principles and research on visual perception, "How Not to Lie with Data Graphics."

The book consists of seven chapters, each with intriguing titles that provide a glimpse of the contents and beckon the reader to look within. "Images and quantities" is concerned with how assessments of quantity are represented in visual expressions. While Tufte devotes much of this chapter to a discussion of a scientific visualization exercise in which a thunderstorm was animated in three dimensions, then redesigned by Tufte to illustrate design principles for 'pictures of verbs', many of the other examples in this chapter are drawn from the field of cartography.

"Visual and statistical thinking" focuses on displays of evidence for making decisions. Tufte uses two effective illustrations, one well-known to medical geographers (Dr. John Snow and the Broad Street pump) and the other a catastrophe that captured the popular imagination (the explosion of the space shuttle Challenger). Snow was an astute clinician who sur-

cartographic techniques

Creation of Publication Quality Shaded-Relief Maps with ArcView GIS

David Barnes
Cartographic Products Specialist
Environmental Systems Research Institute, Inc.
Redlands, California

Introduction

This article describes a project to design a quality map entirely within ArcView GIS. I will briefly outline the purpose and data used, then describe in greater detail the creation of the shaded-relief base

map, and conclude with some comments about proofing and printing the map.

Designing the Map

In order to produce a quality map, we first had to settle on the purpose of the map and the area it would cover, as well as the format of the final product. We decided to make a map of the Salt Lake City region showing the extent of urbanization and the locations of cities, towns, and major roads in the context of the surrounding terrain. As our final product we planned to publish a quality color map using four-color process printing.

Acquiring Data

The next step was gathering the data for the map. For this map we downloaded DEM files from the USGS website, and browsed various publicly available CD-ROM data sets including ESRI sample data. The DEM files are compressed with the GNU "gzip" utility and can be downloaded as compressed or uncompressed files. These files can also be uncompressed with gzip or WinZip, both of which can be acquired from the Internet.
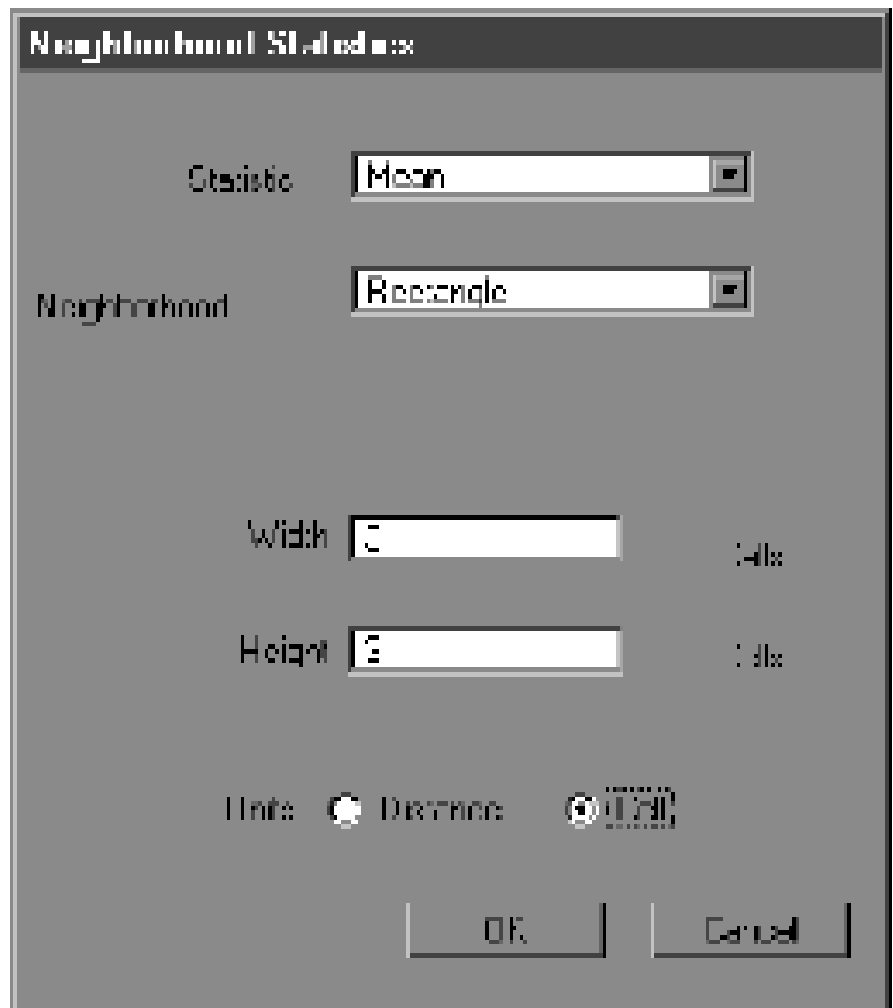

Figure 1. Neighborhood Statistics dialog from the Analysis menu of Spatial Analyst

Adding Vector Data

The vector data were added to the view as themes, and then symbolized and labeled. There are many options and tools available to the user including spline text, auto-labeling, highway labeling tools, and labels with leader lines. Using map queries the user can create subsets within themes and then label the features within the subsets accordingly. The symbol palette allows the user to adjust colors, symbols, line and fill styles, and fonts for labels and text as well as for most map elements.

Color and symbol choices were designed to enhance the appearance and functionality of the map. For example, we made city labels more prominent by using black text, and mountain labels less prominent by using gray text. These choices establish a hierarchy of information on the map.

Creating the Hill-Shaded Base-map

The Spatial Analyst extension has to be loaded when you work with

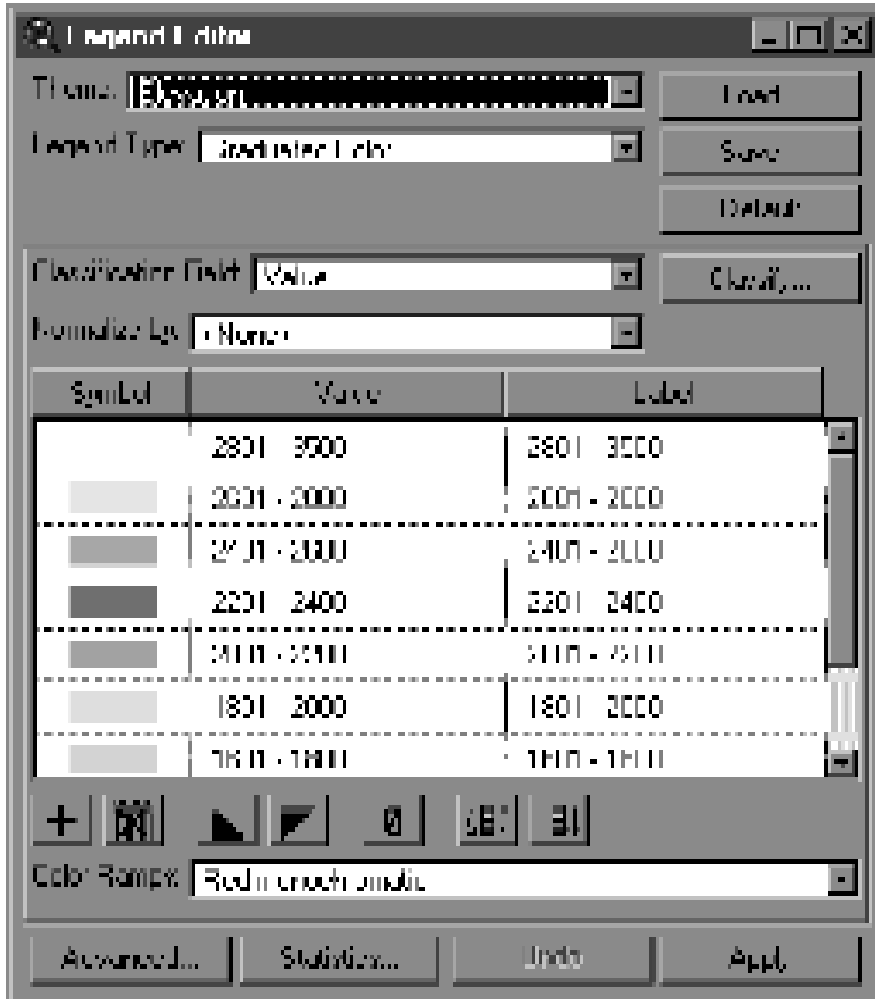*Figure 2. Combined hill-shaded image (Map calculation 1)*

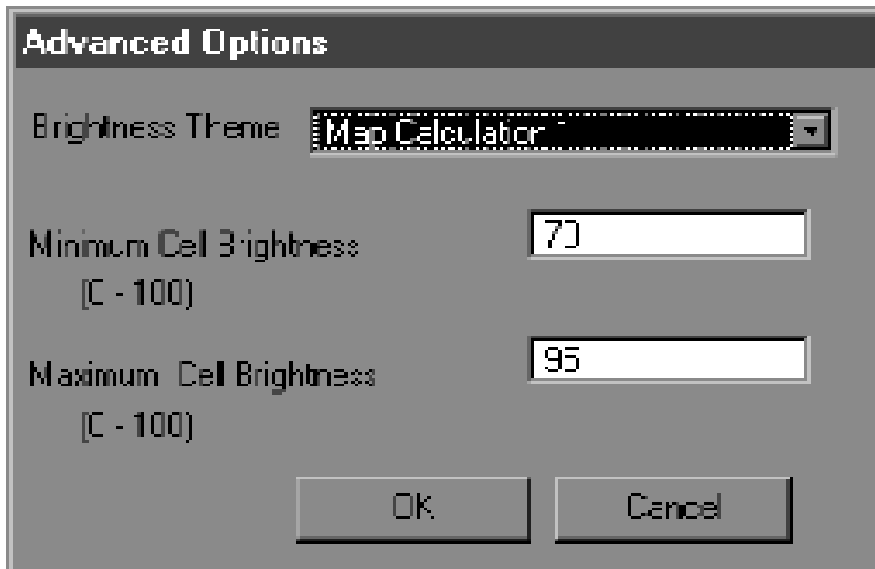*Figure 3. ArcView's raster theme legend editor*

Figure 4. Advanced options accessed from the legend editor

grids in ArcView. It is also important to use the data manager under the File menu if you want to copy, rename, or delete grids. This manager will take care of the related files that ArcView uses when handling grids.

To show the DEM files in the same coordinate space as our vector themes, we had to convert the DEM files from arc seconds to decimal degrees. This was done using a sample script called DEMShift that imports and converts the files. This script is available on ESRI's sample scripts website.

Once the DEM files were converted, we created a smoothed version by using neighborhood statistics under the analysis menu and choosing "mean" at the statistics option (fig. 1). This helps smooth out some of the irregularities and other artifacts introduced by DEM data and sampling methods.

Next we created two separate hill-shaded themes with different azimuths from the smoothed DEM by using another sample script called DEMShade. We used azimuths of 315 and 270 and an angle of 60 degrees to produce the hill-shaded themes for the Salt Lake City map. These two themes were then combined by the use of a map calculation to reduce deep shadows and the effect of cast shadows (fig. 2).

We categorized the original DEM theme by elevation to create layers for hypsometric tints. Under the advanced option in the legend editor we set the brightness theme to the map calculation of the two hill-shaded themes (figs. 3 and 4). Minimum and maximum cell brightness levels were set at 70 and 95, respectively, to achieve the desired effect of subdued background colors.

The brightness option requires grid themes for the brightness theme and the current theme. The brightness theme is used to alter the brightness of the colors in the

current theme. Any kind of grid data can be used. Using a shaded relief theme adds the appearance of three-dimensional terrain to other kinds of thematic information.

It is important to keep in mind the purpose of the map elements when making color choices in order to enhance the appearance and legibility of the map. In our case the color hill-shaded image is the basemap on top of which all of the vector information is placed.

Color Proofing

Once we had created an esthetic and legible map on the layout, we began the iterative process of color proofing. This was necessary because the RGB colors of the computer monitor do not translate directly to the CMYK colors used in printing.

We made preliminary color proofs by printing directly from ArcView to a desktop color printer. As color output from desktop printers can vary considerably due to a number of factors, this was only a first step. Once we felt

Figure 5. Elevation theme with hill-shaded image as brightness theme

reasonably satisfied with the results, we exported the layout to a PostScript (New) file. Our graphics department printed this file to produce a more exact proof.

Imagesetter bureaus, commercial printers, or graphics departments can use color profiles to simulate the inks and papers that will be used to publish the final map. These profiles are used to process PostScript files and produce qual-

ity hard-copy color proofs. The proofs are useful as a guide for adjusting colors before negatives are made for printing. It may be necessary to repeat this process to achieve the desired results.

Printing the Map

Many factors can influence the appearance of the final printed product including the quality and color

of the paper, the inks and color model used, as well as the design of the map. In order to end up with the best printed map, it is helpful to work with the imagesetter and printer throughout the process.

Further Information

The USGS home page is located at http://edcwww.cr.usgs.gov

For more information about 1:250,000 scale DEM files see the USGS web site at http://edcftp. cr.usgs.gov/pub/data and navigate to the DEM/270/00README file.

Sample scripts from ESRI are available at http://andes.esri.com/ arcscripts/scripts.cfm

The gzip program is available via anonymous FTP at the following sites:
    For UNIX: prep.ai.mit.edu:/ pub/gnu
    For MAC: mac.archive.umich. edu/mac/util/compression/ macgziop0.cpt.hqx
    For MS-DOS: prep.ai.mit.edu:/ pub/gnu/gzip-1.2.4.tar

WinZip can be downloaded from

Figure 6. Section of final map (published map is full color)