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This study examines the functional elements and usability of a select group of web-based mapping applications and online mapping services. The goal of the study was to determine the appropriateness of these tools for use in library reference services, their usability by librarians and patrons who have little related experience, and the applicability of these tools as options to complex desktop geographic information systems (GIS). Previous studies have found that desktop GIS software is difficult to learn, includes functionalities that many beginner-level users do not need, and can discourage the use of GIS. This study found that many web-based tools are more user-friendly than desktop programs, require little time to learn, and possess the mapping functions that many beginner users need. However, this study also found that there remain issues with web-based mapping and online services. Examples include limitations in the types of spatial data analyses available and application errors.

Headings:

Geographic Information Systems

Geography/Internet resources

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WEB-BASED MAPPING: AN EVALUATION OF FREE MAPPING APPLICATIONS AND WEB GIS FOR LIBRARY REFERENCE SERVICES

by
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Introduction

Geographic information systems (GIS) technology, since its advent in the 1970s, has generally been considered to fall within the realm of expert programmers, geographers, and natural resources managers. Advances in usability, such as the graphical user interface and data accessibility and interoperability, have brought GIS into the mainstream (Chang, 2010). The popularity of GIS and mapping has grown rapidly in recent years. This growth has led to an increase in demand for access to spatial data in academic and public libraries.

The MAGERT Education Committee (2008) recommends that academic libraries employ librarians who possess expert knowledge of GIS software. However, some academic libraries and most public libraries do not employ staff with this expertise nor do they offer GIS software to their patrons. Additionally, many large academic libraries that have GIS expertise on staff and provide access to desktop GIS software and large repositories of spatial data struggle with providing GIS services due to the complex nature of the software and the time required for typical GIS consultations (Parrish, 2006).

An alternative to providing desktop GIS software and expertise in its use, and a potential solution to the problems faced by reference services staff could be the adoption of one or more web-based mapping tools which would allow a smaller library to offer GIS services albeit somewhat limited. The primary goal of this paper is to evaluate a selection of these web-based tools to determine if they can be used effectively by novice spatial data users. The target user group is reference librarians and patrons who possess little or no GIS experience. The question is whether this emerging technology is accessible to and adequate for beginner-level spatial data users.

Given the high demand by novice spatial data users for assistance from reference librarians, the simple nature of many beginner-level GIS projects, the many web-based mapping tools available for librarians to use at the reference desk, and the current state of the art in web-based mapping technologies, implementation of some of these user-friendly technologies could aid reference librarians in enhancing their library's GIS service or creating one at no cost for software or hardware.

A second goal of the paper is to provide information about web-based mapping tools to reference librarians in an effort to increase familiarity with free mapping technologies and potentially to expand the range of spatial research questions with which reference librarians are prepared to assist. Equipped with this information, reference departments may, for no cost other than staff time, be better able to aid students who are unfamiliar with desktop GIS software by providing them with help in quickly and easily accessing spatial data and creating basic maps. By educating reference librarians in the use of these tools, reference departments would be encouraging spatial research among novice users by essentially increasing their GIS staffing or by adding GIS services where none exists. The more reference librarians know about user-friendly web-based mapping tools, the more these tools will be used and the better their service will be to beginner GIS users. An evaluation of a select group of free and user-friendly mapping tools follows along with recommendations for the integration of these tools in reference services.

Literature Review

Geographic information systems, web-based mapping, Web GIS, GIS services in libraries, and previous evaluations of GIS applications and services are the primary concerns of this paper. This literature review looks broadly at common problems and solutions related to these areas and then applies lessons learned to the specific area of GIS services for novice users in library reference services.

Geographic Information Systems

A geographic information system (GIS) is software and hardware designed to capture, store, query, analyze, and display spatial data (Chang, 2010). A GIS combines relational database management systems, statistical spatial analysis, mathematical modeling, and cartography into a single information system (Abresch, Ardis, Heron, & Reehling, 2008). GIS technology comes in many forms such as web-based systems that can be accessed with a simple web browser, software that is installed on desktops or local servers, and complex systems installed throughout a local area network and linked with relational database management systems and Web servers.

Spatial data, also referred to as geospatial or geographic data, is data that is geographically referenced or linked to a location on the earth and describes characteristics of features found at this location (Chang, 2010). Abresch et al. (2008) conceptualizes geographic data in terms of feature geometry, attributes, and topology. *Feature geometry* represents objects on the earth's surface. *Attributes* describe these features and are linked to them from a table or database. *Topology* describes the behavior of or relationships between these features (Abresch et al., 2008). An example is the relationship that electrical lines have with utility poles. Moving one would, for example, require relocating the other. These data are typically stored locally as files in a simple file system or in a local database such as Microsoft Access but can also be stored remotely on an organization's Web server. Examples of spatial data include demographic data which can be linked to a county; census data which is commonly linked to a census block group; road information which is linked to a segment of a highway or street; and water quality samples which are linked to sample sites along a stream. Everything happens somewhere so all observable phenomena, once linked to a location, can be mapped in a GIS.

The history of GIS stretches back to the 1970s when it was used in natural resources management and terrain analysis (Chang, 2010). Great advances were made in the 1980s with the development of ARC/INFO by Environmental Systems Research Institute, Inc., the precursor to today's industry standard ArcGIS software products. Another important achievement of the 1980s was the development of Geographical Resources Analysis Support System (GRASS) by the U.S. Army Construction Engineering Research Laboratory. Development of GRASS GIS, which in the 1990s became the first free and open source GIS software and led to the creation of the Open Geospatial Consortium, is now under the coordination of ITC-irst – Centro per la Ricerca Scientifica e Tec-nologica (Italy) and maintained by a team of developers from all over the world (Neteler & Mitasova, 2008). Today, there are over 300 free GIS software programs completed or under development (Schilberg, n.d.).

In 2010, the U.S. Department of Labor Employment and Training Administration listed the geospatial industry as a high-growth industry. One example of this growth is the integration of GIS with the Internet. In 1998, Al Gore proposed his vision of a user-friendly information system containing satellite and airborne images of the earth's surface combined with information about the locations of select features on the surface. Beginning in 2005, Google adopted this concept and produced Google Maps. Yahoo! and Microsoft soon followed suit with their versions of an online mapping services (Chang, 2010).

As GIS technologies become more integrated into industry, their popularity among novice users will likely grow. Users new to GIS are often unaware that they are GIS users. Anyone who has ever made a map using Google Maps, Yahoo! Maps, Bing Maps, or a host of other web-based mapping tools or has ever used their PDA or automobile's GPS mapping system to find directions is a GIS user. It is precisely this novice GIS user group that is the target of this study. The data available on Google Maps are an example of reference maps. General reference maps display locations of features such as roads, lakes, and buildings and can be in vector format (points, lines, and polygons) or in raster format (images). More advanced mapping tools allow users to create and view thematic maps. A thematic map displays the spatial pattern of a phenomenon (Sandvik, 2008).

Many novice GIS users are library patrons, as are many reference librarians. These users are increasingly incorporating spatial data mapping into their personal and professional projects. Users from all backgrounds and all levels of experience come to library reference desks with a wide range of spatial data mapping questions. The most common commercial application package, ESRI's ArcGIS, is a robust and sophisticated spatial data visualization and analysis software package that requires a significant investment of time to learn. Because of the complexities and expense of the software, many academic libraries employ GIS librarians possessing expertise in using ArcGIS and in accessing and analyzing spatial data; public libraries generally do not provide this software to their patrons.

Web-based Mapping Applications and Web GIS

The evolution of Web Services technologies and data interoperability standards has led to creative new applications and ingenious data sharing techniques. Web mapping sites and Web Map Services are examples of this advancement in Internet technologies. The terms “web-based mapping” and “Web GIS” refer to different technologies. While the technologies consist of overlapping functionalities and the terms are often used interchangeably, distinctions should be made.

The term *web-based* in this context can refer to the data or to the software. Generally, the simplest mapping tools are entirely web-based, no software is installed on local computers, and no data is required from users. These tools require only a Web browser to view and query base reference maps such as roads and aerial photography. These web sites, which allow users to view data that is stored remotely on the organization's Web server, do not allow users to upload their own data and provide only limited tools for data viewing. Web-based mapping tools are useful for simple location-based queries, data delivery, and personalized map displays. A *location-based service* refers to any application that allows users to process spatial information, such as locating addresses or mapping driving directions, via the Internet (Chang, 2010).

Interactive mapping services show how basic mapping functions have been integrated with the Internet (Chang, 2010). Yahoo! Maps is an example of this type of web-based mapping technology. Beginner-level users with simple needs can produce customized maps for printing. Another example of web-based mapping technology is

SimplyMap. Like Yahoo! Maps, SimplyMap provides access to remotely stored data but also gives the user many more data querying and cartographic tools.

Web GIS, on the other hand, is a more advanced level of web-based mapping applications and requires the installation of desktop software. These tools, many of which are free, are designed to be easy to use and can easily connect to *Web Mapping Services* (WMS, also called GIS Services) for acquiring base images. These data are stored remotely on Web servers. Examples of Web Map Services are the US Geological Survey's National Map and ESRI's ArcGIS Online (formerly known as Geography Network). According to NC OneMap (n.d.), an initiative created by the NC Geographic Information Coordinating Council for data standards and accessibility, there are well over 500 Web Map Servers in its WMS Catalog.

ArcGIS Online, managed and maintained by ESRI, can actually be considered both a WMS and a spatial data clearinghouse. Users can connect directly to the web site and view reference maps using the beta version of My Map and they can also download data layers to their own computer. A *spatial data clearinghouse* is a repository for storing and disseminating data and provides basic mapping tools for interacting with the data. *Spatial data portals*, in contrast, enables access to spatial data but do not provide mapping tools. The data and the mapping tools are hosted on Web servers and do not require installation of software on local computers.

Morris (2006) lists several situations where users may find these services beneficial including those where "the user wishes to preview the data before acquiring it, the user just needs the data for background use, [and] the data is not otherwise available or cannot be efficiently acquired and stored for local use" (p. 290).

Many of these simplified desktop products are free of cost. These tools, sometimes called geobrowsers or Earth browsers, are similar to the simple web-based mapping sites mentioned above in that data is stored remotely and analysis tools are limited. They differ, however, in that there is typically more variety in the available data, cartographic tools for map customization are more sophisticated, and the user has options for uploading local data into the program. Examples of this type of Web GIS are Google Earth and ArcGIS Explorer. Both of these applications can connect directly to Web Map Services like ArcGIS Online.

While these installed programs that allow uploading spatial data and limited analysis blur the lines between web-based mapping, Web GIS, and desktop GIS, they are still considered Web GIS products because of the options for connecting to remote Web Map Servers and accessing online data. This simple option saves the user from locating, formatting, and uploading his/her own data into the GIS and greatly simplifies the user's job.

The capability that Web GIS has for aggregating large amounts of data from various sources is described by Scharl and Tochtermann (2007). These technologies make it possible to integrate a wide variety of spatial data into one information system.

Keyhole Markup Language

While the intent of this paper is to provide information about easy to use mapping applications, no discussion about web-based mapping would be complete without a basic primer on the Keyhole Markup Language (KML).

Google’s KML Documentation Introduction (2010) defines *KML* as a file format used to display geographic data in an Earth browser such as Google Earth and Google

Maps. KML uses a tag-based structure based on the XML standard. Like XML (Extensible Markup Language), KML files can be created from scratch using any text editor such as Microsoft Notepad. This process, however, is generally not necessary due to the many free web-based applications that can convert spatial data, typically stored in spreadsheets or in ESRI shapefile format, to KML automatically.

All Earth browsers, such as Google Earth and ArcGIS Explorer, and many web-based mapping tools allow users to create, export, and import spatial data that is stored in KML or KMZ format. *KMZ* files are simply compressed or zipped files that can contain images as well as the markup language itself. “Just as web browsers display HTML files, Earth browsers such as Google Earth display KML files” (Google, 2010d). Several free applications designed to convert a variety of spatial data file formats to KML format are included in the evaluation section below.

Sandvik (2008) points out that while use of geobrowsers like Google Earth has increased, thematic mapping functionality has not been a focus and recommends using KML for this type of mapping. Using an application designed for producing KML files of United Nations data, Sandvik demonstrated how one can view external data in a geobrowser. Sandvik looked at Google Earth, Google Maps, Microsoft Live Search Maps (now Bing Maps), ArcGIS Explorer, and other geobrowsers to determine KML support. Google Earth was found to have the best support presumably due to Google's ownership of Keyhole, Inc. (Sandvik, 2008).

While geobrowsers typically contain reference data such as aerial and satellite imagery, Sandvik (2008) mentions two methods users can use to visualize their own data in a geobrowser; Application Programming Interfaces (API) and XML scripting such as

KML. Because API use requires intermediate web programming skills, their use is beyond the scope of this paper. KML is covered here because of the many free web-based tools that can automatically convert data to KML format, preventing the user from the task of XML scripting, which is also beyond the scope of this paper.

Sandvik (2008) mentions several problems with using geobrowsers for thematic mapping, however. Coordinate systems can be a problem in 2D applications because current web-based mapping sites use the Mercator projection which is appropriate for small areas but not for world maps due to area distortions. 3D applications that display data on a globe, like Google Earth, avoid this projection problem but introduce another limitation; that being the inability of displaying world data on a sphere in one view. A second problem with 2D viewers is the difficulty of rendering large vector-based files in a Web browser (Sandvik, 2008).

Sandvik (2008) concludes by admitting that some “inventiveness” is necessary to use KML for thematic mapping. KML was not designed specifically for thematic mapping in geobrowsers and consequently, some “hacking” is required (p. 15). Through the development of web-based tools like the Thematic Mapping Engine developed by Sandvik and other tools such as Batchgeo, KMZ Census Mapper, and those mapping sites that provide for exporting KML files, the potential for web-based thematic mapping is greatly improved.

GIS Services in Libraries

Academic libraries that provide GIS services typically use ESRI's ArcInfo software as the primary tool for student geospatial projects. GIS librarians often possess master's degrees in geography or a natural resources field and may or may not have a LIS degree. The reason for this is the sophistication of the software and the wide range of skills required for the position. The MAGERT Education Committee (2008) stresses the need for a strong understanding of the theory of geographic information science in GIS instruction and vision and imagination in applying GIS to a variety of disciplines. Martindale (2004) recommends that those entering GIS librarianship become familiar with technical fields such as programming, relational databases, and spatial metadata.

Academic library GIS services departments must deal with site licenses, hardware and software expenses, data acquisition cost, outreach, training, tutorials, pathfinders, and subject guides (Sweetkind-Singer & Williams, 2001). Workshops, seminars, and joint efforts with other departments on campus are also effective strategies for disseminating geospatial knowledge (Kinikin & Hench, 2005). These efforts are crucial because it is estimated that learning just the basics of GIS analysis can take from 15 to 20 hours (Parrish, 2006).

One study found the mean time for GIS consultations with doctoral students to be 8.69 hours, master students 2.62 hours, and undergraduates 4.79 hours (Parrish, 2006). Parrish suggests that, because of the time consuming nature of GIS projects, undergraduates tend to avoid incorporating GIS into their coursework. Further, Parrish finds that individual GIS patrons typically return on the average four times due to the "highly visual nature" of these consultations. In a study of how novice users use GIS applications, Kowal (2002) identified three levels:

- High level – uses desktop GIS and the Web for locating data.
- Mid level – generally satisfied using simplified web-based GIS that is designed for limited purposes such as "driving directions, environmental conditions, and transportation routes."
- Low level – accesses databases of simple static images such as JPG and GIF images, and reference maps such as outline maps, base maps, and pre-drawn

maps. (p. 109)

Many academic libraries are purchasing access to subscription web-based mapping products and spatial data that is stored on a remote Web server. This family of spatial data and mapping products provide both vast amounts of data and the visualization tools necessary for displaying the data. These tools are much less sophisticated than desktop GIS software and, along with other free mapping applications available on the web, are good alternatives for students whose research projects do not require the use of complex software and can be easily addressed using pre-formatted data connected to a user-friendly display (Yu, 1998).

Yu suggests three methods for improving access to spatial data and promoting GIS in libraries: (1) Simplified user interfaces can add value to raw geospatial data by reducing the number of access options available based on user skill level; (2) Providing multiple levels of usage allows users of varying skill levels to choose the functionality most appropriate for them and their research; (3) Data can often be made more easily understandable with a little processing by a GIS librarian (Yu, 1998). While many user needs can't be anticipated, common tasks such as joining attribute data to geographic data can be accomplished which greatly simplifies student projects and reduces time consuming tasks and frustrations.

Given the nature of GIS software and spatial analysis, many reference librarians not trained in these techniques struggle with student inquiries on geospatial topics. Abresch et al. (2008) lists several challenges for reference librarians including the need to develop instructional programs for librarians as well as for patrons. Librarians could be trained in the use of sophisticated desktop software but this is often counter-productive because it can be time consuming, frustrating to learn, and difficult to retain if not used regularly.

The primary advantage that web-based applications have over traditional desktop GIS software, from a librarian's or patron's perspective, is their relative simplicity and ease-of-use. While this simplicity often means web-based mapping applications are limited in their functionality compared to the more sophisticated desktop software, many user needs can be accommodated by these user-friendly tools.

For example, maps of census data at the block group level with a color scale and county and state boundaries are among the most commonly requested items and the simplest and most user-friendly web-based tools can easily handle these requests. The user doesn't need to search for the different types of data, doesn't need to be concerned with access and retrieval barriers, doesn't need to format the data or worry about interoperability, and doesn't need to import the data into a software program. These steps have already been completed and the user needs only to visit a single web site and use simple tools to create the desired map.

> Libraries can support user discovery and selection of resources by incorporating such [Web Map Server] services into catalogs, GIS data collections, and the physical map room browsing environment. Just as libraries provide support in user selection of maps or datasets, support can also be offered in selection from among competing service options. The notion of the reference interview, as it applies to geospatial data, can be extended to geospatial Web services. (Morris, 2006, p. 292)

Using these user-friendly tools at the reference desk could potentially benefit reference librarians, GIS librarians, and patrons alike. Reference librarians who have limited GIS training can employ these tools in their daily work to expand the range of geospatial questions with which they are comfortable fielding. As Abresch et al. (2008)

points out, basic GIS services using free mapping resources can be provided with minimal training. GIS librarians, with the help of other librarians trained in the use of these web-based tools, can devote more of their time with advanced user needs. And students whose mapping needs are relatively basic can be encouraged to implement spatial data and mapping into their projects by using these easy to use tools and can be saved the difficult task of learning complex desktop software. By providing information about available web-based mapping tools to reference librarians, libraries would be increasing the number of librarians possessing basic GIS skills, could better share information about these time saving alternatives with their patrons, and would be improving their GIS services or creating a new service where one did not exist.

Previous Evaluations of GIS Services and Web-Based Mapping Tools

One important reason for implementing GIS services in libraries that do not have such a service is for advocating geographic literacy. Building on Kowal's (2002) study of how novice users use GIS applications, Kinikin and Hench (2005) found the same three categories of beginner-level GIS uses can be applied to beginner-level GIS needs:

- High-level - full GIS setup in which users with or without assistance from library staff produce projects using GIS software. The user must understand completely the information need and be computer literate.
- Mid-level - GIS applications available via the web which require user input. The user must be comfortable using dynamic web sites to discern which data are appropriate for the specific question.
- Low-level - static maps available through the web. (Kinikin & Hench, 2005, Levels of Service section)

M. Howser and Callahan (2004) suggest that the geographic literacy can be established at the introductory level by instructing new users in the processes of creating simple choropleth maps. *Choropleth maps*, also called thematic maps, use varying colors to show the distribution of a measured phenomena through space, such as census data across the counties of a state. Many web-based mapping sites are designed specifically for this type of mapping. More sophisticated software and tasks could wait until the fundamentals are understood. M. Howser and Callahan go on to recommend that such tasks as georeferencing and spatial data creation and preparation could be considered intermediate level GIS tasks. Like choropleth mapping, many intermediate tasks can also be completed using web-based mapping, in particular, address geocoding.

Understanding the tools and the results of map creation is a fundamental element of geographic literacy. This understanding typically comes from working with a librarian during a reference interview. R. Houser (2006) agrees that GIS consultations are complex and time consuming even for uses conducting beginner-level research. “At one end of user experience and informational needs are those wanting simple facts or statistics that may be generated by stand-alone or Web-based mapping applications” (R. Houser, 2006, p. 320). R. Houser goes on to agree that these patrons may never need to use a complex GIS program.

R. Houser also found that because researchers have access to spatial data and tools that seem user-friendly, they are often deceived into believing that simple and attractive maps can be created from complicated datasets. This deception leads to misinterpretation of results and misconceptions about the difficulties of learning and using GIS. R. Houser, along with Sweetkind-Singer and Williams (2001), agrees that locating and processing spatial data can take twice as long as initially expected.

Literacy among librarians regarding spatial and geographic data is also a concern. R. Houser determined that, while reference librarians have been locating demographic data for years, a visual representation of these data can be more meaningful for them. Demographic data, such as census data, is primarily created by the federal government and Longstreth (1995) found that a primary motivation for the creation of a library GIS service is the abundance of government data and information in digital format. Without access to visualization tools, the benefits of these data are lost. “By integrating GIS services and data in the library environment, the academic community benefits from increased information access” (R. Houser, 2006, p. 2).

Yu (1998) found that in addition to university faculty and students, community groups and small business developers are among the most common GIS users in libraries. Likewise, R. Houser (2006) determined that the "integration of GIS services within libraries may help to level the playing field for community groups and researchers” (p. 9). However, Yu concluded that GIS software is still difficult for users to learn and use. Integrating user-friendly web-based mapping tools into library services, which has the effect of introducing these free tools to those who are unaware of their existence, further levels the playing field by making GIS more accessible.

In a study conducted by M. Howser and Callahan (2004), it was found that a great number of university students have very little access to GIS software or instruction. They view this lack of access as creating an unmet demand that libraries could serve.

According to Milson and Earle (2007), Internet GIS provides “a promising alternative to desktop GIS in educational settings due to their free access, familiar interfaces, and large, up-to-date databases” (p. 227). In a study of the use of web-based mapping tools among ninth graders, Milson and Earle (2007) found that users felt that the ease-of-use of the tools provided them with a sense of freedom and that this freedom was a positive aspect of their use of web-based GIS. This study also showed that the familiar and unimposing Web browser interface helped students work with data and maps without the often time-consuming introduction to sophisticated software.

Yu (1998), in pointing out that data, like mapping tools, should also be easy to understand, quotes results found by Hiller and Johnson (1989) in which they describe three fundamental steps in using GIS, steps which most users have trouble understanding:

- Establishing two separate data sets, one geographic and the other thematic, through completely separate processes;
- Merging of these data sets to give geographic meaning to the thematic information;
- Manipulating the graphics to provide a truly meaningful map (as cited in Yu, 1998, p. 103).

A study by Zwart (1993) of how fast librarians could extract census data showed that no one could complete the task in less than two hours (as cited in Yu, 1998, p. 103). “If the first two steps that Hiller and Johnson indicated can be automated, users will feel more comfortable using GIS” (Yu, 1998, p. 103). This automation, of merging thematic data with geographic boundaries, is precisely the function that web-based GIS is designed to perform.

> Because of the capabilities of this direct Internet mapping and the vast amount of information available, midlevel mapping resources are particularly useful for reference service in the library. Patrons, even proficient users of the Web, are often not aware that these tools exist, but the flexibility, user-friendliness, and customization they offer recommends them for many geographical queries. Most patrons use high-level GIS in libraries for simple mapmaking and do not need its immense capabilities. Thus online mappers often satisfy user needs while mitigating the demand for unnecessarily intensive GIS software (Kowal, 2002, p. 112).

Usability is a central concern in the design and success of web-based tools. While web-based mapping tools are generally easier to use than desktop GIS, Nivala, Brewster, and Sarjakoski (2008) found many usability problems in their study of web-based mapping sites. In this evaluation, Nivala et al. (2008) looked at Google Maps, MSN Maps and Directions (now Bing Maps) and two other sites not included in this study. Through analysis of the use of these sites by novice Internet users and expert cartographers, the researchers found 33 catastrophic problems that often prevented the use of the application and 138 major problems that made the use of the application significantly difficult (Nivala et al., 2008).

These problems were grouped into four categories: “1) user interface; 2) map; 3) search operations; and 4) help and guidance" (Nivala et al., 2008, p. 131). The researchers then made recommendations for improving these applications. To improve the interface, Nivala et al. (2008) suggested simplifying it, arranging the display and tools in a more intuitive manner, removing distracting advertisements, and opening new pages in another browser window rather than in the same window that displays the map and its tools.

To improve the map, Nivala et al. (2008) recommend providing information about map accuracy and validity and additional tools to measure distance, place markers, and add and remove layers. Many of these suggestions have been implemented on most web-based mapping sites since completion of this study, indicating the rapid pace of development of the technology.

For improving search operations, Nivala et al. (2008) suggests providing the capability for saving searches and adjusting default search options to match user entered queries. Again, many of the recommendations made have been implemented by many sites.

In the help and guidance category, Nivala et al. (2008) recommended providing the user with more help with using the map and mapping tools and clarifying error messages. Many sites today provide in depth online manuals and tutorials of varying quality.

M. Howser and Callahan (2004) suggest that, due to the demanding nature of GIS services, libraries planning to implement these services may need to increase specialized staffing. This is most often not possible not only due to funding shortages for staff but also to funding shortages for software and staff training. Web-based mapping tools, because they are both free and user-friendly, avoid these issues

Longstreth (1995) focused on the need for training of librarians in GIS concepts. "Staff must know more than how to operate the GIS software; they need instruction in the issues of GIS theory, GIS databases, and GIS applications in a discipline" (p. 272). Only a GIS librarian can be expected to maintain this level of expertise. Again, the simplicity of web-based tools and the preformatted data to which they provide access, while limiting in their ability to perform spatial analysis, relieves librarians of much of the knowledge Longstreth mentions.

Access to instruction is critical if GIS services are to be successfully implemented and geospatial research is to be successfully accomplished by novice users. This need is even more critical when the primary tool being offered is complex desktop software. User-friendly web-based mapping tools decrease the need to provide instruction.

Difficult and somewhat controversial topics related to GIS services and instruction in libraries have been addressed. Argentati (1997) suggests that "the library cannot and probably should not satisfy all campus GIS training needs" (as cited in R.

Houser, 2006, p. 324). Yu (1998) raises a similar point in stating that “the high demand on librarians' time may be too much for libraries to handle” (p. 102). “On the other hand, the sharp learning curve of GIS may stop many users from trying without some guidance. What should libraries do? Should we wait until GIS software is user-friendly enough for patrons to use intuitively” (Yu, 1998, p. 102). Yu goes on to state “the library should not be merely a free computer lab[;] it should be an active, value-add agency and encourage people to use GIS” (p. 103). Yu bases these findings partly on research conducted by Lang (1992) in which it was determined “that the main challenges are finding software that is easy to use and bringing the products into the mainstream of library operation” (as cited in Yu, 1998, p. 98).

Yu, in admitting that it is difficult to make GIS software that is intuitive, recommends that when libraries choose GIS software, it should be done with the understanding that “users prefer the low-end products because they have fewer functions and are simple to use” (p. 99). Zwart (1993) determined that “users may be satisfied with relatively simple tools to undertake comparatively well-defined tasks on straightforward and simple systems” (as cited in Yu, 1998, p. 102).

> [Zwartz’s] study shows that users tend to use fewer commands than what the system provides. The commands are different depending on the user group. In other words, the simpler the system is, the better users like it. The controversy exists because GIS software producers tend to create powerful GIS packages. Although the user inter- face is becoming more and more friendly, more and more functions are being offered. Given this situation, libraries can play an important role as intermediaries between users and GIS software (Yu, 1998, p. 102).

Methodology

Building on past studies and motivated by the need for simpler GIS services provided by libraries, this research develops descriptions of a set of free mapping applications and analyses of their functional elements from the perspective of a user population of beginner-level spatial data users. This user group is envisioned to contain reference librarians, both public and academic, and library patrons who possess little or no GIS experience. The results of the study provide a cross-sectional view of the current state of the art in web-based mapping as applied to academic and public libraries.

The terms web-based mapping, Web GIS, and desktop GIS can be confusing because the lines separating them are blurry. The following definitions will be used throughout this paper.

The primary difference between web-based applications, such as web-based mapping and Web GIS, and desktop GIS is the location of data. *Web-based mapping* applications provide access to remotely stored data and typically do not allow use of locally stored data. These remotely stored data are often accessed through portals and clearinghouses. *Spatial data portals and clearinghouses* are web sites that provide access to large repositories of data. Many spatial data portals and clearinghouses provide searchable map interfaces that provide easy access to data using visualization tools built in to the Web interface. This automatic access greatly aids in the location and retrieval of cataloged data. Some of these data viewers, or web-based mapping sites, are so advanced that users in need of basic reference maps, maps with layers like roads, terrain, cities, and boundaries, can use these viewers to create, print, save, and export satisfactory maps with only a Web browser.

However, basic reference maps are inadequate when the user needs a map of the distribution of a variable through space, also called a thematic or choropleth map. Generating thematic maps requires a much greater level of technological sophistication.

Hence, web sites that provide this capability are less common and struggle with data retrieval, server uptime, and map display problems.

These web-based mapping sites are often enhanced by other web sites that provide additional non-mapping tools, also entirely web-based. These peripheral tools can be used for converting spatial data into the proper format. Examples of the services that these web-based tools provide include converting addresses or geographic coordinates to points on the earth, also called geocoding; formatting the columns of a spreadsheet containing spatial data; and converting a spatial data file to another format.

Web GIS differs from web-based mapping in that remotely stored data are accessed using small software applications that must be installed on local computers rather than using simple Web browsers. Additionally, these installed programs, unlike the simple and automatic access to data provided by web-based mapping sites, must be instructed by the user to connect to remotely stored data through the use of URLs that point to the data stored within a *Web Map Service (WMS)*. While web-based mapping refers to the ability to produce final map products within a simple Web browser, Web GIS and WMSs refer to the ability to use an installed program to retrieve, over the Internet, data that is stored on a remote Web server. Like web-based mapping sites that provide access to satellite and aerial imagery, roads data, and other data for use as base layers, Web Map Services provide this same service for use by desktop programs and typically provide more mapping features than their web-based counterparts. Also similar to web-based mapping sites, WMSs do not allow for manipulation of the remotely stored base data and provide only limited analytic tools.

While the use of Web GIS technologies and Web Map Services require the installation of small software programs on local computers, these small programs are generally not considered desktop GIS. The term *desktop GIS* is reserved for complete geospatial and statistical analysis programs that require expert knowledge to be used effectively. The focus of the data gathering and evaluation sections of this study are based only on web-based mapping applications and, to a lesser degree, Web Map Services. Desktop GIS programs are beyond the scope of this paper. However, some desktop programs that are available free of cost and are relatively user-friendly are mentioned for informational purposes only. Refer to Appendix A for a list of tools examined and other resources.

The web-based mapping tools that were chosen for this study come from a simple content analysis of library web pages. The libraries chosen for this analysis are located in North Carolina and include both public and academic libraries. All web-based mapping tools and a select few WMS tools mentioned on these web pages were included in the study. In each instance where a library included information about one of these tools on its web site, the library essentially recommends the tool as a user-friendly alternative to complex desktop GIS. Therefore, the author includes these tools because they are subjectively determined to be the most popular and appropriate for use by beginner-level spatial data users, reference librarians and patrons alike.

The data gathering portion of the study is a subjective non-statistical comparison between the tools selected. This evaluation is focused on gathering data about the functional elements and capabilities of these popular web-based mapping tools and Web services.

The evaluation of each tool began with an attempt to use the site without familiarity with directions or documentation. All functionality was explored to determine if the site was intuitive and areas of confusion were noted. Following this first run through, a thorough examination of all documentation was conducted and the tool was re-visited. Finally, options for downloading data and printing maps were tested in order to determine the quality of created maps.

The criteria used for the evaluation includes ease of use, the type of data each tool is able to access, and the variety of mapping capabilities each provides. Ease of use is judged by the author's perception of the difficulty of the tool's use as applied to tasks common among inexperienced users. Mapping tools that are easy to use are those tools that have user-friendly graphical interfaces, easy access to spatial data, basic mapping functionalities, and limited spatial analysis capabilities. Aiding patrons with their geospatial research and mapping needs is defined as making spatial data easily and quickly accessible and viewable while avoiding problems common to searching for and retrieving data, importing data into desktop GIS programs, and creating basic maps.

After comparing the 16 web-based mapping and Web GIS tools evaluated and the two desktop programs included but not evaluated, a set of recommendations was created for public and academic libraries to implement or improve their GIS services. These recommendations focus on free products that are relatively easy to learn and use. The one exception to this is SimplyMap, a product from Geographic Research, Inc. that requires a subscription. This list contains those tools from the study that are entirely web-based, installed tools that have the capability to automatically access data stored remotely and accept local data, and are free of charge. These recommendations can be applied to the practices of reference librarians as well as to beginner-level researchers. Below are definitions of the evaluative criteria used in the scoring rubric in the Comparisons and Recommendations section.

Using studies conducted by Donnelly (2010) and Nivala et al. (2008) as guides, a scoring rubric was designed with novice spatial data users in mind to evaluate the mapping tools in this study. The scoring rubric is divided into three tables. The first table focuses on the experience the user has through interacting with the map interface. The second table focuses on data and analysis tools. The third table focuses on options for creating final map products.

User experience covers variables related to human-computer interaction such as accessibility, usability, and availability. Accessibility, or how the user accesses the application, can be either through a Web browser or by installing a small software program on the user’s local computer. Usability is determined by the design and ease of use of the interface and is ranked as either intuitive, complex, or poor; the quality of the tool’s documentation which can be complete, adequate, or poor; and how much time is required to learn to use the application which can be little or significant. Web site availability is affected by server down time, page load errors, broken links, and download speed and is ranked as either reliable or having few or several problems.

Evaluation of the data and analysis tools covers variables related to human-information interactions such as reference map availability and quality, data themes, and analysis options. Reference data, which includes basic map layers such as aerial photographs and roads, are examined to determine the types that are available and their quality (date of production and author) which is ranked as good, limited, or unknown.

Thematic map availability considers availability of pre-formatted choropleth maps and is ranked as many, few, or none, and their quality which is ranked as good or unknown. Creating features is defined as the ability to draw or place points, line, and polygons in the map display and is ranked as advanced, basic, or none. Analysis options include options for measuring distance and area, geocoding, and other analyses and are ranked as advanced, basic, or none. Analysis also includes creating thematic maps.

The last section examines the options available for users to create map products including importing and exporting data and printing maps. Options for importing data include uploading external data such as shapefiles, KML files, GPS coordinates, and spreadsheet and text data and is ranked in terms of its availability and reliability. Options for exporting data include downloading data layers as shapefiles, KML files, spreadsheets, text files, and images, and converting data to other formats and are ranked in terms of their availability and reliability. Options for printing maps include adding cartographic elements such as title and legend and are ranked has either available or not.

Web-based Mapping Applications and Web GIS

The following resources and applications were chosen based on an analysis of North Carolina library websites. It was determined that these are among the most popular sites among librarians and their patrons. The resources and applications are arranged from the simplest resources and tools, followed by a selection of census data mapping tools, a selection of federally supported geospatial data clearinghouses and mapping sites, and finally an example of a web-based tool that can be used to prepare data for mapping.

D-maps and Other Reference Map Sources

Discussion of the simplest mapping resources begins with d-maps. D-maps provides free outline maps which can be very useful for projects where only a base outline map of a country, state, or state with counties is needed. Maps from around the world can be saved in GIF, PDF, and other formats (Dalet, 2010).

Many other sites provide basic page-sized maps showing boundaries, cities, roads, and other similar data, for example, About.com Geography, Central Intelligence Agency World Factbook, Houghton Mifflin Company Education Place, National Geographic Xpeditions, Perry-Castañeda Library Map Collection at The University of Texas at Austin, United States Maps at the University of Alabama, and the David Rumsey Historical Map Collection.

Bing Maps

Bing Maps is a Microsoft product that provides access to basic reference maps. The reason Bing Maps is included in this study is its relationship with Environmental Systems Research Institute (ESRI), the leading GIS software provider. For users seeking more visualization and mapping functionality than is available on the Bing Maps web site, most Bing Maps content (its reference maps) is freely available as the base map gallery in ArcGIS Explorer by connecting to Bing Maps' Web Map Service. The content that is accessible using ArcGIS Explorer differs slightly from that accessible using a browser (See below for information on ArcGIS Explorer). Roads, land boundaries, water features, satellite imagery, 3D imagery, and imagery overlaid with roads and geographic names are available but not all of the aerial photographs are available.

The Bing Maps web site represents the simplest form of spatial data access and web-based mapping. Data accessible include road maps, state, county, and city boundaries, state and federal land boundaries, surface water features, geographic names, and aerial photographs. Thematic layers, such as health maps from the Department of Health and Human Services, are being added regularly. All data and mapping tools are available with only a Web browser. However, mapping functionality is very limited.

Map navigation tools common among this and similar simple web-mapping sites include zoom, pan, driving and walking directions, and inset maps for better showing the location of the main map display. For users who are able to install software on their local computer, Bing offers a 3D view of aerial photographs that cover buildings and landmarks of some popular locations. In addition, there are more than thirty applications, or Map Apps, that users who have free Windows Live ID accounts can use to manipulate their data and create maps. Some of these applications are created by Bing and others created by third parties. The most useful of these applications is the Distance Calculator.

Users can print the maps they create in Bing Maps but data cannot be exported nor can data be imported. These limitations are typical among these very basic web-based mapping applications. Another primary limitation is the inability to produce a legend. Users who want to customize maps saved from the Bing interface, such as adding a title, will need to do so using an external program such as MS Word or PowerPoint.

Yahoo! Maps

Yahoo! Maps is included in this study because Yahoo! provides address and latitude/longitude geocoding. This feature, however, is not available within Yahoo! Maps. Geocoding is the process of finding the exact location of a street address or geographic coordinate point on a map. The Geocoding Tool v3.1 is an Excel spreadsheet equipped with macros for connecting to the Yahoo! Geocoding API, finding the latitude and longitude coordinates for addresses entered into the spreadsheet, and then producing a KML file that can be viewed in Google Earth or any geobrowser that is able to read KML files. This service requires an Internet connection and a free Yahoo! ID. The spreadsheet is available from other online applications such as Batchgeo (Holmstrand, 2010) and Juice Analytics (Gemignani, 2006). Juice Analytics also provides other macro enabled spreadsheets for finding area codes by state, finding zip codes within a set distance of a location, and for finding addresses within a set distance of a location. See the discussion below for information about Batchgeo. Juice Analytics spreadsheets were not included in this study.

Like Bing Maps, the Yahoo! Maps web site is designed primarily for obtaining driving directions, business locations and information, and viewing imagery. Yahoo's satellite imagery is continuously updated and generally is less than two years old (Yahoo!, 2010). Unlike Bing Maps and Google Maps, there are no gadgets (mapplets) that users can add to their Yahoo! Maps profile so creating place marks, polygons, and lines (other than driving directions) is not possible. Another unfavorable characteristic of the Yahoo! Maps web site is the numerous flashing advertisements. Like Google, however, Yahoo! does provide rich sources of information and assistance to developers wanting to create their own widgets and mashups. Web development and Web programming using Application Programming Interfaces (API) are beyond the scope of this paper.

Google Maps

Google Maps is possibly the most popular web-based mapping application is use. A good variety of data is available including basic reference maps similar to those provided by Bing Maps and Yahoo! Maps and the same imagery available using Google Earth (see below for information about Google Earth). Unlike Bing Maps, Google Maps allows users to view 3D images of select locations without installing additional software. Similar to Yahoo! Maps, satellite and aerial imagery is continuously updated and is approximately one to three years old. While Bing Maps and Yahoo! Maps provide many images embedded in the map display, Google Maps has created a Street View option that allows users to view seamless imagery of the mapped area taken from street level. Other data include public transit information, biking and walking distances and times, and third-party business and Yellow Pages data (Google, 2010b).

Users can create maps of public transportation data. Transit data is obtained through the Google Transit Partner Program (Google, 2010c). Maps of walking and biking routes can be created using optimized routings, avoiding major roads and following pedestrian paths and bike lanes.

Travel costs can also be computed allowing users to find the least cost path to their location. Estimates of the cost to drive from one place to another include distance and “the standard cost per mile that tax regulations allow businesses to deduct” Google, 2010b). “These calculations are based on an annual study of the fixed and variable costs of operating an automobile. Runzheimer International, an independent contractor, conducted the study for the IRS” (Google, 2010b).

For users who have a free Google account, the My Maps feature allows them to use any of the more than 1400 mapplets, also called gadgets, and map layers which they can add to their maps. These gadgets and data layers include distance measuring tools, latitude/longitude finding aids, elevation contours, earthquake and volcano activity, water sampling data, effects of sea level rise, weather maps, public transit data, census data, data related to Antarctica, and much more. While many of these data and tools were created by the federal government, most of the gadgets and data are generated by private third party members of the Google Maps Community.

Users that have their own latitude/longitude point data can create placemarks in Google Maps using Google's Spreadsheet Mapper tool. Spreadsheet Mapper is a Google Docs spreadsheet application that allows users to enter data into a pre-formatted spreadsheet and generate a set of placemarks in KML format that can be viewed in both Google Maps and Google Earth. This tool will accept up to 400 points. For more points, another Google tool, Fusion Tables, not included in this study, is available (Google, 2010e).

GPS Visualizer is a tool that allows users to upload GPS data and convert them to a variety of formats including KML files (Schneider, 2010). (See the Literature Review for a description of KML files.) Another example is BatchGeo which is a free online tool that easily converts addresses from a spreadsheet or text file into points on top of Google Maps and also produces a KML file that can be opened in Google Earth (Holmstrand, 2010). Point data must be in US address format or latitude/longitude format. See the discussion below for more information about Batchgeo.

Additionally, because Google Maps can read KML/KMZ files, any KML/KMZ file that is hosted on a web server can be imported into Google Maps. This means that much of the data that users can find on the Google Earth Community web site can be viewed in Google Maps (Google, 2010b). However, large KML/KMZ files typically do not open correctly in Google Maps and it is suggested that Google Earth be used instead.

Users who have a Google account can also add place marks, lines, and shapes directly to their maps and then save their maps for later. Query functions allow users to search by address, road intersections, latitude and longitude coordinates, and keywords. Keywords can be business names, place names, and geographic features (Google, 2010b).

While users cannot print satellite or aerial photograph images, they can save these images and print all other data. Because Google Maps uses the same imagery that Google Earth uses, users can go to Google Earth to print imagery. After saving the map, text and HTML descriptions, photos, and videos can be added. Users can also email a link to the online map or paste the HTML into a web page (Google, 2010b).

ACME Mapper 2.0

ACME Mapper is an application that is based on Google Maps and provides several features not available from Google. Imagery available includes USGS topographic maps, also called digital raster graphics, and digital orthographic quadrangles which are provided by Microsoft Research Maps through their Web Map Service. Other imagery includes NEXRAD and Mapnik. NEXRAD, Next Generation Weather Radar, is a high resolution radar imagery produced by the National Oceanic and Atmospheric Administration's National Weather Service. Mapnik imagery is attractive road and boundary layers created by ACME using the Mapnik technology.

Several map navigation options in addition to the basic Google Maps navigation are also available (Poskanzer, n.d.). However, the many mapplets available to Google account holders are not accessible in ACME Mapper. Additionally, distance and geocoding tools are limited compared to Google Maps. The primary advantage with ACME Mapper is the full browser view of the map which is much larger and easier to read than the small map viewer in Google Maps. Finally, maps can be printed, emailed, and linked to from another web page.

KMZ Census Mapper

Discussion of web-based mapping sites devoted to census data mapping begins with KMZ Census Mapper. Ralston and Streufert (n.d.) at the Department of Geography at the University of Tennessee have produced an easy to use tool that allows users to select Census 2000 data by census tract, ZIP Code tabulation area, and counties, and then automatically converts the data into KML files for easy viewing in Google Earth and Maps and ArcGIS Explorer.

Data is extracted from Summary File 1 and Summary File 3 of the 2000 Census of Population and Housing (Ralston & Streufert, n.d.). Users can select a single census variable, a color scheme, and a spatial extent of either the whole state or a single county. After these selections are made, a KML file is produced and made available for downloading. Clicking on this file automatically opens the data in Google Earth.

American FactFinder

The US Census Bureau makes its demographic data available through the American FactFinder web site. The data available at this site includes decennial census, American Community Survey, population estimates, economic surveys, and many more. These data are available in table format with a variety of tables for each survey type (U.S. Census Bureau, 2008a).

In addition to the tables, a mapping tool provides visualizations of the census data along with reference maps that show the selected location with boundaries and geographic features such as roads. Thematic maps of census data can easily be created showing patterns in the data such as population and income in varying colors (U.S. Census Bureau, 2008b).

Users can search for survey data using one of three primary methods; keyword search, selecting a survey, year, and geographic location from a list, or selecting a geographic unit from a reference map. To begin a search, users can click Search from the home page or select a data set and chose to view tables and maps. Each of these two search entry points yields slightly different options for selecting geographies and cartographic features.

This method produces a thematic map of the selected data at the chosen geography. There are limitations to selecting a spatial extent and map symbols, however. Another method is to choose a data set, a particular survey, and select Thematic Maps. This method gives the user more cartographic options in the creation of the map.

Tables can be exported but must be processed in order to be viewed in mapping software. It is advisable that users will little or no GIS experience utilize the mapping tools available within the web site.

Longitudinal Employer-Household Dynamics – OnTheMap

The U.S. Census Bureau Center for Economic Studies has created an online mapping tool called OnTheMap that allows users to create maps and reports showing where workers are employed and where they live. OnTheMap is the result of a partnership between the U.S. Census Bureau and 47 states through the Local Employment Dynamics (LED) partnership. This easy to use tool allows users to create, view, print, and download workforce, transportation, and economic related maps, demographic profiles, and reports (U.S. Census Bureau, 2009).

Thematic data that are accessible using OnTheMap include employment data, worker demographics, and employer location information. The employment data come from Unemployment Insurance Wage Records. These records are created by employers and used by each state in unemployment insurance programs. Worker demographics data such as age, earnings, and residence locations come from the Census Bureau (U.S. Census Bureau, 2009).

Reference map data, or base maps, are derived from 2008 TIGER/Line shapefiles, the Federal Aviation Administration, Federal Railroad Administration, Employment and Training Administration, National Center for Education Statistics, and the Local Employment Dynamics (LED) Partnership. These base map data include the full range of reference data such as roads, schools, rivers, cities, boundaries, census enumeration units, and much more (U.S. Census Bureau, 2009).

The fundamental questions this tool helps users answer are "Where do workers live?" and "Where are workers employed?" These locations are referred to as Home or Residential Area and Workplace Area respectively. In order to answer these kinds of questions, OnTheMap provides functions for two types of analyses, a profile analysis and a shed analysis.

A Home Area or Work Area Profile Analysis produces a map showing the distribution of workers living or working inside the study area. A Commute Shed or Labor Shed Analysis produces a map showing where workers are employed who live in the selection area (called a Commute Shed) or where workers live who are employed in the selection area (called a Labor Shed) (U.S. Census Bureau, 2009). If the user is focusing on the Home/Residential Area for the study, the analysis options will include the Home Area Profile and the Commute Shed analyses. On the other hand, if the user is focusing the study on the Workplace Area, the analysis options will include the Work Area Profile and the Labor Shed analyses. While these choices may seem confusing, the methods and instructions for selecting these data and analysis options are clearly organized and easily accessible documentation of how to use the site and what various terms mean is provided.

Reports are also produced for each type of analysis. The Profile Analysis report includes basic demographic information (age, earnings, and industry) and the Shed report shows home and work locations (U.S. Census Bureau, 2009). All of these reports can be downloaded as Excel, PDF, and HTML files.

Users of OnTheMap follow five steps in the analysis and mapping process. First, the layers for the base map are selected. Second, data options for the analysis are chosen. Third, a geographic are is defined for the analysis. Fourth, the analysis type is selected. And finally, the results are displayed for viewing, printing, and downloading (U.S. Census Bureau, 2009).

As mentioned above, there are many options for base map layers. The data options allow the user to focus either on work locations or home locations. The first options determine how labor force characteristics, geographic concentrations, and home-to-work travel patterns are represented in the resulting maps and in the reports. The geographic study area can be chosen using a variety of methods. The most useful is the points method where users select geographic units for the analysis from a drop down list and click the map on each unit of interest. Other methods include creating a user defined area using drawing tools, importing a shapefile, a KML file, or points, or creating a buffer around an area. During the evaluation, however, importing a shapefile resulted in server errors and importing a KML file took too long to be useful.

Map symbology for the resulting analyses includes points of varying sizes and thermals or shaded contours similar to isolines. The points represent the number of workers that live or work in a census block, tract, or county. The thermals represent the density of workers as workers per square mile. The resulting map can be printed or downloaded as a shapefile, a KML file, or a database file (DBF) (U.S. Census Bureau, 2009).

SimplyMap

SimplyMap, from Geographic Research, Inc., is a web-based mapping application that enables novice users to easily create thematic maps and reports. The data provided are extensive collections of demographic, business, and marketing data. A licensing agreement must be purchased, however. Because the application is already in use by many public and academic libraries, it has been included in this study.

The data includes landmark layers (Base map data) such as state and county boundaries, highways, local streets, parks, and bodies of water. The bulk of the data covers over 70,000 variables related to demographics, employment, real estate and housing, crime, businesses, consumer spending, and points of interest (Geographic Research, Inc. 2010). The geographic units for which data can be mapped are block groups, census tracts, ZIP codes, cities, counties, states, and the entire United States.

Data providers include Easy Analytic Software, Inc. (EASI) which provides 2000 Data, 2008 Estimates, and 2013 Projections of Demographics variables; Retail Sales, Store Groups, and Food Service Variables; Quality of Life Variables; Health variables; Consumer Price Index Variables; Employment variables; Consumer Expenditure Variables. Dun & Bradstreet Points of Interest Data includes information on over 4.5 million places. Applied Geographic Solutions provides historical data of 1980 census in 2000 geography, 1990 census in 2000 geography, and 2000, 2008, and 2013 population, education, and household data. EASI/Mediamark Research Incorporated (MRI) Propensity Data includes thousands of marketing and consumer behavior variables (Geographic Research, Inc. 2009).

This application includes tools for creating maps of locations and selected census and marketing data organized by user defined geographic units, tools for creating reports of the selected data, and tools for querying the data variables selected.

All data can be saved into the user's workspace, printed, or exported. Images can be exported in GIF or PDF format, reports in Word, Excel, or CSV format, and data in shapefile format which can then be imported into external GIS applications such as ArcGIS Explorer (see description below).

Social Explorer

Similar to SimplyMap, Social Explorer allows users to create thematic maps of demographic data using nothing more than a Web browser. The site is a web-based application that easily creates maps and reports and provides access to all available census data. Social Explorer provides both a subscription version and a free version with scaled-down functionality and data. For libraries using the free version, this scaled-down functionality could be a major limitation.

Census data is available from 1790 to 2000. Data is provided by The New York Times, the National Historical Geographic Information System, and the Association of Religion Data Archives. Base layers include only state and county boundaries and census enumeration units.

There are easy to use tools for map navigation, adding layers, printing, saving, and exporting maps. Maps can be viewed as static maps or users can create slide shows of many maps by simply dragging each map to the desired location in the slide sequence. This is particularly useful for showing changes in demographics over time.

Reports are produced by first selecting a census year then choosing census geographies and variables. Geographies can be selecting using a list or Federal Information Processing Standard (FIPS) codes. Variables can be chosen from a list of pre-selected tables relating to a particular census topic or users can create customized tables. Reports can be downloaded in CSV and Excel formats (Social Explorer, 2010).

The National Map, Geospatial One Stop, and National Atlas

Discussion of federally supported geospatial data clearinghouses and mapping sites focuses on the work of the U.S. Geological Survey’s National Geospatial Program Office (NGPO). This office is responsible for providing federally maintained geospatial data to the public. With the Federal Geographic Data Committee providing the standards for creating and sharing geospatial data, the National Map, Geospatial One Stop, and National Atlas make up the foundation of the National Spatial Data Infrastructure (Newell, 2008).

These services can be ranked from low to high usability for novice spatial data users. The National Map Viewer is designed for viewing data in a map display, analyzing the data, and exporting data layers. The Geospatial One Stop is also designed for retrieving detailed individual data layers but also provides many prepared maps and more options for saving and printing from the map display. These first two services function primarily as data clearinghouses with additional advanced data viewing options. The National Atlas, on the other hand, is a full featured web-based mapping site providing a rich source of printable maps, dynamic maps, and many map layers that can be viewed in the Map Maker. Because of these features, the National Atlas can be considered the most appropriate of the NGPO sponsored sites for beginner-level spatial data users.

As an advanced data clearinghouse, the National Map provides access to topographic data from several federal agencies in the form of map displays within a browser, hard copy products that can be ordered, and downloadable data sets along with several analysis tools. Data include aerial photographs, also called orthoimagery, elevation, geographic names, hydrography, administrative boundaries, transportation, structures, and land cover (Newell, 2008).

The National Map Viewer is just one of the many services provided by National Map but is possibly the most useful for novice spatial data users in need of help visualizing and basic manipulation of data. The viewer uses an advanced delivery platform created by the National Geospatial Intelligence Agency (NGA). This service allows users to create customized maps of data from the eight data sets listed above, export data layers, import shapefiles and KML files, create features, and perform several analyses (USGS, 2010). Unfortunately, printing from the Map Viewer is not supported.

The tools included in the Map Viewer cover fundamental map navigation plus advanced analysis functions such as distance and area measuring, adding data, querying and selecting data, creating buffers, drawing points, lines, and polygons, modifying annotations, and identifying features and spot elevations. Data can easily be downloaded using the Map Viewer. Downloads can be limited to the area visible in the Map Viewer or at much larger extents. Four vector data themes are available: structures, transportation, boundaries, and hydrography. Three raster data themes are also available: land cover, elevation, and orthoimagery. In addition, features that the user creates – points, lines, and polygons – can be downloaded in shapefile format (USGS, 2010).

The Map Viewer provides support for certain KML elements for uploading. Features such as place marks, icons, points, lines, and, for instance, polygons created in Google Maps or Google Earth can be uploaded into the Map Viewer. The National Map also provides support for connecting a desktop GIS, ArcGIS Explorer for example, to its Web Map Service (USGS, 2010).

Another data clearinghouse is the Geospatial One Stop. This service is an inter-government initiative of 19 agencies managed by the US Department of the Interior in partnership with the Federal Geographic Data Committee (USGS, n.d.). The program is focused on providing free access to spatial data and maps from all of these federal agencies. The site is a portal or catalog of geospatial information containing metadata records and links to maps and mapping services, downloadable data sets, and images.

A wealth of data and maps is available on the site. Live Data and Maps is a Web Mapping Service (WMS) that allows users to view and interact with data using the

Geospatial One Stop Map Viewer or other WMS tools such as ArcGIS Explorer. Data Download allows users to download individual data layers.

Many popular maps have been prepared and are offered for downloading. These prepared maps cover a range of environmental topics for the entire US. Many of these maps include multiple data layers and can be viewed and interacted with through the Map Viewer. The Map Viewer is a web-based mapping application based on ArcExplorer Web technology that allows users to interact with data, prepare maps, and save or print the maps as images. Users can add data layers from the geodata.gov map service or other services, display multiple layers in one map, locate places and addresses, and identify map features (USGS, n.d.).

Like the popular prepared maps, there are several Communities of Special Interest and Data Categories. These Communities feature lists of maps many of which can be viewed and interacted with in the Map Viewer. An example of a Special Interest Community is the Local Governments Community which allows counties, cities, towns, villages, parishes, and consortiums of governments to share information and website links.

As mentioned above, much of the community data can be viewed in the Map Viewer. However, in several cases, only links to external sites are provided for data downloading. In addition, there are often problems with server down time and broken links. Geospatial One Stop use statistics indicate that downloading data is the most commonly used function of the site with use of the Map Viewer a distant fourth possibly due to the problems listed above (USGS, n.d.).

In addition to the features of a data clearinghouse such as raw data downloads, the National Atlas provides access to prepared maps and tools for making and printing maps. The scale for most data is 1:2,000,000 which is suitable if little map detail is needed. For more detailed data, users are directed to the federal agency that provided the data to the National Atlas or to the National Atlas' Raw Data Download site. Most of the layers that can be viewed with the Map Maker are available for download.

Users can search for data by browsing by Chapters (data categories) or by Products such as Map Layers, Printable Maps, or Dynamic Maps. Using the Map Maker, users can assemble their own maps for printing using the many available map layers. Map layers include agriculture, environment, people, biology, geology, transportation, boundaries, history, water, climate, and places. Because of the focus on web-based mapping, data cannot be downloaded directly from the Map Maker.

Printable maps are maps that have already been assembled from a variety of data layers. These maps can be downloaded for printing but are not interactive. Layers found in the collection of printable maps include political boundaries, precipitation, satellite data, and much more.

Dynamic maps show change over time or include links that users can click on for more information. A serious disadvantage is that these prepared maps cannot be downloaded. They include many layers such as invasive species, volcanoes, geology, vegetation, and disease.

Batchgeo

The evaluation ends with an example of a web site that is designed primarily for preparing data for mapping, in this case, determining the latitude and longitude coordinates of addresses. Batchgeo is a free service that lets users create maps of address locations from addresses stored in a spreadsheet. It will then calculate distances, convert addresses to latitude/longitude coordinates or KML, find postal codes for addresses, and allow users to print and save maps of addresses (Holmstrand, 2010).

The geocoding functionality uses the Yahoo! Geocoding service and the maps produced are built on Google Maps. Users can also choose to build the points on Yahoo! Maps. The reverse geocoder function accepts GPS coordinates in latitude/longitude and places them on a map as well as retrieves addresses for each coordinate. Once the addresses or coordinates have been geocoded, the Google Map can be saved or printed and the points can be converted to KML for viewing in Google Earth and Maps (Holmstrand, 2010).

Desktop GIS Programs

Desktop GIS ranges from small simple applications to large complex programs. The simplest desktop applications function as geobrowsers that give users access to remotely stored data generally with no analysis tools. Intermediate software includes sophisticated but relatively user-friendly programs that allow users to upload their own data and choose from a wide selection of analysis tools. The most complex desktop GIS programs are full-featured statistical and spatial analysis programs, both free open source and commercial.

The following discussion focuses on an evaluation of two of the most commonly used geobrowsers. Information about two user-friendly intermediate level desktop GIS programs is provided for informational purposes only with no evaluation. Full-featured statistical and spatial analysis GIS programs, such as ESRI's ArcGIS and the free open source GRASS GIS, are not evaluated in this study.

Earth browsers, also called geobrowsers, and Web Map Services (WMS) are very recent developments in Web and GIS technologies and are rapidly developing. Access to base data, such as aerial photographs and roads, much of which is often provided automatically, is available once the browser software is downloaded and installed on a local machine. In addition to this base data, local data can be uploaded into the browser. Other data that can be viewed in these Earth browsers includes data that is available through external web services. However, connections with many WMS sites are problematic due to server down time and the lack of adequate listings or directories of available web services. Two examples are included here: ArcGIS Explorer and Google Earth.

ArcGIS Explorer

ArcGIS Explorer, produced by ESRI, Inc., is a free viewer that must be installed on a local computer. One can then view base maps stored remotely on ESRI's Web Map Server (WMS) and can add locally stored data. The application has earth browser features that are very similar to Google Earth with a user interface that resembles many Microsoft Office 2007 programs. A web-based version is in beta testing at the time of this writing.

ArcGIS Online is a service hosted by ESRI that provides a platform for ArcGIS users to discover and share geographic content and to build GIS applications. Users can directly connect to maps, layers, and tools published by ESRI and other users. The primary feature for novice users is the ability to access published maps, reference layers, user guides, and tutorials. These services are free of charge for noncommercial uses.

An Internet connection is necessary for full functionality as the application connects to ArcGIS Online which provides the base maps and some of the applications tools. However, ArcGIS Explorer will work in a disconnected environment with limited functionality. For example, a user will be able to view and manipulate local data but will not be able to access base maps on ArcGIS Online or use the Find feature which searches base maps for specified locations. This limitation is minor as the bulk of the applications features are available off line.

To add data, users can select base layers from ArcGIS Online Basemaps or can add content from ArcGIS Online's other standard map services, shapefiles and rasters stored locally, KML files stored locally or remotely, geodatabase files, text files, GPS data, images, or can connect to other GIS Services (Web Map Servers) for external data.

The Basemap Gallery allows a choice of ready-to-use basemaps, such as World Imagery, World Streets, World Topographic Maps, or a Bing Map service. In addition to these base maps, ArcGIS Online provides several options for viewing prepared demographic maps, reference maps such as elevation, and specialty maps such as world political maps and navigation charts.

Web Map Services other than ArcGIS Online are also available. Examples include ESRI's ArcGIS Online, Geospatial One Stop, and the USGS GISDATA Map Studio Map Services. However, many of these external services are not easy to locate, are not intuitive to use, and are regularly offline. To simplify the experience, it is recommended that ArcGIS Explorer users use ArcGIS Online for all Web Map Services.

In addition to these online sources of data, users can add locally stored data in a variety of formats. ESRI geodatabases and shapefiles, images such as JPGs and TIFs, and

KML and KMZ files can all be imported into ArcGIS Explorer. This interoperability greatly increases the potential for the application. For example, most spatial data that is freely available online, such as data from federal government web sites, come as shapefiles, geodatabases, and raster images. Likewise, compatibility with KML and KMZ files makes the application fully integrated with Google Earth, Google Maps, and other geographic applications that accept these files.

Symbology of layers is accommodated only at the most basic level. While a layer of county boundaries can be displayed with all the boundaries, information about each county, such as census data, cannot be shown. In order to display a layer containing census data, a prepared layer form ArcGIS Online must be downloaded.

ArcGIS Explorer provides several tools that allow users to create their own maps and analyze data. These include tools for determining point latitude and longitude in degrees-minutes-seconds and decimal degrees, line and area distances in multiple units, and map distances in multiple units, buffers, 3D visualization, address geocoding, location finding, optimized routing, creating presentations, and adding notes and web links. While these tools are free to use, there are limitations to the batch function of the geocoding tool. There is no limit to the number of addresses that can be individually geocoded, but only 1000 addresses can be batch geocoded per user per year. A subscription service allowing 25,000 addresses for batch geocoding per user per year is available if the free version is too limited for a library's needs. (See Other Applications below for information about free online geocoding tools.)

Some limitations of the program include exporting data and printing. Data stored within ArcGIS Online cannot be exported for use in other GIS applications. These data are available only within ArcGIS Explorer. Printing is also limited. While printing is easily accomplished, printing of legends within the map body is not supported.

There are many limitations in working with locally stored data. Shapefiles are linked to attribute tables which contain data about the features in the layer. For example, a polygon layer of watersheds will typically contain information about each of the polygons. In ArcGIS Explorer, this attribute table is not accessible. The polygon layer of watersheds can be displayed but the additional data about each watershed stored in the attribute table cannot. Additionally, displaying raster images is limited. The most common raster data type is the ESRI proprietary GRID format. These rasters must be converted to another format such as Imagine Image, JPG, GIF, or TIF. Once converted, however, these rasters display without difficulties.

ArcGIS Explorer is an easy to use application and provides quick access to vast amounts of spatial data and simple map making tools. With such easy access to online and local data, many common barriers to accessing and displaying data are avoided. For example, one problem commonly encountered by new GIS users is coordinate systems. Data layers come in a variety of coordinate systems and in order to display multiple layers in one map, each must be in the same coordinate system. If each data layer has a defined coordinate system, ArcGIS Explorer can automatically integrate datasets with others by projecting data on the fly into the map.

Google Earth

Google provides two versions of the popular Google Earth product. Google Earth Pro is available for purchase while the original version is free. Google Earth is an Earth browser similar to ArcGIS Explorer and must be installed on a local computer. Once installed, a wealth of data is available for viewing.

Imagery that can be viewed in Google Earth includes satellite and aerial photographs, roads, buildings, boarders, labels, photographs, points of interest, and much more. At the time of this writing, Google also offered over 2,700 KML and KMZ files for viewing and downloading. In addition, Web Map Service images can be imported to Google Earth as image overlays. External images (JPGs, GIFs, etc.) can be imported as non-georeferenced image overlays and photographs and then georeferenced using Google Earth base layers (Google, 2010a).

There are many options for importing data into Google Earth. Data such as addresses and GPS coordinates saved in a spreadsheet, ESRI shapefiles, and images can be imported once converted to an appropriate format. Text files of addresses and geographic coordinates cannot be opened or imported directly into Google Earth (free version) but there are other free online applications that can be used to import point data. For example, Spreadsheet Mapper is a Google Docs spreadsheet that allows users to enter data and generate a set of placemarks in Google Earth and Google Maps. This tool will accept up to 400 points. For more points, use Google's Fusion Tables. GPS Visualizer is another tool that allows users to upload GPS data and convert them to a variety of formats including KML files (Schneider, 2010).

Another example is BatchGeo which is a free online tool that very easily converts addresses from a spreadsheet or text file into points on Google Maps and also produces a KML file that can be opened in Google Earth. Point data must be in US address format or latitude/longitude format.

Google Earth tools include drawing tools that allow users to add place marks, polygons, and paths. Map legends are not supported in the free version but one method for displaying formatted legends, of census data for example, is to use the University of Tennessee's KMZ Census Mapper to convert TIGER census data to KMZ format and open this file with Google Earth. There are also integrated tools for querying the displayed data, finding directions, creating routes, and measuring distances.

Few options for printing exist and the resulting image is of low but adequate quality. Maps can also be saved as images and these images can be modified in external applications like PowerPoint. Base images can be printed but not exported. The same images that are viewable in Google Earth can also be viewed in Google Maps.

Displayed maps can be saved as images. Placemarks, polygons, and paths can be saved as KML/KMZ files and imported into other applications that accept these files such as Google Maps, ArcGIS Explorer, and many others.

Intermediate Level Desktop GIS

The following software programs contain many more functions and features than ArcGIS Explorer and Google Earth, allow for importing of many more data formats, and provide superior cartographic options. Consequently, these applications are more difficult to learn and operate but much easier to learn than commercial GIS programs.

Libraries that have already implemented GIS services and provide commercial software such as ArcGIS may find these tools beneficial as additions to their services rather than as replacements (Donnelly, 2010). The benefits of free desktop programs would be enjoyed primarily by "small to medium libraries" where software that is free of cost, including software that is also free and open source (FOSS), "could be a solution for providing some GIS services as opposed to providing none at all" (Donnelly, 2010, p. 148).

The following programs are free of cost. Quantum GIS and DIVA-GIS are recommended for novice users who are willing to commit some time to learning the software. Advanced desktop GIS programs not included in this study but that deserve mention include GRASS GIS and MapWindow. All of these desktop GIS programs are free of cost and are included for information purposes only. While they are not recommended for use by librarians providing reference services, they could be considered by library managers wishing to begin providing more advanced GIS services.

Quantum GIS

Quantum GIS (QGIS) is a user-friendly open source GIS that is under constant development by a large group of developers. The goal of the program is to be easy to use and provide common mapping functions and features. The map interface helps users quickly and easily create maps, identify features, create labels, add cartographic elements, export data and printable maps, and much more (Quantum GIS Development Team, 2010).

Users can import and view many data formats without conversion such as shapefiles, JPG, PNG, and many other image types, tables and text files, and Web Map Service data. QGIS provides a wide range of advanced analysis tools and plugins that give users even more analysis options. Of particular importance are the integrated GRASS GIS tools, another free and open source GIS program that is designed for complex spatial data analysis and modeling (Quantum GIS Development Team, 2010).

In evaluating open source GIS programs for use in libraries, Donnelly (2010) found that none of those chosen for the study, that of producing a thematic map, were able to match the power of ArcGIS. "However, when an individual FOSS package was paired with some plugins or other tools, several performed reasonably well relative to ArcGIS" (Donnelly, 2010, p. 138). Donnelly stressed the importance and benefits of plugins several times during the evaluation, most of which QGIS supports. Donnelly also pointed out that the user interfaces of these free GIS programs were very similar to that of ArcGIS.

"While FOSS GIS has not evolved to the point where it matches ArcGIS in every aspect of the thematic mapping process, it does represent a viable alternative" (Donnelly, 2008, p. 144). Donnelly concludes the evaluation by stating two important issues libraries should consider before providing open source GIS to novice users: working with projections and attribute tables. For the purposes of this study, however, these issues are considered to be intermediate level concerns and more advanced for the novice users who may prefer simpler web-based tools.

While QGIS is sophisticated in its development and functionalities, it is easy to use. For beginner-level users, however, importing data and working with coordinate systems, issues inherent in all desktop applications that allow importing multiple data formats, this software may be difficult to learn. This difficulty is minimized by the friendly user interface and possibly justified by the wide variety of features and, as Donnelly points out, by library support of the open source movement (Donnelly, 2010).

DIVA-GIS

DIVA-GIS is a free desktop program that is maintained by Robert Hijmans, a faculty member at the University of California – Davis. The objective of his project is to provide a free and simple GIS program that is useful particularly for studying the biodiversity. Users who cannot afford proprietary GIS software or do not have the time to learn complex programs will find DIVA-GIS very helpful in viewing spatial data and creating attractive maps (Hijmans, 2005).

Many of the most common file types are supported by DIVA-GIS. These include the ESRI shapefile (SHP), Grid files (GRD), image files JPG, TIF, SID, and DBF files making the program compatible with MS Excel.

While users can import their own data, DIVA-GIS comes with a climate data set for the entire world. With the data set open in the map viewer, users can click on the map to retrieve climate data for that location. This data set also allows users to map climate variables over specified areas. The DIVA-GIS website provides access to many other free spatial data sets such as administrative boundaries, roads, railroads, elevation, land cover, population density, biological population counts, and satellite images (Hijmans, 2005).

DIVA-GIS is a relatively simple user-friendly desktop GIS that is free to download and install but will require some time to learn to use. Because its functionalities are limited the more basic and common analyses, learning to use the software will be much less time consuming than many other desktop GIS programs.

Comparisons and Recommendations for Reference Services

The following tables were designed using studies conducted by Donnelly (2010) and Nivala et al. (2008) as guides. Donnelly conducted a comparison of open source GIS products for use in libraries which helped in creating a method for comparing the functional elements of web-based mapping tools and Web GIS. Nivala et al. conducted a usability study on web-based mapping sites, including Google Maps and MSN Maps and Directions (now Bing Maps), comprised of evaluations from expert cartographers and ordinary users. These studies helped to determine which web-based mapping sites and which mapping features and functions should be the focus of this comparison. The studies also helped in the creation of the following rubric of evaluative criteria.

The rubric is comprised of three tables. The first table focuses on the experience the user has through interacting with the map interface. This experience is evaluated by considering how the application is accessed, its usability, and any issues that may affect its availability. The second table focuses on data and analysis tools. Reference and thematic data types and quality are considered as well as analysis tools provided. The third table focuses on options for creating final map products. These options include importing data, exporting data, and printing maps.

Specific recommendations will depend on the type of library under consideration. Academic library reference librarians and their patrons have different needs than those of public libraries and their patrons. Among university students and faculty, studies in the physical and environmental sciences dominate the GIS user community. However, as technologies become more intuitive, use of GIS and spatial data among researchers from the health and life sciences, social sciences, and business will increase. In the public library community, use of GIS and spatial data by patrons is rare in comparison but common among library administrators. “Public libraries use GIS for administrative purposes and as a research tool” (ESRI, n.d.).

This contrast in GIS use between these two user groups is reflected in the fact that there are abundant publications focusing on providing GIS services in academic libraries but very little literature on public library GIS services. Because of this dissimilarity, and the goal of this paper to provide recommendations for both academic and public libraries, the following tables and discussions provide general suggestions based on a flexible set of evaluative criteria.

The following table covers variables related to the user experience such as accessibility, usability, and availability. Accessibility, or how the user accesses the application, can be either through a Web browser or by installing a small software program on the user's local computer. Usability is determined by the design and ease of use of the interface and is ranked as either intuitive, complex, or poor; the quality of the tool's documentation which can be complete, adequate, or poor; and how much time is required to learn to use the application which can be little or significant. Web site availability is affected by server down time, page load errors, broken links, and download speed and is ranked as either reliable, few problems, or several problems.

Application	Accessibility	Usability	Availability
Bing Maps	Browser	Intuitive interface; Adequate documentation; Little learning time	Reliable
Yahoo! Maps	Browser	Poor interface (ads); Adequate documentation; Little learning time	Reliable
Google Maps	Browser	Intuitive interface; Complete documentation; Little learning time	Reliable
Google Spreadsheet Mapper	Browser	Complex non-mapping interface; Complete documentation; Significant learning time	Reliable (Google Docs spreadsheet)
Juice Analytics Excel Gecoding (Yahoo! Geocoder)	MS Excel and Internet connection	Complex non-mapping interface; Poor documentation; Little learning time	Reliable (MS Excel spreadsheet download)
ACME Mapper	Browser	Intuitive interface; Poor documentation; Little learning time	Reliable
American FactFinder	Browser	Complex interface; Complete documentation; Significant learning time	Some problems: speed
OnTheMap	Browser	Intuitive interface; Complete documentation; Significant learning time	Several problems: speed, server errors with large
SimplyMap	Browser	Intuitive interface; Complete documentation; Little learning time	Some problems: speed,
Social Explorer	Browser	Intuitive interface; Adequate documentation; Little learning time	Reliable
National Map	Browser	Intuitive interface; Adequate documentation; Little learning time	Reliable
Geospatial One Stop	Browser	Intuitive interface; Adequate documentation; Little learning time	Several problems: speed, server errors, broken links
National Atlas	Browser	Intuitive interface; Adequate documentation; Little learning time	Reliable
D-Maps	Browser	Intuitive non-mapping interface; No documentation; No learning time	Reliable
Batchgeo (Yahoo! Geocoder)	Browser	Intuitive non-mapping interface; Adequate documentation; Little learning time	Reliable
KMZ Census Mapper	Browser	Intuitive non-mapping interface; Adequate documentation; Little learning time	Reliable
ArcGIS Explorer	Installed	Intuitive interface; Complete documentation; Significant learning time	Some problems with WMS
Google Earth	Installed	Intuitive interface; Complete documentation; Little learning time	Reliable

Table 1. User Experience

Tools that are entirely web-based requiring neither installation of software or connection to remote mapping services are much simpler to understand and use than those that do require software installation and connections to WMSs. However, Google Earth is recommended due to its ease of use and variety of reference data. ArcGIS Explorer is recommended for those interested in gaining familiarity with ESRI products but is not recommended for use at the reference desk.

Usability has improved significantly in recent years. Generally, the more complex the purpose of the site, the more complex the interface. Google products typically provide the most attractive interfaces (no flashing advertisements), the most complete documentation, and the most variety in reference data. For example, Street View could aid small business developers and other interested in viewing images of properties taken from the street without making the trip themselves.

For geocoding, Batchgeo is the easiest to use among the non-mapping sites (those that provide a spreadsheet style interface) and produces final maps very quickly. For census data, KMZ census mapper is much easier to use, faster, and freer of errors than American FactFinder but with limited options for data access. Social Explorer provides much more census data and advanced mapping options. OnTheMap provides unique thematic data and mapping options, but using the site resulted in many download problems. All sites were evaluated from within the UNC-CH network which should reduce problems with download times.

National Atlas is perhaps the most complete web-based mapping site produced by federal agencies and is more intuitive and reliable than other federal clearinghouses.

The following table covers variables related to data and analysis tools such as reference map availability and quality, data themes, and analysis options. Reference data are examined to determine the types that are available and their quality (date of production and author) which is ranked as good, limited, or unknown. Thematic map availability considers availability of pre-formatted choropleth maps and is ranked as many, none, or few, and their quality which is ranked as good or unknown. Creating features is defined as drawing or placing points, line, and polygons in the map display and is ranked as advanced, basic, or none. Analysis options include options for measuring distance and area, geocoding, or other analyses and are ranked as advanced, basic, or none, and creating thematic maps.

Application	Reference Data	Thematic Maps	Creating Features	Analysis
Bing Maps	Good variety; Unknown quality	Few types; Unknown quality	None	Basic analysis tools
Yahoo! Maps	Limited variety; Unknown quality	None	None	None
Google Maps	Good variety; Unknown quality	Many types; Unknown quality	Yes	Basic analysis tools
Google Spreadsheet Mapper	NA	NA	Yes; Points only	None
Juice Analytics Gecoding Tool	NA	NA	Yes; Points only	Geocoding
ACME Mapper	Good variety; Unknown quality	None	Yes; Points only	Basic analysis tools
American FactFinder	Good variety; Good quality	Census: Good quality	None	Basic analysis tools; Thematic maps
OnTheMap	Good variety; Good quality	Census and other demographic data: Good quality	None	Advanced analysis tools; Thematic maps
SimplyMap	Limited variety; Good quality	Demographic, business, marketing; Good quality	None	Thematic maps
Social Explorer	Limited variety; Good quality	Census: Good quality	None	Thematic maps
National Map	Good variety; WMS option; Good quality	None	Yes	Advanced analysis tools
Geospatial One Stop	Good variety; WMS option; Good quality	Few types; Good quality	No	Basic analysis tools
National Atlas	Good variety; Good quality	Few types; Good quality	No	None
D-Maps	Limited variety; Unknown quality	NA	NA	NA
Batchgeo (Yahoo! Geocoder)	NA	NA	Yes; Points only	Geocoding
KMZ Census Mapper	NA	Census: Good quality	NA	Thematic maps
ArcGIS Explorer	Good variety from WMS; Good quality	Many types (WMS); Good quality	Yes	Basic analysis tools
Google Earth	Good variety; Unknown quality	None	Yes	Basic analysis tools

Table 2. Evaluation of data and analysis tools.

Reference data provided by web-based mapping sites, such as roads and aerial and satellite imagery, are typically one to three years old but publication dates are usually not provided. Identification of the authors of reference data is often difficult to determine due to lack of documentation. In some cases, the author is known but the date is not.

The popularity of demographic data among community organizers, planners, and small business owners and developers makes several of the web-based mapping sites reviewed in this study particularly useful. SimplyMap, Social Explorer, OnTheMap, American FactFinder, the KMZ Census Mapper are easy to use web sites devoted to this purpose and their use can easily be implemented at the reference desk. From this list of sites, Social Explorer and KMZ Census Mapper are the easiest to use for accessing basic census data. For more census options, and for other demographic data, American FactFinder and SimplyMap, respectively, are recommended.

Web-based mapping sites typically provide only the most basic map navigation tools and limited analysis tools. Google Maps is the exception in that over 1,400 analysis tools are available. Google Maps also maintains an ever increasing library of thematic maps. Likewise, for creating user-defined features such as points, lines, and polygons within the maps display, Google Maps and Google Earth are recommended. The National Map, while designed primarily as a data clearinghouse, provides an impressive selection of advanced analysis tools.

The following table covers variables related to final map production such as importing data, exporting data, and printing maps. Options for importing data include uploading external data such as shapefiles, KML files, GPS coordinates, and spreadsheet or text data and is ranked as yes, not reliable, or no. Options for exporting data include downloading data layers as shapefiles, KML files, spreadsheets, text files, and images, and converting data to other formats and is ranked as yes, not reliable, or no. Options for printing maps include adding cartographic elements such as title and legend and are ranked has either providing these options or not.

Application	Importing Data	Exporting Data	Printing Maps
Bing Maps	No	No	Yes; No cartographic elements
Yahoo! Maps	No	No	Yes; No cartographic elements
Google Maps	KML; Small files only	KML of user created features	Yes; No cartographic elements
Google Spreadsheet Mapper	No	KML of user created points	NA
Juice Analytics Gecoding Tool	No	KML of user created points	NA
ACME Mapper	No	No	Yes; No cartographic elements
American FactFinder	No	Shapefiles, spreadsheet, and text files	Yes; Contains basic cartographic elements
OnTheMap	SHP, KML, GPS; Small files only	XLS, PDF, SHP, KML, DBF	Yes; Contains basic cartographic elements
SimplyMap	No	DOC, XLS, CSV, SHP	Yes; Contains basic cartographic elements
Social Explorer	No	XSL, CSV	Yes; Contains basic cartographic elements
National Map	SHP, KML, WMS	SHP, GRID	No
Geospatial One Stop	No	SHP, GRID	Yes; Contains basic cartographic elements
National Atlas	No	SHP	Yes; Contains basic cartographic elements
D-Maps	NA	No; Images only	Yes; Basic country and state outlines
Batchgeo (Yahoo! Geocoder)	No	KML	Yes; Google Maps with no cartographic elements
KMZ Census Mapper	No	KML	Yes; Google Maps with no cartographic elements
ArcGIS Explorer	SHP, KML, GRID, Text, GPS, GDB, WMS, Images	SHP of user created features	Yes; Contains basic cartographic elements
Google Earth	KML	KML of user created features	Yes; No cartographic elements

Table 3. Map Production.

Importing data into a web-based mapping site is not always reliable. During testing, each of these sites produced errors or very slow upload times. This feature is not recommended for novice users. Similarly, there many problems were encountered during downloading of data. In general, downloads of large files from a web-based mapping site is problematic. Small files, however, generated very few problems.

Printing of final maps is probably the task in which novice users are most interested. Options for cartographic elements such as title, legend, north arrow, and scale bar are important elements for any map. Unfortunately, these options are rare among web-based mapping sites. Sites that provide basic cartographic elements include the census sites, including American FactFinder, OnTheMap, SimplyMap, and Social Explorer, and federally maintained sites such as the National Atlas.

Limitations of the Study

This study is not exhaustive. Many web-based mapping tools, WMS, and desktop GIS are not addressed. Only those tools common among North Carolina library web sites were included, with emphasis on free tools. This was based on an assumption that the state is not greatly different from others regarding library GIS services. Commercial software was not the focus and consequently only one commercial product was included.

The author makes other assumptions during this study. First, it is assumed many web-based GIS tools could be of great value to researchers new to GIS who are attempting to incorporate geospatial data mapping into their research projects. Second, it is assumed that a significant number of novice GIS users have simple mapping needs that these tools can accommodate. A third assumption is that patrons who look to reference librarians for information regarding spatial data and mapping could be satisfied with web-based tools as alternatives to more robust desktop software. If these assumptions are valid, there would be a direct relationship between use of web-based mapping tools and Web GIS at the reference desk and patron success with GIS projects.

Further research of web-based mapping sites and Web Map Services is needed in order to fully understand the advantages and problems with their implementation in libraries and use by novice spatial data researchers. Such studies could focus on the usability of web-based mapping and Web GIS interfaces by observing their use by a group of beginner-level GIS users, a survey of reference librarians who have little or no GIS training or experience designed for determining GIS skill and comfort level, and a study of the applicability of these same tools for advanced spatial data and GIS users. Implementation of the recommendations made in this study and follow up surveys could help in determining the validity of the assumptions made in this study and the effectiveness of web-based mapping tools and Web GIS in library reference and GIS services.

Conclusion

The intent of this study was to evaluate a selection of web-based mapping sites and Web GIS applications for use by librarians and their patrons who possess little or no GIS or spatial data experience. Because many reference librarians employed in public and academic libraries fall into this user group, these tools were also evaluated for their appropriateness as reference service tools. Given the rising popularity of GIS among all user groups, it is hoped that the results of this study may be useful to librarians and LIS students as a source of information about the current state-of-the-art of web-based mapping and Web GIS.

Desktop GIS software programs that provide the full range of spatial and statistical analysis and cartographic options, such as ESRI's ArcGIS and Geographical Resources Analysis Support System (GRASS) GIS, are often much more software than users need. These complex tools can, for many, block the use of GIS and spatial data and result in frustration for beginner-level users. Without user-friendly mapping tools, the benefits of the wealth of free spatial data available to the public, the encouragement of the implementation of GIS into beginner-level projects, and advances in geographic literacy will be missed. Fortunately, there are many talented Web developers creating easy to use mapping applications and these tools continue to improve.

Through evaluation of the tools selected for this study, it was determined that, while there exist several very efficient and effective applications, many obstacles remain. Server errors, slow download times, and broken links were the main problems found that could result in limited use by beginners. These are relatively easy problems to fix, however, and advances in the technology are expected to continue rapidly.

The most impressive sites are those that are devoted to a specific type of data or a specific type of analysis. Sites that provide access to census data for mapping, for example, functioned best of all. This is probably due to the wealth of free census data available, the usefulness of the data for a variety of purposes, and the popularity of census data among the public. These forces have acted as fulcrums for moving web-based mapping of census data forward.

Environmental analysis and mapping is another area that is focusing development of the technology on ease of use for the benefit of novice users. Federal agencies are devoted to providing their spatial data to the public. Given the geographic nature of this type of data, a key requirement for its adoption by beginner users is easy to use visualization tools. The federal government has created sites for visualization and mapping of the data online and other sites for accessing the raw data layers for downloading.

Web-based mapping is an exciting and evolving area of Web development. As these sites become easier to use and more efficient, their use will certainly increase. Increasing the use of spatial data and advancing the cartography skills of novice users, reference librarians included, will, like all improvements in human-information interactions, enhance our understanding of the world around us. Use of web-based mapping technology in library reference services will encourage the use of GIS and spatial data among novice users and consequently encourage this improved understanding.

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Appendix A

Web addresses for web-based mapping sites, free desktop GIS download sites, and mapping and spatial data information sources referred to throughout the paper.

1. About.com Geography http://geography.about.com/
2. ACME Mapper 2.0 http://mapper.acme.com/
3. American FactFinder http://factfinder.census.gov/home/saff/main.html?_lang=en
4. ArcGIS Explorer http://www.esri.com/software/arcgis/explorer/index.html
5. ArcGIS Explorer Beta http://www.arcgis.com/home/webmap/viewer.html
6. Batchgeo http://www.batchgeo.com/
7. Bing Maps http://www.bing.com/maps/
8. Central Intelligence Agency World Factbook https://www.cia.gov/library/publications/the-world-factbook/
9. David Rumsey Historical Map Collection http://www.davidrumsey.com/
10. DIVA-GIS http://www.diva-gis.org/
11. d-maps http://d-maps.com/
12. Geospatial One Stop http://gos2.geodata.gov/wps/portal/gos
13. Google Earth http://earth.google.com/
14. Google Earth Community http://bbs.keyhole.com/
15. Google Fusion Tables http://tables.googlelabs.com/
16. Google Maps http://maps.google.com/
17. GPS Visualizer http://www.gpsvisualizer.com/
18. GRASS GIS http://grass.itc.it/
19. Houghton Mifflin Company Education Place http://www.eduplace.com/ss/maps/

20. Juice Analytics Area Codes by State

http://www.juiceanalytics.com/ (search for “area codes by state”)

21. Juice Analytics Distance Tool v1

http://www.juiceanalytics.com/ (search for “distance tool”)

22. Juice Analytics Excel Geocoding Tool

http://www.juiceanalytics.com/writing/excel-geocoding-tool-v2/

23. Juice Analytics Finding Zip Codes Close to an Address

http://www.juiceanalytics.com/writing/finding-zip-codes-close-to-an-address/

24. KMZ Census Mapper http://ctasgis02.psur.utk.edu/tokml/

25. MapWindow http://www.mapwindow.org/

26. Microsoft Research Maps http://msrmaps.com/webservices.aspx

27. National Atlas http://nationalatlas.gov/

28. National Geographic Xpeditions http://www.nationalgeographic.com/xpeditions/

29. National Map http://nationalmap.gov/

30. OnTheMap http://lehd.did.census.gov/led/datatools/onthemap4.html

31. Perry-Castañeda Library Map Collection at The University of Texas at Austin

http://www.lib.utexas.edu/maps/

32. Quantum GIS http://www.qgis.org/

33. SimplyMap http://www.geographicresearch.com/simplymap/

34. Social Explorer http://www.socialexplorer.com/

35. United States Maps at the University of Alabama http://alabamamaps.ua.edu/

36. Yahoo! Maps http://maps.yahoo.com/