



A Decision Support System for Map Projections of Small Scale Data

Scientific Investigations Report 2004-5297

U.S. Department of the Interior
U.S. Geological Survey

A Decision Support System for Map Projections of Small Scale Data

Michael P. Finn, E. Lynn Usery, Stephan T. Posch¹, and Jeong Chang Seong

U.S. Geological Survey
Rolla, Missouri

Northern Michigan University
Marquette, Michigan

Phone: 573-308-3931; Fax: 573-308-3652

mfinn@usgs.gov

KEY WORDS Decision Support, Transformation, Map Projection, Cartography, GIS

ABSTRACT

The use of commercial geographic information system software to process large raster datasets of terrain elevation, population, land cover, vegetation, soils, temperature, and rainfall requires both projection from spherical coordinates to plane coordinate systems and transformation from one plane system to another. Decision support systems deliver information resulting in knowledge that assists in policies, priorities, or processes. This paper presents an approach to handling the problems of raster dataset projection and transformation through the development of a Web-enabled decision support system to aid users of transformation processes with the selection of appropriate map projections based on data type, areal extent, location, and preservation properties.

INTRODUCTION

Many models of global natural and anthropogenic change depend on data formatted as raster cells (or matrices of pixel values, or grid cells). Research has shown that errors from mathematical projection are of such magnitude that they may jeopardize model results (Steinwand and others 1995; Tobler and others 1995; Usery and others 2003a). There is little guidance for users of Geographic Information System (GIS) and other software packages that offer the capability to project these regional and global raster datasets (Usery *et al.*, 2003b). Since numerous projections exist within each software package (each with its own set of parameters), and since there is an ability to customize each projection, many GIS users may not have the knowledge to select a projection appropriate to the area of the world, data type, or particular problem being examined. Most may not know if there are inherent errors in commercial software packages for projection transformation, if an error

¹ Now with Dynetics, Inc., Huntsville, AL.

has occurred, or if their model is generating erroneous results because of the inaccurate transformation of data.

A Decision Support System (DSS) delivers information that can assist in policies, priorities, or processes. The challenge in conducting scientific research is ensuring that results are used to enhance societal decision making (Lee and Birk, 2003). DSSs can vary from a more pure scientific Earth-systems type to a more community-participation type, but many DSSs contain a strong geospatial component. Armstrong and others (1986) refer to Spatial DSSs (SDSS) as programs that assist decision makers in evaluating alternative solutions to spatial problems through the integration of software such as GIS.

The U.S. Bureau of Reclamation's Agricultural Water Resources Decision Support - Evapotranspiration Toolbox system is a good example of a DSS with a strong spatial component. It enables operations managers to make better decisions. The system couples both a GIS land use layer and evaporation estimates for each raster cell of a project area to an environmental model (U.S. Bureau of Reclamation, 2004). Other good examples of DSSs containing strong spatial components are participatory GISs that utilize GIS data to allow groups to deliberate criteria that describes problems at various scales (Jankowski and Nyerges, 2001).

More than a decade ago, some work on DSS-like tools specifically for map projections was investigated by Nyerges and Jankowski (1989) and Smith and Snyder (1989). Nyerges and Jankowski presented a specification of a knowledge base used in an expert system for map projection selection and focused on what knowledge should exist rather than how it should be represented. Smith and Snyder developed a computer software package called the Expert Map Projection Selection System, that uses object-oriented structures and artificial-intelligence programming methods. Their system is for use in designing thematic maps and other customized map products generally constructed within a GIS environment.

DISCUSSION

DESIGN & IMPLEMENTATION

We designed a DSS for map projections of small-scale datasets. The design and implementation is a Web-enabled DSS for map projection selection. Usery and others (2002) demonstrated an initial development of a DSS to guide users in the selection of an appropriate map projection. We have expanded this system for selecting an optimum projection considering various factors, such as pixel size, areal extent, number of categories, spatial pattern of categories, resampling methods, and error correction methods, although not all features currently are implemented (U.S. Geological Survey, 2004).

INTERACTIVE INTERFACE

The DSS poses questions interactively. The choices selected by the user determine the path in a decision tree to a solution. The design includes an interactive interface to solicit information from the user and guides him to the selection of an appropriate projection (or alternate projections) based on his responses (figure 1). Although the interface

is rather intuitive and straightforward, Posch and Finn (2003) provide a user's guide for assistance.

The screenshot shows a Mozilla browser window titled "Decision Support System for Map Projections of Small Scale Data - Mozilla". The address bar displays the URL "http://isis.er.usgs.gov/research/DSSMain/DSSApplet.html". The browser's menu bar includes File, Edit, View, Go, Bookmarks, Tools, Window, and Help. Below the menu bar are buttons for Back, Forward, Reload, and Stop. The browser's status bar shows "Home", "Bookmarks", "The Mozilla Organiza...", and "Latest Builds".

The main content area features the USGS logo and the title "Decision Support System for Map Projections of Small Scale Data". Below the title are four dropdown menus:

- Select Type of Area to Map
- Select What to Preserve
- Select Type of Data
- Select Type of Raster Data

Below the dropdown menus is a "Submit" button. At the bottom of the form, there is a text instruction: "Click on 'Submit' after making your choices."

Figure 1. Interactive Interface for DSS.

AERIAL EXTENT AND CHARACTERISTIC TO PRESERVE

In recommending a map projection for small-scale regional data, the system considers geographic location as well as directional extent. The primary input to the DSS is the area to map. This is posed as a choice among global, continental, or regional area of coverage (figure 2). The next input is the preservation of shape, area, or simply a compromise. This drives the decision to a conformal or equal-area projection, or a compromise between the two (figure 3). We included a compromise selection such as the Robinson projection, which is neither conformal nor equal area, yet has nice visual appeal because of its utility for data display instead of its utility for analyses.

Decision Support System for Map Projections of Small Scale Data - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Print W

Address <http://isis.er.usgs.gov/research/DSSMain/DSSApplet.html>

USGS

Decision Support System for Map Projections of Small Scale Data

Global

Select Type of Area to Map

Global
Continental
Regional

Select Type of Raster Data

Submit

Click on "Submit" after making your choices.

Figure 2. Drop Down Menu for Type of Area.

Decision Support System for Map Projections of Small Scale Data - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Print W

Address <http://isis.er.usgs.gov/research/DSSMain/DSSApplet.html>

USGS

Decision Support System for Map Projections of Small Scale Data

Global

Select What to Preserve

Select What to Preserve

Area
Shape
Compromise

Select Type of Raster Data

Submit

Click on "Submit" after making your choices.

Figure 3. Drop Down Menu for What to Preserve.

The system handles continents based on their geographic location and directional extent. For example, the DSS handles continents with greater longitudinal range (Asia, Australia, and Europe) differently than those with greater latitudinal range (Africa, North America, South America) or

polar location (Antarctica). It recommends a projection in real time factoring in the area of the continent and the geometric characteristic to preserve. For regional cases, which generally are smaller (larger-scale mapping) than a continent, the DSS allows the user to interactively define an area of interest, while also allowing the choice of conformal or equal-area projection. Like the continental selection page, it recommends a projection in real time. The interface for regional area selection is shown in figure 4.

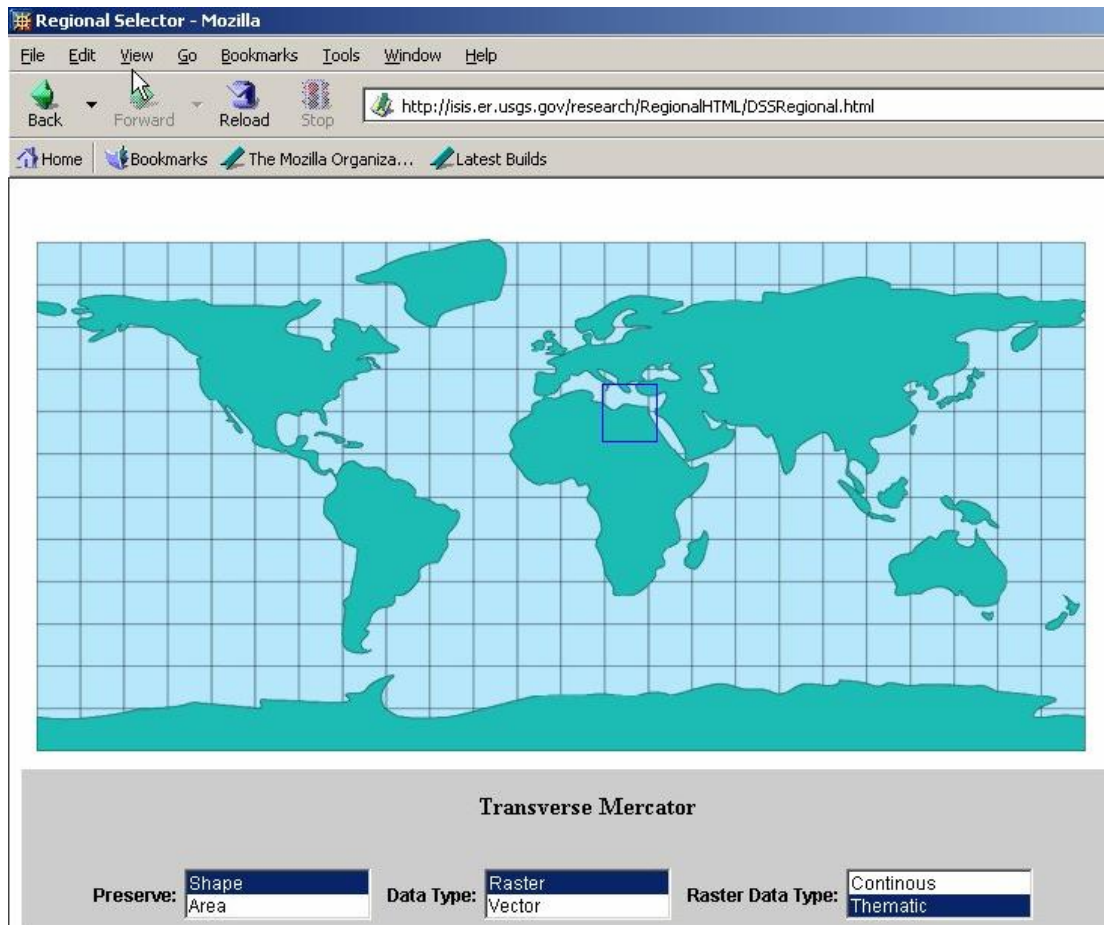


Figure 4. Regional Area Selection Interface.

DECISION TREE

The DSS relies on conventional theory for the selection of projections (Maling, 1973; Voxland, 1978; Snyder, 1987; Snyder and Voxland, 1989), and the design utilizes a specific decision tree that handles regional and global raster projection (figure 5 a-d). We supplemented these selection criteria with results from research performed by Usery and others (2003a, 2003b).

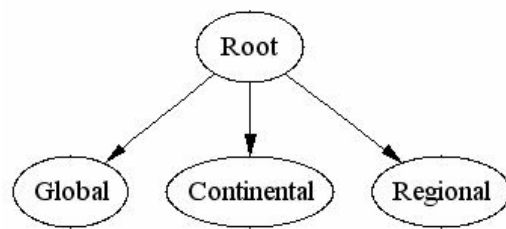


Figure 5a. Decision Tree; Level 0, Root.

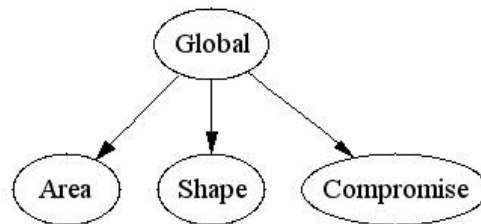


Figure 5b. Decision Tree; Level 1, Global.

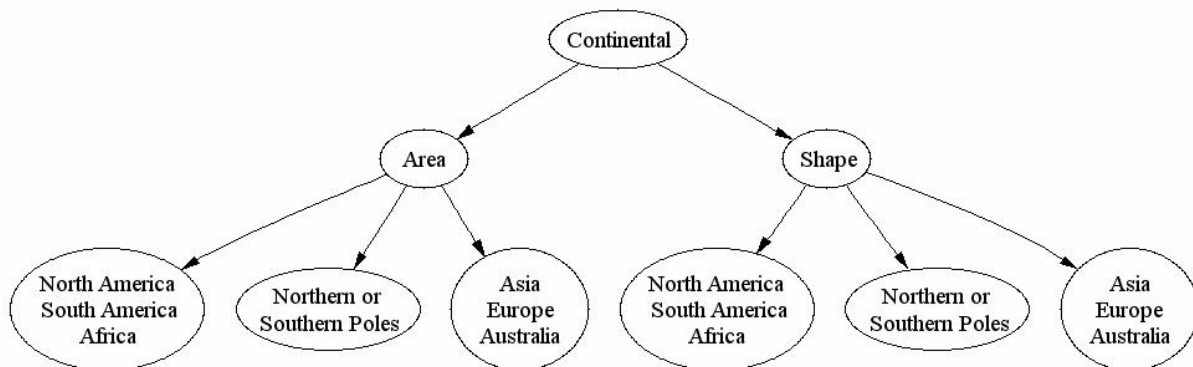


Figure 5c. Decision Tree; Level 1, Continental.

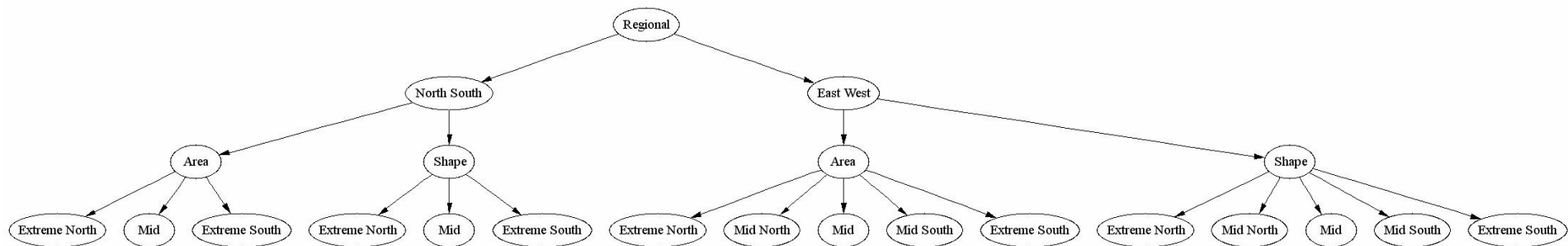


Figure 5d. Decision Tree; Level 1, Regional.

FURTHER REFINEMENTS

Refinements planned for the current prototype DSS include other user choices for raster versus vector data model, and thematic versus continuous data type. The prototype currently is in testing phase. The objective is to develop a DSS that will include an integrated, Web-based map projections tutorial, somewhat similar to the design described by Jankowski and Nyerges (1989) and with an eye towards using the agent-based framework for integrating spatial data into an SDSS developed by Sengupta and Bennett (2003). Further implementation of the DSS will expand the user input to include data type, volume or resolution, and other appropriate options. In addition, this DSS will be refined to include recommendations of appropriate projection parameters to coincide with the suggested projection, such as the standard parallels or central meridian.

CONCLUSIONS AND RECOMMENDATIONS

This study has implemented a DSS to help users select an appropriate projection based on factors that commonly cause problems, including location of regional area, extent direction, characteristics to be preserved, and data type. Future work will improve and expand the DSS to include a complete tutorial, and examine the capabilities for displaying raster data of varying resolutions and recommending appropriate projection parameters.

REFERENCES

- Armstrong, M.P., Densham, P.J., and Rushton, G., 1986, Architecture for a microcomputer Based Spatial Decision Support System, in Proceedings of the 2nd International Symposium of Spatial Data Handling, Williamsville: International Geographical Union, p. 120 - 131.
- Nyerges, T., and Jankowski, P., 1989. A Knowledge Base for Map Projection Selection, in *The American Cartographer*, 16(1), p. 29-38.
- Jankowski, P. and Nyerges, T., 1989. Design considerations for MaPKBS-Map Projection Knowledge-Based System. *The American Cartographer*, 16(2), pp. 85-95.
- Jankowski, P. and Nyerges, T., 2001. *Geographic Information Systems for Group Decision Making: Toward a participatory, geographic information science*. Taylor & Francis, London.
- Lee, Tsengdar and Birk, Ronald J., 2003. Connecting Earth Observation to Decision Making. *EOM: Earth Observation Magazine*, 12(2), pp. 2-4. Professional Surveyors Publishing Company, Inc., Fredrick, MD.
- Maling, D.H., 1973. *Coordinate Systems and Map Projections*. London: George Philip and Son Ltd.

- Posch, Stephan T., and Michael P. Finn, 2003. *User's Guide to the Decision Support System for Map Projections*. Internet at: http://mcmcweb.er.usgs.gov/carto_research/DSS_User_Guide.pdf. Accessed 1 November 2004.
- Sengupta, Raja R. and David A. Bennett, 2003. Agent-based modeling environment for spatial decision support, *International Journal of Geographical Information Science*, 17(2), pp 157 - 180.
- Smith, Doyle G. and John P. Snyder, 1989. Expert Map Projection Selection System. In *United States Geological Survey Yearbook Fiscal Year 1988*. U.S. Government Printing Office. Pp. 14 - 15.
- Snyder, John P., 1987. *Map Projections - A Working Manual*. U.S. Geological Survey Professional Paper 1395. Washington, DC.
- Snyder, J.P. and P.M Voxland, 1989. *An Album of Map Projections*. U.S. Geological Survey Professional Paper 1453. Washington, DC.
- Steinwand, D. R., Hutchinson, J. A., and Snyder, J. P., 1995, Map projections for global and continental data sets and an analysis of pixel distortion caused by reprojection. *Photogrammetric Engineering and Remote Sensing*, 61(12), 1487-1497.
- Tobler, Waldo, Uwe Deichmann, Jon Gottsegen, and Kelly Maloy, 1995. *The Global Demography Project*. Technical Report TR-95-6, National Center for Geographic Information and Analysis, University of California, Santa Barbara. 69 p.
- U.S. Bureau of Reclamation, 2004. *ET Toolbox*. Internet at: <http://www.usbr.gov/pmts/rivers/awards/ettoolbox.html>. Accessed 5 January 2004.
- U.S. Geological Survey, 2004. *Decision Support System for Map Projections of Small Scale Data*. Internet at: <http://helios.er.usgs.gov/research/DSSMain/DSSApplet.html>. Accessed 5 January 2004.
- Usery, E. Lynn, Michael P. Finn, J.D. Cox, Tom Beard, Shelia Ruhl, and Morgan Bearden, 2003a. Projecting Global Datasets to Achieve Equal Areas, *Cartography and Geographic Information Science*, 30(1), pp. 69-79.
- Usery, E. Lynn, Michael P. Finn, Douglas Scheidt, 2002. Projecting Global Raster Databases, *Proceedings Symposium on Geospatial Theory, Processing and Applications*, Ottawa, Canada. International Society for Photogrammetry and Remote Sensing.
- Usery, E. Lynn, Jeong Chang Seong, Daniel R. Steinwand, and Michael P. Finn, 2003b. Accurate Projection Of Small-Scale Raster Datasets, *Proceedings 21st International Cartographic Conference*, Durban, South Africa. International Cartographic Association.

Voxland, Philip M., 1978. *World Mapping and Projection Program: Reference Manual*. Regents of the University of Minnesota. Minneapolis, MN.