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The Evolution of GIS Services in Academic Libraries

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Summary: This paper focuses on the role that academic libraries play in the provision of GIS related services. The paper argues that academic libraries are safe, friendly, and neutral places that are poised to take a major role in expanding GIS applications across campuses. An extensive review of the literature and a survey of GIS librarians chronicle a remarkable transformation that has resulted in the steady expansion in the complexity and scope of GIS services offered by libraries. The findings suggest that the evolution follows the classic model for the diffusion of innovation. While libraries at a few major research institutions experimented with GIS in the early 1990s, however, the general pattern has been for librarians to offer new services only after the technology has been simplified and made effective. Over the past three decades the rate of adoption has been impacted by the demand for services, the motivation of the librarians, the enabling technology, and the availability of resources. These factors have resulted in widespread adoption of GIS for at least simple web-based mapping applications. An analysis of web sites for more than 190 academic libraries suggests that colleges and universities fall into at least three levels of maturity in terms of the scope of services they provide. At the entry level an institution often provides simple web sites that point to resources. At the intermediate level, a library may provide consultation regarding access to data and software. However, at an increasing number of universities the library has become the focal point for enterprise wide GIS support and training. In fact, at many institutions that do not have geography departments there is an increased demand for librarians to get directly involved in educating their users about spatial literacy and sophisticated analysis. At the same time, the research community is requesting assistance with long term data management plans, and librarians are actively involved in the maintenance of portals that provide tools for discovery, review, and acquisition of spatial data. This paper also highlights the important role that Esri has played in the expansion of GIS services at academic libraries. Of particular note was the company's sponsorship of the Association of Research Libraries (ARL) GIS literacy project in the early 1990's, the implementation of a university site licensing program, and transformation to online, cloud-based services such as StoryMaps.

Introduction

Over the past three decades academic libraries have expanded their mission to include support for geographic data discovery, visualization, and analysis. In many cases, the library has assumed the focal point for campus wide GIS support. Furthermore, a major survey of GIS services found that:

> "The academic map librarian from the 1970s or 1980s would hardly recognize todays' geographic information service center. What was once a room of map cases and shelves of atlases and gazetteers is now a bustling geospatial center" (Holstein, 2015)

Many librarians view the provision of GIS services as a significant new opportunity to expand services to students and faculty. In fact, some have referred to it as "our goal, our geographic moon shot for each of us and of our institutions, associations, and professional bodies" (Boxall, 2014) to seize the moment and plan for ways to meet user needs.

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According to Esri's education division, in 2011 it was estimated that "there are 2,500 academic libraries and 500 public libraries using Esri products" (Angela Lee, e-mail, April 26, 2011). Each of these represents an opportunity for growth. It is also clear that Esri has been the catalyst for change through its university site licensing program and transformation to online, cloud-based services that are less challenging than desktop applications. There is evidence that the technical barriers and steep learning curves librarians faced over the past three decades have been eliminated. With minimal training, most staff can provide initial GIS support. In other words, GIS services are becoming a core function of even small academic libraries. For example:

> "By helping connect the humanities with science and technology using story maps, librarians can create a neutral environment for learners to conduct interdisciplinary research and develop spatial literacy." (Kallaher and Gamble (2017).

This analysis of the status of GIS services in academic libraries involved a comprehensive review of more than 180 published documents and a review of services currently provided by more than 82 colleges and universities. The analysis also included email exchanges, telephone conversations and campus visits. It is also based on feedback from twenty-eight academic librarians who responded to an online survey. Holstein, who conducted a major a survey of ARL institutions in 2015, concluded:

> "The question for academic libraries today is no longer "whether to offer GIS services but what level of service to offer." Nearly all surveyed libraries (94%) have staff that can assist students specifically with software use for class assignments and projects, while 90% provide assistance with more generalized use of the software".

The Evolution of GIS services

The editors of the Journal of Map & Geography Libraries recently suggested that the evolution of map and spatial information librarianship over the past 25 years can be divided into three eras (Bidney and Piekielek 2018). These eras coincide with changes in available technology. The first era was closely linked to the availability of census data on CD-ROM following the 1990 decennial census and access to GIS software on standard personal computers. The authors note that this initial stage of GIS services was often located in the government documents section of the library. The authors also note that this effort formed the initial campus home for GIS. The second era focused on scanning technology that resulted in the digitization of photos and maps often located in a map library. These scanning efforts made collections much more accessible, especially as they moved to the internet. Bidney and Piekielek found that this process required librarians to gain new skills and to become GIS Librarians. The authors associate the current era with the proliferation of geospatial services. They suggest that the evolution through these three states has had a profound impact on libraries:

> "The transition to a digital world was a blow to the former prominence of map collections in academic research libraries throughout the first two paradigm shifts, but now in many cases geospatial services are being touted as a major contributor to the modernization of library services. For map and GIS librarians whose tenures have spanned these transitions, it has been a roller-coaster ride indeed." (Bidney and Piekielek 2018).

Diffusion of Innovation

The evolution of GIS services by academic libraries over the past three decades follows Everett Roger's 1962 model for the diffusion of innovation (Rogers). In his model there are five stages of progression from (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards (Fig. 1) In terms of the provision of GIS services, the rate of adoption by academic libraries has been impacted by a set of change agents that include the demand for services, the motivation of the librarians, the enabling technology and the availability of resources. It is argued that over the past thirty years the support for GIS services has expanded from a few major research libraries to an environment where some level of GIS service is now available in thousands of academic libraries. A list of important dates in this evolution started in 1978 (Fig. 2). Many of the milestones listed refer to the hardware and software environment that support GIS. Essentially, these translate into a lower cost of entry, the ability to use common personal computers, intuitive interfaces, cloud-based data, and base maps.

The academic literature suggests that the stages of adoption align with the decades of the 1990's, 2000's, and 2010's. As with any innovation, a few risk takers were willing to experiment with cumbersome, expensive, and unstable technology. The starting point for widespread experiments was the Association of Research Libraries (ARL) GIS literacy project that Esri and other companies supported in the early 1990's. This initiative was enabled by the combination of the user-friendly software (ArcView) running on personal computers and the existence of the Census TIGER files that provided free nationwide data. The project was designed "to introduce, educate, and equip librarians with the skills necessary to provide access to spatially referenced data in all formats, and to provide effective access to selected electronic information resources in library collections." (Lang, 1992). Jack Dangermond, the president of Esri, enthusiastically supported the project, stating he "believes the effort will foster public access and move libraries into the future" (Lang 1992). Throughout the decade of the 1990's there were a few adventurous users that were willing to follow the lead. By the turn of the century about 121 universities had participated in GIS literacy programs. The project represents the critical first stage in the evolution of library-based GIS services. As noted by Davie et al. noted:

> "If it were not for the ARL GIS Literacy Project, grant funding, and help from Esri, GIS services in North American academic libraries probably would not have developed as quickly, thus spurring the evolution of GIS services starting in the late 1990s." (Davie, D. K., Fox K, & Preece, B. 1999).

It is important to note that not all the universities that participated in the GIS literacy Project established permanent programs. While the allure of providing GIS support was quite strong, the technology was still very challenging. Librarians were facing a challenge that required them to establish a new line of service and with a new set of tools and new set of patrons. As Soete, stated in 1997:

> "Just about everyone who has written about geographical information systems (GIS) agrees that they pose daunting service and collection challenges for libraries. Such systems can be expensive and can require skills not yet adequately developed in library staff. "(Soete, 1997)

At the turn of the century, several forceful leaders urged their colleagues to take on the challenge and warned about consequences of not seizing the opportunity. At the end of the decade the Map

& Geospatial Information Round Table (MAGIRT) of the American Library Association held a conference with the theme "GIS in EVERY Library: Making it Happen." (Weimer, 2011).

By the middle of the decade of 2000s there were plenty of web mapping sites and successful stories to share. The Journal of Map & Geography Libraries was initiated in 2004 and the ARL published SPEC Kits that provided valuable guidance for establishing new services. A major catalyst for change was Esri's adoption of a campus wide site license structure. This eliminated financial barriers and provided an opportunity for libraries to assume a major role, especially where there was no geography department. While desktop GIS became much more user friendly, the emergence of Google Maps in 2005 was a major game changer. It made mapping a mainstream application and highlighted the possibility for exciting new spatially oriented research. Libraries began to develop web sites that and provided links to major federal GIS data resources from the Bureau of Census and the US Geological Survey. A review of the literature suggests that by 2010 libraries had reached the Early Majority stage in the diffusion process.

During the last decade, support for mapping and GIS became a common service provided by academic libraries. From a technical viewpoint the emergence of cloud-based applications and data eliminated the final barriers for adoption. Esri's ArcGIS Online and its Living Atlas of the World, with about 4000 curated themes, made GIS services accessible without the need to install software or maintain databases.

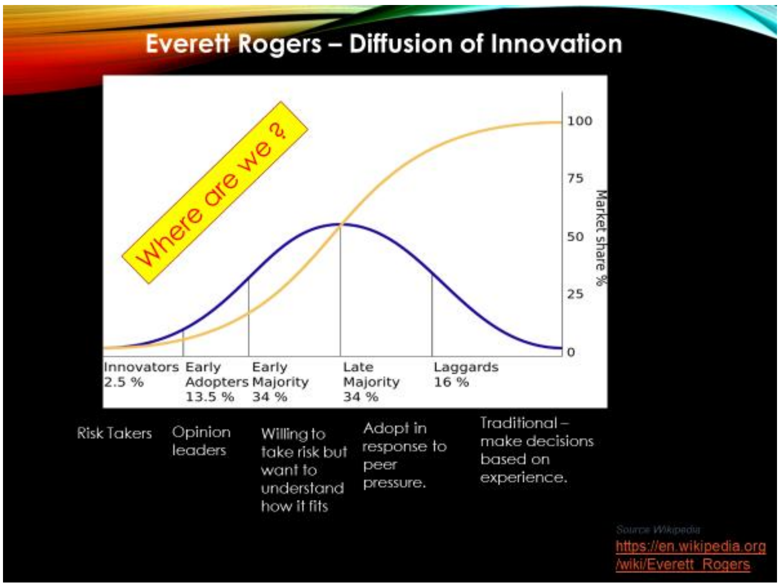

Figure 1. Stages of Roger's diffusion of innovation. Modified from https://en.wikipedia.org/wiki/Everett_Rogers.

TIME LINE	Impact
1970	
1978 Map & Geoinformation Curators Group	
1980	
1980 - MAGERT (Map and Geography Round Table) of the ARL (Now MAGIRT)	
1980 - North American Cartographic Information Society (NACIS Information Society.	
1990	
~ 1990 - ESRI Site License	Provided Campus wide Use - including libraries
1990 - Census TIGER files –	Free - Nation Wide Data
1991 - Esri ArcView 1.0	Windows - simple User interface
1992 - ARL GIS Literacy Project – supported by Esri	Important Initiative
1994 - The Alexandria Digital Library Project –	NSF sponsored project that defined Geolibrary
1995	
1995 - Special GIS issue of Journal of Academic Librarianship–	Major effort to introduce GIS to Libraries
1996 - MapQuest –	First web-based mapping system
1997 - ARL Spec Kit 219 –Transforming Libraries issues and innovations in GIS	Discribed the issues
1999 - ARL Spec Kit 238 Survey of ARL institutions .	Survey of 72 libraries
1999 - National Research Council Report - Distributed Geolibraries	Laid Out The Vision
2000	
2004 - Journal of Map And Geography Libraries	
2004 - Open Street map	Free - World wide User Generated
2005	
2005 - Google Maps and Google Earth	Free Smart Phone with imagery
2005 - ARL SPEC Kit 291-Survey of ARL institutions	Another major Survey
2010	
2010- MAGIRT Symposium - GIS in Every Library - Make it Happen	Call to
2014 - Esri Story Maps	Simple Web Creation Spatial Application
2015	
2015 - GeoBlacklight	Open Source Geographic Search Web Application
2015 - UCSB Spatial Discovery of Linked Research Datasets	Protocol for Linked Data within Esri Platform
2020	

Figure 2. Significant dates in the evolution of GIS services in academic libraries.

Change Agents

A critical part of the adoption of new technology is the influence of opinion leaders who can share success stories. The impetus for adoption is often linked to factors that ease the transition and minimize the risk. In terms of the GIS support the following change agents have minimized the risks and encouraged new adoptions:

- Partnership with Esri
- Esri Site License
- Spatial Awareness
- Institutional support
- Simple Applications (ArcView) on Personal Computers
- Free Federal Data - TIGER & DLG
- Moore's Law – capacity to handle ever larger applications
- Inexpensive Storage
- Cloud Computing
- Software as a Service
- Google Maps - huge impact on society
- Arc GIS Online and The Living Alas
- StoryMaps – 1.7 million and counting
- Stable funding

Today's technology has eased the pain for traditional map librarians who were reluctant to accept a new group of users. Data stored in the cloud and software as a service enables new users to have successful outcomes in a manner of minutes. Instead of attending workshops and training sessions librarians can access online tutorials and YouTube videos to acquire new skills. New users are familiar with Google and can quickly learn new GIS light applications such as StoryMaps. In many cases, the library has taken the lead to serve as the focal point for GIS support across the campus by sponsoring GIS Day events, holding workshops, posting web resources, supporting the site license, and conducting in class training programs. The recent literature highlights a remarkable transformation that has the potential to change the way an academic library can serve the research community and even the public. Given the remarkable rate of expansion of StoryMaps, which now has more than 1.7 million applications, libraries are in an excellent position to promote and support expansion across their campuses. Through demonstrations, workshops, and some in class training there is no limit to the possibilities. There is also extensive evidence that StoryMaps represent a "Gateway Application" for sophisticated GIS applications.

An interesting assessment of how smaller academic libraries or the "laggards" are dealing with the decision to adopt GIS services is offered by Kallaher and Gamble (2017). Their experience at the New College of Florida demonstrates that a successful GIS support program can be easily implemented with low risk. By delaying their decision to adopt, these libraries have avoided the pitfalls that faced innovators and even recent adopters. This is especially true in terms of technology and staffing. Rather than taking a "minimum of fifteen hours to learn the basics of some GIS programs" (Holstein; 2015) students and faculty can have successful outcomes in less than an hour. In this case, a library-centered model of GIS management can be effective in introducing humanities scholars to the capabilities of GIS in their disciplines. Where disciplines such as geography, geology and environmental sciences once dominated the applications, we now see innovators in humanities, history and other cultural disciplines taking the lead. A growing number of business schools are directing their students to the library to access the data and tools.

Current Environment

The previous discussion traced the adoption of GIS services; however, it is important to recognize that while providing GIS services can be exciting, it may also be disruptive and challenging. As Bidney, recently stated (2019).

> "As map librarians, we work in an awkward place within libraries – we straddle the line between a user services department and special collections."

She advocates that the library publicizes the unique resources in its collection. Scanned maps and photos provide a valuable resource for historical and cultural research. As she states:

> "Instead of the map library being seen as simply a provider of geospatial information, we can use this opportunity to show our communities that our collections can be used as a means for teaching critical thinking – not just about geospatial information, but about information in general. Bidney, M. (2019).

Bidney and Piekielek (2018) see the provision of GIS services as an opportunity for new collaboration across a campus. As they state:

> "In our view, the map and geospatial librarian community needs a diversity of people, opinions, expertise, collections, and institutions in order to be successful in the current paradigm that places so many high expectations of map and geospatial librarians."

Based on their long history in the field, Bidney and Piekielek believe that modern map 1ibrarians fulfill several roles, including:

- digital scholarship service provider.
- discipline-agnostic advanced spatial methods expert; and
- some modern version of a map librarian that is a person with an MLS and a GIS certificate or an advanced degree in a subject related to geography/cartography.

Providing GIS services poses an interesting challenge for a library. The mission statements for three major academic libraries reflect the scope of services and interaction with faculty and students:

- Support interdisciplinary GIS education, data discovery and literacy, and outreach for spatial data and methods to a broad range of users through workshops, consultations, and online materials. Collect and curate spatial data and maps.
- The Map and Geospatial Hub is ASU's library-based center for geographic information systems (GIS), remote sensing, cartography, and the related technologies needed to transform geospatial data into powerful, value-added information. We tell stories with maps and data.
- We help students and faculty with GIS tasks, finding data, giving presentations to classes. Would like to potentially spend more time with higher level analysis/programming/advanced capabilities, but due to limited personnel the amount of time tend to focus on basics.

The fact that all but one Carnegie I research university maintains an Esri site license demonstrates the importance of GIS as a research tool. Furthermore, while only Dartmouth College has a Geography Department, all eight of the members of the Ivy League provide a home for GIS support in their library. Yale University has made a major commitment to providing GIS services. It has hosted three "GIS Days" and operates a very active StoryMap Network. Furthermore, the Map and Geospatial Information Center at Princeton offers a remarkable set of 19 workshops:

1. Introduction to ArcGIS Pro
2. Introduction to QGIS
3. How to Create and Collect Geographic Data using ArcGIS Pro
4. How to Create and Collect Geographic Data using QGIS
5. Select and Analyze Geographic Features and Data with ArcGIS Pro
6. Select and Analyze Geographic Features and Data with QGIS
7. Finding the Best Location using ArcGIS Pro
8. Finding the Best Location using QGIS
9. Using Tables and Maps together in ArcGIS Pro
10. Using Tables and Maps together in QGIS
11. Making Maps and Presentations using ArcGIS Pro
12. Making Maps and Presentations using QGIS
13. Supervised Image Classification using ArcGIS Pro
14. Supervised Image Classification using QGIS
15. Using ModelBuilder in ArcGIS Pro
16. Using Tools to Create Models in QGIS
17. Essential ArcGIS Pro Tools for Research
18. Essential QGIS Tools for Research
19. 19.Create Web Mapping Applications Using ArcGIS Story Map

- https://library.princeton.edu/collections/pumagic/workshops

Another measure of the demand for GIS services within libraries is the number of employment opportunities. A recent search for "GIS Librarians" identified 48 openings. These included a range of titles such as:

Social Science and Geospatial Data Librarian
Spatial Data Science Librarian
Geospatial Data GIS Map Librarian

Director Data GIS statistical services
Developer foe Digital Spatial research and Scholarship
Senior Programmer Analyst
Systems Engineer

GIS Maturity Model for Academic Libraries

Maturity models are a popular way to way to assess status of the capabilities and depth of institutional support. They provide a basis for evaluating whether the services are meeting user needs and provide a way to compare the quality service between different organizations. For several years Esri has encouraged colleges and universities to provide a deeper and broader levels of support for GIS research and training. It suggests that a university that offers a diverse and mature level of GIS support and applications would be called a spatial university. Esri has defined a spatial university as one that has the following characteristics:

- Spatial thinking across the curriculum.
- Geospatial workforce development.
- Geographically oriented collaborative research.
- GIS applications for campus administration and logistics

As libraries take a more central role in providing GIS services, they become part of the campus infrastructure. A recent study by Alrwais (2016) provides a way to evaluate the maturity of GIS services, assess the current state of competence and to set a roadmap for organizational improvement. He suggests that a maturity model:

- Provides a starting point for internal discussion.
- Helps assess the current situation,
- Suggests strategies for advancement.

Through a self-assessment process an institution should evaluate

- Organization / Institutional Issues
- Instruction / training programs
- Support for the research community

A systematic assessment of the current level of support could include the following check list.

- Does the library have a mission to provide GIS services?
- Does it include training
  - Workshops
  - In class
  - For credit classes
- Is there awareness /support from the central administration?
- What are the technical skills of the current staff?
- Is there a collection of maps and photos?
  - Does it provide access through web services?
- Does the library collaborate with the geography department or another discipline?
- Is there a GIS center?
  - As part of the library?
  - Outside the library?
- Does the library maintain a spatial data portal?
- Does the library help curate long term research data?

Alrwais proposed that a three-tier system for GIS implementation. These stages can be defined as

- Exploration Stage: Simple links to resources
- Exploitation Stage: Some level of support to locate data and software
- Enterprise Stage: Full fledged services including workshops and consultation.

It is interesting that these stages parallel the findings of Kong et.al. (2017) who suggest that users can mature through three stages.

- The first level of GIS service was described as serving users with little experience, where a basic mapping tool is introduced.
- The second level of GIS service targets users with some experience, where spatial data manipulation, query, and customization are introduced.
- And the third level is for proficient users needing assistance with data capture, storage, and information analysis.

Libraries as GIS Centers

To better understand the relationship between centers, libraries and geography departments, Guan and Hess from Harvard examined how the presence of a geography department impacted the provision of GIS services. Their extensive survey of 81 GIS centers at academic institutions examined the following issues:

- Is there a prevailing administrative home for GIS centers?
- What are the most common functions of GIS centers?
- Is there a prevailing funding source for GIS centers?
- Is there a prevailing size (by funding or FTE) for GIS centers?
- What are the factors affecting the funding level and functions of GIS centers?
- What are the most common challenges and promises that GIS centers face? .´

The feedback indicates that the majority of GIS centers operate at public universities with a Geography Department (Table 4) However, there are 32 centers at private universities. The authors noted that 21 of the 81 centers that responded to the survey were housed in a library. The authors draw some interesting conclusions about how responsibilities for GIS services are shared between libraries and geography departments.

> “A majority of the centers provided technical services such as data processing and analysis, consultation or project scoping, and data discovery and acquisition. Centers in a university without a geography department were more likely to provide these services and cartographic production or help desk, while centers in a university with a geography department were more likely to provide services on application development and hosting, and automation scripting or tool development.

The authors draw some conclusions regarding the future location of GIS services. They highlight the following:

> “Centers in universities with a geography department were more likely to rank the lack of financial stability as their biggest challenge, perhaps because they were more heavily relying on research grants as main funding sources, while centers in universities without a geography department were more likely to rank the lack of institutional recognition and user awareness as their biggest challenges.”

Their findings may have a profound impact on libraries. Dedicated GIS Centers housed in academic departments are heavily reliant on external funding. Training and technical support for outside users are often provided by research staff on soft funding. Conversely, a library budget is usually considered part of campus infrastructure and therefore has long term stability. This strengthens the position of the library as it vies for an expanded role in campus wide GIS support.

Librarians as Teachers

A measure of the level of maturity of the GIS services provided by a library is the sophistication of analyses conducted by the clients. Increasingly, entry level applications such as StoryMaps have whetted the appetite for a deeper understanding of the processes at work and interpretation of spatial relationships. Consequently, librarians are being challenged to expand their skills in areas relating to spatial analysis, spatial statistics, image processing and even artificial intelligence. Emma Slayton and Jessica Benner, librarians at Carnegie Mellon University, are conducting a major research project to examine how librarians are addressing the problem. The project, entitled The Role of Libraries in Geography and GIS Education (ROLGGE) is funded by the National Center for Research in Geography Education (NCRGE) with the objective to "foster the development of a community of libraries, data practitioners, and educators to enable effective teaching, consultation, and outreach around spatial literacy education". Brenner and Slayton believe that Geo-educators need to be:

- knowledgeable of many disciplines in order to understand what our users need,
- proficient in the use of maps, various data formats and a variety of GIS tools,
- nimble enough to balance professional expectations to publish/present with time to maintain and learn new skills
- able to effectively market their teaching services due to the informal nature of teaching in
- libraries

Based on their recent research they found that geo-educators confront a number of questions such as

- What is the job of geo-educators working in libraries? What skills are needed?
- How do we work with various disciplines and support our communities?
- How do we teach and how do we track our effectiveness in teaching?
- How do we manage our time and develop new skills?

New Approaches to Spatial Search

In 1994, project Alexandria researchers at the University of California Santa Barbara implemented the first Geolibrary defined as "a library containing georeferenced objects with a search mechanism based on geographic location as the primary search key". (Goodchild). Over the past five years several academic libraries have created a new breed of Geolibraries. According to Julie Sweetkind-Singer at Stanford:

> "Geographic discovery catalogs using search mechanisms optimized to handle spatial search are well-established and in use at many institutions. GeoBlacklight is one such platform now in use by dozens of universities across the United States. This open source platform has been built to not only display the content available through the holding institution, but to pull in the metadata for other institutions creating a union catalog of geospatial data, scanned maps, and imagery. For example, Stanford's instance, Earthworks, displays content held locally and by 19 other groups who participate in the OpenGeoMetadata effort. This provides a single

> point of access for those using Earthworks to look across repositories to find content that may meet their needs. (Sweet-kind, 2019)

With GeoBlacklight a spatial search is based on a bounding rectangle (or GeoName), an OGC web mapping application and a download service. According to the major developer at Stanford, librarians wanted to simulate "the book on the shelf experience" or serendipitous discovery of neighboring materials. (Maples, 2019) The development of these geographic search portals marks a significant step in the diffusion of GIS services. Rather than simply using commercial software, librarians are now developers and have established their own support group and training. All the necessary components are available from GitHub and new instances can be implemented in a few hours. These geographic search tools provide an important complement to the entire geospatial process. In this new environment a user can locate data though GeoBlacklight, download it, open it with ArcGIS Online and incorporate it into a StoryMap that is posted as online term paper.

Challenges

In 2017 March and Scarletto suggested that libraries were poised to take advantage of the wealth of technical advancements. These efforts provide great opportunities for librarians:

> "The shift to cloud computing (e.g., ArcGIS Online) and open data sharing (e.g., OpenGeoportal, OpenStreetMap, the Big Ten Academic Alliance Geoportal, and others) have made it easier to share this work" March and (2017).

At the same time, they also summarized some of the current challenges facing academic libraries:

> "after more than three decades, there are persistent challenges in providing GIS services in the following areas: staffing, service, technology, and data provision. As GIS services evolved from 2010 to the present, two overarching issues remain—limited budgets and GIS expertise."

They identified the following specific challenges:

- Data quality will require more attention in the coming years.
- And we need to ensure that standards are in place and being used when creating and sharing metadata, establishing stable file formats, and securing storage options.
- In the era of open data and cloud storage, data literacy is extremely important. As more and more data is created and shared, people need to understand how it can and cannot be used.
- Data security is now an ever-increasing challenge, whether the data is geospatial or not. Even if data is preserved in a stable format, its management is important, both now and going forward.

As part of the online survey, academic librarians were asked to identify their major challenges. The list includes the following:

- We struggle to find enough qualified employees - student or staff. For the full-time faculty and staff, this means long hours in order to do all that needs doing beyond meeting with students and faculty.
- As a one-person operation it has been rather slow to develop, but due mainly to my own capacity being divided at any given moment. The biggest issue for me is how to increase service levels without a concomitant bump in staffing/funding.
- We could always do better in providing wider support (multiple GIS software packages or mapping approaches) and deeper support (developing more expertise in the functions available with each package or approach).

- We have been able to host workshops and assist through research consults on faculty, staff and student workshops. Some more complex projects relying on coding or large data processing can at times be outside of our expertise
- We WISH to be involved in the teaching & support but first need to get up to speed ourselves.
- More staff, better teaching facilities (computer labs), software available on library computers. Better training materials made freely available.
- We are in the early stages of establishing data services with the goal of building these services on the framework of quantitative literacy.

Building on the work of others, Holstein provides an excellent summary of the issues facing the next stage of development for GIS services:

> "GIS represents a significant investment in hardware, software, staffing, data acquisition, and ongoing staff development. Either new money or significant reallocation is required. Establishing new or enhancing GIS services in the library requires the "serious assessment of long-term support and funding needs. Commitment of the university as a whole, or at least support from senior administration, library administration, and related campus departments is crucial to its success. Receiving more funding will mean more staff, better trained staff, a more in-depth collection, better hardware and software, and the ability to offer multiple types of GIS services." (Holstein, 2015).

Conclusions

This analysis suggests that over the past three decades the provision of GIS services has evolved in stages outlined by Rogers as a diffusion of innovation. By taking advantage of technological advancements, academic libraries have almost universally implemented some level of support for GIS. An analysis of current practices suggest that colleges and universities fall into at least three levels of maturity. At one end of the continuum research universities that were the original innovators now maintain major GIS centers and offer support for sophisticated analysis and spatial search. At the entry level even, small liberal arts colleges have developed research guides with links to GIS services and instructional materials. Clearly, Esri has played a significant role in supporting the expansion of these services. From the GIS literacy project in 1992 and the campus wide site licensing through the provision of easy to use web-based resources, the company has been an important partner. The feedback from a several institutions suggests that libraries are poised to take a leadership role in training, consultation and even support for software licenses. A strong case can be made that academic libraries provide the best avenue for expanding interdisciplinary use of GIS across a campus.

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