EVALUATING AND COMPARING DIGITAL GEOSPATIAL PUBLISHING TOOLS

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GEOPUBLISHING SPATIAL INFORMATION

Evaluating and Comparing Digital Geospatial Publishing Tools

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Evaluating and Comparing Geospatial Publishing Tools

ABSTRACT

Geopublishing is a new branch of Geographic Information Science. Similar to desktop publishing, geopublishing has special requirements in the way that the layouts are published as a digital atlas. This requires tools that allow an atlas designer to assemble large spatial data sets in a way that is easy for the intended audience to use. ArcView and TNTview were used to assemble three pairs of nearly identical atlases to evaluate how well the assembled atlases met publishing cost, view only or digital paper, interactive, analytical, and annotating - republishing criteria. ArcReader and TNTatlas were both able to meet the geopublishing criteria, but the combination of TNTview - TNTatlas allowed for more interactive, analytical, and republishing options at a lower cost. Using these expanded capabilities is dependent on the end users willingness to ask and seek answers to their own GIS questions and access the training needed to make use of the tools available.

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I would like to thank my kids, Lauren, Scott, and Jason. Without them asking how my homework was going, I may have never kept working on organizing the data they helped me collect for the Football Field study area in this thesis. They also provide the goal of graduating before they did, even if I did not meet all of those target dates.

I would also like to thank my thesis committee, especially my thesis advisor Dr. Ming-Chih Hung, for his patience as I submitted revisions for his review and comment on an intermittent schedule.

LIST OF ABBREVIATIONS

CAD – Computer Aided Drafting

CIS - Cartographic Information System

CLU - Common Land Use

CSV - Comma Separated Values

DOQ - Digital OrthoImage Quad

GPS - Global Positioning System

KML – Keyhole Markup Language

KMZ – Keyhole Markup Zipped

NDVI - Normalized Difference Vegetation Index - calculated as (NIR-VIS)/(NIR+VIS)

NIR - Near InfraRed canopy reflectance at 880nm

NRCS - Natural Resources Conservation Service

PDF - Portable Document Format (Adobe)

PMF - Published Map Files (ESRI)

RVC - Raster Vector CAD format (MicroImages, Inc.)

USDA - United States Department of Agriculture

USGS - United States Geological Society

VIS - Visible (Red) canopy reflectance at 650nm

INTRODUCTION

Geopublishing is a relatively new development in Geographic Information Science. It is similar to desktop publishing for written documents. It provides a way to quickly distribute reference layers, user inputs, and the results of spatial analysis to a wider audience. As GIS advances and more businesses build large spatial databases, the ability to distribute this information to managers who can use it on a daily basis becomes more important. Geopublishing is a compromise between implementing an extensive company-wide GIS education program that attempts to turn every manager into GIS analysts and the simpler viewer tools available in most web-based systems.

The rise of Google Earth (and other web based mapping systems) over the last three years confirms that there is a strong demand for casual geospatial data browsing if the information can be organized and made easily accessible. “In that time, the software package has been downloaded on half a billion computers. Visitors spend one million hours a day perusing Google Earth and the related Google Maps” (Revkin 2009). Google Earth has raised the public’s awareness of geospatial information and created a demand for the ability to manipulate that published information for their own use. “In the three years since its public unveiling in 2005, Google Earth has become a mainstay of students, travelers, businesses and researchers seeking a one-stop place for posting or finding information about the world — on topics as diverse as hotels and hiking trails, species’ ranges and climate data” (Revkin 2009).

Another recent innovation in geospatial publishing is the inclusion of georeferenced Adobe Acrobat and Adobe Reader documents in the Portable Document Format (PDF). Third party companies such as TerraGo have provided tools (GeoPDF Toolbar) for using coordinate information in a PDF file (TerraGo 2008). These companies have also provided add-on tools that extend the Adobe Reader program so it can use the coordinate information in these georeferenced PDF documents. Coordinate information for the cursor's location in the document can be displayed, and GPS tracking and measuring tools are available.

Adobe has also added some native geospatial support with an Object Data Tool and a Geospatial Location Tool built into Adobe Reader 9.0. A built-in Layer Manager allows you to toggle different spatial layers on or off to change the displayed map. Using the full Adobe Acrobat Pro Extended software allows you measure map elements onscreen and even directly import some geospatial files. You can also enable PDF documents to allow distance and area measurements within the latest Adobe Reader program (Moran 2008). GIS software companies like ESRI (ESRI 2008) and MicroImages (MicroImages, Inc. 2009b) have supported this new capability by making it relatively easy to render PDF documents, including complex poster layouts, with useful coordinate information. This extension of the leading general publishing format to include some geospatial abilities shows just how important and popular maps with built-in location awareness have become, even outside of traditional GIS areas.

The geospatial data and tools available for use on common desktop personal computers in modern commercial GIS software are really amazing. A GIS coordinator can easily download many gigabytes of georeferenced data and then perform complex spatial analysis by combining this free data with data they collect. That data can then be organized and manipulated to tell a story as a poster layout for printing. Printing a poster on paper is one of the most common ways of putting together the final product or project deliverable. A printed map has several limitations for managers who use that poster:

1) it is static and unchangeable by that map's audience; 2) they cannot really interact with it to see different "what if" combinations of the layers collected there; 3) there is no efficient way to update the printed map, mark it up, or annotate it to pass along the information they have to others who need it.

Publishing the same information through a digital atlas can overcome many of these limitations. Moving from paper to published maps on computers have improved the usability and currency of the information displayed on these maps (Cammack 2003). Managers can choose the appropriate scale to view the data. They can annotate the map. They can work with the layers to combine them interactively. They have access to the underlying database information that is available in a GIS. They can also create their own digital snapshots of the data they need to communicate to others.

Geopublishing through a digital atlas can also be useful for presenting the results of research done within a study area. Including the raw inputs along with the intermediate layers and the final results could improve the way that the results of the study are communicated to that study's audience.

In either case, the atlas designer must consider the audience for the final product. Will they just have a casual interest in viewing the final maps? If this is the case, then a single printed map or Adobe Acrobat document may be the appropriate end product or project deliverable. Will they want to bring their own ideas and background to interpret or put the information contained in the study area to some use? Do they need to zoom in to see more details at a larger scale? Will they want to interact with the data on that map to add annotations of their own or to measure distances between several points on the map? Do they need some way to easily access all of the collected data at several points on the map even if this information is stored in several different layers? While using the term “Electronic Atlas” rather than Digital Atlas, Delazari and Cintra (2000) asked “Is an Electronic Atlas a GIS?” and classified electronic maps as view only, interactive, and analytical atlases. If the audience just wants to look at the final product, a view only poster or digital document is all that is needed. If they need to interact with or do further analysis of the spatial data being published, then a digital atlas is required.

Either audience, the manager who needs to direct work within a trade area or the person interested in the results of a study area, can benefit from interacting with the information in their own way. In an influential essay published in the Atlantic Monthly, Bush (1945) popularized the idea that most people store and recall memories and associations in the form of “…a web of trails…” between different sources of information to build a mental picture. The ability for someone to interact with multiple layers in a digital atlas can be enhanced if the viewer software displaying that information can operate at many different levels. It must be able to act as a casual viewing tool (like a printed poster) and have some simplified GIS tools to allow someone with more complex needs good access and interaction with the spatial data.

Research Objectives

This project compares ways of cost effectively publishing geospatial information. Two types of map publishing (one type for smaller study areas and the other type for managed areas covering a larger extent) will be studied for this project. These digital atlases will be published for use in ArcReader (a free spatial data viewer from ESRI) using ArcView GIS with the Publisher extension and TNTatlas (a free spatial data viewer from MicroImages, Inc.) using TNTview. The ability of each set of programs to create useful stacks of geospatial information, or geopublishing, will be compared. More details regarding the criteria used to compare these geopublishing systems will be covered in the Results and Discussions section. The ability of the free spatial data viewer programs to serve a wide range of needs (from casual map viewing to more in-depth analysis or trade area management) will also be compared. A business application of the published information is described for this research question:

"Which combination of commercially available geopublishing software along with their free viewers (ArcView with ArcReader or TNTview with TNTatlas) can publish research results for a small study area and also meet the needs of a business using spatial data to manage some of its daily operations?"

Geopublishing is a relatively new development in GIS and there has not been much written about simple geopublishing tools outside of Internet or Web base ones. However, publishing other types of documents digitally has become pretty commonplace. A good example of this is the Adobe Acrobat – Reader combination. By freely distributing the Reader program, Adobe has made it very easy for anyone to widely distribute interactive documents for a very low cost. Thrall (2005) described similarities between the relationship of Acrobat – Reader and ArcView GIS with Publisher extension – ArcReader. In each example, you do not need to be an expert to publish collected information (spatial or aspatial) so a larger audience can use it.

This is important for the target audiences discussed here. The researcher is focused on collecting and analyzing data in a well-defined study area. The GIS coordinator collects information within a trade area or governmental zone. They may not be computer experts or have a budget to install spatial servers or administer complex spatial websites, but both need to deliver the spatial data they have studied and organized to an audience who can make use of it. Producing a useful geospatial deliverable should be as simple as making a Adobe Reader document so this valuable spatial information does not become “locked up” on one GIS computer’s desktop. It needs to be put in the hands of managers who can benefit from quick and simple access to these stacks of data compiled by a research project or a GIS coordinator.

LITERATURE REVIEW

GIS in Agriculture and Other Organizations

The uses for GIS in business and government are established and well known. Any organization that provides services for customers who manages natural resources or property operates in the physical world and can benefit from a business-wide mapping system. Nearly all agricultural cooperatives today operate in a large geographic area with many service locations. They must be able to operate and manage operations over a large geographic area, but still need detailed spatial information at a much larger scale.

Many types of businesses have multiple locations that need access to the same spatial information. In addition to spreading the cost of spatial data over multiple locations, four challenges many systems face include managing GIS over distances or widely dispersed offices, managing the data created through this organization, make spatial data a central part of their business, and develop a business plan to discuss ways of integrating their information with GIS data for both internal and external customers (American Cadastre, Inc. 1999). Forester (2000) discussed how lower computer costs, widespread data availability, improved GIS software, linkages to large databases, and data distribution systems make wider use of geospatial technology possible. There are many ways that companies with geographically widespread operations can benefit from these advances, especially for operations planning and logistics.

A farmer's cooperative supplies fertilizer, chemical and seed placement services for a wide range of customers who grow crops on farmland. Precision farming uses a Geographic Management Information System (GMIS) to mange cropland. Spatial background data, activity layers, current layers, management layers, and action maps for crop production need to be organized for easy access in a crop production network (Skrdla 2004). The advances in Information and Communication Technologies (ICTs), Agricultural Knowledge System (AKS), and increased knowledge management in agriculture (Rusten et al. 2003) matches similar information management changes made in most other industries. Recent trends in precision agriculture include mapping and managing variability as well as spatial nutrient management. Measuring the effects of precision farming on farm profitability is also important. New sensor systems, data types, and information management needs along with agricultural data networks are advancing quickly worldwide affecting agriculture everywhere, including China (Zhang et al. 2002). Geopublishing can become a process that makes this data more accessible to anyone who needs to use this increase knowledge in a spatial way.

Public agencies can have problems managing and distributing spatial data for individuals and private companies that use it. Businesses use this information for location modeling, real estate investment, site analysis, facilities management, routing, and target marketing. Public employees who distribute the spatial data must have a better understanding of the needs of businesses that use it (Mariahazy 2002). This data is very useful in the private sector, even for precision measurement of features. The Minnesota Department of Roads evaluated the accuracy of updated digital orthophoto quadrangles (DOQs) developed by the Farm Service Agency (FSA) and the state of Minnesota. The horizontal accuracy was evaluated with a 95% confidence in flat terrain ranging from 0 to 100 feet (6 ft. accuracy), moderate hills ranging from 100 to 250 feet (10 ft. accuracy), and hills with a local relief ranging from 250 to 1,000 feet (11 ft. accuracy). One hundred points were evaluated over 5 DOQs with varying relief. Ninety–five percent of the sample points fell within an error range less than 10 or 6 ft. They found that public and private contractors could locate features with good accuracy using this updated imagery (Rogers et. al 2006). Good spatial data is also important for economic development and for the economy of developed nations. Spatial data should be widely distributed and available for use (Longhorn and Blakemore 2003).

Governmental organizations, like the U.S. Army Corps of Engineers, must manage, consolidate, and republish large amounts of spatial data. Consolidating GIS data from several divisions so that this data can be distributed and used for all divisions in a district is a strong incentive for a comprehensive plan. Adjusting and updating data as new geographic information becomes available is an important consideration (Baker GeoResearch 1999). The Department of Natural Resources in Nebraska distributed CDs that included aerial photographs, topographical maps, roads, streams, sections and county boundaries covering every county in the state and viewable in the freely distributed ArcReader program. Some of the tools in ArcReader were disabled and special data distribution strategies were used to simplify access to the data (Jester 2002).

Organizing a GIS

Spatial data must be collected and organized before it is needed. A well designed GIS needs to be easy to use for anyone who needs to use the information stored there, especially if they need to be able to easily access it in a hurry. One good example of this can be seen when emergency response to an event is required. Making interfaces for GIS data access, the quality of data available, and the addition of up-to-date data are important. Better data integration with populations, social interactions, data quality ratings, and a way to get the data organized and presented to people who need it are issues that need further research (Cutter 2003). Mapping systems can fail to meet their design goals. The usability of these systems is sometimes poor. In some systems, no formal system design is implemented, allowing the GIS to develop with few standards of usability in place. A Multipurpose Land Information System development model can be a guide for working towards implementing a useful GIS (Tulloch 1999).

There are several stages of implementing a well designed GIS for any organization. These include stages of funding and stages of implementing an enterprise GIS. Other stages include forming a GIS team, planning for the GIS, and data management issues (Brodzik 2004). Tomlinson (2003) described a 10-stage plan for implementing GIS for any enterprise. Strategic planning, detailing the implementation plan, pilot projects, defining information data products, and limiting the scope of the system should all be established before a GIS is built. Data design and models, hardware requirements, benefits and costs analysis and an implementation plan round out the steps described for a successful enterprise GIS implementation.

Collecting, consolidating, organizing, and republishing spatial information within a business or other type of organization has several advantages. Publishing that information means getting it into the hands of people that may not be GIS experts but still want to locate, review, measure, annotate, and print out the spatial information they need to do their job. How can you have both an easy to use system and some of the necessary GIS tools an experienced GIS professional would expect to have? Not everyone needs to become a GIS expert. There are several ways to begin "Building the Geospatial Workforce." Many different levels of skill are needed to produce professionals who can use GIS technology. Since GIS can be applied in many different industries, it is difficult to standardize the skills needed in the profession. Competency models can be used to identify roles, deliverables, work quality levels, ethical challenges, and future trends for professionals in GIS. Training goals can be set for any level of spatial data interaction from this model (Gaudet *et al.* 2003).

Geopublishing - An Emerging Branch of GIS

Organizing information electronically is not a new idea. While described using the technology of his day, the article titled "As We May Think" was published in 1945 by the Director of the Office of Scientific Research and Development discussing how memory and associations between different topics can be improved using technology available in the late 1940's (Bush 1945). His essay is an early discussion of hypertext. He predicts links between different source materials that are now seen in the World Wide Web. The same linking of supporting information and map layouts can be applied to maps organized as digital atlases. Integrating multi-media and real-time video from webcams can improve the usefulness of these digital atlases. Integrating photography with maps using linked point symbols can improve your understanding of the features on the map. Long descriptive text, published documents, and websites can also be linked to symbols on a map. Webcams can become an important tool for providing real time information in any digital map (Monmonier 2000).

Frequent updates are sometimes needed to keep a published atlas current. As boundaries or data within permanent boundaries change, printed reports or books containing statistics covering spatial areas can quickly become out of date and no longer valid (Ulugtekin *et al.* 2001). Another goal of a digital atlas is to allow casual users to visualize statistical information normally presented in printed tables in a more accessible, spatially friendly way. Linking statistical information stored in database tables to editable rasters, points, or boundary layers can give you the flexibility to quickly update information stored in one or more layers distributed in a digital atlas.

The ability to access these maps and supporting documents in the field is also an important development. When you can take digitally published maps into the field, you can directly interact with the map and the geography as you are moving through it. You are not limited to static maps. Instead, you can interact with these live maps that change based on where you actually are viewing that map in the physical world. "In developing these representations we also need to think about standards for the integration of space and place" (Brown and Perry 2002). Dynamic map updates are possible in an "Atlas Publisher-Storehouse-User Paradigm" where a spatial data publishing system has the goal of lowering traffic congestion and improve safety for travelers on a roads network. Elevation models, GPS, and roads vectors are combined with sensor networks to keep the database updated. "Intelligent linkages between multiple data sets…" are a key to providing large amounts of information in an easy to use way (Verma et al. 1997). Changes in the media that maps are displayed on changes their portability. Moving from stone to paper to publishing maps on computers has improved the usability and currency of the information on those maps. Location based services using GPS and wireless voice and data networks are important developments (Cammack 2003). These new media formats and the additional features that are possible because of the move from paper to digital maps is something that geopublishing should take advantage of.

Shulei described a CIS, or Cartographic Information System, as a multimedia presentation system that contains a GIS with special aspects of cartography (Shulei and Chen 2004). One key feature of a CIS is that the end user is the center of the targeted spatial product. This requires correcting problems often encountered with this type of digital atlas and finding a balance between presenting an overly complex interface and set of data and an overly simplistic viewing tool with little useful data. Striking this balance between complexity and usability is a key concept every atlas designer needs to meet if the digital atlas he is publishing will become useful for his target audience.

"Is an Electronic Atlas a Geographic Information System?" Interfaces of GIS and atlases are different. A GIS provides more analysis tools, but an electronic atlas can act like a GIS by providing a limited set of analytical and database access tools. Electronic maps can be classified as view only, interactive, and analytical atlases (Delazari and Cintra 2000). A view only atlas needs fewer tools for analysis and database access, an interactive atlas needs additional database access tools, while an analytical atlas can provide many tools for analysis.

An electronic atlas that includes some basic spatial analysis tools (an analytical atlas) can be considered a limited GIS. Defining the end user is an important question in understanding the target audience for an atlas. Understanding just how much analysis the end user wants to learn can help determine if a published atlas has enough capabilities to meet their needs. Performance and usability along with flexibility separate a view only, interactive, and analytical atlas.

There are several advantages to linking 2D maps with 3D representations. Anyone who is designing a "high standard" atlas needs to improve interaction to compete for the users' interest with other computer-based products (Huber and Seiber 2001). If the entire atlas was published as 2D maps, it seems reasonable to make it easy for the atlas user to generate 3D representations on-demand, over just those areas where they feel a 3D view can improve their understanding of the spatial layers contained in the 2D digital atlas. Providing an interactive way for the end user of an atlas to "self-publish" sections of that atlas in a 3D viewer would be a powerful compromise and a way for them to re-publish parts of the 2D atlas if it was implemented in an easy to use way.

Ormeling (1995) describes a complex, 3-dimensional system of at least 9 categories and structural types of Atlas Information Systems that paper atlases now meet. Ormeling suggests comparing different types of atlases to help determine the requirements of different types of digital atlases. These additional categories range from historical to economic to management atlas systems. This seems to be mostly dependant on the scale and the intended audience. An economic atlas may appeal to governmental groups in charge of economic policy at a country or state scale while a management atlas can be useful for any scale of business that has customers or operates in a physical space.

Two software programs that are able to assemble and publish spatial data sets are TNTview and ArcView (with the ArcGIS Publisher extension). Both programs have free to download viewing software. This makes the geopublishing workflow similar to using Adobe Acrobat as a publishing tool and Adobe Reader as a free viewer. Several technical and data organization methods must be considered when designing and publishing digital atlases with TNTview. Multiple layouts, single layouts, hidden layers, datatips, naming conventions, groups and layer organization for atlases are important considerations. Multiple ways of supplying metadata and links to external text, websites, photos and other spatial layers along with security settings for data stored in distributed digital atlases are also useful (Skrdla 2001). The retail prices for NAFTA point of use copy TNTview is US$500 for desktop PC, single user licenses (MicroImages, Inc. 2009) and the TNTatlas viewer program is free to distribute.

The ArcGIS Publisher extension for ArcView from ESRI also allows you to publish spatial data. The relationship of Adobe Acrobat and Adobe Reader is similar to

ArcView GIS with the Publisher extension and ArcReader. This combination of the Publisher extension for ArcView and the ArcReader program is important "…as they nearly eliminate the learning curve and heavy investment required to share geographic data with non-technical users" (Thrall 2005). The Published Map Files (PMF) format (or "data bundling") can be distributed as data is stored with relative path names (Jester 2002). The ESRI Store contains the latest prices for desktop versions of ArcGIS and several extensions. The prices listed that are important for this research include the ArcView Single Use License Desktop GIS for mapping, data integration, and analysis – US$1,500 and ArcGIS Publisher Single Use License - Map and data publisher for ArcGIS - US$2,500 for a combined cost of US$4,000 (ESRI Store 2009).

Both TNTatlas and Arc Reader should not only allow you to view spatial data, but should also allow you to "micro-publish" maps in some way. Adobe Reader has been a good way to digitally distribute maps for accurate printing. The professional version of Google Earth includes the ability to quickly add georeferenced rasters, CAD, and other layers from a GIS into the Google Earth viewer. Simplifying access to GIS data for managers and others whose primary interest is in getting their job done more easily is an important benefit of GIS data publishing tools like Google Earth (Wuthrich 2006).

It can be very challenging to publish spatial information in a way that works over a broad geographic area and contains enough geographic detail to remain useful at a larger scale while still remaining easy for a novice to use. Building informative layouts and scoring how well the resulting atlases, or stacks of geospatial information, fill these somewhat divergent goals are the two main objectives of the methodology and results sections of this thesis.

Study Area

There are three study areas for this project. The first study area is a high school football field in Palmyra, Nebraska as shown in the ArcReader layout format in figure 1. This large scale, small study area project highlights some of the problems that can come from working within a very small study area. It is difficult to find publicly available data (for example, imagery) at a resolution that is appropriate for small study areas like a football field. Other problems include accuracy of collected data (GPS errors in data collection can be magnified in a small study area) and collecting enough data to accurately model the field. Another challenge is to publish an atlas that covers a small area but is still easy for others to understand.

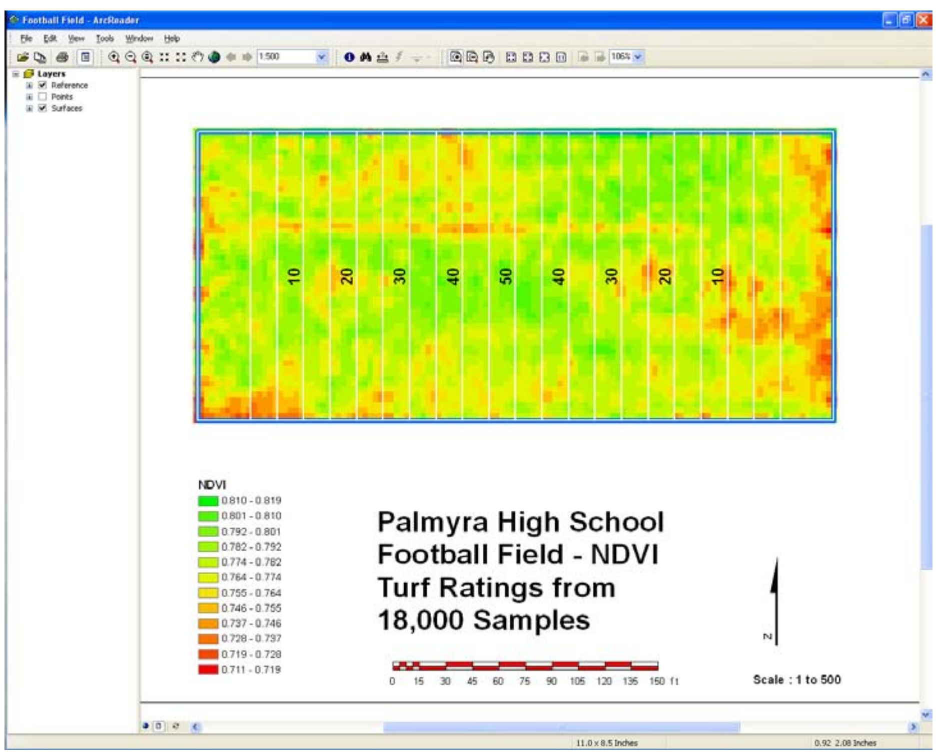


Figure 1 – ArcReader layout of the Football Atlas

The second and third study areas are county-size trade areas that can be considered geopublishing for management. Two counties from different states were used to determine the types of data that are available, how that data can be organized, and how it can be used for managing an agricultural business. The second study area is Otoe County, Nebraska as shown in the TNTatlas layout in figure 2. Like the Football Atlas, the Otoe County Atlas is a page layout atlas, where the layout includes scale bars and other cartographic elements.

The Otoe County layout includes links to native ESRI data files from both display programs. The image background is stored in the MrSID compressed format while the other layers are stored in an ArcGIS geodatabase file. This allows the geospatial layers for creating Otoe County atlas to be shared between TNTatlas and ArcReader in this

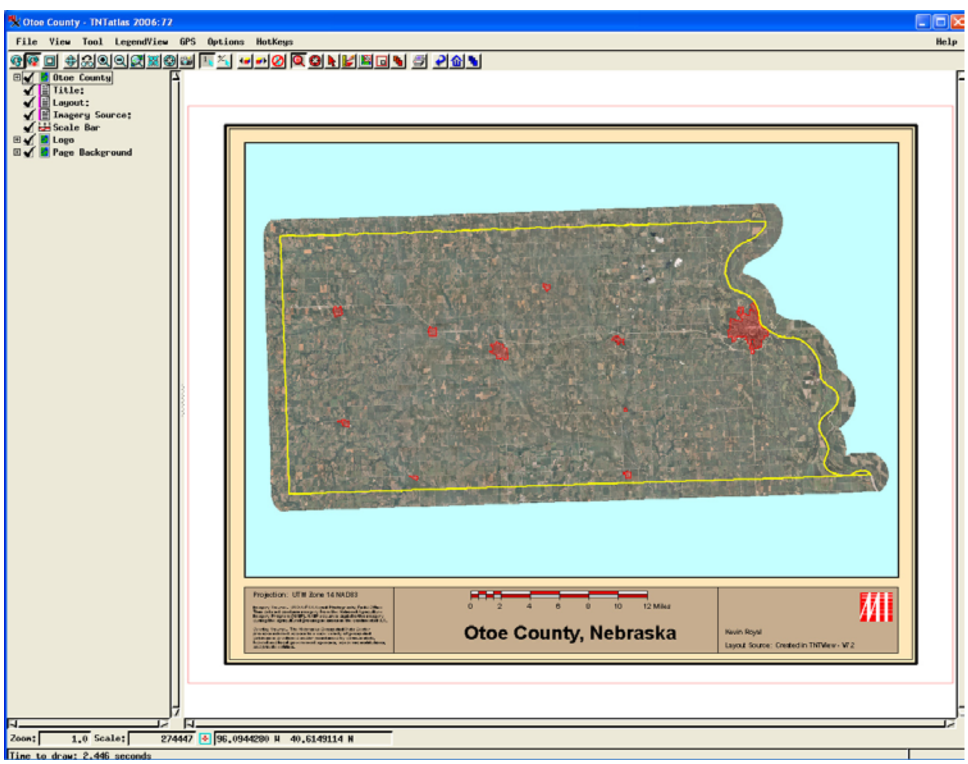


Figure 2 - Otoe County, Nebraska in TNTatlas

Layout View. Both viewing programs are accessing the same layers stored in the common geodatabase, allowing a direct comparison of the two viewers.

The second county is Davison County, South Dakota as shown in figure 3. It is the simplest layout of the three. This layout does not contain any cartographic elements and maintains the original projection since it is designed to remain in a Data View rather than a Layout View like the Football atlas and the Otoe County atlas. A Layout View allows you to add cartographic map elements, like scale bars, orientation arrows, and legends. Using a Data View allows you to view MapTips (a short pop-up description to explain features while the cursor is in position) in ArcReader. MapTips will only work in the Data View mode of ArcReader. MapTips become an important way to locate yourself on this map as you zoom in and attempt to locate a field of interest.

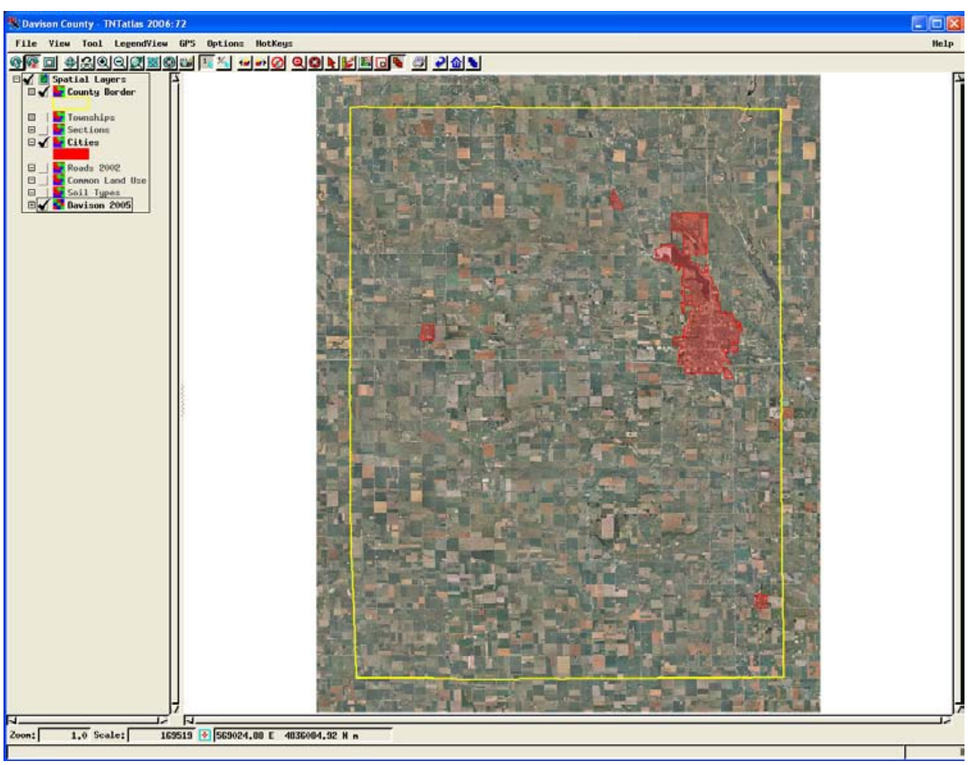


Figure 3 - Davison County, South Dakota in TNTatlas

Data Preparation

Much of the data preparation was completed using TNTmips. The Football Atlas is a poster/page or Layout View atlas that required the most processing and data collection. The machine carrying the sensor was driven at 1.5 mph, resulting in one sample being taken about every 24 inches as shown in figure 4. The field of view for the sensor was just over 20 inches and several passes were made, so coverage of the field was very good.

Approximately 18,000 points of turf canopy reflectance values were collected with a Trimble brand Differentially Corrected GPS (DGPS) and a Crop Circle canopy sensor system from Holland Scientific. The Crop Circle included a data collection

Figure 4 - Measuring Turf Reflectance Values (photograph by author)

module that saved the GPS position along with the Latitude, Longitude, Visible, Near Infrared, and calculated NDVI values as a simple Comma Separated Value (CSV) text file (example shown in table 1) to an SD memory card. This CSV file was imported into TNTmips and converted into vector points. Three surfaces (for visible, near infrared, and NDVI values) were created from the file using a minimum curvature surface fitting method and a cell size of one meter. The resulting surfaces (one for each value collected or computed by the Crop Circle sensor) were then exported as a GeoTiff for importing into ArcView. The raw vector points were exported to an ESRI shapefile for later import into an ArcView geodatabase.

Other files created in TNTmips for the Football Atlas included the yard markers and field border. The field border was drawn first in the Editor portion of TNTmips, and a collection of parallel lines were generated at 5 yard intervals. Database records were attached to the even yard-lines. These attributes were later used to generate the yardage labels for both layouts in ArcView and TNTview. The finished vectors were exported as shapefiles for later use in ArcView.

The Otoe County atlas is another page layout atlas like the Football Atlas, but it shares all spatial files between the layouts built in ArcView and TNTview for use with their respective reader programs. Most of the vector layers were processed in TNTmips,

Table 1 - CSV Turf Reflectance Samples

```
40.7038656,-96.3959503,0.675,5.160,0.769
40.7038657,-96.3959523,0.731,6.439,0.796
40.7038658,-96.3959543,0.737,6.611,0.799
40.7038658,-96.3959562,0.738,6.626,0.800
40.7038659,-96.3959582,0.734,6.526,0.798
40.7038659,-96.3959602,0.722,6.190,0.791
40.7038660,-96.3959622,0.696,5.575,0.778
```

including the geodatabase and imagery, but all of them were eventually converted into shapefiles and then imported into ArcView's internal geodatabase structure. The county border, townships, sections, Common Land Use (CLU), cities, ZIP codes, roads, and soil layers are all stored in a single, 44 megabyte personal geodatabase. ArcView directly uses the vector layers present in this layout, but TNTview also links to the existing layers stored in the geodatabase. This allows for very efficient disk storage of both layouts since each layout's vectors are stored only once, as shown in figure 5. The imagery layer is a 128 megabyte MrSID compressed file that is also used by both of the layouts, like the Davison County Atlas.

The Davison County Atlas is designed to be used as a Data View atlas without any poster/page layout or cartographic features. Several data layers were edited in TNTmips before they were added to the ArcView and TNTview layouts. The city borders were generated by a script in TNTmips that searched for lines associated with town borders in a vector created by importing TIGER data. A new vector layer was created that has a single database attribute of that town's name attached to each polygon created by that script. The county border, townships, and sections were downloaded from a state GIS website and required some editing in TNTmips before they were ready for

Imagery		File Folder
Otoe County Map.mxd	363 KB	ESRI ArcMap Document
Otoe County Map.pmf	200 KB	ESRI Published Map
Otoe.atl	1 KB	TNTatlas Startup File
Otoe.rvc	8,528 KB	MicroImages Project File
Otoe_County.mdb	44,116 KB	Microsoft Office Access Database

Figure 5 - Shared Personal Geodatabase and Imagery

importing into ArcView. The Common Land Use (CLU) and Soil Types were downloaded from the USDA/NRCS Geospatial Gateway as shapefiles for use in both ArcView and TNTview (USDA 2006). Since this data was downloaded, the CLU product is no longer available to the public from this website.

The Davison 2005 imagery was downloaded as a MrSID compressed file. Both ArcView and TNTview can directly link to this type of file, so it was kept in its original downloaded format as an 88 megabyte file. This large raster file is the only file that is shared between both the ArcReader and the TNTatlas Data View layouts for the Davison County Atlas.

Building Layouts and Geopublishing with ArcView

ArcView was used to construct the layouts for publishing with ArcReader. Using the prepared data described above, two types of layouts were constructed. The Football Atlas (figure 1) and the Otoe County Atlas (figure 2) are page layout posters, or Layout Views, with titles, scale bars, legends, and other cartographic details. Group Layers (figure 6) were used to help split up the different layers of the Football Atlas into similar groupings. For example, all three turf rating surfaces were put into a Surfaces group (figure 7) while the Reference layers (yard markers and field boundary) were stored in the Reference group. The Otoe Atlas is also a poster layout, but with only one group containing all of the layers in a UTM Zone 14 - NAD83 projection.

The Davison County layout (figure 8) is a Data View, or display layout without any cartographic details. It is built for quick access to individual sections without using a poster layout. It is also built as a single group. The layer list appears to be very similar

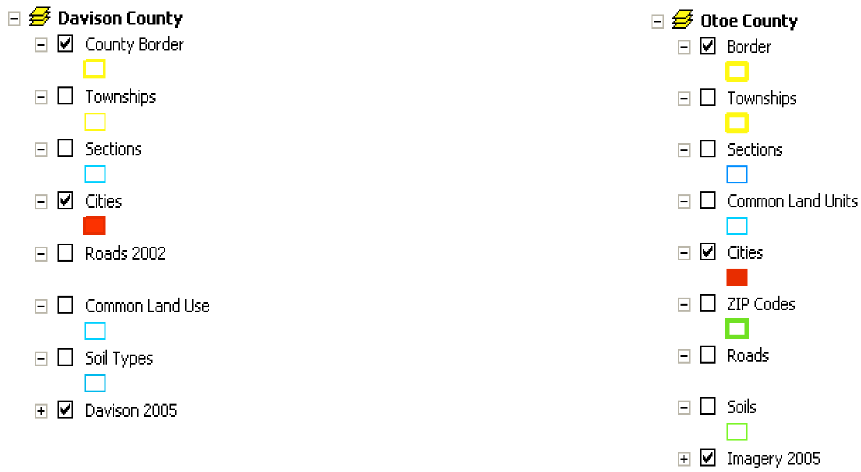


Figure 6 - Groups in ArcView

to the Otoe County Atlas, but the cartographic elements makes the two layouts look much different. All three layouts built with ArcView use native or internal data formats stored inside of the personal geodatabase format except for the TIFF surfaces in the Football Atlas and the large MrSID images used in the Otoe County and Davison Atlases.

Important settings that can increase the usability of the ArcView layouts are stored in the layers' property settings. Four of the more important settings that improve the usability of a layout includes the Symbology, Legends, Scale Range, and MapTips.

Like any well designed printed map, the symbology and the legends used in the digital atlases makes a large difference in the usability of the layout. For example, using

Figure 7 - All Layers in a Single Group in ArcView

Figure 8 - Davison vs. Otoe County Atlas with Cartographic Elements

a transparency setting for the city boundaries symbol in figure 9 allows you to zoom in closer within the city borders, but still see the underlying imagery. Using a raster legend for the NDVI and other raster layers in the Football Atlas lets you see how these values differ when you toggle ON the different raster layers in this layout.

Setting scale ranges and MapTips for a digital atlas begins to add dynamic elements not possible with printed posters. When you zoom in beyond a scale range of

Figure 9 - Map Symbols and Legends Make Layouts More Informative

1:20000, the city border shown in figure 9 shuts off, allowing you to clearly see the imagery underneath the city's border. MapTips setup for this boundary identifies the city as Loomis when you move your mouse over the boundary symbol. MapTips have a few limitations in ArcView. They are usable only for the top, displayed layer. They won't work in Layout Views like the Football Atlas or the Otoe County Atlas unless you change to a Data View. They are available only in the Data View mode, like the default view of the Davison County Atlas.

You can publish the layers after the layouts are made. Using ArcView, map layers are normally published with the Publisher Extension using the Publish Map menu item under the Publisher extension. Another option is to use the Create Data Package Publisher feature, but this bundles all of the data (including large images) into a separate directory, re-sampling any imagery in the published layout into a new file.

Making a layout that you can distribute requires you to set one important global setting in ArcView. The Document Properties - Data Source Options must be set to "Store relative path names to data sources" as shown in figure 10. This setting will allow you to write the published data to a CD or other media for distribution to your target audience. Data sources will be missing if the relative path option is not set correctly when publishing the layout.

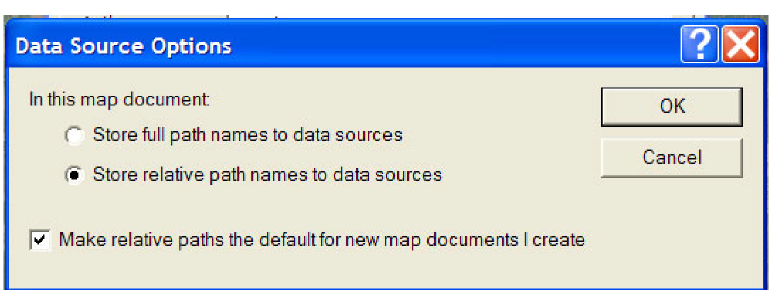


Figure 10 - Relative Path Names Allows You to Distribute a Layout

The Publisher Settings gives you a lot of control over what optional functions you can include in the published layout as shown in figure 11. You can also determine what layers to include and what type of views to include. You also include some security options with the published layout, such as limiting the data to be viewed only by ArcReader (not in ArcView) and enabling a timeout date when the layout will not be allowed to open.

Once the settings are made and you actually publish the layout, a PMF file (Published Map Document) is created. Figure 5 shows the PMF file and the other files created for the Otoe County Atlas. All of the directories and files shown in figure 5 (except for the Otoe.atl and Otoe.rvc files) are needed for the layout to open and be viewed correctly in ArcReader.

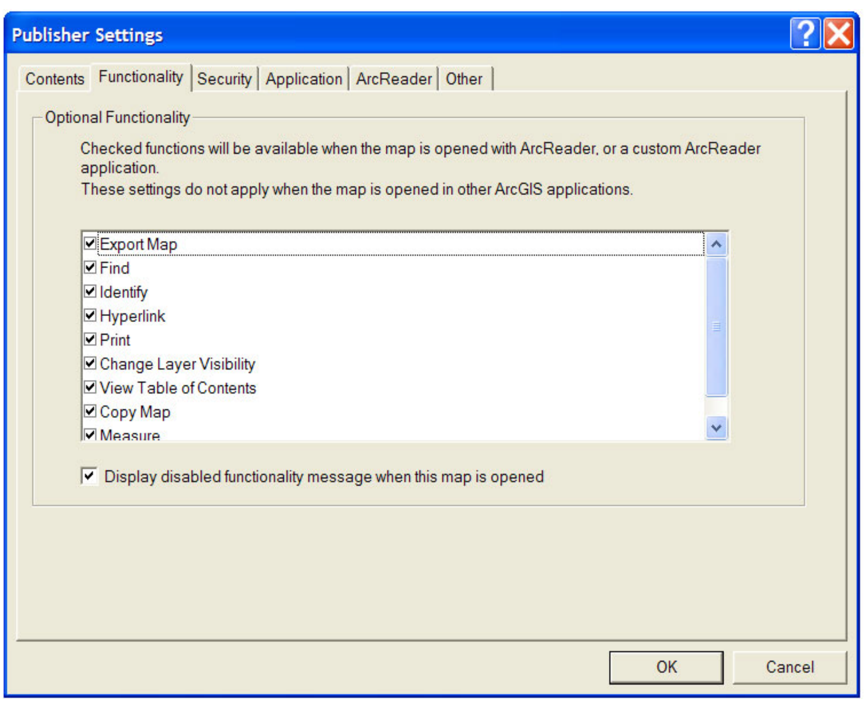


Figure 11 - Publisher Settings with Optional Functionality

Building Layouts and Geopublishing with TNTview

TNTview behaves differently from ArcView. You can work with multiple Display and Page layouts at the same time. Figure 12 shows the Football, Otoe County, and Davison County layouts all loaded at the same time in the TNTview layer manager window. You can quickly switch between the different layouts by selecting any layouts name. The view window containing that layout pops-up to the top of the stack of view windows you have open. You can also load the same layout multiple times or open multiple view windows of the same layout. Multiple views can be "geolocked" together, so you can pan and zoom several open views at once, each with different layers

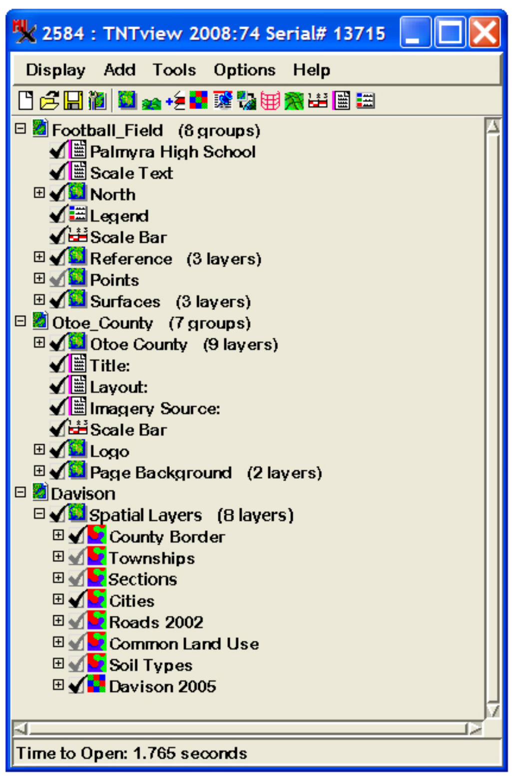


Figure 12 - Multiple Display and Page Layouts in TNTview

displayed, allowing you to see different layers at the same time in each view window of the same layout.

Figure 12 also shows the way these different layouts are organized in TNTview. The Football Field and the Otoe County Page layouts (similar to the Layout View in ArcView) contain multiple groups. Some of these groups contain cartographic layers like the Legend and Scale Bar groups. Other groups contain multiple layers of spatial information, like the Surfaces (3 layers) group in the Football Field layout and the Otoe County (9 layers) group. Groups can be placed and scaled independently on a Page, allowing you to build complex page layouts. Groups can also be attached to each other geographically so that the coordinates of the layers inside of each group defines how they overlay groups of other layers. The Davison layout opens in the Display mode. It contains just a single group (though multiple groups are possible) with 8 layers in that group. Scale ranges to toggle layers on or off depending on the zoom level can be set in TNTview from a single panel (figure 13) or from the individual layer or group controls. Symbology is set in a similar way in TNTview as in ArcView. A transparency setting in filled polygons allows you to see the underlying imagery while still seeing city boundaries (figure 14). Legends in the legends panel can help display the range of NDVI values in the Football Atlas (figure 15).

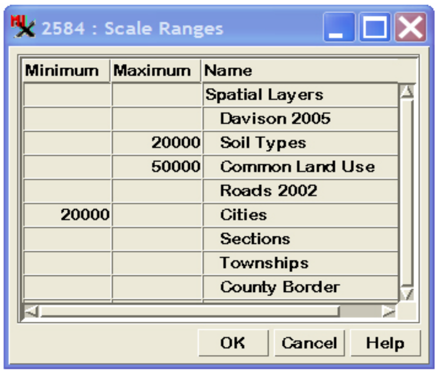


Figure 13 - Display Scale Ranges Can be Set for Multiple Groups and Layers

One important difference between TNTview and ArcView are the DataTips options available in TNTview. They are similar to the MapTips in ArcView that shows designated database information at the cursor's location that changes as you move the cursor. TNTview goes further with an ability to show database information from multiple layers at once, even if those layers are hidden or not the topmost layer in the layout. There are options to control which DataTips you see, including None, Active/Top Layer, Visible Layers, Maximum, Automatic by Scale, or Object Names. These viewing preferences can be set in either TNTview or the TNTatlas viewing program. The DataTips must be defined (including a prefix and suffix) within TNTview.

TNTview does not contain any special publisher settings like the ArcView program does for setting or removing optional functionality like printing restrictions or a

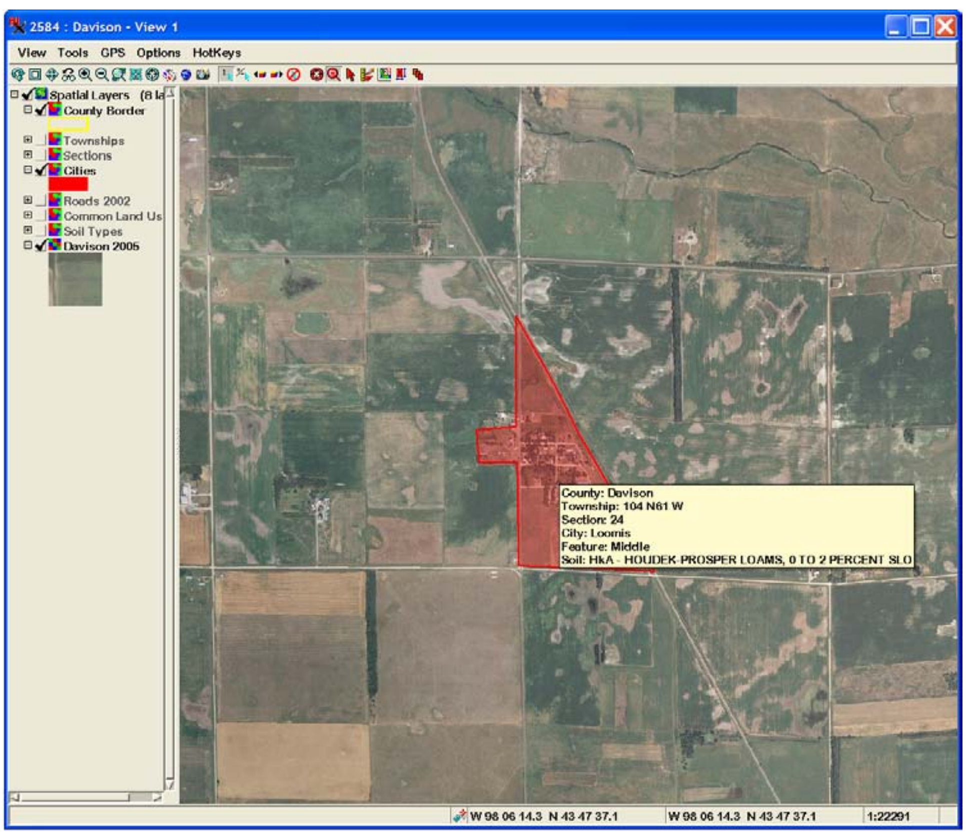


Figure 14 - Multi-Layer DataTips in Davison County Atlas

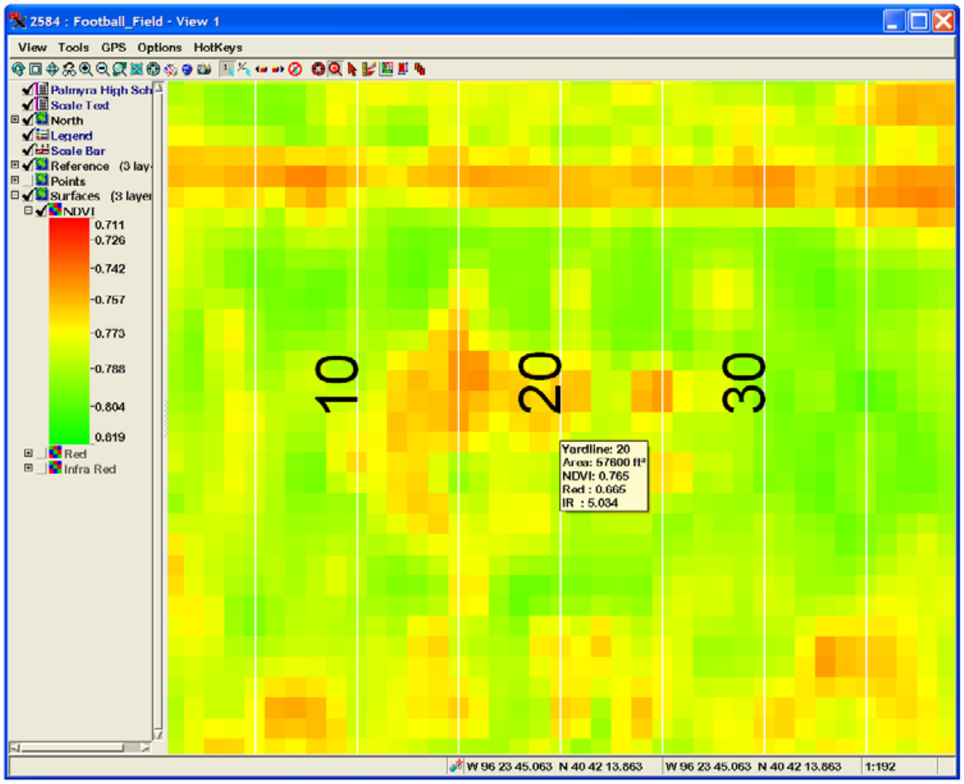


Figure 15 - Multi-Layer DataTips in the Football Atlas

layout expiration date. TNTmips, the full GIS program from MicroImages, does include additional preferences and tools for assembling and publishing restricted atlases or layouts, but these additional geopublishing tools are not a part of TNTview. Some preferences can be set in an .atl file that loads a layout in TNTatlas. An .atl file is a small text file that points to the actual layout information saved by TNTview inside of an RVC file (the native file format for TNTview). Figure 16 shows the Davison.atl icon used to load the object Davison stored inside of the Davison.rvc file. As the layout opens, the active tool is set to the zoom tool. The graphic tool type (for measurements) is set to 4 (the polygon or area measurement tool). The units of area measurement are set to 10

```
[TNTatlas]
File=X:\Davison\Davison.rvc
Object=Davison.DLAYOT
Title=Davison County

ActiveTool=zoom

[disptoolcombo]
ActivePage=1
GraphicToolType=4
MeasToolElevationUnits=4
MeasToolPositionUnits=4
MeasToolAngleUnits=0
MeasToolAreaUnits=10
MeasToolLengthUnits=4
```

Figure 16 - Defaults Settings in an .atl File for the Active Tool and Units of Measure

(acres) while the length measurements are set to feet (4). The end user of the published atlas can change to different tools or measurement units, but it is useful to be able to set up a good default measurement tool type and units of measurement to get them started using the atlas more quickly. The Davison atlas starts with the area measurement tool and area units set to acres since it is made for managing agricultural fields in that county located in the United States. The Football atlas, which covers a much smaller study area, gets the same starting measurement tool type (area), but the units of measurement are set to square feet rather than acres. Square footage is a more appropriate unit of measurement for managing turf than acres where this field is located and English units are the turf industry's standard unit of measure.

TNTview always saves layouts with a "make relative paths" setting as the default. The easiest thing to do when assembling either atlas type is to move all of the input files into a common parent directory, geodatabase, or RVC file before assembling any layouts that refer to these layers. As long as the files included in the final atlas layout are not stored on a network location or in a directory that is not included under the parent directory where the atlas was assembled, the files can be written to a CD, memory card, or some other device for distribution to the target audience.

Evaluation Criteria

The resulting layouts were published in both ArcReader and TNTatlas as shown in Appendix A. The resulting pairs of atlases look nearly identical when viewed in the two viewer programs. Since very similar (in some cases, identical) data was used in the layouts built for publishing these atlases, we can compare the usability of each atlas by the way that each viewer program, ArcReader or TNTatlas, makes the atlases useful for the target audience. Five criteria (cost, view atlas, interactive atlas, analytical atlas, and republish) were used to evaluate these atlases.

Costs

The first criterion looks beyond the viewing programs to include the cost of assembling the layouts for publishing. We can examine the cost of ArcView and TNTview since these programs are the tools used to make the published spatial layouts available for distribution in free viewing programs. The cost of the GIS software used to modify the raw data will not be a part of the cost analysis. This can be considered a normal cost of doing GIS work. This study is focused on publishing the spatial data no matter what program is used to create it. Both ESRI and MicroImages also offer web-based solutions. While web-based distribution lowers the cost of materials, other costs arise. The additional costs of server software, maintaining an Internet server, and bandwidth are outside the scope of this geopublishing study.

Three Types of Atlases

Classification of electronic maps (Delazari and Cintra 2000) as view only, interactive, and analytical can be used as a guide for evaluating the resulting atlases and their viewing programs. How well does each viewing program make the published layout behave as view only or a digital poster (criterion 2), how interactive are the assembled layouts as presented by each viewer (criterion 3), and how much spatial analysis can a user perform with each viewing program (criterion 4) are reasonable ways to evaluate each atlas.

Republishing

The fifth criterion added to expand Delazari and Cintra’s list for evaluating the publishing process evaluates the tools provided by each viewer program allow the end user to annotate and re-publish sections of each atlas. Allowing a manager or researcher to mark up and forward a customized view of a larger atlas can allow an organization to better communicate spatial details to coworkers or customers that manager supports.

Comparing the Results

The five criteria described in the previous sections were organized into a chart shown in table 2. Each study area or atlas described above will be ranked according to the evaluation criteria on this table. Once the completed atlases were tested, they can be displayed on the same computer screen. Since these pairs of atlas are very similar, they can be scored with a relative ranking against each other. A ranking system is proposed as an attempt to provide objective evaluations. The concept of this ranking system is similar to GPA (grade point average, accumulated points divided by accumulated courses) used in university or college transcripts. Under each criterion, there may be multiple items to examine. Each atlas will receive points from each item at the following threshold: 0 points if the function is not available, 1 point if only one basic tool is provided to perform this function, and 2 points if more tools are provided to perform this function. At the end, all of the points will be summed up and divided by the total items to get an average point (AP). The average point will be on a scale of 0 to 2, where 0 is the worst and 2 is the best.

The Average Point (AP) system used here is an un-weighted ranking system. Every item evaluated in these geopublishing systems are treated equally. If someone wanted to customize these AP scores to modify the influence of one criterion over the others, a scaling factor could be included to either increase or reduce the importance of that criterion. For example, if you were going to distribute many copies of an atlas and had decided that the Cost would not have large influence when you evaluate these geopublishing systems, you would want to add a fractional scale factor to reduce the influence of this criterion.

Table 2 – Five Criteria for Evaluating a Geopublishing System

Criteria:	Cost	View	Interactive	Analytical	Republish
ArcReader	x	x	x	x	x
TNTatlas	x	x	x	x	x

RESULTS AND DISCUSSIONS

Assembling and testing the matched pairs of atlases allowed for a direct comparison between these two viewing programs, ArcReader and TNTatlas. Without these carefully matched atlases in both ArcView and TNTview, it is difficult to compare how well each viewer fills the five evaluation criteria established for comparing ArcReader and TNTatlas. Matched atlas layouts help to limit the effects of data on the relative comparisons of the viewer software. The next five sections evaluates and scores how well each viewer software meets the geopublishing cost, view, interactive, analytical, and republishing criteria.

Cost of a Geopublishing System

The cost of buying ArcView and TNTview for publishing spatial layouts is an important consideration. We can determine from ESRI's website (ESRI Store 2009) that the base cost for ArcView without any additional extensions is US$1,500. This allows you to assemble layouts and view them in ArcView. You can also pass the assembled layout to another ArcView user, but this really imposes a US$1,500 per seat cost of distribution to a target audience. To make layouts available for distribution with the free ArcReader program, the Publisher extension in ArcView processes the layers in the layout and makes them readable by ArcReader. The cost for the Publisher extension is an additional US$2,500 (ESRI Store 2009), making the total cost of using ArcView as the layout assembly program for distributing layouts with ArcReader US$4,000.

TNTview cost US$500 (MicroImages, Inc. 2009). Layouts assembled with TNTview can also be displayed by other TNTview users, making the cost of distributing layouts to other TNTview users $500 per seat. However, layouts assembled with TNTview also are directly viewed with TNTatlas. This means that there is no additional cost to publish layouts assembled by TNTview for distribution with TNTatlas. The combination of ArcView – ArcReader received a 1 for this cost criterion and the TNTview – TNTatlas combination received a 2. The point average is 1 for ArcReader and 2 for TNTview.

View Atlas or Digital Posters

Regarding the view only or digital poster criterion, Appendix A shows that both ArcView and TNTatlas can display page layouts or posters with backgrounds, titles, legends, scale bars, and other cartographic details. Both the Football Field and the Otoe County atlases demonstrate these details. Aside from some differences in the way the legends are displayed for the NDVI values of the Football Atlas, both sets of poster layouts appear nearly identical. Both received a 2 for the View atlas category. The point average is 2 for both ArcReader and TNTview.

Interactive Atlas

The interactive criterion used to evaluate these atlases shows a split between these two viewers. MapTips (ArcReader) and DataTips (TNTatlas) provide one of the more interactive ways to pull data out of the database records associated with features stored in a layout. Figures 14 and 15 shows the multilayer DataTip advantage of TNTatlas. The options to control which DataTips to show (None, Active/Top Layer, Visible Layers, Maximum, Automatic by Scale, or Object Names) in TNTatlas outpaces the Topmost and Visible only setting for viewing MapTips in ArcReader. Figure 17 shows some of the

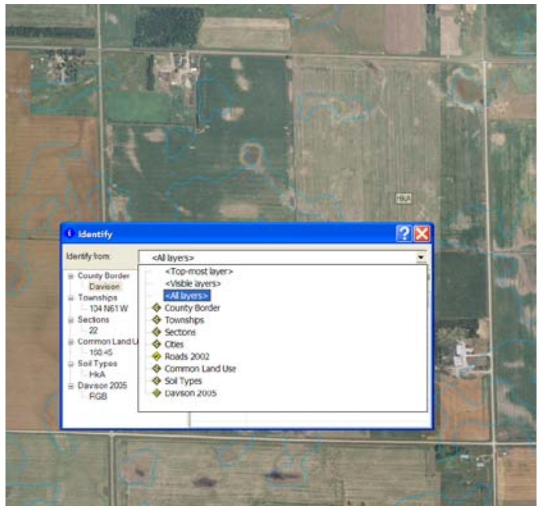


Figure 17 - Identify Options in ArcReader

soil-type MapTip HkA as the only visible MapTip. The Identify tool has some similar controls to TNTatlas (Top-most layer, Visible layers, All layers), allowing you to view database information from multiple layers under the “Identify from:” column by left mouse clicking in the view window, but it is less interactive than simply moving the cursor around and pointing at any feature you want to see database information for, like the DataTips in TNTatlas. This is especially important for orienting yourself in the extents of an atlas as you zoom in, zoom out, or pan to adjust the display extent. Identifying the township name, section number, and road name by pointing the cursor at a feature visible in the image and retrieving the database information from hidden layers overlaid on that image can help you find a field or area of interest more quickly than viewing a separate database window and clicking when you want the information to update to the cursor’s current location.

Table 3 summarizes these Interactive Atlas features. Extra steps are needed to use the Identify or Select tool and the Database searching features in both viewers. This is less interactive than simply pointing the cursor at a feature and reading all of the data

Table 3 – List of Interactive Atlas Features.
Numbers in parentheses indicate points received from each item.

Interactive Features	MapTips - DataTips (points)	Identify Tool (points)	Searching Databases (points)	AP
ArcReader	1 setting (1)	3 layers (2)	all layers (2)	1.67
TNTatlas	6 settings (2)	1 layer (1)	one layer (1)	1.33

about that location designated the atlas designer. ArcReader scored a 1.67 while TNTatlas scored a 1.33.

Analytical Atlas

Evaluating the analytical capabilities of each atlas leads to some of the more complex features of each viewer. The built in Find capability of ArcReader allows you to search any layer in an atlas for locating a feature on the map. Figure 18 shows a search result for a soil type in the Davison County Atlas. This search was restricted to the soil type feature, but any attribute of any layer can be searched all at once. You can pan to the

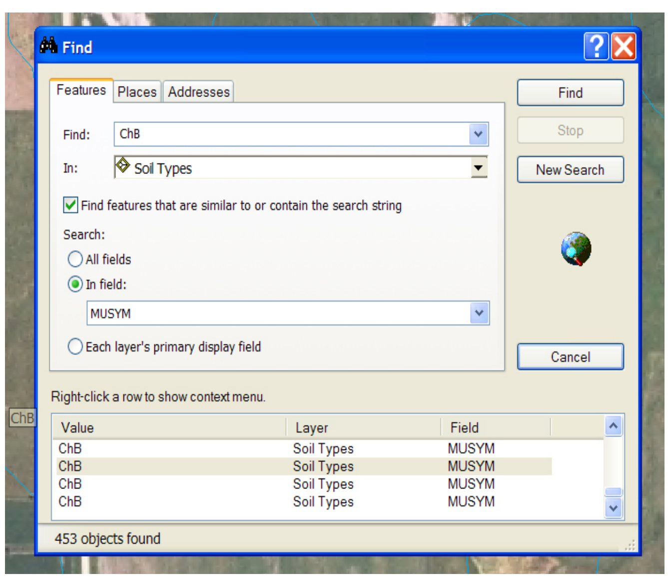


Figure 18 - Search built in to ArcReader

found map elements and add them to a list of my places, allowing you to revisit them quickly to determine where the found elements are relative to each other. TNTatlas limits you to a search within a single feature or layer from the Layer Manager window. You can create a complex search query (for example, to search for multiple soil types at once using an AND statement), but unless a special script is built, the searches are limited to one feature or layer at a time.

Basic measuring tools are necessary for any analysis, especially in a turf management or field management atlas like the ones built in this work. Measurement tools are available for both ArcReader and TNTatlas, with both viewers having the ability to measure linear distance and area. TNTatlas contains a very comprehensive measurement system called GeoToolbox. GeoToolbox includes standard measurement tools to provide an integrated way to analyze spatial data published in an atlas. GeoToolBox goes beyond the simple line, area, and feature measurement tools available in ArcReader. This single tool integrates measurements, Global Positioning System (GPS), element selection, sketching, and region analysis in one place within TNTatlas (figure 19). These tools (combined with feature element selection capabilities) demonstrate that TNTatlas is a unique way to distribute an analytical atlas. One example of the analytical power of this combined toolbox is shown in figure 20 using the Football Atlas. A turf manager poses the question: "How many square feet of turf is relatively poor within 20 foot of the centerline of this football field?" A raster threshold region of the NDVI surface was generated, creating a boundary enclosing only those areas of the football field where the NDVI was between .71 and .77, resulting in a measured area of 16524 square feet. A centerline was drawn using the Ruler tool and a 20 foot buffer zone

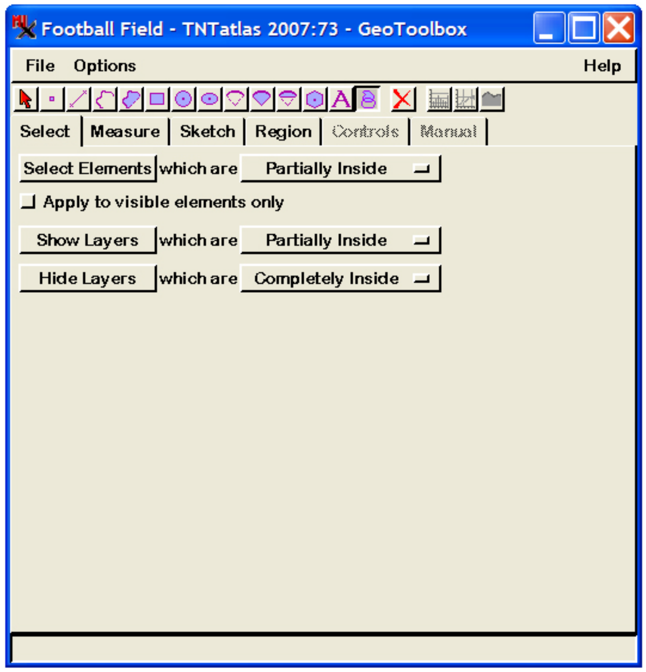


Figure 19 - GeoToolbox in TNTatlas

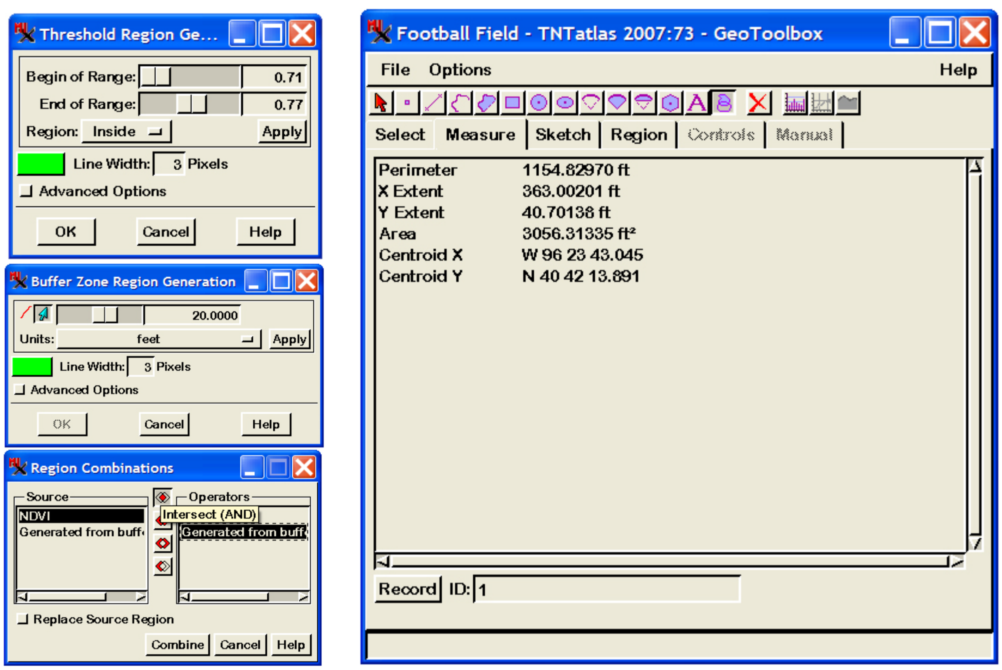


Figure 20 - Three Step Turf Analysis in a Buffered Region

was generated. The two regions were combined using the Intersect option, resulting in a measured area of 3056 square feet. This answers the turf manager's complex GIS question using simple tools available in TNTatlas. That manager can vary his GIS question (changing the NDVI threshold, the centerline location, or the buffer distance) himself, exploring the data provided in the atlas.

Figure 21 demonstrates selecting features from a layer in the Otoe County Atlas. A field manager may ask "What soil types are within 60 feet of the waterway in this field?" The Line measurement tool was used to draw a 1660 foot line following the waterway shown in the imagery. A 60 foot buffer zone (green boundary shown in figure 21) from the line drawn tracing the waterway was generated, and that region was used to select two soil polygons (stored in the ESRI geodatabase) with map unit symbols of MsC3 and Nd. Table 4 summarizes the points from the analytical atlas criterion for ArcReader and TNTatlas. ArcReader scored .8 while TNTatlas scored 1.6.

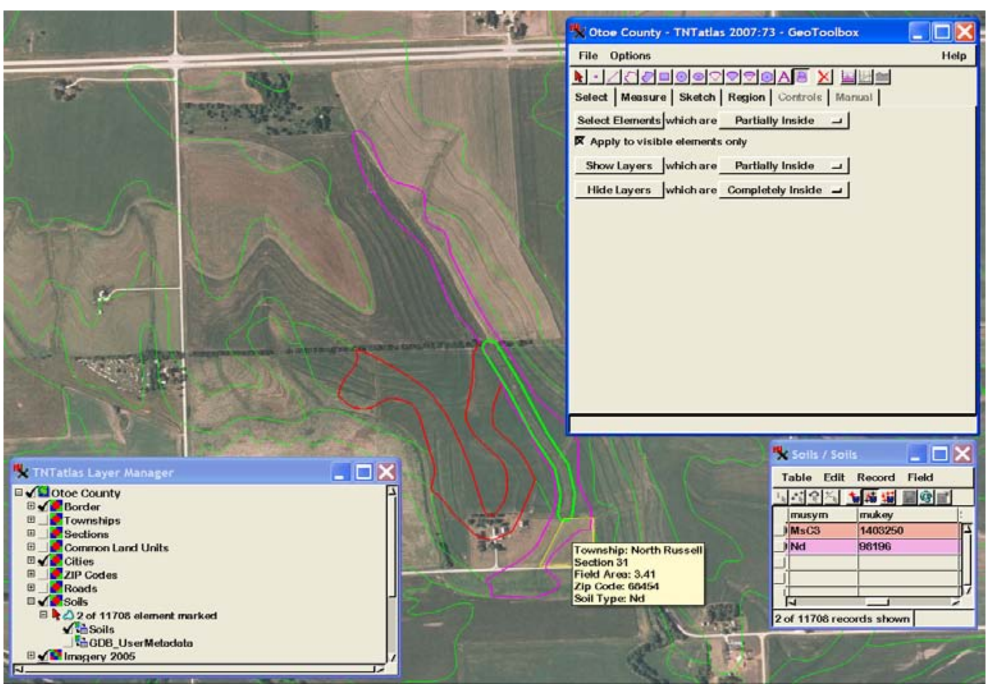


Figure 21 - Selecting Layer Features by Buffer Zone Region

Table 4 – Analytical Atlas Capabilities of ArcReader and TNTatlas. Numbers in parentheses indicate points received from each item.

Analytical	Search	Measuring	Regions	Combine	Reporting	AP
ArcReader	all layers (2)	3 tools (2)	0 (0)	0 (0)	0 formats (0)	0.8
TNTatlas	1 layer (1)	11 tools (2)	12 (2)	4 (2)	1 format (1)	1.6

Annotation and Republishing Tools

The final criterion is to evaluate annotation and republishing tools. The tools provided by each viewer program allowing the end user to annotate and re-publish sections of each atlas can be a very powerful way to communicate spatial information. ArcReader has a markup tool that allows you to highlight parts of maps for emphasis (figure 22). You can also print maps with these highlighted areas and the page layout in the Layout View mode. ArcReader does a good job of adjusting the scale bar and maintaining the cartographic elements of the Layout View made in ArcView by the atlas designer. The markup tools are fairly simple. You can change the drawing tool's transparency, width, and color by selecting from a pick list of options. Exporting to the standard bit-mapped graphic format (.bmp) allows you to generate a digital copy of the print for email or distribution to others who need to view the modified map

TNTview is needed to make a poster with cartographic elements similar to figure 22 created with ArcReader. TNTatlas has less emphasis on generating Layout View with cartographic elements, but more flexibility in generating overlaid markup, or sketch.

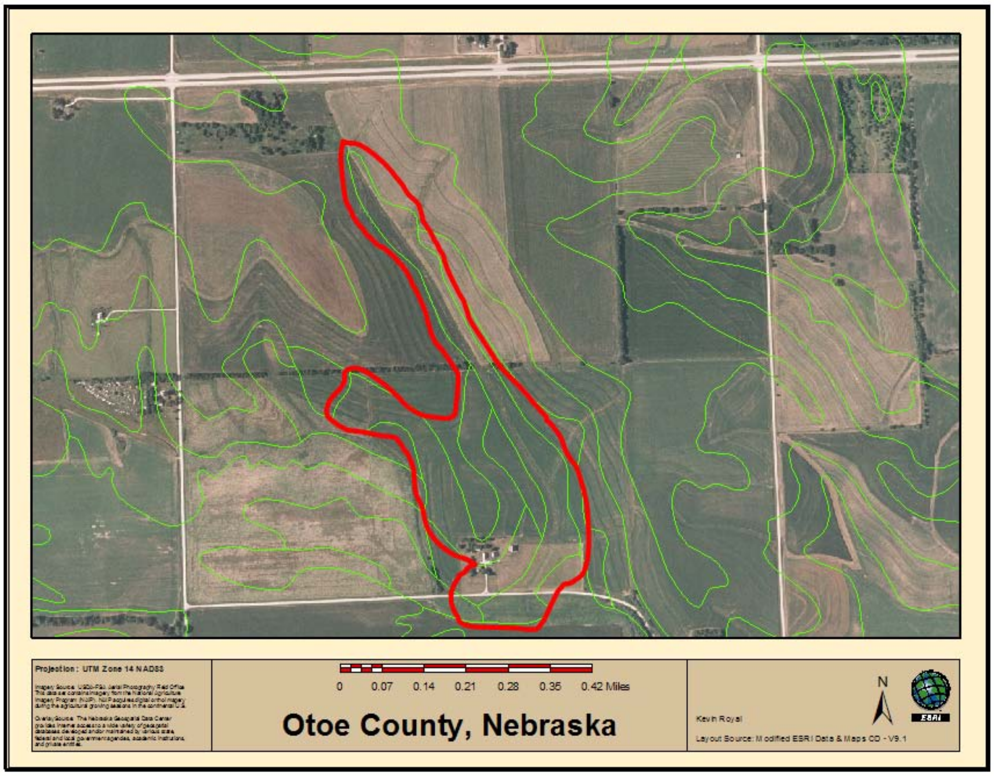


Figure 22 - ArcReader Layout View with a Markup Area

Using the GeoToolbox again, the selected soil types (figure 21) can be converted to a region and (like any region no matter how it is created) added to a sketch object. This new object is temporarily added to the layer list of layout view in TNTatlas. The sketch elements can be styled and text can be added. Figure 23 shows the Sketch tab of the GeoToolbox and the annotated atlas with a new, temporary layer named “Soils Near Waterway” created in TNTatlas. Using the Print Snapshot tool opens a printer settings window. One of the included printer models is Adobe Acrobat File (.pdf), allowing you to generate a digital file for redistribution.

The Quick Snapshot tool in TNTatlas provides another way to generate annotated, digital files for redistribution. Several graphic file formats (JPEG, TIFF) are available. Interestingly, several georeferenced raster formats are also available, including GeoTiff.

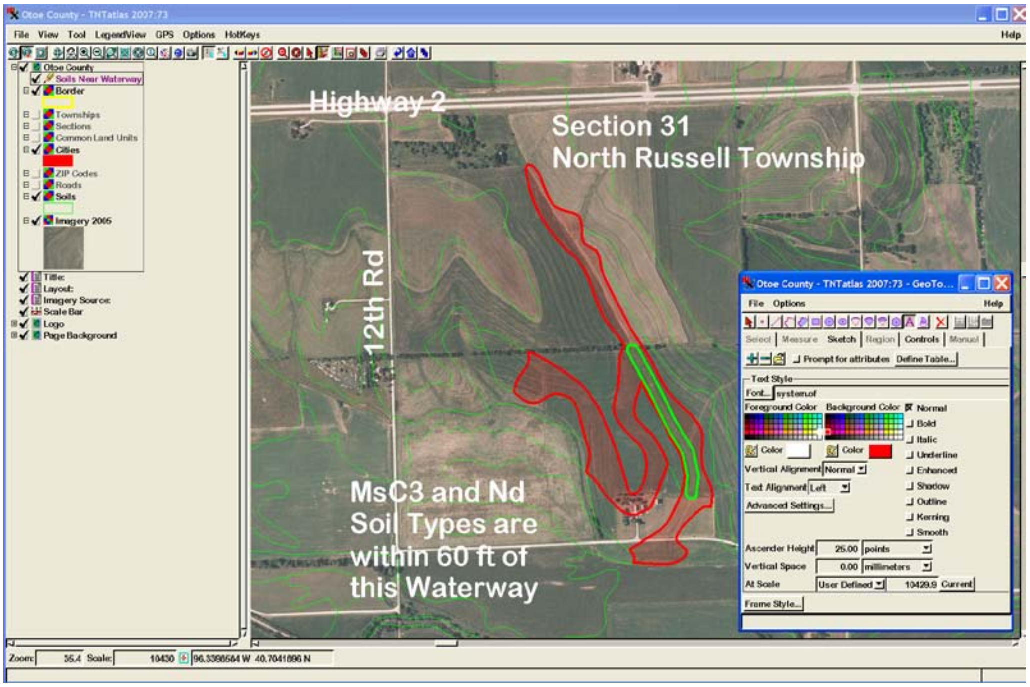


Figure 23 - Regions and Text Can Be Added to a Sketch in TNTatlas

Some of the formats allow you to immediately view the snapshot in Google Earth (figure 24). The overlaid sketch and TNTatlas layers are accurately placed in Google Earth if the layout designer used a Latitude Longitude coordinate system when designing the atlas. The Quick Snapshot Settings allow you to set the image format, Quick Save Folder, and Prefix with the next snapshot adding to the Next Index number. This allows you to quickly snapshot several views of an area from TNTatlas for viewing in Google Earth. You can bundle those snapshots into a Google Earth Keyhole Markup Language (KML) or the compressed version Keyhole Markup Zipped (KMZ) file for distribution to anyone who has Google Earth installed on their computer.

Table 5 is a count of the different formats (digital only) and the number of drawing and markup tools (including text) available from each viewer. TNTatlas allows

Table 5 – Digital Republishing Formats and Measurement / Markup Tools
Numbers in parentheses indicate points received from each item.

Tools or Formats	Format Save As	Format Print To	Tool Measuring	Tool Annotation	AP
ArcReader	1 (1)	1 (1)	3 (2)	1 (1)	1.25
TNTatlas	20 (2)	7 (2)	12 (2)	13 (2)	2.0

you to use any of the measuring tools as markup or region creation tools, but also adds a CAD text annotation tool.

To summarize the ratings described in this section: TNTatlas rated a higher score in the Cost evaluation due to the much higher cost of ArcView with the required

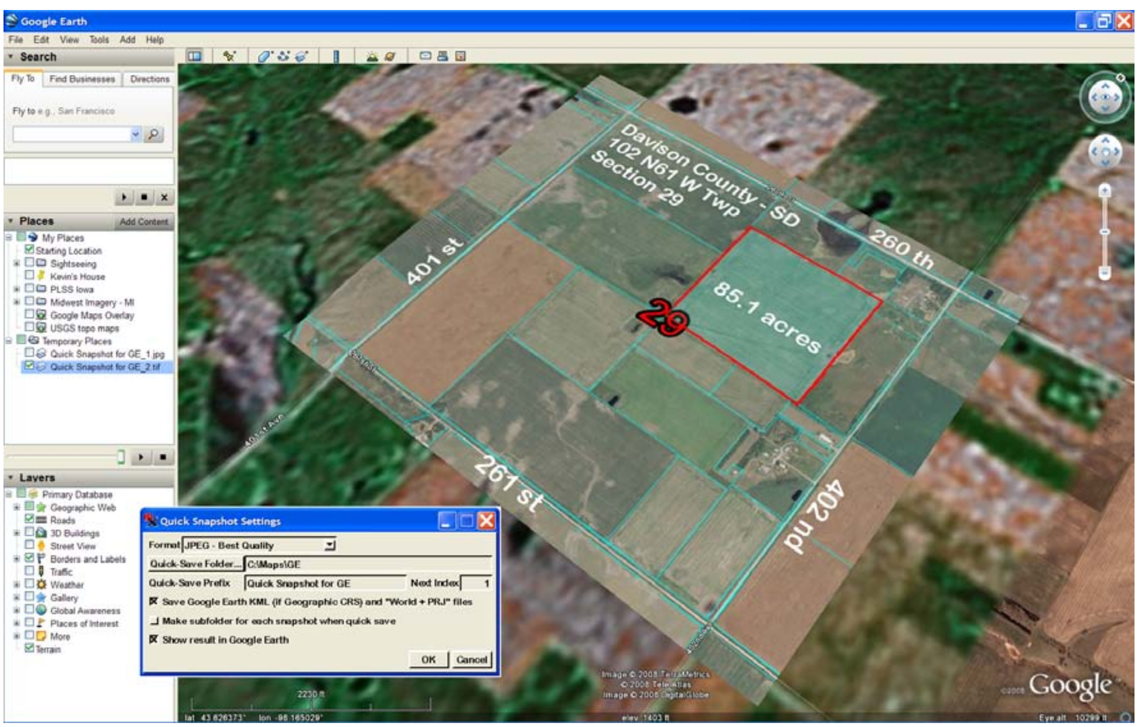


Figure 24 - Quick Snapshot of a Field from the Davison Atlas in Google Earth

Publisher extension when compared to TNTview. Cost criterion scored a 1.0 for the combination of ArcView – ArcReader and a 2.0 for TNTview – TNTatlas.

Both ArcReader and TNTatlas scored a 2.0 for the View atlas category. As an Interactive atlas, ArcReader scored a 1.67 while TNTatlas scored a 1.33. Meeting the Analytical atlas criterion, ArcReader scored a .8 for the Search tool and TNTatlas a 1.6 for region analysis tools that are a part of GeoToolbox.

The Republishing capabilities of both ArcReader and TNTatlas were good, with ArcReader scoring a 1.25 due to its variable Layout View mode allowing cartographic details to adjust when you print a zoomed view. TNTatlas scored a 2.0 for its ability to annotate the view area with text, convert regions to sketch layers, and to output georeferenced snapshots for immediate viewing in Google Earth.

The total combined score for ArcReader was 1.21. The total combined score for TNTatlas was 1.71. Table 6 shows the breakdown of these scores described in the criteria listed above.

Table 6 – Final Scores Evaluating ArcReader and TNTatlas.
Numbers in parentheses indicate points received from each criterion.

	Cost (1 item)	View (1 item)	Interactive (3 items)	Analytical (5 items)	Republish (4 items)	AP (14 items)
ArcReader	1.0 (1)	2.0 (2)	1.67 (5)	0.8 (4)	1.25 (5)	1.21 (17)
TNTatlas	2.0 (2)	2.0 (2)	1.33 (4)	1.6 (8)	2.0 (8)	1.71 (24)

CONCLUSIONS AND SUMMARY

Three pairs of atlases were built to compare different ways of distributing geospatial data to others who can use it for better management within an organization such as a farmer's cooperative, crop consultant, or turf grass management company. All three organizations operate in a geographic space where communicating spatial information to others is important in daily operations. Two different types of atlases were constructed. A large scale, small study area Football Field atlas was designed as a Page Layout atlas containing high resolution turf health information within the field's boundary. This type of atlas is useful for a turf management company, but the other organizations may have crop test plots or other intensively studied areas where a similar scaled study area may be important for the business.

The second type of atlas was on a smaller scale, covering Davison County in South Dakota and Otoe County in Nebraska. The Davison County Atlas was a Data View atlas, with no cartographic details. The Otoe County Atlas was a Page Layout atlas that was similar to the Football Field Atlas with cartographic details including scale bars, logos, and text. The Otoe County Atlas was unique in that all of the layers were shared layers in both the ArcReader and TNTatlas viewing programs. All three atlases were built twice: Once in ArcView to be viewed in ArcReader and again in TNTview for distribution in TNTatlas. By making all three pairs of atlases as similar as possible, a direct comparison of these geopublishing systems could be made.

Five criteria were used to evaluate the two geopublishing systems. The first criterion was total system costs for publishing geospatial layouts. TNTview - TNTatlas compared favorably with a single cost of US $500 for a TNTview license and no additional charge for distributing the TNTatlas viewer. ArcView - ArcReader was more expensive due to the initial cost of ArcView (US $1,500) to assemble the spatial layouts and an additional US $2,500 cost of the Publisher extension required to make layouts created by ArcView readable with ArcReader. Cost evaluation scored a 1.0 for the combination of ArcView – ArcReader and a 2.0 for TNTview - TNTatlas.

The next three criteria were suggested by Delazari and Cintra (2000). Both ArcView and TNTatlas were able to perform as view - only electronic atlases. The Page Layout atlas designs of the Football Field and Otoe County atlases contained useful cartographic information and provided an inexpensive way to distribute the electronic equivalent of paper maps or posters. Both scored a 2.0 for the View category.

ArcReader scored slightly better when meeting the interactive criterion established by Delazari and Cintra (2000). Search capabilities and the Identify tool in ArcReader provided useful access to features' attributes, Multi-layer DataTips makes for effortless access to database attributes attached to features contained in the atlases by simply pointing the computer's cursor at the feature shown on the layout with good control for the atlas designer over which information is displayed. Prefix and suffix options clarify the information presented with the DataTips in TNTatlas. Whether the layer was the topmost, hidden, geometric, or raster, all layers' database attributes were available for instant viewing with the DataTips in TNTatlas. MapTips in ArcReader were much more restricted, allowing access to just the visible or topmost layer in the atlas. Neither viewer met Delazari's and Cintra's (2000) exact criteria and freedom so that "...the user can change the color scheme; choose the classification method or number of classes." This may be an advantage for both programs, leaving it up to the atlas designer to build useful theme maps and color schemes that cannot be modified by their target audience that may lack the experience to make meaningful classifications of any included layers. However, anyone with limited computer experience would be able to navigate and gather some useful information from both ArcReader while TNTatlas provides simple "point the mouse and read" access to all features' database records designated by the atlas designer. ArcReader scored a 1.67; TNTatlas scored a 1.33.

While ArcReader has very useful search tools allowing the atlas user to find features from multiple layers or themes in one window, the analytical atlas defined by Delazari and Cintra (2000) is very nearly met by TNTatlas through the GeoToolbox and Region tools. "In these atlases, data sets can be combined and manipulated and the user is not restricted only to those themes chosen by the cartographer. The user can make calculations and conduct analysis in different areas and themes. In addition, some GIS capabilities are provided." Multiple tools were used to create regions based on raster NDVI thresholds and drawing tool buffer zones in the Football Field Atlas. These regions were combined to calculate the area within a 20 foot centerline of the field, answering the GIS question an end user may ask.

The Otoe County Atlas used a buffer zone region to select features from the soil theme that fell within the 60 foot buffer distance, another GIS type question answered. The free TNTatlas viewer has more than 30 different ways to generate regions, including floodzone, watershed, viewshed, raster texture, feature database queries, and others. Any collection of regions can act as a Source and Operators and be interactively combined using an Intersect (AND), Union (OR), Exclusive Union (XOR), and Subtract operation. This allows an end user to pose many different GIS questions and with some training, combine many themes for generating calculations (like square footage within an NDVI threshold near the centerline of the field in the Football Field) or generate selection boundaries (soils that fall within a buffered distance of a waterway in Otoe County) built into an atlas published with TNTatlas. ArcReader scored a 0.8 for the Search tool and TNTatlas a 1.6 for region analysis tools.

Finally, the fifth criterion reviewed the tools provided by each viewer program to allow an end user to annotate and re-publish sections of each atlas. This can be a very powerful way to communicate spatial information, allowing a casual atlas user to add his experience and annotations to generate a part of a map he can pass along to a customer or coworker. ArcReader has strong printing capabilities for the Layout View atlases (Football Field and Otoe County atlases). It can dynamically modify a scale bar depending on the zoom level of the viewer and maintain the layout cartographic elements in the final print. It falls short with very simple annotation tools that are limited to highlighter like drawing capabilities. TNTatlas can use the uniquely integrated GeoToolbox to create Computer Aided Drafting (CAD) sketch layers from region analysis that can be styled in various ways. An end user can manually sketch and even add text and database attributes to sketch layers that are automatically loaded into the active group in the layer list. Sketches and saved regions can also be saved for later use in that atlas or can be sent back to the atlas designer for additions or updates to layers of the next version of atlas or can be shared with other atlas users working in the same study area. Snapshot prints can be generated as Adobe Reader (.pdf) documents or Quick Snapshots can be saved to several different graphics formats, some that include georeferenced information. Quick Snapshots from layouts published in a Latitude - Longitude coordinate system can be saved as Google Earth layers, automatically launching Google Earth when the snapshots are generated. An experienced atlas user can assemble KMZ map bundles to distribute collections of snapshots generated from

TNTatlas to others for viewing in Google Earth. ArcReader scored a 1.25 due to its variable Layout View mode allowing cartographic details to adjust when you print a zoomed view. TNTatlas scored a 2.0 for its ability to annotate the view area with text, convert regions to sketch layers, and to output georeferenced snapshots for immediate viewing in Google Earth.

Reviewing the comparison process and criteria, the cost and analytical scores show the greatest difference between the two publishing systems. The cost is set by each software company and can not be changed by the end software users. The ability to take advantage of the difference in analytical tools can be affected by the person publishing the atlases. It is really a matter of training for both the atlas designer and the target audience or end users of a digital atlas.

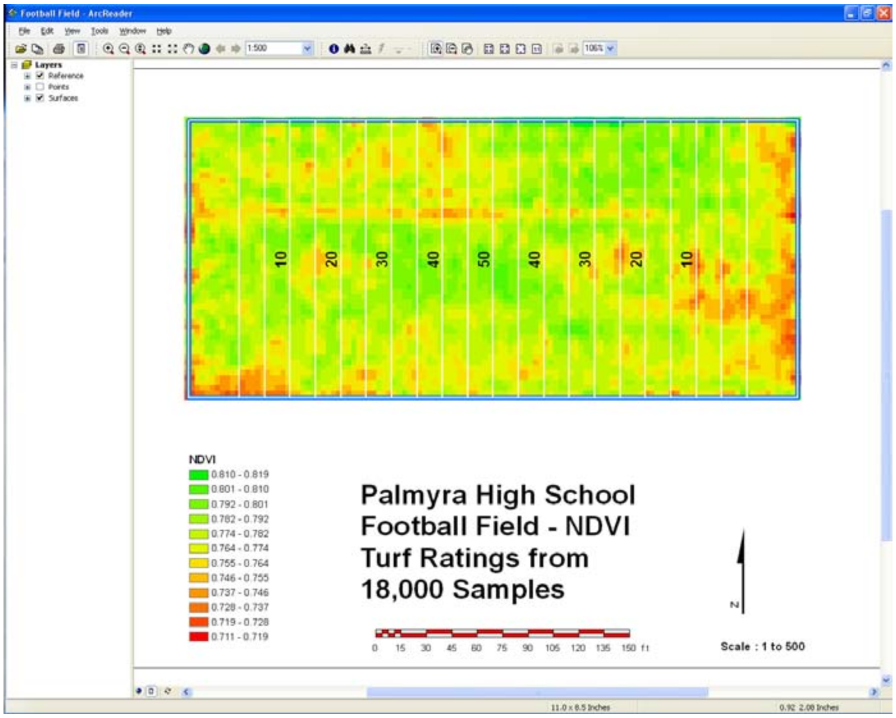
The Average Point (AP) ranking method used to evaluate these two geopublishing systems is an ordinal ranking system. The Cost criterion simply evaluates which geopublishing system cost more or less than the other. Even though the US$4,000 ArcView – ArcReader geopublishing system cost 8 times more than the US$500 TNTview – TNTatlas geopublishing system, the AP score is 1 (for ArcView with Publisher extension) and 2 (for TNTview). These scores cannot be used to directly compare how much more the ArcView system cost than the TNTview system.

The assigned values for the View, Interactive, Analytical, and Republish criteria simply indicates if the feature or tool is present or not, with a score of 1 when one basic tool is available or a 2 if two or more tools are available for any function. This ordinal scoring system does not directly compare how many more tools are available or how much better one system is compared to the other. It indicates that none, one, two, or more tools are present within either the ArcReader or TNTatlas viewers.

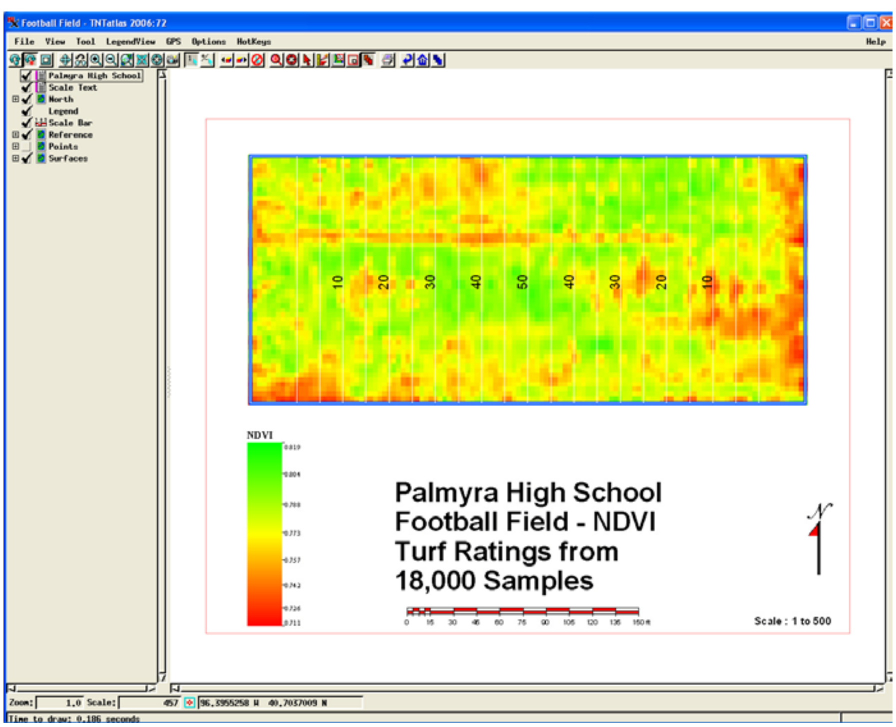
Further research into the advantages of providing training and task specific documentation (including videos) for the target audience to help maximize the way they access a geopublishing system would be useful. Surveying managers who are asked to use an atlas as a part of their normal workflow could indicate how long it takes to feel comfortable with the GIS tools included in the viewing software. Measuring the number of GIS tools used and they way they apply those tools would be useful to determine how additional training improves the effectiveness of a management oriented atlas.

Both the ArcView - ArcReader and TNTview - TNTatlas geopublishing systems have strengths that make them better suited for geopublishing in a cost effective way than other standard desktop publishing tools. The TNTview - TNTatlas geopublishing system better met the five criteria used to evaluate these two systems. It has room to grow with the end user as they start to ask GIS questions that can not be anticipated or designed into a predefined layout published by an atlas designer.

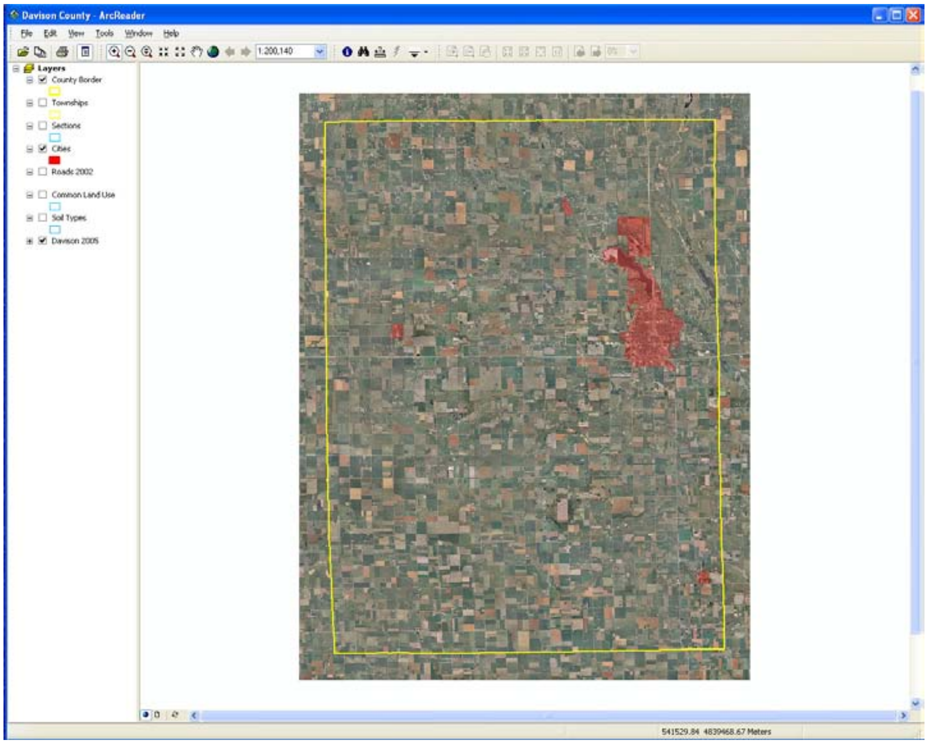
APPENDEX A



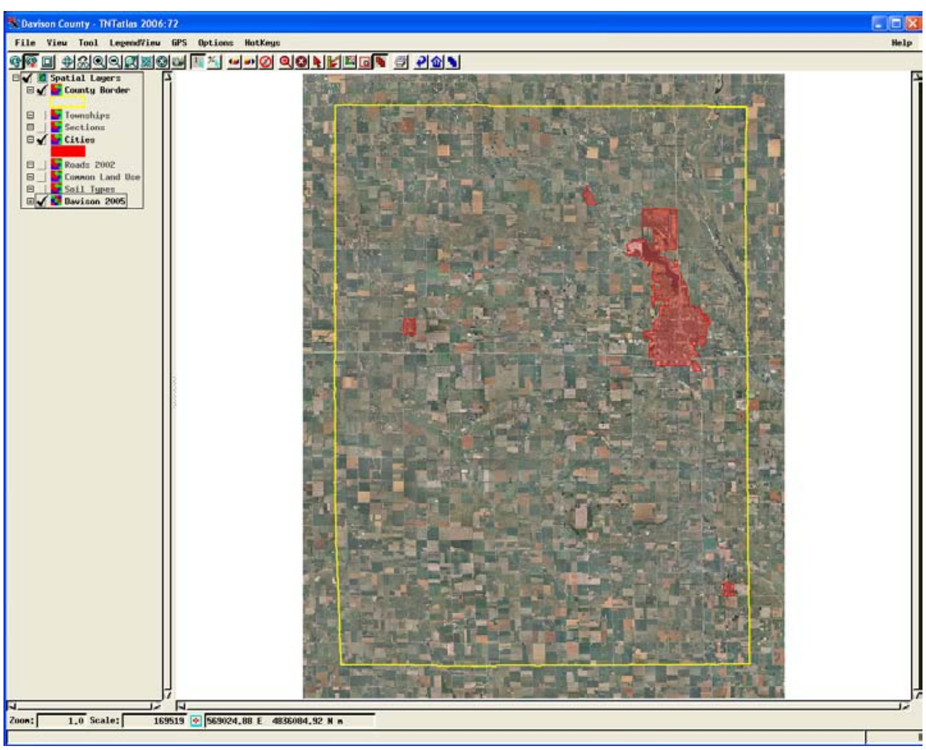
Football Atlas in ArcReader



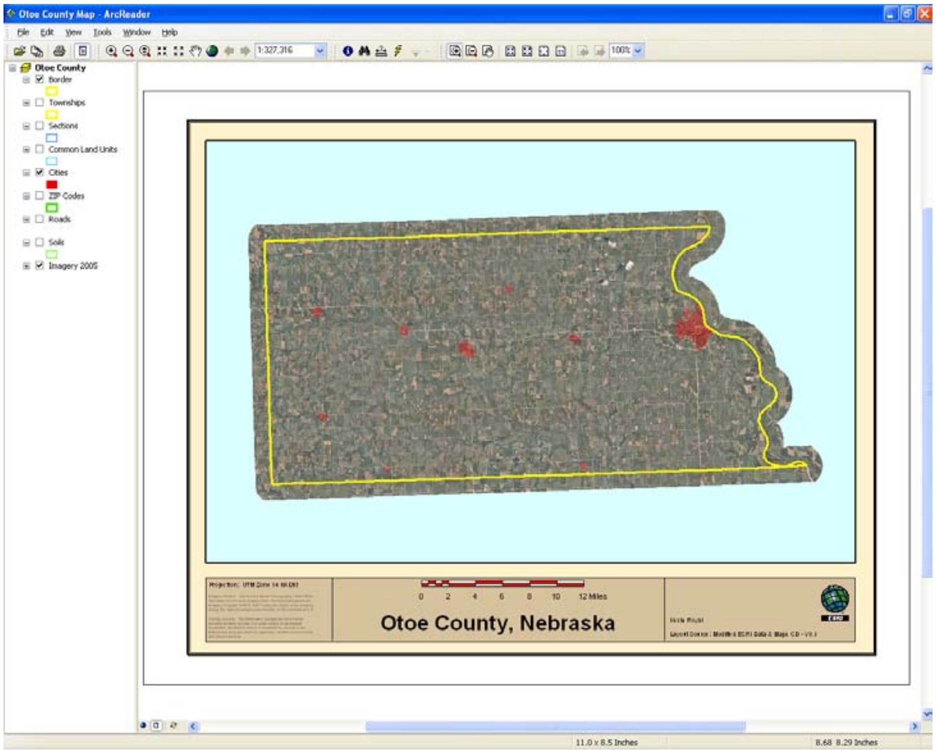
Football Atlas in TNTatlas



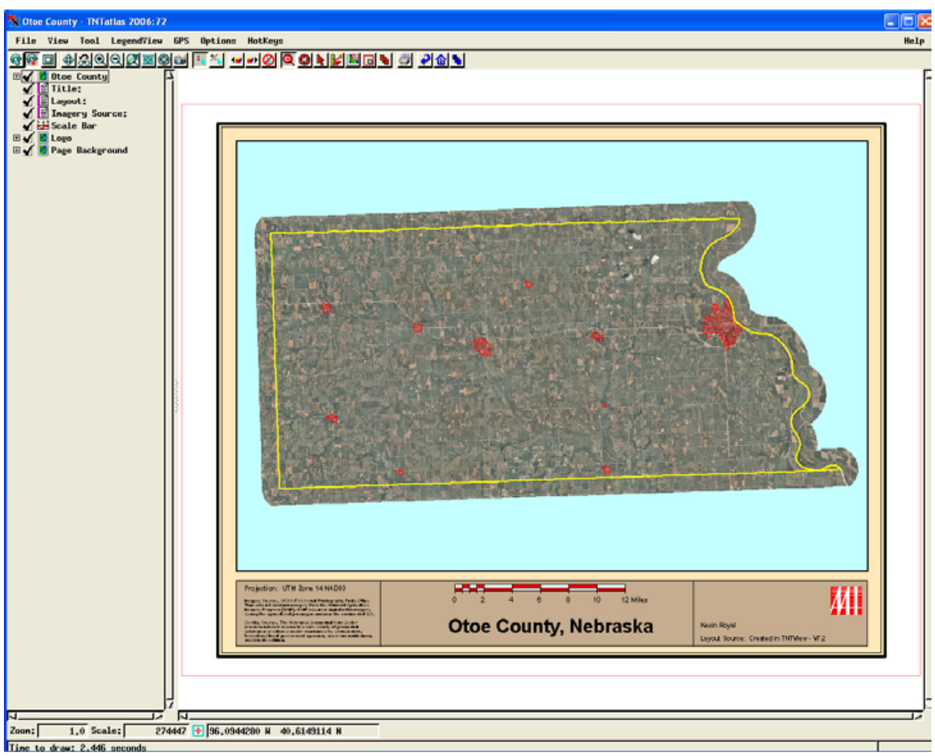
Davison Atlas in ArcReader



Davison County Atlas in TNTatlas



Otoe County Atlas in ArcReader



Otoe County Atlas in TNTatlas

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