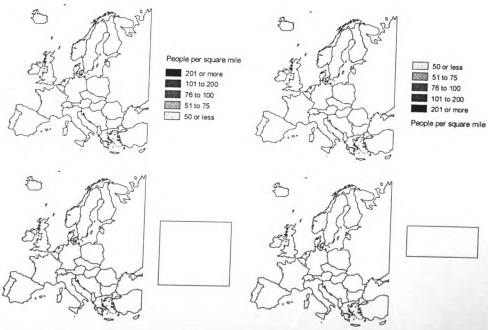
__ Neither; they are equally important

Which is more important?

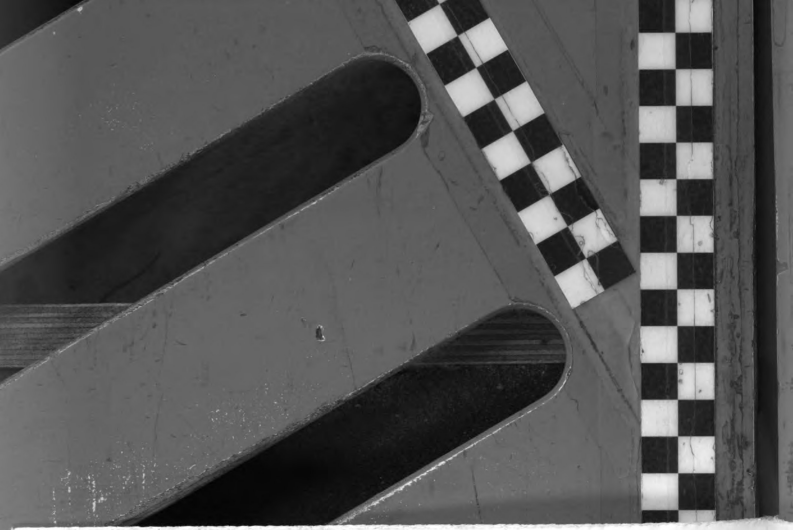
X Sequencing of Legend Features

OR

Legend Shape

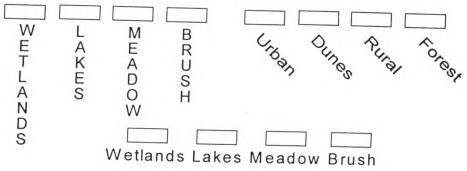


Neither; they are equally important



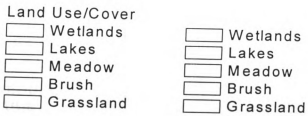
Which is more important?

— Text Angle



OR

— Clarity of (all) Legend Wording

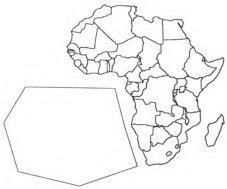


X — **Neither; they are equally important**

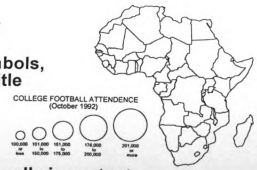
Which is more important?

— Legend Shape

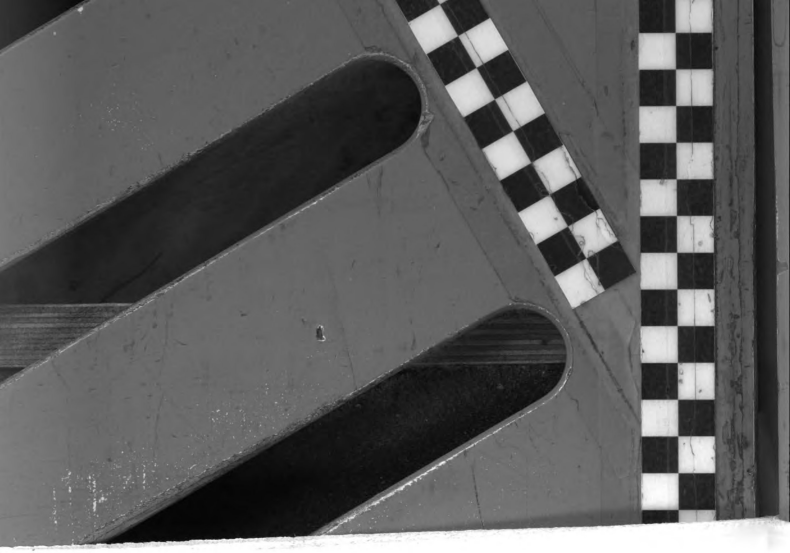
OR

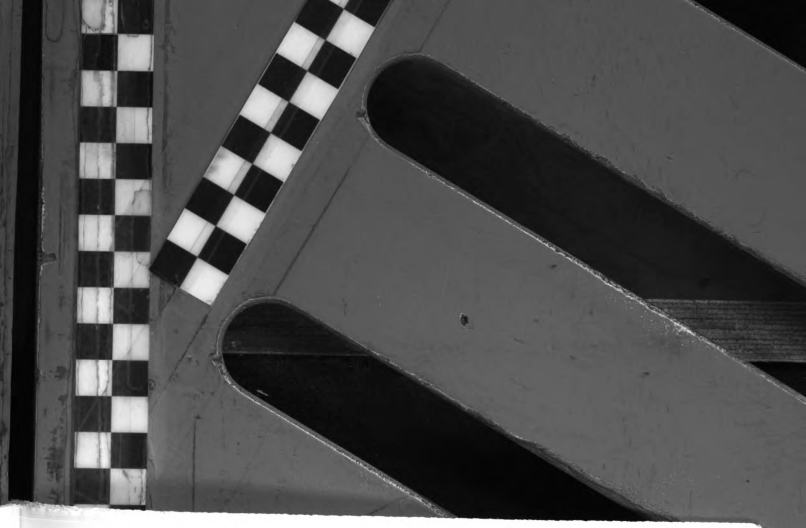


X — Visual Proximity of Legend Features (how close the symbols, descriptions, and title are to each other)



— Neither; they are equally important





Which is more important?

— **Text Spacing**

Urban
Forest
Commercial
Rural
Dunes

Urban
Forest
Commercial
Rural
Dunes

Urban
Forest
Commercial
Rural
Dunes

OR

— **Typeface**

Land Use/Cover
☐ Urban
☐ Forest
☐ Commercial
☐ Rural
☐ Dunes

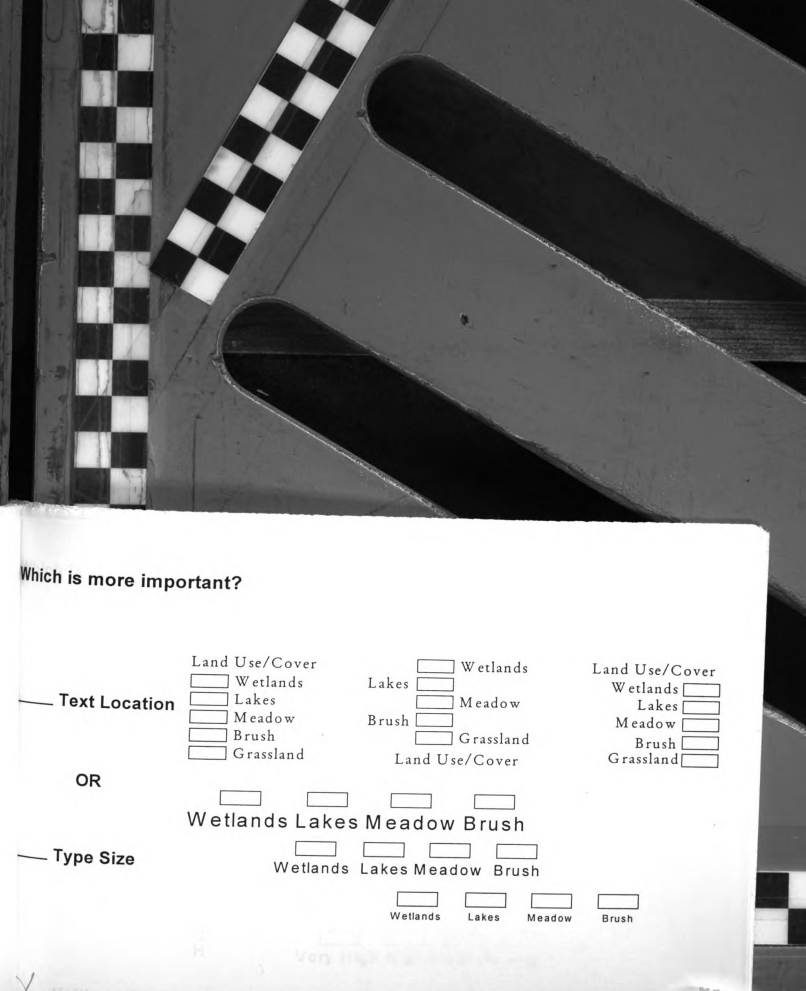
Land Use/Cover
☐ Urban
☐ Forest
☐ Commercial
☐ Rural
☐ Dunes

Land Use/Cover
☐ Urban
☐ Forest
☐ Commercial
☐ Rural
☐ Dunes

Land Use/Cover
☐ Urban
☐ Forest
☐ Commercial
☐ Rural
☐ Dunes

— **Neither; they are equally important**

Which is more important?



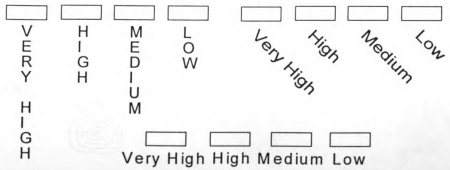
Which is more important?

Typeface

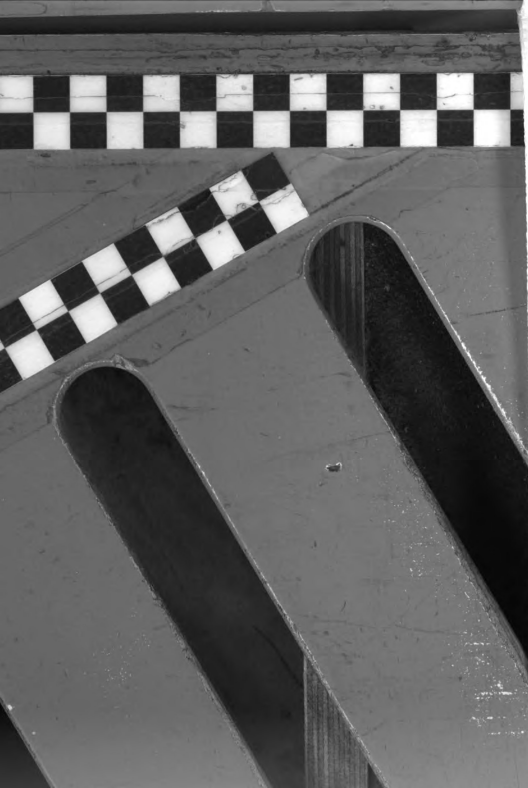
Crop Suitability	Crop Suitablity	Crop Suitability	*Crop Suitability*
Very High	Very High	Very High	*Very High*
High	High	High	*High*
Medium	Medium	Medium	*Medium*
Low	Low	Low	*Low*
Not Suitable	Not Suitable	Not Suitable	*Not Suitable*

OR

Text Angle



Neither; they are equally important



Which is more important?

__ Legend Shape

OR

X Arrangement of Legend Features

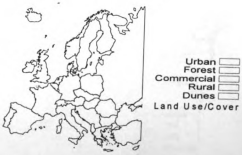
__ Neither; they are equally important

Which is more important?

— Visual Proximity of Legend Features (how close the symbols, descriptions, and title are to each other)

OR

— Arrangement of Legend Features



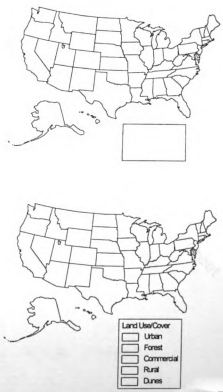
X — Neither; they are equally important

Which is more important?

— Legend Shape

OR

— Inclusion of a Legend Neatline



X — Neither; they are equally important

Which is more important?

Conciseness of (all) Legend Wording

Land Use/Cover
- ☐ Urban
- ☐ Forest
- ☐ Commercial
- ☐ Rural
- ☐ Dunes

Legend

Land Use/Cover
- ☐ Urban land use
- ☐ Forest land cover
- ☐ Commercial land use
- ☐ Rural land use
- ☐ Dunes land cover

OR

Text Angle

☐ URBAN ☐ DUNES ☐ RURAL ☐ FOREST

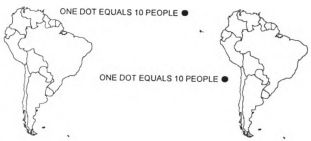
☐ Urban ☐ Dunes ☐ Rural ☐ Forest

☐ Urban ☐ Dunes ☐ Rural ☐ Forest

Neither; they are equally important

Which is more important?

___ **Legend Location**



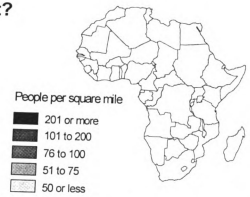
OR

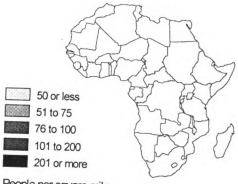
___ **Legend Shape**

X ___ **Neither; they are equally important**

Which is more important?

— Sequencing of Legend Features



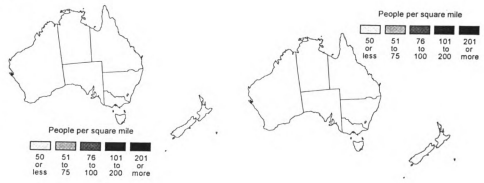


OR

— Arrangement of Legend Features

X — Neither; they are equally important

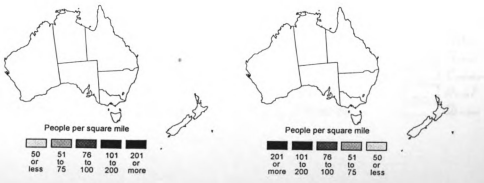
Which is more important?



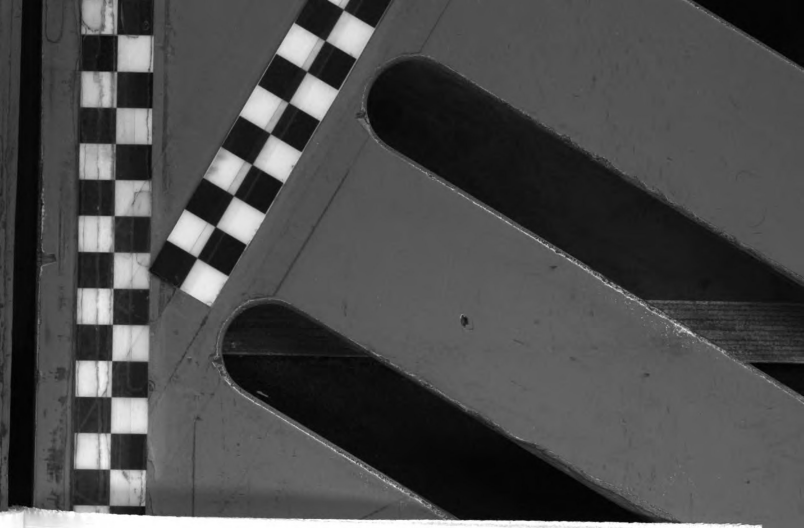
— Legend Location

OR

X Sequencing of Legend Features



— Neither; they are equally important



Which is more important?

UrbanDunesRuralForest

— **Type Size**

Urban Dunes Rural Forest

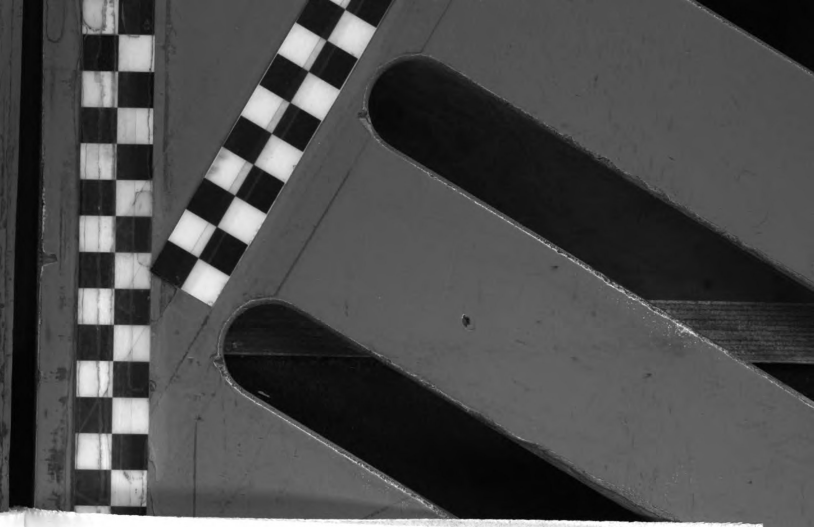
Urban Dunes Rural Forest

OR

— **Typeface**

Land Use/Cover	Land Use/Cover	Land Use/Cover	*Land Use/Cover*
Urban	Urban	Urban	*Urban*
Forest	Forest	Forest	*Forest*
Commercial	Commercial	Commercial	*Commercial*
Rural	Rural	Rural	*Rural*
Dunes	Dunes	Dunes	*Dunes*

— **Neither; they are equally important**



Which is more important?

X **Text Location**

Crop Suitablity
- ☐ Very High
- ☐ High
- ☐ Medium
- ☐ Low
- ☐ Not Suitable

High ☐ Very High
☐
☐ Medium
Low ☐
☐ Not Suitable
Crop Suitability

Crop Suitability
Very High ☐
High ☐
Medium ☐
Low ☐
Not Suitable ☐

OR

— **Type Style**

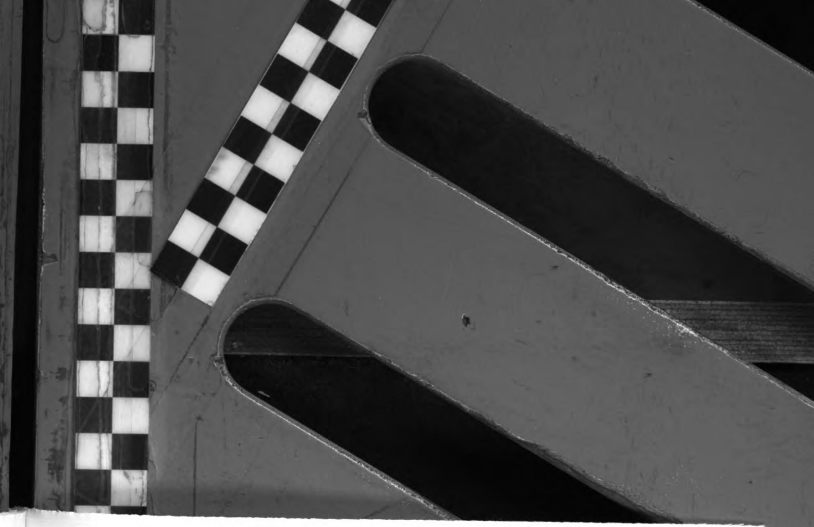
Very High
High
Medium
Low
Not Suitable

Very High
High
Medium
Low
Not Suitable

Very High
High
Medium
Low
Not Suitable

Very High
High
Medium
Low
Not Suitable

— **Neither; they are equally important**



Which is more important?

— **Type Style**

Very High	*Very High*	***Very High***	*Very High*
High	*High*	***High***	*High*
Medium	*Medium*	***Medium***	*Medium*
Low	*Low*	***Low***	*Low*
Not Suitable	*Not Suitable*	***Not Suitable***	*Not Suitable*

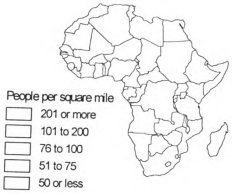
OR

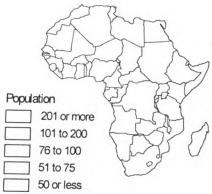
X **Type Size**

☐ Very High	☐ Very High	☐ Very High	☐ Very High
☐ High	☐ High	☐ High	☐ High
☐ Medium	☐ Medium	☐ Medium	☐ Medium
☐ Low	☐ Low	☐ Low	☐ Low

— **Neither; they are equally important**

Which is more important?



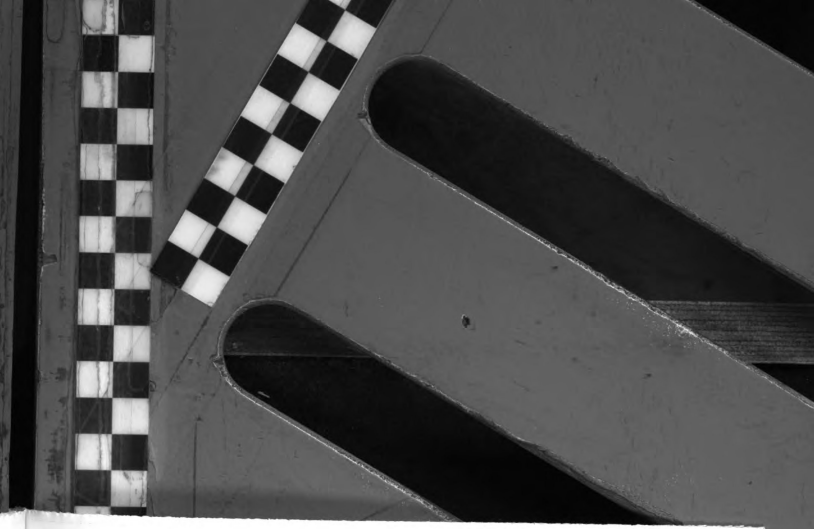


X **Clarity of (all) Legend Wording**

OR

Type Size

Neither; they are equally important



Which is more important?

— **Type Style**

Wetlands	*Wetlands*	***Wetlands***	*Wetlands*
Lakes	*Lakes*	***Lakes***	*Lakes*
Meadow	*Meadow*	***Meadow***	*Meadow*
Brush	*Brush*	***Brush***	*Brush*
Grassland	*Grassland*	***Grassland***	*Grassland*

OR

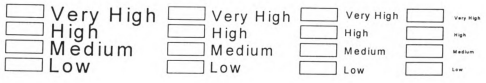
X **Typeface**

Land Use/Cover	Land Use/Cover	Land Use/Cover	*Land Use/Cover*
☐ Wetlands	☐ Wetlands	☐ Wetlands	☐ *Wetlands*
☐ Lakes	☐ Lakes	☐ Lakes	☐ *Lakes*
☐ Meadow	☐ Meadow	☐ Meadow	☐ *Meadow*
☐ Brush	☐ Brush	☐ Brush	☐ *Brush*
☐ Grassland	☐ Grassland	☐ Grassland	☐ *Grassland*

— **Neither; they are equally important**

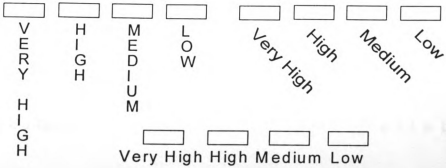
Which is more important?

— Type Size



OR

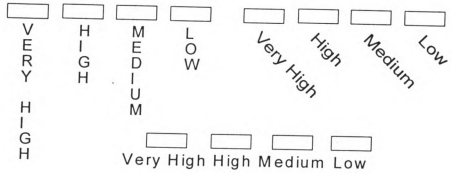
— Text Angle



X — Neither; they are equally important

Which is more important?

— **Text Angle**



OR

Very High High Medium Low

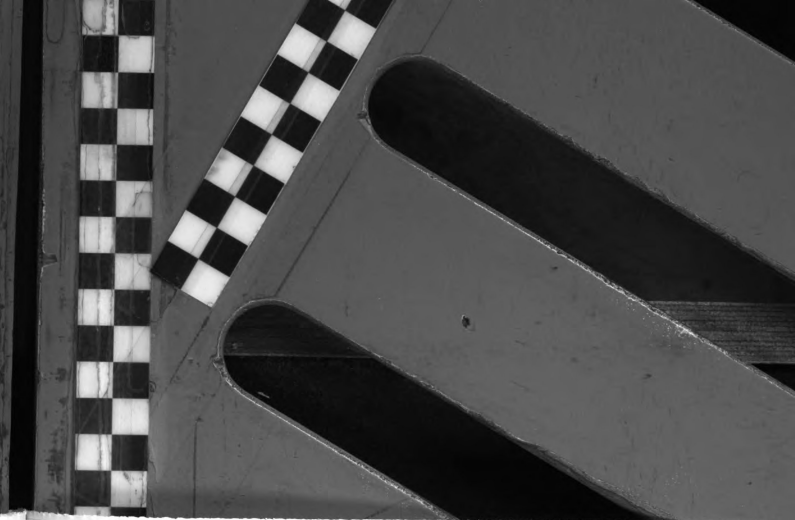
— **Text Spacing**

Very High
High
Medium
Low
Not Suitable

Very High
High
Medium
Low
Not Suitable

Very High
High
Medium
Low
Not Suitable

X — **Neither; they are equally important**



Which is more important?

— **Typeface**

Crop Suitability	Crop Suitablity	Crop Suitability	*Crop Suitability*
☐ Very High	☐ Very High	☐ Very High	☐ *Very High*
☐ High	☐ High	☐ High	☐ *High*
☐ Medium	☐ Medium	☐ Medium	☐ *Medium*
☐ Low	☐ Low	☐ Low	☐ *Low*
☐ Not Suitable	☐ Not Suitable	☐ Not Suitable	☐ *Not Suitable*

OR

X **Clarity of (all) Legend Wording**

Crop Suitability	
☐ Very High	☐ Very High
☐ High	☐ High
☐ Medium	☐ Medium
☐ Low	☐ Low
☐ Not Suitable	☐ Not Suitable

— **Neither; they are equally important**

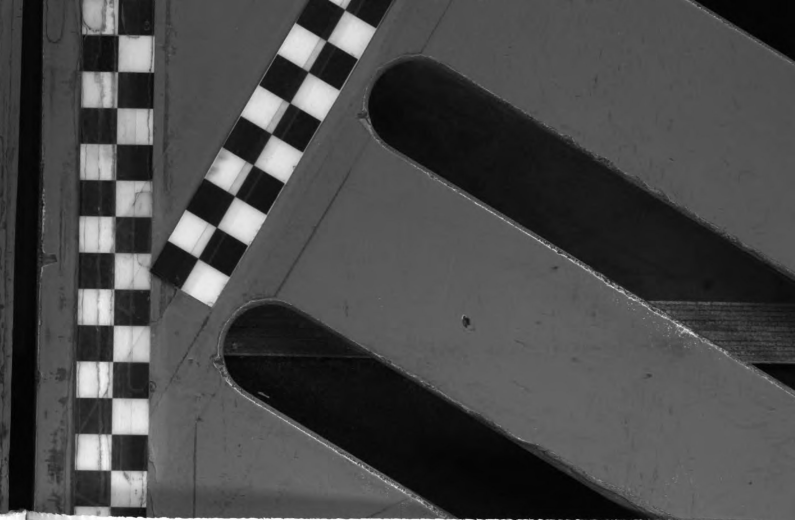
Which is more important?

— Legend Location

OR

✓ Visual Proximity of Legend Features (how close the symbols, descriptions, and title are to each other)

— Neither; they are equally important



Which is more important?

— **Typeface**

Land Use/Cover	Land Use/Cover	Land Use/Cover	*Land Use/Cover*
☐ Wetlands	☐ Wetlands	☐ Wetlands	☐ *Wetlands*
☐ Lakes	☐ Lakes	☐ Lakes	☐ *Lakes*
☐ Meadow	☐ Meadow	☐ Meadow	☐ *Meadow*
☐ Brush	☐ Brush	☐ Brush	☐ *Brush*
☐ Grassland	☐ Grassland	☐ Grassland	☐ *Grassland*

OR

X **Text Location**

Land Use/Cover		Land Use/Cover
☐ Wetlands	☐ Wetlands	Wetlands ☐
☐ Lakes	Lakes ☐	Lakes ☐
☐ Meadow	☐ Meadow	Meadow ☐
☐ Brush	Brush ☐	Brush ☐
☐ Grassland	☐ Grassland	Grassland ☐
	Land Use/Cover	

— **Neither; they are equally important**

Which is more important?

— **Type Size**

OR

— **Text Spacing**

Urban
Forest
Commercial
Rural
Dunes

Urban
Forest
Commercial
Rural
Dunes

Urban
Forest
Commercial
Rural
Dunes

— **Neither; they are equally important**

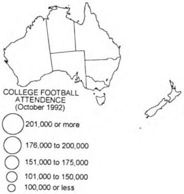
Which is more important?

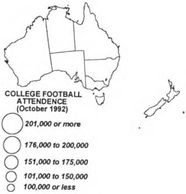
___ **Type Style**

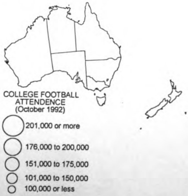
OR

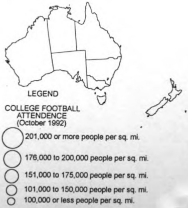
X **Conciseness of (all) Legend Wording**

___ **Neither; they are equally important**









R.M. Conley
M.A.
1994