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Pretty maps: evaluating GIS adoption of cartographic design standards and best practices in professional publications

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PRETTY MAPS:
EVALUATING GIS ADOPTION OF CARTOGRAPHIC DESIGN STANDARDS AND BEST PRACTICES IN PROFESSIONAL PUBLICATIONS

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ABSTRACT

PRETTY MAPS: EVALUATING GIS ADOPTION OF CARTOGRAPHIC DESIGN STANDARDS AND BEST PRACTICES IN PROFESSIONAL PUBLICATIONS

by David Medeiros

The nature of GIS maps, as tools designed for visual communication, puts them in the realm of art that is in many ways unique among scientific tools. As a visual form of communication, maps are responsive to methods of visual design, affecting the map's appeal and function. Through cartography, a well established body of standards and best-practices exists to help GIS users avoid common design errors and create effective and meaningful maps that support their work. This research examines the adoption rate of those standards amongst professionals using GIS software for creating maps for journal publications. A selection of 80 GIS-produced maps from the AAG's *Professional Geographer* were examined and compared to a uniform set of cartographic standards to look for trends in the adoption rates of map design standards amongst GIS map makers. Maps were rated by the author on their use of cartographic standards based on map content and purpose as opposed to their aesthetic quality. The data show trends in GIS cartographic design use that closely follow the inclusion of default values in common GIS software. The implication is that GIS professionals making maps are typically not applying cartographic standards on their own, but mostly following the standards set up in their software of choice. This suggests that there is still significant work to be done in teaching the value of cartographic principles to GIS students and practitioners.

ACKNOWLEDGEMENTS

It is difficult to see forward in time and predict well enough the direction of our lives amidst turmoil to know how our actions will affect our trajectory. I could not have imagined how beginning my masters (an act of career desperation in some way) would have led me to where I ended up. I could also not have imagined how difficult success would make finishing the work I started.

I am greatly indebted to Dr. Kathryn Davis for reaching out to pull me back towards my unfinished work at SJSU just as I was beginning to settle into the idea that it wasn't worth returning to. To Dr. Kerry Rohrmeier for taking an active role in helping guide my research and creating a clearer path forward. To my colleagues at Stanford University, Stace Maples and Julie Sweetkind-Singer who were willing to give me the space and encouragement I needed at work to accomplish this task. And to my family, my wife Rebecca and my two sons, Leonardo and Samson, for whom I did this in the first place. Without them I would have had no reason to try.

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TABLE OF CONTENTS

LIST OF FIGURES

Introduction

Geographic information systems (GIS) and cartography share maps as a means of communicating spatial information, but each method emphasizes different aspects of map use and creation. While there is some disagreement over the exact nature of the GIS/ cartography hierarchy (Lee, 1995), there is no question that both make significant use of maps for communicating spatial information. GIS is concerned with a broad spectrum of functions around spatial data, including capture, storage, exploration, manipulation and display (URISA.org). Cartography, by comparison, is chiefly concerned with the visual representation of spatial data as well as the technical aspects of map creation. For map production, GIS is often synonymous with poorly designed maps, especially with regard to map layout, color use, and overall legibility (Lee, 1995). Cartographic design in GIS is sometimes equated with a loss of data fidelity through design methods that often simplify, generalize, or aggregate otherwise critical spatial information.

Cartography's body of knowledge and best practices set the "ideal" for map design. While cartographic design today is arguably less rigid than in the past (Wood, 2003), there is an expectation that properly applied cartographic design standards will usually produce a better functioning and better looking map than would otherwise be the case. The reality of what can be found in GIS map production does not appear to live up to that ideal. Despite easy access to design resources and information specifically created for GIS users, and the much improved design capabilities of modern computers, it is still relatively easy to quickly gather together a line up of poorly designed GIS maps online.

Figure 1 is a United States Geological Survey (USGS) map of lead distribution in soils across the U.S. The rainbow color ramp used in the USGS map is common in scientific cartography, and one that although catchy, can be difficult to read for subtle value changes (Moreland, 2009). The USGS map also exhibits a data scale issue where by the data detail used is overly detailed for the scale at which the map is produced. Excess detail around the edges of natural features like rivers and coastlines gives the map a raw and unfinished appearance (Krygier and Wood, 2005).

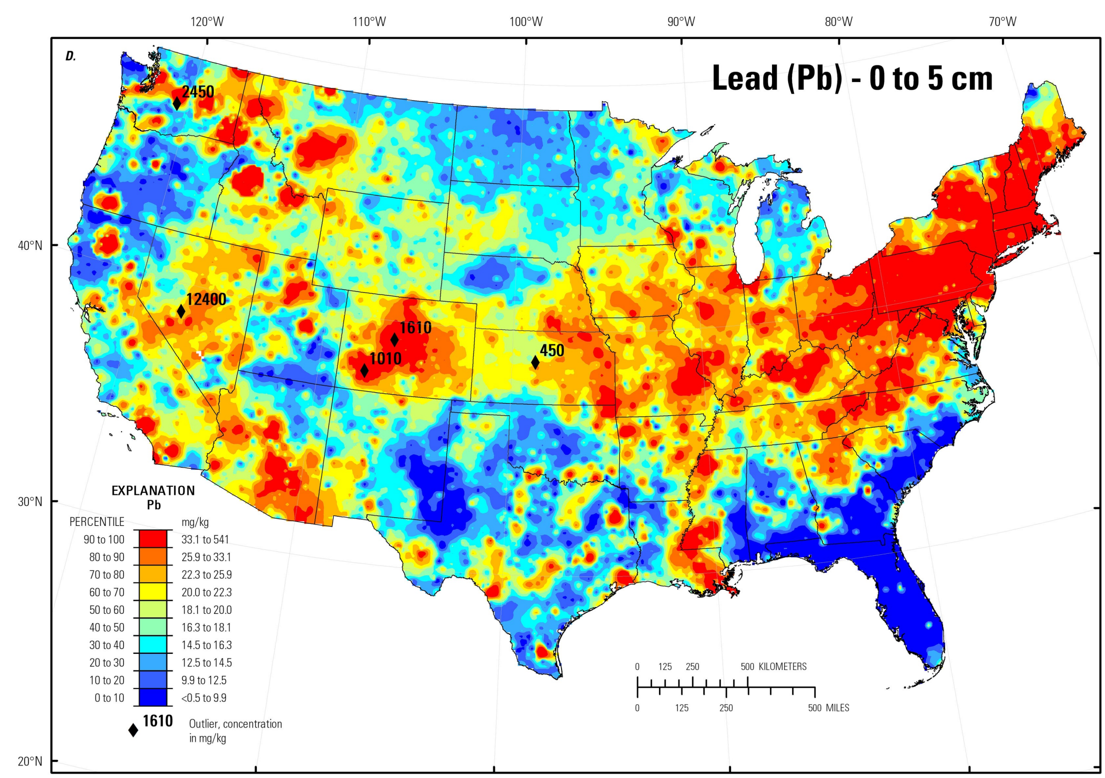


Figure 1. Distribution of lead in soils, USGS 2014. Map exhibits overuse of intense rainbow colors common in scientific mapping. Utilizes an overly detailed national boundary file for published scale. Reprinted under public domain from the USGS.

Figure 2 is a National Renewable Energy Laboratory (NREL) map of solid biomass resources by county in the U.S. Amounts of biomass given are linear from less than 50 thousand tonnes/year to more than 500. Typical map symbology for linear values is a color ramp of a single value increasing from light to dark saturation. The single color reinforces the idea that the values being mapped are for the same feature or phenomenon type, the saturation change reflects the value changes of the features. The NREL map, however, uses changes in color hue to reflect changes in value, where different color hues typically reflect different feature types. Because different colors do not have inherent values, there is no way to make a value comparison by directly reading the map; the map user must consult the legend to decipher the mapped symbols.

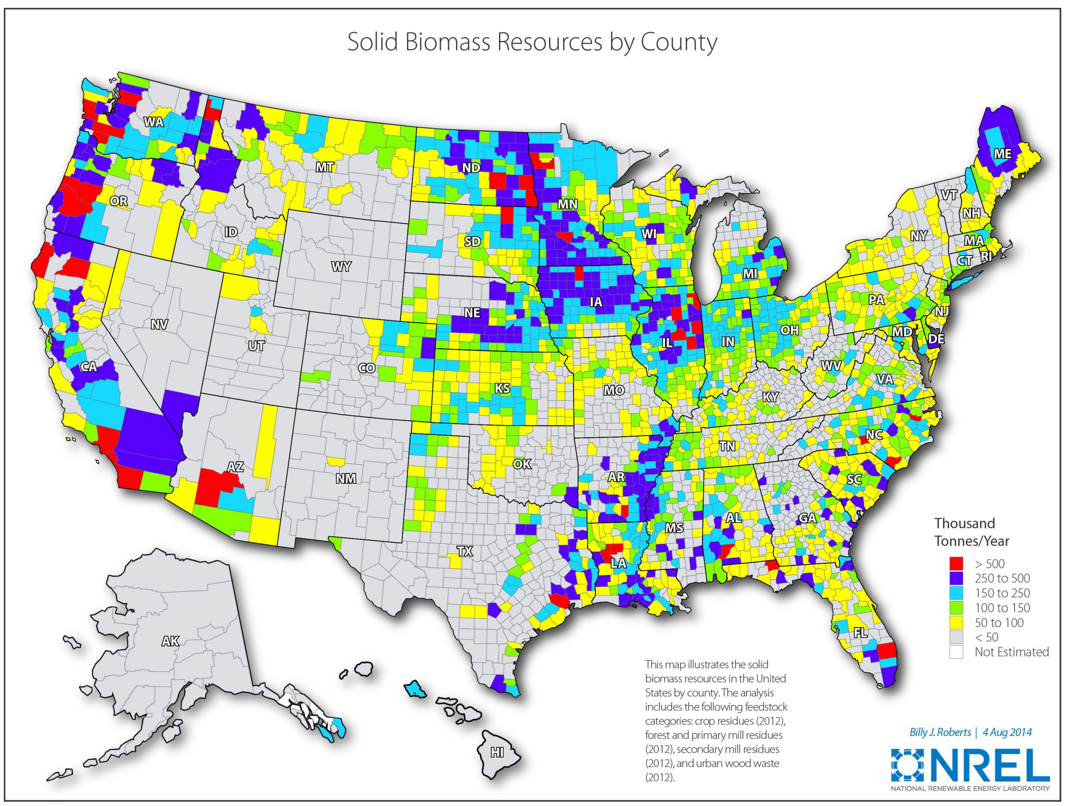


Figure 2. Solid Biomass Resources by County, NREL 2014. Incorrect visual variable (hue instead of saturation) for quantitative data. Reprinted under public domain from NREL.

Contributing factors for lack of design acuity in GIS can range from limited design capabilities of GIS software (Weibel & Buttonfield, 1992) and GIS degree programs that lack a design emphasis (Weibel & Buttonfield, 1992; Fisher, 1998) to GIS professionals and educators who view design as a merely aesthetic consideration (Lee, 1995), irrelevant to the data driven purpose of a GIS map. What is unknown are the effects of those factors in GIS map production, not in terms of a map's aesthetic quality, but in proportion to GIS-produced maps that follow the "ideal" set out in cartographic design. How large is the gap, if any, between the cartographic ideal and GIS reality? What specific areas of map design are the most or least adopted by GIS professionals?

While maps of all kinds are routinely judged on their aesthetic merits as part of student and professional map competitions the world over, no meaningful studies could be found by this author that analyze the adoption rate of cartographic design principles themselves. This research aims to answer these questions by analyzing GIS publication maps and tallying the proportion of maps that exhibit some use of basic cartographic design standards against those that do not. This is not an evaluation of the map's visual quality or aesthetic appeal, but rather a measure of the degree to which these maps employ cartographic design techniques. Any intentional use of a design principle is assumed to be an indication of design awareness, regardless of the outcome in quality.

How Did We Get Here

It is difficult to argue that GIS tools themselves were not the main limiting factor in design quality at the onset of GIS map making. The capabilities of desktop computers in the earliest days of GIS would have made mimicking production cartography techniques difficult, if not impossible. But as computer graphic design performance progressed over time, GIS software tools for design lagged behind. It was only in 2007 that Esri, developer of ArcGIS Desktop and other leading GIS applications, introduced cartographic representation tools specifically geared towards dealing with GIS design issues within their software (Esri, 2007). In combination with the lack of design function in many GIS tools (and possibly related to it), there has historically been a lack of awareness amongst GIS practitioners regarding the role of design in map making. There is also an issue of data and technology bias in GIS, what Harley (1989) describes as the "culture of technics." GIS map makers have whole heartedly embraced the precision and implied accuracy of computer-based mapping and often regard cartographic refinement as a dilution of data accuracy. There are seemingly two types of maps in GIS, maps of data and pretty maps, pretty being shorthand for pretty but dumb.

In his survey of map design among professional GIS users, Lee (1995) found that when asked what they could do to improve the look of their maps, 35% of his respondents indicated their maps could not be improved. When asked if design quality was of any importance to GIS map output, only 35% said that it was of any importance with just 15% ranking design quality as one of the top three considerations. Significant emphasis was placed on locational and temporal accuracy as well as speed of production. This reinforces the anecdotal perception of everyday GIS map makers as having little to no interest or intersection with design in map making.

As the growth of GIS for map production has expanded over the past few decades, there has been a corresponding call for more awareness of design training in GIS education (Fisher, 1998; Weibel & Buttonfield, 1992; Lee, 1995). While it is difficult to assess the changes in GIS curriculum itself, it is fairly easy to see that today there are far more resources directly aimed at GIS map design knowledge than ever before. There is no shortage of GIS-specific design textbooks (*Designing Better Maps; GIS Cartography: A Guide to Effective Map Design; Making Maps: A Visual Guide to Map Design for GIS*), web applications (ColorBrewer, TypeBrewer, ProjectionsWizard.org), or websites, blog posts, and essays (CartoTalk, Cartastrophe, Map Making Advice for Students, Cartographic Design and Aesthetics FAQ) available to help raise the level of awareness and capability of anyone producing maps with GIS today. Despite the availability of these and many other resources it is possible to quickly compile a set of contemporary GIS publication maps from online that ignore many of the most fundamental map design standards.

Why Should Cartography Inform GIS Map Making

Adoption of GIS as an analysis and map production tool does not seem to have been slowed by poorly designed maps, begging the question "why does it matter that GIS maps be graphically well designed at all?" To understand how cartography intersects with GIS map making, it may be useful to define some common terms as they are used in this research. *Cartography* is the study or practice of making maps, combining science, aesthetics, and technique (Merriam Webster Dictionary). A *geographic information* *system* is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data (URISA.org). While GIS mapmaking is obviously cartographic, this research treats the field of GIS as distinct from the field of cartography in terms of the development and application of cartographic design principles. *Cartographic design* as referenced here refers to the body of knowledge around the visual design of maps as well as the use of a design process (or creating for a specific purpose and function) in the production of maps.

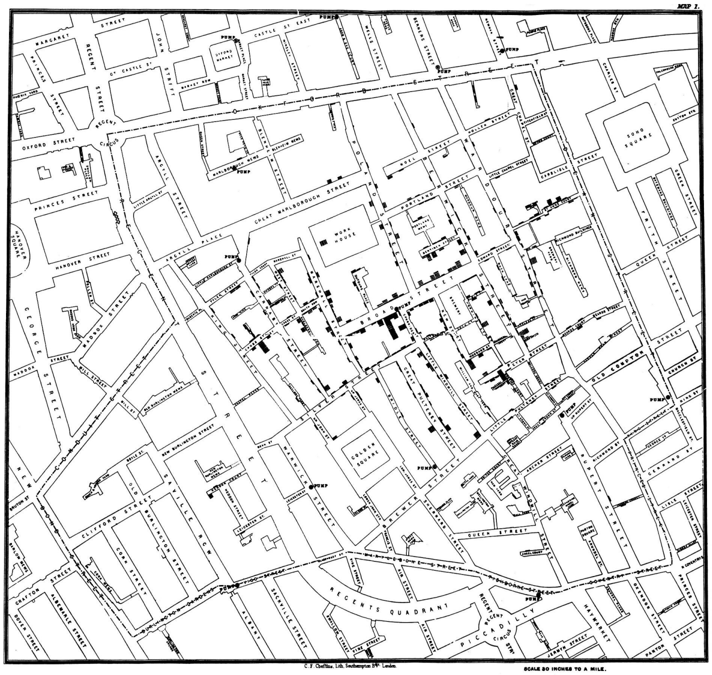
Those distinctions aside, cartography and GIS are broadly overlapping fields and have a shared history in map use for visual communication. Cartography is a key precursor to modern GIS, and GIS has modeled many of its visualization methods after cartographic representations of spatial data (Fisher, 1998). Over the course of its history, cartography has generated a rich knowledge base and set of best practices related to the visual display of geographic information, developing a strong set of concepts around the design and production of visual representations of the Earth (MacEachren, 1997). These principles have become codified in both cartographic and GIS map design resources.

GIS and cartography share more than the simple use or creation of maps; they also share a need for effective visual communication. Maps, whether for traditional cartography or GIS, are tools for communicating, sharing, exploring, and analyzing spatial data (Krygier and Wood, 2005). Maps are not created to hold spatial information in a vacuum; they are created to be read and used. In many cases GIS maps are intended to be part of a decision making process where interpreting their content directly effects a set of actions to be taken. Any map destined for an audience is a map for which good visual communication is key. Maps serve an almost limitless variety of functions and can be tailored to almost any reader (Drakes & Spence, 2008). All maps will have some purpose and audience for which they are intended, and all maps share a need for clear, effective communication.

Bertin (1983) distinguishes between three major functions for graphics: recording, communicating, and processing (i.e., analysis) of information. Map roles specifically are often broken into two broad categories: *communication* and *visualization* (MacEchren, 1997; Jiang, 1996), with the recording of visual information being inherent in both.

Communication in maps can be as simple as the representation and transfer of spatial information. These are maps for storing and transmitting "spatial facts" (MacEchran, 1997), similar to any general reference map. The vital function here is to serve as a mechanism for holding and presenting spatial information the way a phone book holds numbers and addresses. The information is ready for lookup but little to no interpretation or analysis is required by the user.

Visualization roles for maps can be thought of as maps that require interpretation and analysis or enable exploration and action. MacEchren (1997) and Jiang (1996) define visualization as a cognitive process resulting in prompting visual thinking and construction of new knowledge, and not simply the visual representation of a map. Visualization involves a pair of overlapping map uses for visual thinking. First is visualization for data exploration, or using a map to explore unfamiliar information and potentially prompt new questions or ideas. Second is visualization for analysis, the manipulation of known data to search for new relationships or to answer questions (MacEchren, 1997). Classic pre-digital examples of these roles can be found in the John Snow Cholera map (Figure 3A) and the Charles Minard map of Napoleon's March (Figure 3B). Both maps served as tools to explore patterns in spatial data and make a strong case for the existence of visualization functions in mapping long before the advent of GIS tools (Jiang, 1996). The snow map covers covers the spread of cholera in 1854 in the Soho district of London, connecting the incidence of cholera deaths to the Broad Street water pump. While Snow developed his suspicion of the source of the outbreak before compiling the map, it was the map that helped translate that information into a convincing visual argument for community leaders. The Minard map depicts, in graph and chart form, Napoleon's 1812 march first east towards Moscow then west again towards France. The line thickness describes the number of men on the move set against geography, date, and temperature. As temperatures plummet, the once massive column of soldiers is reduced to a trickle. While the information was known, the map made it both accessible and compelling.



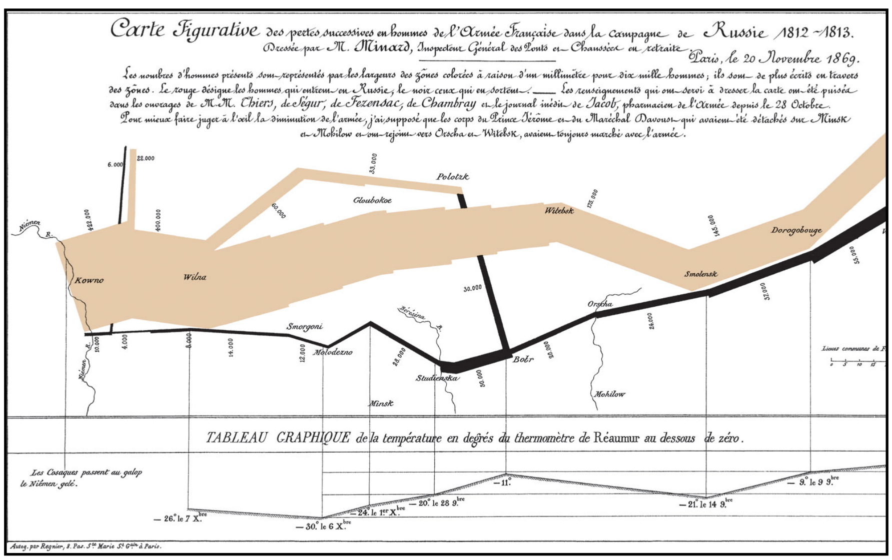


Figure 3A. Map of cholera deaths in London, John Snow 1854. Reprinted under public domain. *Figure 3B.* Map of Napoleon's Russian campaign of 1812, Charles Minard 1869. Reprinted under public domain.

In reality, few maps serve a single purpose and there is often a fair amount of overlap between communication and visualization. All map use involves some degree of both visualization and communication, what differs is the emphasis (MacEchren, 1997). Presentation maps are concerned primarily with communication, but may also include prompting of new insights for the reader. Presentation maps for decision-making includes a cognitive function as readers must be able to asses content accurately and make a choice over outcomes. The ultimate outcome to most analysis driven GIS projects is a presentation map and most stakeholders interact with the project solely through its visual output, i.e. maps (Longley et al., 2011).

Why Design Matters

The interplay between visual communication and analysis in graphics speaks to the role of aesthetics and design in map appearance, but also in map function. Effective communication is the ultimate goal of any publication map, so effective visual design must also be a primary concern. An effective map is one that communicates clearly, efficiently, and reaches its stated communication goal (MacEchren, 1997). Good design enhances communication while poor design breaks down communication. In this sense design is not just an aesthetic concept but one of function. Beauty in cartographic design for GIS is not the primary goal, although it is often a secondary outcome.

Design affects the function of maps in many ways, the most fundamental may be in simply capturing and holding the reader's interest. A poorly designed map may not grab one's attention or may be so difficult to interpret that the reader quickly moves on before getting all of the information. If the purpose of the map is to communicate information, failure to engage the reader is a failure to communicate.

Minor design details can have a cumulative effect on the perception of map quality overall (Tufte, 1990), and may extend to the perception of research and data quality as well. For readers who only interact with the map output from a GIS project, the map's design quality is their visual cue to the work quality.

Perhaps worse than failing to communicate at all, is the map that miscommunicates. Not following certain standards for visual design can have an impact on both the clarity of information as well as the interpretation of that information. Humans have certain expectations, both visual and cultural, that affect how we interpret what we see in an image. Failure to design maps with those expectations in mind can lead to misinterpretation of the intended message.

The art in "the art & science of cartography" suggests the often personal and unstructured nature of visual design in map making. Cartography does, however, provide a well-established body of best practices and principles that help guide mapmakers away from critical design flaws. They are as follows.

Purpose and audience. Knowing who a map is intended for, how it will be used, and how it will be presented help guide almost all design decisions about that map. An effective map is one that has a clearly identified communication goal in terms of its audience and purpose.

Layout. One of the most fundamental of design considerations, layout, has less to do with the design of the map itself then with the presentation of the map and its various components including titles, legends, scale bars, north arrows, and texts blocks.

How a map is laid out affects how smoothly the reader's eye will travel over the map and its elements (Krygier and Wood, 2005). Considerations like the balance and alignment of these elements link together to create either a harmonious layout or one that disrupts the visual flow across the final map. When a map's layout is successful the reader will not notice it, but when it fails the reader ends up distracted from the map's true purpose and goals (Krygier and Wood, 2005).

Visual hierarchy. All images have a visual order or depth from foreground to background. Some elements of a map stand out while others recede to the back (Krygier and Wood, 2005). The location of a feature in the visual order suggests its relative importance to the map, while the relative distance in the visual order between features will suggest their relationship to one another. Like features appear in the same or minimally contrasting hierarchy, while unrelated features should appear on different levels of the hierarchy. A strong visual hierarchy helps separate background or contextual information from the subject information. This figure-ground separation enables faster map reading and is a key technique for directing readers to the elements that are most important for a given map topic. A weak visual hierarchy, in contrast, places all map elements on the same visual plane and forces the reader to do all of the work separating important from unimportant visual information in the map. On a very detailed map the reader can quickly become fatigued with having to visually sift through the background features to see the principle map data.

Color. Color is so powerful in terms of visual weight, and so easy to apply in computer mapping that it is easily abused in a GIS. Applying strong, bright colors to a map seems like an excellent way to focus attention but it can overwhelm a reader's senses and bury the more subtle details of data. A small amount of color on a muted background creates a strong visual hierarchy (Tufte, 1990) without added distraction. Where color is not absolutely necessary a grey scale map can be very effective (Krygier and Wood, 2005). Using heavy bright or oversaturated colors on all the features of a map leaves the map reader wondering where they should focus their attention and what is supposed to be background or contextual information. In addition to being overpowering, color can be confusing when applied incorrectly. Color is a natural quantifier (Tufte, 1990), making it ideal for thematic and analytic mapping, but it must be applied in the correct manner to the data. Color in a map can be varied by its hue (the particular different colors we see) or its value (how light or dark a single color appears). Changes in color hue match changes in types of data for qualitative data, such as different colors for different land classes. Color value is best used to match quantitative data, or data that change in value for a single data type (light red to dark red for population density values). When color hue is used to represent quantitative data the reader is forced to consult the legend for each color change to know what is more or less in the map. Varying the colors by value allows direct reading and relative value comparison in the map rather than between the map and legend. Some features in a GIS map will have expected or conventional colors (like blue for water). Not using the correct color convention can be confusing and distracting. In some cases color connotations carry unwanted meanings like the “good” and “bad” implications of a red-green color ramp.

Visual variables. Originally defined by Jaques Bertin (1974) the visual variables describe the ways in which graphic marks can be modified to reveal changes in visual information. This has been adapted to specific use in cartography to help cartographers make the best use of symbol changes based on the type of data they are depicting. Symbology changes are affected by geometric type (point, line, area) and characteristics of the data (qualitative or quantitative). Certain visual variables are better suited for certain types of data and the visual variables guide helps ensure a match between changes in symbology and data.

Data scale. In a GIS one typically wants the most detailed data available for analysis as detail equates to precision and accuracy. In representing that information, however, one does not always want to present the most detailed version of all the data. Extremely detailed data shown at a very small scale can make seeing larger regional features difficult while overly generalized data shown at a large scale will appear very coarse. Mixing data at different data scales can make representing the data tricky as boundaries that should be coincident appear with large gaps or overlaps.

Projections. Projections are used to transform the round globe into a flat map but that transformation comes at a cost through the distortion of various characteristics of the map, including area, shape, distance and direction. For small areas a map’s projection may have little impact but for larger areas it can dramatically change the way a map is seen and interpreted. Projections that distort area make it difficult to compare densities between locations. In terms of map layout it is important to adjust the projection of any insets and locators to whatever projection best suits the inset location, as opposed to simply extending that main map's projection into the insets. Inset projections should also be centered on the inset's central meridian and rotated to have north up.

Context. Maps are by their nature limited views of the world. They cannot contain every detail of a location, and it is often in the best interest of the map's goals to aggregate, simplify, and generalize the representations. Oversimplification can, however, lead to confusing interpretations of unfamiliar geography. Leaving contextual details in the map helps orient the map user.

Labels. Map text is vital to the function of a map. Labels identify the primary elements of many maps and are often map features and symbols in their own right. Haphazardly placed labels confuse and frustrate the map user, while well placed and styled labels help direct the users attention.

Methods

A Cartographic Baseline

"The solution of a mathematical problem is either right or wrong, but the solution of a problem in cartography is, within certain limits, only good or bad" (Imhof, 2007).

The problem with evaluations of map design is that the "rules" of cartography can be subjectively applied and one's impressions of a map's quality strongly affected by personal preferences and bias. The language of most cartographic design topics is often written to help the reader make adjustments in terms of what Imhof described as the "good or bad" of cartography, not the right or wrong. A map's failure to meet a particular aesthetic standard does not mean certain cartographic principles were not adopted in its creation. This study, being an attempt to measure the rate of design principle use and not their outcomes, required a unified body of design criteria written and applied such that they identify the proper use of a design principle, while removing the focus on its aesthetic outcome.

In order to make that evaluation of a set of GIS maps minimally biased and to measure the adoption rate of design tactics rather than their outcome, it was necessary to create a set of the most common cartographic design concepts that dispensed with aesthetic considerations and simply identifies the need for the concept and its presence or absence in the map. The first step in creating a design guide for the evaluation of maps was to collect the most commonly agreed upon cartographic design topics from a range of texts on cartography (See Appendix A for the list of texts). Each of these texts was examined and the various design topics cataloged and compared against each other for commonalities in descriptions and impacts on map function. Design topics that were shared between the various texts were synthesized into a table of "universal" cartographic design standards. There were 29 specific standards identified in 8 main categories: *Layout, Visual Hierarchy, Color, Symbology, Data Scale, Projections, Context, and Labels* (See Appendix B for full table of standards). Additionally, the language for the synthesized descriptions was written to help identify the presence or absence of a particular design standard, and dispenses with details that focused on quality of design.

Evaluation of Published GIS Cartography

With a guide to cartographic concepts synthesized, the next step was evaluation of a set of GIS maps. *The Professional Geographer*, a journal published by the American Association of Geographers (AAG), was selected as the content source and a single year of publications, 2014 Volume 66, selected for evaluation providing 80 unique maps within 38 articles. Assumptions for *Professional Geographer* selections were that its contributors are typically GIS professionals or other researchers with specific GIS training who are writing about applied geography. Additionally, the use of an academic journal limits the pool of evaluation maps to those specifically intended for publication while removing variability associated with online map collections, drafts, student projects, and other works not intentionally designed for public viewing.

Each map figure was evaluated in turn against the check list of cartographic design standards, and scored as either +1 for *standard applied*, 0 for *standard met*, -1 for *standard not applied*, or NA for *standard not applicable*. The primary difference for standard applied versus standard met is that of intention. If it appeared that a map maker had to purposefully apply the standard instead of relying on software defaults, the applied standard received a +1 value. If the standard application appeared ambiguous, or was the likely result of a default setting, it received a 0. Maps that obviously required the standard but failed to apply it were given a -1.

Results

Results were initially tallied as a total score for each design concept derived by subtracting the *standard not applied* count from the *standard applied* count. The total possible score range for each concept was ±80. In the process of evaluating maps, it became apparent that zero and NA scores had a significant impact on interpreting adoption rates for each concept. An alternative metric of percent positive or negative was calculated from the total of all non-0 and non-NA scores. This better reveals how often a particular concept was purposefully used versus required and unused. These scores, along with the zero and NA values were compiled into a heat map for all concepts (Figure 4).

Looking at heat map totals, the most adopted cartographic design concepts include N arrows, visual variables, legend relevance, and data classification symbology. However, as previously stated, the evaluation total scores do not take into account maps that showed either ambiguous use or no application of a standard. While zero scores indicate that the design concept is demonstrated in the map, its application was ambiguous, meaning it was difficult to differentiate between purposeful use and default style settings in GIS software. NA counts identified design concepts that were unused or irrelevant to the map being evaluated, such as color classification concepts for gray scale maps.

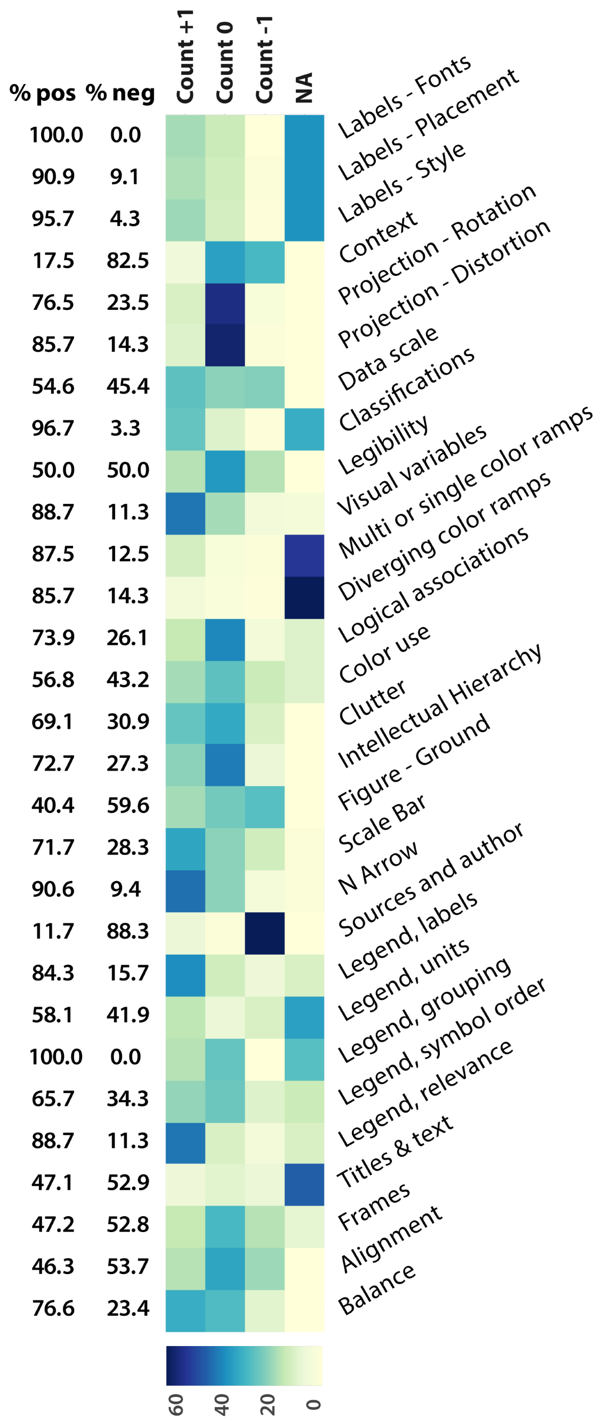


Figure 4. Heat map of cartographic evaluation results by design topic. Depicts the number of maps for each cartographic category by points assigned; NA (not applicable), -1(standard required but not applied), 0 (standard met, but not required), or +1 (standard required and applied). Percent positive and percent negative values for each category are indicated to the left of each topic row.

The three label concepts for Fonts, Style, and Placement all had very high percent positive scores. Font use was the highest scoring concept by percent positive at 100%. The specification is that a map includes no more than two fonts or any decorative fonts in the main map (excluding titles or text blocks). Style scored 95.7% with a specification that states all type be styled uniformly by feature class. Placement scored 90.9%. Very few maps in the study set included any text and most GIS software handles label style and placement by default, so scoring here would likely be high in all cases unless an author purposefully manipulated his or her defaults.

Classifications scored 96.7% positive use. This standard specifies that there be no more than six unique color classifications for quantitative data. As with fonts, few maps included quantitative data and the default for classes in both ArcGIS Desktop and Q-GIS are five classes.

North Arrow use scored 90.6%. Visual Variables and Legend Relevance scored 88.7% each. Single/Multi Color Ramps scored 87.5%. Projection Distortion and Diverging Color Ramps scored 85.7% each.

In general, these top ten highest scoring concepts all have strong natural or default settings in common GIS software, and many of them showed very low use overall in the study set. By simply not making adjustments to the default settings in their software, most GIS maps would be likely to score positively for these concepts.

The opposite seems to be true of the lowest scoring design concepts where there is less automation or default symbology available to guide the mapmaker. For the design concepts of Alignment, Frames, Sources, Figure-Ground, Legibility, and Context, authors may be more likely to need to actively apply a concept rather than rely on a default setting in order to earn a positive score. That the lowest scoring concepts are less typically automated in GIS software suggests these are design topics with which map authors in this study were unfamiliar.

Conclusions

In broad terms, for the study sample, map authors appear to have been largely reliant on software to dictate the proper application of core cartographic design concepts. When unaided by defaults, authors were more likely to omit a needed design tactic or apply the concept incorrectly. The implication is that success at cartographic design for GIS professionals seems to be linked more to software settings and defaults than background knowledge or previous education in cartography. This highlights a continuing gap in GIS professional's valuation of basic cartographic principles in GIS map work. Without taking an active role in the design of their work, GIS map makers leave a significant amount of control over visual quality and effective design to the mechanics of their software defaults.

Researchers using GIS software and GIS maps as a means to communicate their work are handicapping themselves by not giving what are arguably some of the most potent parts of their work the same attention to detail they are likely to give to the text that surround those maps.

It should be noted that “correct” and “incorrect” applications of design standards here are relative only to the commonly used standards for map design synthesized as part of this research. As with any art, there are many cases of well-designed maps that break traditional design rules. Nonetheless, as this study sampled journal publication maps created by GIS professionals, it is unlikely that any of the maps reviewed were intended to be novel or counter approaches to traditional cartographic design.

Limitations with this study pool were evident in the number of concepts for which few, if any, of the maps had an application. An expansion of this study into more venues for a wider variety of GIS publication cartography would be a logical next step for research. Potential sources for study might include a mix of GIS industry specific journal publications, GIS map competitions, and GIS map anthologies (such as the Esri Map Book). It would also make sense to expand the study back over time for the same sources, looking for temporal trends in the use of cartographic standards.

The rough breakdown of concept scores along default and non default settings in GIS software merits further research as well, looking at specific overlaps between software defaults and concept best practices. The synthesized cartographic concepts list from list from this study could be used to determine how common GIS software compare to each other with regards to default settings for each concept.

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Appendix A

List of Cartographic Design Texts

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Appendix B

Table of Cartographic Design Concepts

Topic	Description (desired result)	Impact on map goals
Layout		
Balance	Visual weight of map elements balanced against each other and empty space in layout. Balance is not necessarily symmetrical.	Poor balance is distracting, good balance directs attention. Heavy elements tend to be large, dark, bright or compact. Light elements tend to be smaller, lighter, dull irregular.
Alignment	Map elements aligned to invisible grid. Spacing between elements evenly distributed.	Alignment to invisible sightlines enhances maps stability and balance. Elements not aligned to a uniform grid may appear disjointed and unrelated to each other in the layout.
Frames	Frames (insets, locators, text boxes or legends) do not distract from main map. Heavy frames and too many sequentially placed frames should be avoided. NA if no frames.	Thick frames overpower other map elements. Too many sequential frames creates visual noise in the layout (1+1=3 effect).
Titles & text	Map title is clear and descriptive (*what, where, when*). NA if no title.	Titles provide important contextual information to the map reader and should be clearly visable.
Legend, relevance	Legend includes only unfamiliar or subject related items. NA if no other features shown besides data features.	The legend is the readers key to understanding the map. Busy legends make finding important information more difficult.
Legend, symbol order	Symbol order from top to bottom should be labels, points, lines, areas, and images.	Follows the visual stacking or drawing order of the map, making finding legend items more intuitive.
Legend, grouping	Related features are grouped together in legend.	
Legend, units	Units are clearly indicated (e.g. PPM or CFM). NA if no values.	Reader can not interpret map values if the units are un known. Or the reader may assume an incorrect unit.
Legend, labels	Labels are written in plain language, no underscores, no all caps.	
Sources and author	Map lists data sources and author.	Map credability may be harmed if the reader can not determine the provinance of it's creation or sources.

Topic	Description (desired result)	Impact on map goals
N Arrow	N arrow not included on maps where orientation to N changes (e.g. conic projections). N arrow is not required on maps of very large and familiar areas.	0 if variation can't be determined, 1 if left off non uniform maps, -1 if left.
Scale Bar	Scale bar uses whole number divisions. Scale bar should not be included on map projections where distance is not preserved (esp. very large areas).	0 if variation can't be determined, 1 if left off non uniform maps, -1 if left.
Visual Hierarchy		
Figure - Ground	Map elements arranged visually from background to foreground (or from figure to ground). Clear seperation between background and map data.	Maps with no VH appear flat and make it difficult to determine what features are more important than others.
Intellectual Hirearchy	The VH suggests feature importance and aligns with the maps purpose.	The VH, or visual depth in a map should refelct the intellectual hiareacrchy, or feature importance to the map. A VH that does not match the maps purpose can be misleading.
Clutter	Map dispenses with elements that are not part of the IH or do not support the purpose of the map.	An effective VH does away with features or elements are not supportive or important to the maps purpose. Too many un ralted features or layers in the VH make map reading difficult.
Color		
Color use	Judicious use of bright colors. Map avoids using heavy, bright, or fully saturated colors over large areas. NA for greyscale.	Broad use of brigth or fully saturated colors can be disracting.
Logical associations	Conventional colors used for familiar features (e.g. blue for water; green for veg). Bright or saturated colors suggest high values, light or faint colors suggest low values. White suggests no data. NA if greyscale.	Ignoring logical or expected color associations can be disorienting to the map reader.
Diverging color classes	Diverging color ramps used with diverging data. Critical value is indicated for diverging data. NA if greyscale or not classified.	Ramps that change away from a central neutral color suggest diverging values with a critical value. Applying this sceme to normal, linear data suggests a critical value that is not present.

Topic	Description (desired result)	Impact on map goals
Multi or single color ramps	Single color ramps for linear data. When multiple colors are used for linear data, ramp transition through neutral to non-neutral color for increasing values (yellow to dark blue vs. red to green). NA for greyscale.	Two colors, neutral to non neutral suggests a linear value change. Transitioning through to non neutral colors suggests a divergence in values or a change from "acceptable" to "unacceptable" as with green to red color scemes.
Symbology		
Visual variables	Data symbology is varied by the appropriate visual variable for qualitative or quantitative data. NA for non data driven maps.	Hue & shape for qualitative, value & size for quntitative.
Legibility	Symbols and labels are readable and distinguishable at published map scale.	
Classifications	No more than 6 unique color classifications by value. Applies to quanititatvie data only.	Humans generally can't reliably distinguish between around 6 different shades of the same color. Extra classes ok when using different shades of the same hue for class groups (e.g. dark green forest, light green grass).
Data scale	Data resolution is appropriate to the map scale and extent. Map avoids using very detailed data at small scales or overly simplified data and large scales, or mixing overly detailed and generalized data.	
Projections		
Distortion	Map uses a projection that fits the map scale and extent and avoids strong visible distortion. 0 in casses where projection is undectable.	
Rotation	Projection for main map and any insets are rotated individually.	
Context	Map avoids “island effect” by including some background data outside of immediate area of interest. Background detail matches map subject (e.g. a map of well locations may dispense with detailed minor roads but leave on local river networks).	Readers can have a hard time interpreting the maps geography when all base map details are clipped to the study area extent.
Labels		
Style	Type is styled uniformly by feature class. Label appearance compliments its meaning.	Labels are symbols, and their appearnce can enhance their meaning. Uniformity of style by feature helps reinforce the VH. Haphazzard styling may cinfuse the reader.

Topic	Description (desired result)	Impact on map goals
Placement	Labels are placed with their features whenever possible. Labels are placed to avoid crowding, breaking lines, and overlapping other features. Labels are aligned to their features. Area labels are letter spaced to help indicate area. Line feature labels for large areas are curved to follow feature. Labels are placed right side up (or "feet falling").	
Fonts	No more than 2 font families on the map. No decorative fonts in the body of the map.	Excess font use, or non conplimentaty fonts creates a distracting map. The eception might be maps for posters or contests.