

GEOGRAPHIC TOOLS FOR GLOBAL PUBLIC HEALTH

AN ASSESSMENT OF AVAILABLE SOFTWARE

MEASURE Evaluation

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The inclusion of a software program in this document does not imply endorsement by the MEASURE GIS Working Group or its members; or by MEASURE Evaluation, the U.S. Agency for International Development, NICHD, or the U.S. government.

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Acronyms

3-D	three-dimensional form
CDC	U.S. Centers for Disease Control and Prevention
COGO	coordinate geometry
CPU	central processing unit
E2G	Excel to Google Earth
Esri	Environmental Systems Research Institute, Inc.
FOSS	free and open source systems
GIS	geographic information system
GRASS	Geographic Resources Analysis Support System
KML	Keyhole Markup Language
MDG	United Nations Millennium Development Goals
NDVI	Normalized Difference Vegetation Index
NGO	nongovernmental organization
NICHD	Eunice Kennedy Shriver National Institute of Child Health and Human Development
OVC	orphans and vulnerable children
OSGeo	Open Source Geospatial Foundation
PDA	personal digital assistant
QGIS	Quantum GIS
PC	personal computer
RAM	random-access memory
UTM	Universal Transverse Mercator projection
UNICEF	United Nations Children's Fund
USB	universal serial bus
WG	MEASURE GIS Working Group

Executive Summary

There is a growing list of software options for those wishing to map data. Users in global public health often have little time or money to invest in developing the technical expertise and data required for mapping, and are therefore confronted with capacity and data constraints that can make mapping difficult to implement. This makes the process for selecting the most appropriate software especially challenging. Also, because the leading mapping programs are built for general purpose audiences, these programs do not necessarily provide an interface that is intuitive for public health analysts and decision makers. Finding the right balance of features, Ease of use, and cost can make the difference between software that is used optimally and software that sits neglected on a computer.

Table ES1 provides a list of specific tasks related to global health and the analysis and tools necessary to complete the tasks with geographic information system (GIS) or mapping software programs.

Unfortunately, there are limited resources available to help potential public health users compare capabilities of the leading software options. This document seeks to address that gap by performing assessments of the features and Ease of use of five commonly used mapping software programs. The objective of this document is to provide potential users of the software with an overview of features and ease of use within a public health context. Conversely this document can also help software developers by highlighting sample use cases and key tasks the public health community perform, and by identifying difficulties public health users encounter with the software packages. Developers can use this knowledge to enhance existing functionality or to create new functionality to address these issues.

The MEASURE GIS Working Group evaluated the features and ease of use of five commonly used mapping applications: ArcGIS, Quantum GIS (QGIS), Epi Info, Google mapping tools (including Google Maps, Google Earth, and the related MEASURE E2G tool), and DevInfo. These software were selected because they are in common use. There are other software options that exist; a list of some possible software alternatives are presented in Appendix A. Multiple public health use cases were simulated in each software package, and each application was assessed on its ability to execute the specific tasks. The use cases selected are not a comprehensive overview of every possible potential task for global public health professionals, but were selected to represent some commonly performed tasks: program targeting, assessing accessibility, and programmatic roll-out.

The results of the assessment show wide variability in features across the five applications and considerable variability in ease of use. A summary of features and ease of use for the five software programs evaluated is provided in table ES2.

Based on this assessment, full featured GIS programs (ArcGIS and QGIS) provide the most features but can be hard to use. The other software evaluated still provided adequate functionality for the four use cases studied; however, they often required extra effort to modify the data or perform specific tasks. The Google tools and DevInfo were lacking in features necessary for completion of HIV/AIDS Prevention and Malaria targeting.

Table ES1: Global Health Activity by Type of Tool Typically Needed

Global Health Activity	Type of Study Often Needed	Type of Analysis Typically Needed	Type of Tool Typically Needed
Service availability/access	Population catchment (via road network OR simple distance buffers)	Road network analysis, distance calculations	Network topology tools, measurement (along a line and to/from a line or point), buffer creation, point selection tools, simple statistics
Targeting a prevention program	Identification of locations in relation to roads or population centers, geographic allocation of resources	Point location, line location, measurement, population density calculations	Choropleth maps (data classification, shading/color choices), line buffering, distance measurement
Evaluating program usage	Data management, visual (map) analysis, time series creation	Database creation, data classification, map creation, periodic report generation	Choropleth maps (data classification, shading/color choices), geographic database, map layout/editing tools
Targeting a disease with known epidemiology	Hot spot (activity area) identification, use of background data to identify causation	Land use/land cover identification, other contextual data, population data, geographical data collection tools (such as GPS)	Zonal statistics and other raster-based tools (i.e., ability to work with DEMs--digital elevation models); GPS data creation

Table ES2: Ease of Use for Five Programs Evaluated

	ArcGIS	QGIS	DevInfo	Epi Info	Google
<i>Functionality</i>					
1 Evaluate health care access	●	●	○	○	●
2 Target an HIV/AIDS prevention program	●	●	●	●	●
3 Develop and evaluate an OVC program rollout	●	●	●	●	●
4 Develop a targeted approach to righting malaria	●	●	○	●	●
<i>Ease of Use</i>					
1 Evaluate health care access	●	●	○	○	●
2 Target an HIV/AIDS prevention program	●	●	●	●	○
3 Develop and evaluate an OVC program rollout	●	●	●	●	●
4 Develop a targeted approach to righting malaria	●	●	○	●	●

- **Robust:** Exceptional compared to other software.
- **Acceptable:** Average compared to other software.
- **Lacking:** Capabilities don't exist or poor compared to other software.

The choice of software is unique to each circumstance. It is not possible to say unilaterally that one particular application is universally best suited for everyone. In fact, many users often rely on multiple software programs in order to get the full set of functionality they need. Additionally, software programs change regularly and new capabilities are added or existing features are removed. Such changes mean that assessment of software is a process that users may have to do on a regular basis. The features of each software tested in this document were current as of the end of 2012.

Geospatial software is finding increased use in global public health; this document can help public health professionals and software developers strengthen the use of such software.

Introduction

A geographic information system (GIS) is much more than just software for creating maps. In global public health sector, a GIS can be used to manage data associated with health facility locations, population-based health indicators, and other health-specific data; creation of a multi-sectoral perspective based on linking of data sets using common geographic identifiers; modeling and analysis of data that takes advantage of geographic context, such as analysis of geographic access to health services; and publication of program results that reflect the unique contribution of spatial data. As a result, GIS technology is increasingly being used to strengthen the decision-making process for public health programs, which includes the local capacity to plan, target, and monitor diseases and interventions over time. However, cost, complexity, and lack of functionality have all been cited as constraints to its widespread adoption, especially in limited-resource settings.¹ In addition, many of the GIS solutions being used by the public health community have limitations with respect to functionality, usability, or both.

In this context, the MEASURE GIS Working Group (WG) met in Washington, DC, in April 2010 to discuss the most common GIS functionality needed by public health professionals. The group identified the need for a resource that would give potential users an overview of features in software and help those users identify suitable software for their needs. The group also identified the need to inform the software development community about global public health use cases. Software developers seek to produce software that is functional and easy to use; however, because of the unique operating constraints of the global public health community, software developers may not be aware of their needs.

The objective of this document is to provide public health professionals with an assessment of the functionality and usability of some of the leading mapping software solutions available to them. To accomplish these goals, this paper evaluates the functionality and usability of several leading mapping programs, both commercial and free and open source systems (FOSS), being used in the public health arena. This document identifies gaps in functionality and presents areas where existing functionality could be made more user-friendly.

Use cases were developed to represent common needs within the global public health community that benefit from the inclusion of geographic context: Assessing health accessibility, program targeting and programmatic roll-out. Specifically they are:

- assess rural accessibility to health services;
- target an HIV/AIDS prevention program for villages situated along major highways;
- develop and evaluate an orphans and vulnerable children (OVC) program roll-out; and

¹ Fisher RP, Myers BA. 2011. Free and simple GIS as appropriate for health mapping in a low resource setting: a case study in eastern Indonesia. *Int J Health Geogr.* 2011;10:15; Vanmeulebrouk B, Rivett U, Ricketts A, Loudon M. Open source GIS for HIV/AIDS management. *Int J Health Geogr.* 2008;7:53.

- target areas for mitigation of malaria risk.

Five commonly used mapping software packages were selected by WG members for evaluation based on their use within global public health. The mapping software packages selected for evaluation based on their common use within public health are as follows:

- ArcGIS version 10 from Environmental Systems Research Institute, Inc. (Esri), Redlands, CA, USA;
- DevInfo versions 6 and 7 from the United Nations Children’s Fund (UNICEF), New York, NY, USA;
- EpiMap version 6 from the U.S. Centers for Disease Control and Prevention (CDC), Atlanta, GA, USA;
- Google mapping tools from Google Inc., Mountain View, CA, USA;
- Quantum GIS (QGIS) version 1.7 from the Open Source Geospatial Foundation (OSGeo), Beaverton, OR, USA.

The evaluation was based on two main criteria: the software’s applicability for the tasks in the use case, and ease of use. **Functionality** was judged on whether the application met the needs of the user producing an effective, comprehensive output in a format that could be used in further analysis and/or included as is in a report; where appropriate giving the user options for how best to display the data. **Ease of use** assessed whether the task was straightforward to accomplish without an elaborate workaround; the approach was intuitive; or whether good documentation was available to answer questions.

To increase the objectivity of the assessment, evaluators attempted to compare the chosen software with other software from the perspective of a novice user. The software was classified based on how it performed compared to all available software (not just the five programs evaluated). Each package was classified as follows:

- **Robust:** Exceptional compared to other software.
- **Acceptable:** Average compared to other software.
- **Lacking:** Capabilities don’t exist or are poor compared to other software.

Software users are not the only target audience for the document. Software developers can benefit from an understanding of the needs of a software package’s potential user base. The growth of interest in mapping software in the global health community represents a new user base that developers may want to reach. This document can help developers better understand the needs of the health community and lead to improvements in software interfaces.

This guide is organized into three parts: (Part I: Mapping and Spatial Analysis in Public Health; Part II: Brief Overview of GIS Software Packages Evaluated; and Part III. Use Cases).

The guide also contains the following appendices: Appendix A: Background on ArcGIS, QGIS, Epi Info, DevInfo and Google’s Tools; other Tools; Appendix B: Detailed Use Case Analysis; and Appendix C: References and Resources.

Part I: Mapping and Spatial Analysis in Public Health

Hippocrates, considered the father of epidemiology, recognized that there were differences in the geographic distribution of disease. In the modern era, one of the most well-known examples of geographical mapping of disease is that of maps created by Dr. John Snow in 1859 to trace the origin of a cholera outbreak in London. Simple maps have been used since then to follow disease spread, identify sources, determine target areas, and assess epidemic risk. In recent years, computer scientists have developed increasingly robust and complex software packages to automate the map-making process, conduct complicated spatial analyses, and create three-dimensional models. The last several years have seen significant progress in the development and uptake of both commercial and FOSS geographic analysis and mapping tools to support public health decision-making.

Increasingly, many data analysis tools include a mapping component. It is important to note that not every program that allows its users to make maps should be considered a GIS. This document provides an overview of a mix of software; some of which may be accurately described as true GIS software, some of which may be considered simply data display tools that allow users to map data. To be a true GIS, a software program must have the capability to link and integrate spatially tagged attribute data from disparate sources. This geographic information (spatial and attribute) can then be queried and analyzed. A true GIS can thus use the geography underlying data to help break down data stove pipes and make it possible to take full advantage of the available data infrastructure.

GIS technology also supports the query and analysis of programmatic data, revealing trends, correlations, dependencies and spatial relationships that are not as evident when data are stored in a simple tabular format. Moreover, experience shows that mapping of events not only facilitates epidemiological analysis but is also a very effective tool for advocacy through the media and for generating action by the decision makers and the population at large. With a full GIS program, decision makers can more easily assess where the populations are in relation to specific problems (disease and health events) and in relation to available resources (e.g., health and social services, water supply, and education). Scarce public health resources can be more rationally planned and targeted to those communities most in need.

While many public health professionals now recognize the power and value of GIS, several obstacles constrain the full operational implementation of GIS/mapping applications, especially in limited-resource settings. These include the following:

- **Cost:** Commercial GIS software can be expensive to purchase, though there are often grant programs to provide software at reduced or no cost to nongovernmental organizations (NGOs), educational institutions, or charities. Like any software, mapping and GIS software can require significant training and re-training of users and, depending on the specific circumstances, can require significant investments in hardware and system administration personnel.

- **Complexity of the software:** Many GIS software packages, both commercial and FOSS, can be complex. In addition, most GIS packages are designed as general use toolboxes and do not provide a user interface that is customized for public health professionals. As a result, training materials can sometimes be difficult to understand, and may contain jargon and examples that are not particularly relevant to global health practitioners. Also as a result, organizations may have concerns that a GIS is difficult and can be used only by experts.
- **Lack of standardization:** Public health databases are often in varying formats and may not use standardized geo-referencing. This can make their integration into a GIS time-consuming and difficult.
- **Limited data availability:** Public health users may not have ready access to digital data such as boundary maps, elevation maps, information on the location of population settlements, etc. or the GIS skills necessary to convert existing data to use in their software.

Increasingly, these obstacles are becoming less of an issue. Software programs are becoming easier to use and costs associated with learning and using the software may be more manageable than before. Additionally, in many countries, geographic boundary data are becoming more available thanks to growing national spatial data infrastructure efforts within countries.

A number of software packages are useful in the health field. Each of these packages has its strengths and weaknesses and the one best suited for any particular user will be a matter of weighing the strengths and weaknesses.

Table 1 provides a list of some of the more common types of global health activities that might benefit from using a mapping program or GIS. While this document does not address every tool or analytic approach, it does illustrate how some of the more basic needs may be met by the software.

Table 1: Global Health Activity by Type of Tool Typically Needed

Global Health Activity	Type of Study Often Needed	Type of Analysis Typically Needed	Type of Tool Typically Needed
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Targeting a disease with known epidemiology	Hot spot (activity area) identification, use of background data to identify causation	Land use/land cover identification, other contextual data, population data, geographical data collection tools (such as GPS)	Zonal statistics and other raster-based tools (i.e., ability to work with DEMs--digital elevation models); GPS data creation

Part II: Brief Overview of GIS Software Packages Evaluated

WG chose to evaluate the five systems described below because they are currently widely used in public health. There are other software options available to public health users. The systems chosen here represent a mix of GIS programs and software that provide the capability to map data. Appendix A has a list of other software that users may want to consider.

Esri Arc Family

ArcGIS 10, ArcView: Esri has been producing GIS software since the release of ARC/INFO in 1982. At the time of the creation of this document, ArcGIS 10 was the current desktop GIS product, though the company has developed a Web-based ArcGIS online application that allows users to produce basic maps. The desktop program is a relatively complex system that for most users requires additional training in order to allow the software to realize the full utility such as its ability to do scripting, develop models, conduct network or spatial analysis or take advantage of its advanced labeling and publishing capabilities. Esri provides many online training options and has a network of Esri-certified training facilities and instructors around the world.



DevInfo 7

DevInfo 7 is a data visualization application originally developed by United Nations Children's Fund (UNICEF) to track progress on the United Nations Millennium Development Goals (MDG). More recent versions of DevInfo 7 have added a greater variety of visualizations and data importing and exporting options. It is not technically a GIS; however it does provide the option to map the data. The user application has many tools available in a spreadsheet program, such as Microsoft Excel, to edit and format the objects. It is simple to create flip books, simple videos, or publish to Web sites. It is very powerful and well suited for generating standard reports or country profiles.



Epi Info 6 and 7

Epi Info was developed by the U.S. Centers for Disease Control and Prevention (CDC) for disease surveillance and to educate of public health professionals about the geography of health. Epi Info 6, used for testing in this document, consists of five modules that can be used together or separately to enable:



- data collection (the Make View and Enter Data modules);
- advanced statistical analyses (Analysis module);
- visualization with GIS mapping capability (Epi Map module), and
- custom reports (Epi Report module).

It is easily used in places with limited network connectivity or limited resources for commercial software and professional IT support. Since its initial release, Epi Info™ users have self-registered in over 181 countries covering all continents including Antarctica. It has been translated into 13 languages. Note: Since this document was created, a new version Epi Info 7 is available with additional mapping capabilities.

Google Geographic Data Tools

Google has an extensive and ever-growing library of Web-based tools for mapping and displaying data. Google makes available satellite imagery, county and sub-county boundaries, roads, and places of interest. Google Earth is a free, user-friendly desktop application which can show the entire globe at once and also allows three-dimensional form (3-D) visualization and “flyovers” or virtual tours. Google Maps is a free Web-based application and has good navigational features. Both require a Web connection to view the underlying proprietary base data and imagery.



Other geographic data can be imported by users on top of any of this base information in Keyhole Markup Language (KML) format, a format that can also be imported and exported to and from ArcGIS and QGIS. Google can also store tabular data in fusion tables, which can be linked to KML files, classified, and displayed in Google Maps.²

Some of Google Earth’s features that might be helpful to public health users are only available with a Google Pro license, which is fee-based. However, as Google Earth and Google Maps are available free of charge to those with Internet connection and can be quite useful due to both their ease of use and large visual library of images and base maps, they are discussed here as viable mapping tools.

In order to use some functionality, data may need to be uploaded to Google servers. Because of the sensitive nature of health-related data, having data exist on external servers may be a concern. Users are advised to investigate fully whether storing data on Google’s servers violates confidentiality requirements associated with the data or other applicable regulations about data.

Quantum GIS

The first version of QGIS, an incubator project of the Open Source Geospatial Foundation (OSGeo),³ was released in 2009. In low resource settings, it offers two competitive advantages

² MEASURE Evaluation has produced a tool called Excel to Google Earth (E2G) which can map data from a Microsoft Excel file, producing a color-coded KML file complete with legend that can be displayed in Google Earth. It comes complete with sub-country boundaries (first- and second-level administrative boundaries) for 40 countries.

³ The Open Source Geospatial Foundation, or OSGeo, is a not-for-profit organization whose mission is to support and promote the collaborative development of open geospatial technologies and data. The foundation provides financial, organizational, and legal support to the broader open source geospatial community. In addition, it provides outreach and advocacy as well as a common forum and shared infrastructure for improving cross-project collaboration.

over commercial applications. First, the software is free and the user has complete access to the source code to modify it. Second, QGIS has a small file size compared to commercial GISs and requires less random-access memory (RAM, a form of computer storage) and processing power; hence it can be used on older hardware or running simultaneously with other applications where a computer's central processing unit (CPU) power may be limited.



At last count, developers had translated QGIS into 31 languages. It is continually updated and maintained by an active group of volunteer developers who are developing modules to increase its functionality.

Part III: Use Cases

While there may be no typical use of GIS in public health, a number of core features can be identified. At the most basic level, users must be able to link easily their own public health indicators of interest to any available geographic feature such as a village, health facility, district, region, or country and continue to update and maintain their data for subsequent mapping, analysis, and reporting. Public health administrators are likely to have a core set of indicators that must be reported on a periodic basis. Therefore, the ability to create data entry forms or import data in other formats quickly, check for missing data and validate values, and create standard reports would be of high value. They are also likely to be called upon to share their data with other agencies, both within the country and across its borders, requiring standard indicators and standardized geo-coding of indicators. Given the nature of work, the need may frequently arise to generate ad hoc maps.

A series of representative use cases have been developed to highlight core features and functionality commonly called upon in the public health field.

For this document the same set of maps and/or analysis for each use case was created in each of the software packages. Each of the four high-level use cases has one or more specific tasks within it. The steps required to complete each specific use are enumerated below it. The assessment of each software package's capabilities was made by GIS analysts at MEASURE Evaluation and was a subjective evaluation of the software based on experience providing technical assistance to public health professionals in the field. To reach a higher level of objectivity when assessing software, the capabilities of novice GIS users were the standard applied.

Each program was assessed in functionality and ease of use. Functionality refers to a software's ability to do a specific task. Ease of use refers to how easy it was to perform the task. Needing to manipulate data extensively, confusing or awkward menu choices, or lack of clear help/documentation would affect a program's ease of use. Software programs were assigned a ranking of "robust", "acceptable" or "lacking". Programs earning a "robust" rating represent programs who stood above the other software tested in terms of its functionality or ease of use. An "acceptable" rating indicates a middle ground. These software programs contained the listed functionality but required extra effort to accomplish it or the steps necessary for the task were not as intuitive as in robust software. Software given a "lacking" score indicate that the functionality did not exist or were poor compared to other software. It also indicated that it was challenging to figure out the steps necessary to accomplish the task or there was no documentation to help users accomplish the task.

Software changes and new features are added over time and subsequent assessments might result in different conclusions. The objective is to evaluate software not produce a step by step guide for specific tasks. To that end, it is important to note that different approaches can be taken to achieve the outputs listed in each use case. The specific tasks listed represent only one possible approach to the larger use case.

Use Case 1: Evaluate Village Accessibility to Health Care

Background: The ministry of health in a country is looking at the issue of health care access in a rural province of the country where health indicators are below the country's average. The ministry wants to understand the scope of the problem. One way to visualize this rapidly is to use one of the following:

- *Use Case 1.1:* Look at how many villages/settlements are situated over a certain distance from any health facility.
- *Use Case 1.2:* Calculate average distance from un-served villages/settlements from closest health facility.
- *Use Case 1.3:* Create a map that shows the population of un-served villages/settlements and/or distance from closest health facility using multi-variable classifications.

Table 3 provides a summary of how the five GIS tools performed.

Table 3: Use Case 1 Summary of Functionality and Ease of Use for Five Programs Evaluated

	ArcGIS	QGIS	DevInfo	Epi Info	Google
<i>Functionality</i>					
Case 1.1: Identify villages beyond a specified distance from health facilities.	●	●	○	○	○
Case 1.2: Calculate Euclidean distance from villages with no service to nearest health facility.	●	●	○	○	○
Case 1.3: Map multiple variables on a map of un-served villages and show village population and average distance of village to nearest facilities.	●	●	○	○	○
<i>Ease of Use</i>					
Case 1.1: Identify villages beyond a specified distance from health facilities.	●	●	○	○	○
Case 1.2: Calculate Euclidean distance from villages with no service to nearest health facility.	●	●	○	○	○
Case 1.3: Map multiple variables on a map of un-served villages and show village population and average distance of village to nearest facilities.	●	○	○	○	○

- **Robust:** Exceptional compared to other software.
- **Acceptable:** Average compared to other software.
- **Lacking:** Capabilities don't exist or poor compared to other software.

Table 4 provides a list of outputs and steps involved in Use Case 1.1.

Table 4: Use Case 1.1 Outputs and Steps

<i>Use Case 1.1:</i> Identify villages beyond a specified distance from health facilities.	
Outputs:	1. Map for visualization; 2. Count of un-served villages; 3. List of un-served villages; 4. Shapefile of un-served villages for further analysis.
1.1.1	Create circle-based buffers around point-based health facility locations with 5km radius.
1.1.2	Dissolve individual buffers to create a single buffer.
1.1.3	Select points from a second geographic layer that fall within the single, dissolved buffer.
1.1.4	Invert the selection from the second geographic layer (to identify points that do not fall within the buffer).
1.1.5	Count the number of selected features.
1.1.6	Save the selected features as a shapefile for additional analysis and/or mapping.

Results Overview for Use Case 1.1: All of the applications except Epi-Info are able to render circle-based buffers around point features, and only ArcGIS and QGIS can dissolve individual buffers to create a single buffer. Some applications use a default unit of measure (either decimal degrees or meters) to measure buffer distances while others let the user pick the unit from a list. QGIS and ArcGIS will select points from a second geographic layer that fall within the single, dissolved buffer and invert the selection to identify points that do not fall within the buffer as well as count selected features and save as a new shapefile. The other applications cannot evaluate feature overlap so a workaround is needed (see below).

ArcGIS for Use Case 1.1:

(“Buffer” geoprocessing tool, “Select by location” command.)

Functionality:

- Full functionality at each step; user can specify meters, miles or decimal degree; produce the full range of desired outputs.
- *Limitations:* None identified.

Ease of Use:

- Process straightforward, efficient, and well documented.
- *Weaknesses:* None identified.

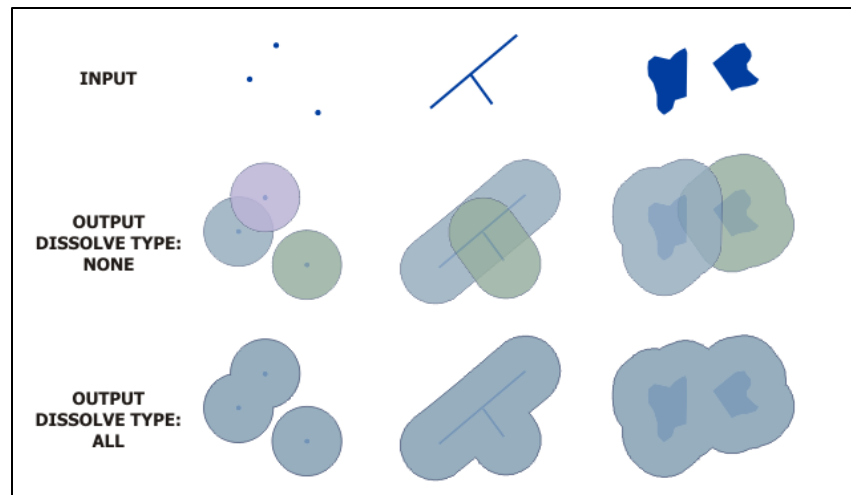


Figure 1: Examples of types of buffers (point, line, or polygon) in ArcMap.

QGIS for Use Case 1.1

(“Buffer” geoprocessing tool, “Select by location” research tool.)

Functionality:

- Full functionality at each step; user can specify meters, miles or decimal degree; produce the full range of desired outputs.
- *Limitations:* none identified.

Ease of Use:

- Process straightforward, efficient, and well documented.
- *Weaknesses:* None identified.

DevInfo for Use Case 1.1

Functionality:

- Can produce a map for visualization and derive a count of total number of un-served villages by subtracting the number of villages in the buffer (buffer layer summary statistics) from the total number of villages (village layer summary statistics).
- *Limitations:* limits buffer analysis to units of distance measured in meters with no other option provided; limited outputs - no capacity to select features by attribute or location (inside or outside buffer); no capacity to export shapefiles.

Ease of Use:

- Existing functionality intuitive to use.

- **Weaknesses:** functional constraints as noted above.

Epi Info for Use Case 1.1

Functionality:

- Limited ability to achieve the full range of desired outputs.
- **Limitations:** limits buffer analysis to units of distance measured in decimal degrees; no point-in-polygon operation; requires work-around. Summary statistics can be calculated on the new layer.

Ease of Use:

- Existing functionality intuitive to use.
- **Weaknesses:** The work around is inefficient and error prone compared to ArcGIS and QGIS.

Google Maps/Earth for Use Case 1.1

Functionality:

- There is no built-in buffer function. However, there are third-party tools to draw circles around given points and view them on the map on the fly. (See, for example: http://maps.forum.nu/gm_sensitive_circle2.html.)
- **Limitations:** This tool is quite limited in functionality, allowing only one circle to be drawn at a time. However, base data for visualization is generally excellent.

Ease of Use:

- Third-party tool is intuitive and free.
- **Weaknesses:** Very limited functionality; provides visual feedback only. Points located in buffer must be manually recorded. No export to shapefile available.

Table 5 provides a list of outputs and steps involved in Use Case 1.2.

Table 5: Use Case 1.2 Outputs and Steps

<p><i>Use Case 1.2:</i> Calculate Euclidean (straight-line) distance from the “un-served” villages to the nearest health facility.</p> <p><i>Outputs:</i> 1. Table containing results of distance calculations; and 2. a new geographic file (e.g. shapefile, KML) based on query results.</p>	
1.2.1	Measure or calculate Euclidean distance between village centers and health facility locations.
1.2.2	Save Euclidean distance calculations into a table that can be queried.
1.2.3	Query distance output table to identify villages greater than, less than, or equal to a specified distance.
1.2.4	Query village center shapefile based on identifiers for records selected from distance output table.
1.2.5	Export village center shapefile selection as a new shapefile.

Results Overview for Use Case 1.2: Only ArcGIS and QGIS have the functionality required for the full analysis.

ArcGIS for Use Case 1.2

Functionality:

- ArcGIS (when using the full ArcGIS license version) has a number of tools that can help with proximity analysis, including the “Near” tool. In addition to performing buffer operations, ArcGIS can perform multiple distance calculations and generate the results in a table (figure 2)
- *Limitations:* None identified.

FID	Pop_2011	NEAR_DIST
0	650	25.4
1	420	19.4
2	1550	42.9
3	2510	3.5
4	11240	3.6
5	5600	15
6	5980	19.2
7	25640	2.5
8	16420	6.3
9	8950	0.6
10	4780	18.9

Figure 2: Table generated by using the “Near” tool from ArcGIS’s Spatial Analyst package shows distances from a number of towns of varying sizes to their nearest health facility.

Ease of Use:

- Measuring distances is a cumbersome process. Calculating distance is more efficient. A person with a basic knowledge of ArcGIS can perform this analysis quickly and easily with the aid of the Desktop Help provided by the software.
- **Weaknesses:** Some knowledge of Python programming (or the use of a separate spreadsheet program) is needed to manipulate the data table.

QGIS for Use Case 1.2

Functionality:

- QGIS can generate a distance matrix and output it in .csv format.
- **Weaknesses:** A separate spreadsheet program (such as Microsoft Excel) is required to make use of this matrix and perform the operations in this use case.

Ease of Use:

- Knowledge is required of both a basic understanding of QGIS (how to input shapefiles and project layers to Universal Transverse Mercator (UTM) projection if using meters or kilometers as a measurement unit) and a basic understanding of a spreadsheet program such as Microsoft Excel (for performing data queries and classification).

DevInfo for Use Case 1.2

Functionality: None.

Epi Info for Use Case 1.2

Functionality: None.

Google for Use Case 1.2

Functionality: Google Earth has the ability to measure straight-line distance between two or more given locations or along a path in a wide variety of measurement formats (e.g. meters, miles, decimal degrees). Line measurement segments can then be saved as KML files. (This feature is not currently available in Google Maps.)

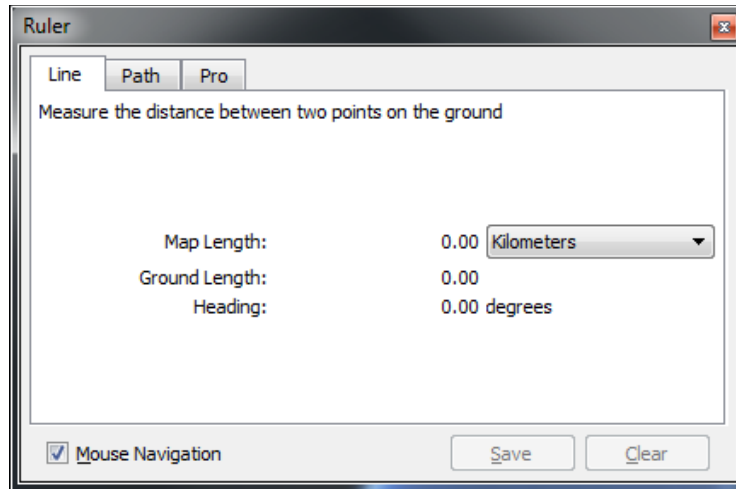


Figure 3: The ruler dialog box in Google Earth, showing measurement units set to kilometers.

Table 6 provides a list of outputs and steps for Use Case 1.3.

Table 6: Output and Steps for Use Case 1.3

Use Case 1.3: Map multiple variables on a single map that shows the average distance of un-served villages/settlements to nearest health facility and the population of those un-served villages.	
Output: Map showing proportional symbols of population of un-served villages with color-gradient classification of distance to nearest health facility.	
1.3.1	Create multiple buffers which show color gradient of distances from each health facility.
1.3.2	Display health facilities and villages on map.
1.3.3	Rank villages according to population size.
1.3.4	Display village sizes as proportional circles.

Results Overview for Use Case 1.3: Only ArcGIS and QGIS have the functionality required for the full analysis.

ArcGIS for Use Case 1.3

Functionality:

- ArcGIS can classify population values and generate proportional symbols according to those values. It can also display multiple buffer distances in a graduated color scheme (see figure 4).
- *Limitations:* Some knowledge of working with shapefiles and projections is needed.

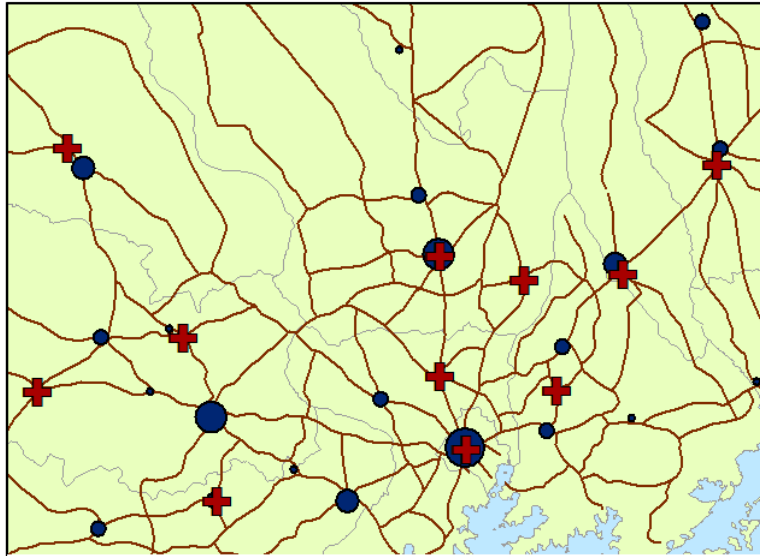


Figure 4: Health facilities are shown in red, towns in blue, classed by size. (Town names have been removed for anonymity; health facilities use theoretical locations.)

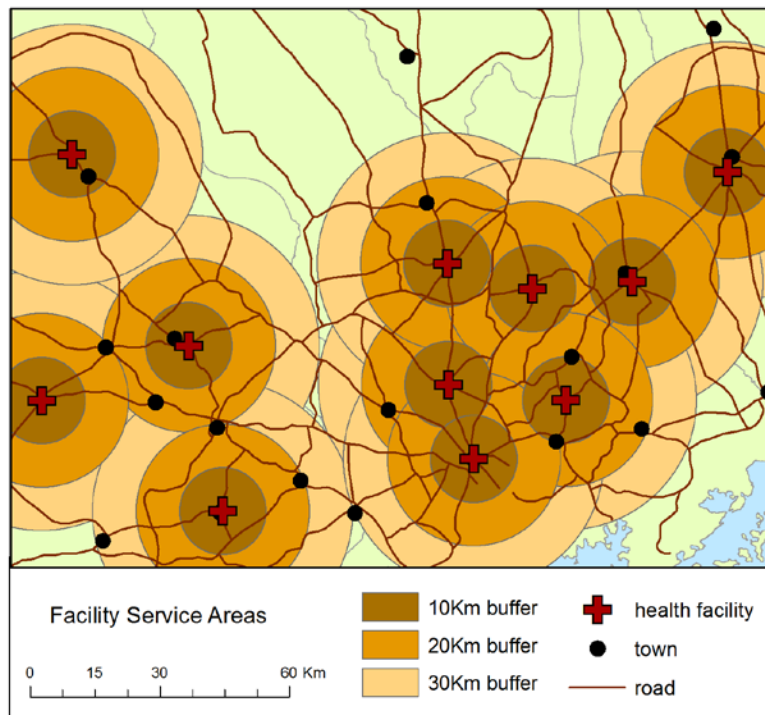


Figure 5: Health facilities are shown in red. Distance buffers are shown as color gradients.

Ease of Use: Some knowledge of the software is required to perform city size classification and to generate buffers and display them in various colors. **Weaknesses:** none identified.

QGIS for Use Case 1.3

Functionality:

- QGIS can generate buffers of varying sizes which can be displayed as map layers.
- QGIS can also generate proportional symbols and classify the population of each village to display it in this manner on the map.

Ease of Use:

- Knowledge is required of a basic understanding of QGIS, including manipulation of shapefiles.
- **Weaknesses:** Ability to input additional symbols from a vector graphics program also useful, as symbols included with program are somewhat limited. Working with proportional symbols in QGIS is a relatively new feature of the software and can be awkward and buggy.

DevInfo for Use Case 1.3

Functionality: None.

Epi Info for Use Case 1.3

Functionality: None.

Google for Use Case 1.3

Functionality:

- Google Fusion Tables provides the ability to classify and display the population data for the towns, but Google cannot map multiple buffers to show distance to facilities.
- In order to produce a multiple buffer map, users must do the task described in step 1.1.1 (see table 4) multiple times.

Ease of Use: Some knowledge of Google Fusion tables is required to upload and map the village data.

Use Case 2: Target an HIV/AIDS Prevention Program to Villages Situated along Major Highways

Background: In recent years, it has become evident that truck routes are a major factor in the widespread transmission of HIV/AIDS across many African nations. A ministry of health is developing an AIDS prevention program that will target sex workers in villages and towns situated along major highways in the country. In an effort to staff the program appropriately, the ministry wants to know which villages will need to be served. In addition, a GIS will help estimate how many staff members are needed in each health district based on the total population served by the program (in a ratio of two staff members per 100,000 population).⁴

Table 7 provides a summary of how the five GIS tools performed.

Table 7: Use Case 2 Summary of Functionality and Ease of Use for Five Programs Evaluated

	ArcGIS	QGIS	DevInfo	Epi Info	Google
<i>Functionality</i>					
Case 2.1: Identify villages within a specified distance from major highways.	●	●	○	○	○
Case 2.2: Allocate staff resources based on population.	●	●	○	○	○
<i>Ease of Use</i>					
Case 2.1: Identify villages within a specified distance from major highways.	●	●	○	○	○
Case 2.2: Allocate staff resources based on population.	●	●	○	○	○

- **Robust:** Exceptional compared to other software.
- **Acceptable:** Average compared to other software.
- **Lacking:** Capabilities don't exist or poor compared to other software.

⁴ Staffing level is arbitrary and for illustration purposes only.

Table 8 provides a list of steps involved in Use Case 2.1.

Table 8: Use Case 2.1 Steps

<i>Use Case 2.1: Identify villages within a specified distance of major highways.</i>	
2.1.1	Create a buffer of a specified radius around road network segments.
2.1.2	Dissolve buffers into a single polygon.
2.1.3	Use dissolved polygon to select features from a second, point-based layer (shapefile).
2.1.4	Count selected features in second layer.
2.1.5	Save selected features as a new shapefile, "ProjectVillages.shp".
2.1.6	Allow attribute table for new shapefile to be viewed and queried.

Results for Use Case 2.1: Only ArcGIS and QGIS can buffer line features and dissolve those features into a single buffer. QGIS and ArcGIS will also select points from a second geographic layer that fall within the single, dissolved buffer and invert the selection to identify points that do not fall within the buffer as well as count selected features and save as a new shapefile. DevInfo and Epi Info cannot evaluate feature overlap so a workaround is needed. Google can only buffer a single point through third-party tools, as described earlier, and also cannot use the buffer to select features from another layer.

All applications performed as in Use Case 1.1, except that Google cannot buffer a line instead of a point.

Table 9 provides a list of steps involved in Use Case 2.2.

Table 9: Use Case 2.2 Steps

<i>Use case 2.2: Allocate staff resources based on population.</i>	
2.2.1	Create a new attribute "HealthDistrict" in the village shapefile (from 2.1).
2.2.2	Use point-in-polygon to assign a health district value to each village.
2.2.3	Calculate the population of each health district by summing the population values for each village that are stored in the geographic layer's attribute table.
2.2.4	Create a new field in the attribute table: "Number of staff needed".
2.2.5	Create a user defined calculation to populate field (e.g. divide "health district population" by 100,000 and multiply by 2 to get total number of staff needed).

Results Overview for Use Case 2.2: This analysis is straightforward in ArcGIS and QGIS. DevInfo, Google's tools, and Epi Info do not have the point-in-polygon functionality. DevInfo

could calculate the numeric field but could not create the text field. If the villages already have a health district attribute defined then DevInfo and Epi Info could complete the use case.

ArcGIS for Use Case 2.2

Functionality: Full functionality.

Ease of Use: Process is straightforward, efficient, and well documented.

QGIS for Use Case 2.2

Functionality: Full functionality.

Ease of Use: Full functionality, intuitive.

DevInfo for Use Case 2.2

Functionality:

- Can create and populate numeric attribute.
- **Limitations:** Cannot create “HealthDistrict” attribute — cannot include non-numeric fields, no point-in-polygon operations.

Epi Info for Use Case 2.2

Functionality:

- No point-in-polygon functionality.
- Cannot open and edit the attribute table in the mapping interface.

Ease of Use:

- Work-around is possible, but time-consuming.
- **Weaknesses:** Major functionality constraints — work-around is labor intensive and error prone.

Google for Use Case 2.2

Functionality: Can create and populate a numeric and text field in a table using Google Fusion. Has no point-in-polygon functionality.

Ease of Use:

- For users familiar with Google Fusion tables, process is straightforward.
- **Weaknesses:** Cannot conduct point-in-polygon analysis.

Use Case 3: Develop and Evaluate an OVC Program Roll Out Involving Multiple Service Providers Across a Country

Background: A large foundation has decided to roll out a large-scale program to improve the lives of orphans and vulnerable children in a country. The program will be implemented across the country by a consortium of local and international NGOs. To assess the impact of the program, the foundation has chosen to adopt the OVC program module from MEASURE Evaluation's Community-Level Program Information Reporting for AIDS/HIV Programs (CLIPR) framework.⁵

The foundation has identified two ways in which GIS will be used to support program development and evaluation. First, it will generate a map showing the number of orphans by region in order to allocate the funds according to the level of need where each NGO operates. Second, it plans to map the program outcomes individually, as well as in a composite Child Status Index (CSI) value. CSI includes six indicators: food security, shelter, care, abuse and exploitation, wellness, and health care services. The foundation is also interested in learning:

- which services or combination of services are most beneficial;
- whether the likelihood of a positive outcome is related to the total number of services received;
- which implementing partners are most effective; and
- which regions show the most improvement.

Therefore, the foundation will require that each program record information at the level of the individual participant, as well as data that will support aggregation to higher levels including district, region/province, and country.

As a prerequisite to the mapping work, the foundation plans to create a template database for the implementing partners with the CLIPR framework preloaded with data entry forms with conditional skip patterns, data validation, and custom calculations already programmed. Implementing organizations will submit quarterly reports of regional summary statistics for their program. The foundation will combine the data from all programs into a single database that they plan to publish on the Web.

Table 10 provides a summary of how the five GIS tools performed.

⁵ The CLIPR tool kit, available online at the MEASURE Evaluation Web site, has a set of illustrative indicators, data collection forms and indicator reference sheets for prevention, home-based care, and OVC programs that can be adapted as necessary for a specific program or context.

Table 10: Use Case 3 Summary of Functionality and Ease of Use for Five Programs Evaluated

	ArcGIS	QGIS	DevInfo	Epi Info	Google
<i>Functionality</i>					
Case 3.1: Design and implement a data management system for the program.	●	●	●	●	●
Case 3.2: Map the number of orphans by region.	●	●	●	○	○
Case 3.3: Generate map(s) plotting multiple variables.	●	●	●	●	●
Case 3.4: Produce a time series of Child Status Index by region.	●	●	●	●	●
<i>Ease of Use</i>					
Case 3.1: Design and implement a data management system for the program.	○	○	●	●	●
Case 3.2: Map the number of orphans by region.	●	●	●	○	○
Case 3.3: Generate map(s) plotting multiple variables.	●	●	●	●	●
Case 3.4: Produce a time series of Child Status Index by region.	●	●	●	●	●

- **Robust:** Exceptional compared to other software.
- **Acceptable:** Average compared to other software.
- **Lacking:** Capabilities don't exist or poor compared to other software.

Table 11 provides a list of steps involved in Use Case 3.1.

Table 11: Use Case 3.1 Steps

<i>Use Case 3.1: Design and implement a database for the program.</i>	
3.1.1	Develop a database to track individual client level information including personal demographic information, services, surveys and outcomes.
3.1.2	Replicate database for multiple service providers
3.1.3	Streamline data collection and entry.
3.1.4	Aggregate data to appropriate geographic level.
3.1.5	Combine data from multiple sources.
3.1.6	Create a standard report template to facilitate periodic reporting.
3.1.7	Replicate components of database management system for each agency.

Results Overview: The evaluated applications differ substantially in their approach to data management. ArcGIS and QGIS applications leave the development of a data management system entirely to the user. DevInfo and Epi Info applications each include a data management component. Epi Info stands out as the only application of the ones studied that supports tracking client level information and data aggregation to the appropriate geographic level within the application. Google tools provide some functionality regarding the ability to manage individual data and produce data products such as table and charts. It has limited ability to produce standard report templates.

ArcGIS for Use Case 3.1

Functionality: ArcGIS can store client level information; however, it does not allow for a separate client-records data entry system. The ArcGIS database is not suitable as a stand-alone client management system and does not include stand-alone database management applications.

Ease of Use:

- Necessary to develop a database in another application such as Microsoft Access, Open Office Database, PostGre SQL/PostGIS or other data management program.
- Provides functionality necessary for tasks 3.1.1 to 3.1.6. Each task may in and of itself be simple but entire workflow is complex.
- **Weaknesses:** Requires extensive specialized knowledge of database management.

QGIS for Use Case 3.1

Functionality: Equivalent to ArcGIS.

Ease of Use: Equivalent to ArcGIS.

DevInfo for Use Case 3.1

Functionality:

- DevInfo version 6 includes an “administrator level” database application and a “user level” application. User-defined data must fit into the structure of combinations supplied by the software (must include indicator, unit, and subgroup).
- Map files, attribute data, and metadata are integrated into the data structure, ensuring that any created data structures will all be accessible in exactly the same way. The software also has the capacity to generate standard reports and data collection templates at global, national, or sub-national geographic levels.

- A limited amount of base data is available for easy display on maps, including such things as roads, cities, and rivers.⁶
- Is quite user-friendly for data entry staff once it is set up, and the software has a good variety of output and visualization capabilities for the data including a number of different kinds of graphs (see figure 6).
- There is a bit more of a learning curve involved in customized database creation, and it is recommended that the DevInfo team be contacted if you wish to customize the application to work with your own shapefiles.
- DevInfo version 7 includes an online version of the software, with links to several large United Nations databases.⁷
- *Limitations:* This is not a stand-alone GIS (another program is needed to put shapefiles in the format which works with the software). Not all sub-country administrative levels or base data are available for all countries. It does not support data collection at the individual (i.e., point) level, nor does it support non-numeric (i.e., string) attribute values. Importing shapefiles with multiple polygons is cumbersome. It does not support data collection at the level of individual participants.

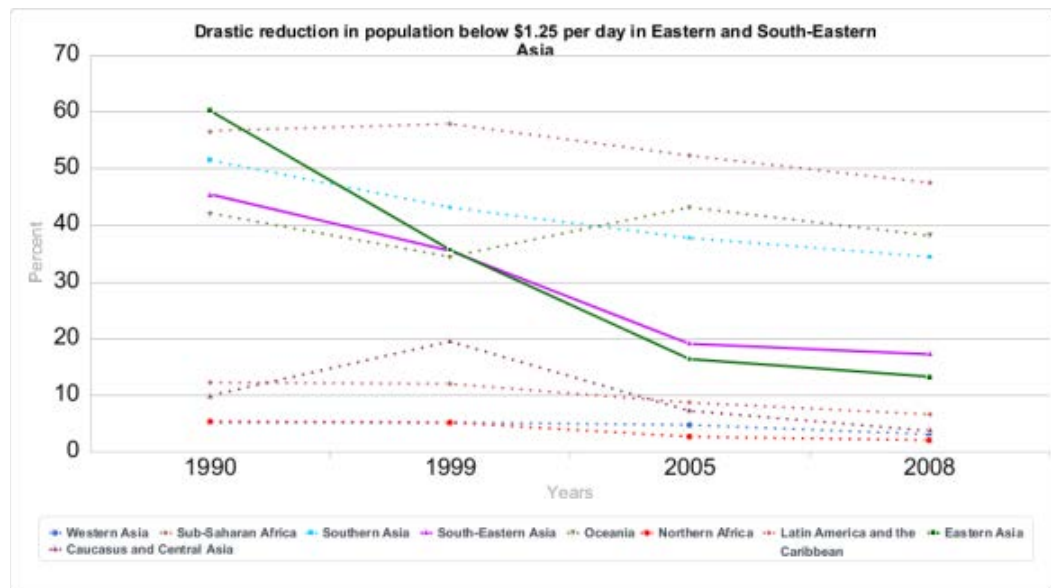


Figure 6: An example of one of many types of graphs that can be created and shared easily in Microsoft Excel and other formats using DevInfo.

Source of figure: DevInfo Online Gallery, accessed March 26, 2013.

Ease of Use:

⁶ Availability and accuracy of base data vary by country and are updated only sporadically.

⁷ Current available online data include M49 World, MDG (millennium development goal) regional data as of 2011, and United Nations Economic Commission for Africa data, as well as other UN-collected data on nutrition, literacy and school enrollment, gender parity, health, and the environment.

- Set-up is slightly cumbersome.
- DevInfo uses its own terminology that newcomers might find initially confusing.
- Some knowledge of database structures is recommended, and the DevInfo team might need to be involved if the software is to be customized for use at a sub-country level.
- Easy to ensure consistency when working with multiplefiles.
- Easy to copy, merge, or split databases.
- Easy to port and share; works well when moving to/from Microsoft Excel or Microsoft Access and other common database software.
- **Weaknesses:** Works best with United Nations-supplied data. Database and shapefiles must conform to very specific structures and import of complicated shapefiles can be time-consuming and cumbersome.



Figure 7: The data selection window in DevInfo, for use once a database has been set up.

Functionality:

- Database and mapping modules can be used independently.
- Supports data collection at the level of individual participants.
- Analysis module supports aggregation of data to appropriate levels, capacity to generate standard report and data collection templates.
- Data entry form can be set up with data validation for individual fields.
- **Limitations:** None identified.

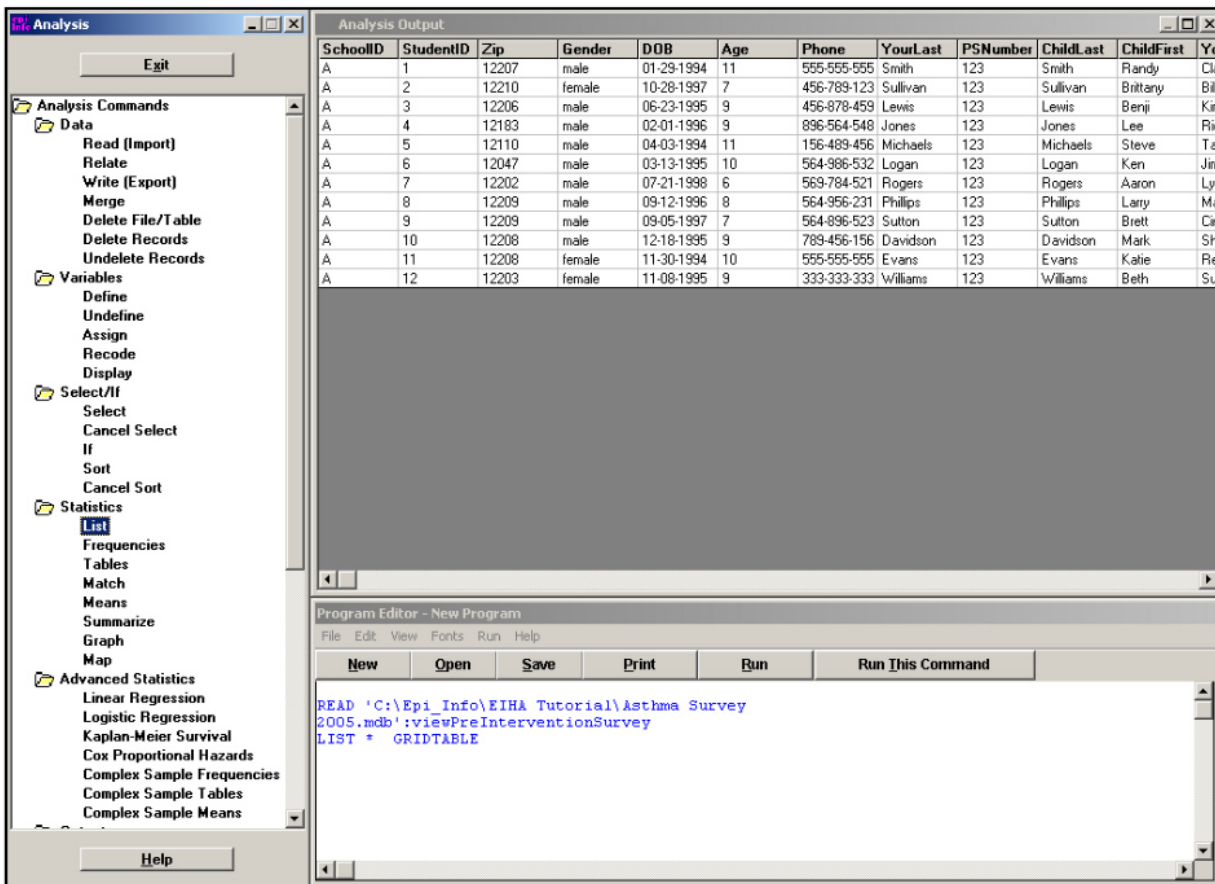


Figure 8: The workspace in Epi Info.

Ease of Use:

- Easy to create a simple database to track client demographic information and pre- and post-surveys without specialized knowledge of database management.
- Data can be easily aggregated in the Analysis module.
- Standard report and data collection templates can be generated easily.

- **Weaknesses:** While recurring services can be tracked, some programming is required – although the process is well documented, database will have external dependencies (since the shapefiles cannot be integrated into the database).

Google Tools for Use Case 3.1

Functionality:

- Data must be input (and can be designed) using Google Fusion Tables, which can also import from Google Spreadsheet or another spreadsheet program, such as Microsoft Excel.
- Geographic locations can be entered either as lat/long points or a KML file, or as street addresses (in locations covered by Google’s on-the-fly geocoding).
- **Limitations:** A Google account is needed for sharing and editing data. Data security requirements for some users may not be met when data are stored and accessed via the Internet. In such cases it could comprise the confidentiality of the data and there could be conditions in Google’s terms-of-use that could be problematic for some health data.

ZAF_admin1_data Share

test_5_test_4 - Edited on December 13, 2011

File Edit Tools Help Rows 1 Cards 1 Map of geometry

Filter No filters applied Saved

1-9 of 9

PROVINCE	code	test_data	description	geometry
Eastern Cape	ZAF001	0.77	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
Free State	ZAF002	0.09	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
Gauteng	ZAF003	0.14	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
Kwazulu-Natal	ZAF004	0.58	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
Mpumalanga	ZAF005	0.29	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
North-West	ZAF008	0.64	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
Northern Cape	ZAF006	0.54	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
Northern Province	ZAF007	0.74	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...
Western Cape	ZAF009	0.25	<html xmlns:fo="http://www.w3.org/1999/XSL/Format"...	KML...

Figure 9: Data in a Google Fusion Table, ready to be classed and mapped.

Ease of Use:

- The interface for Google Fusion Tables is quite intuitive and includes a good deal of flexibility as far as importing and entering data.
- **Weaknesses:** Limited calculation capability for records management. Geocoding may not be available at all locations. Additionally, individual client records may be subject to confidentiality constraints that might make storing data on remote servers unacceptable.

Table 12 provides a list of steps involved in Use Case 3.2.

Table 12: Use Case 3.2 Steps

<i>Use Case 3.2: Map the total number of orphans by region for a country.</i>	
3.2.1	Classify attribute values into value ranges.
3.2.2	Represent value ranges with different colors, fill patterns, symbol size, dot density and charts for one variable.
3.2.3	Label features with choice of variables stored in attribute table.
3.2.4	Insert map presentation objects: North arrow, scale bar, legend, title, neat line.
3.2.5	Create customizable map layout for export or printing.
3.2.6	Save map template to streamline periodic reporting.

Results Overview: The evaluated applications all performed substantially the same when displaying a single area-based (polygon) variable at single moment in time. There are minor differences that affected the use case results but do not impinge significantly on the presentation quality of the map including the number and type of classification schemes available, the relative richness of options to display the data (symbology), and the ability to produce high-quality, publication ready maps. All the systems allowed the user to save map templates, allowing updated data to be quickly visualized. DevInfo stands out in this regard, however, because it allows the user to easily generate map templates that can be associated with a particular set of indicators that can then be automatically applied to any region at any level.

ArcGIS for Use Case 3.2

Functionality:

- Provides full functionality at each step.
- Options are available for themes: color, fill type, dot density, chart (bar, pie, line), proportional symbol and value labels.
- **Limitations:** None identified.

Ease of Use:

- The process straightforward, efficient, and well documented.
- **Weaknesses:** None identified.

Figure 10 provides an example of an ArcMap layout window.

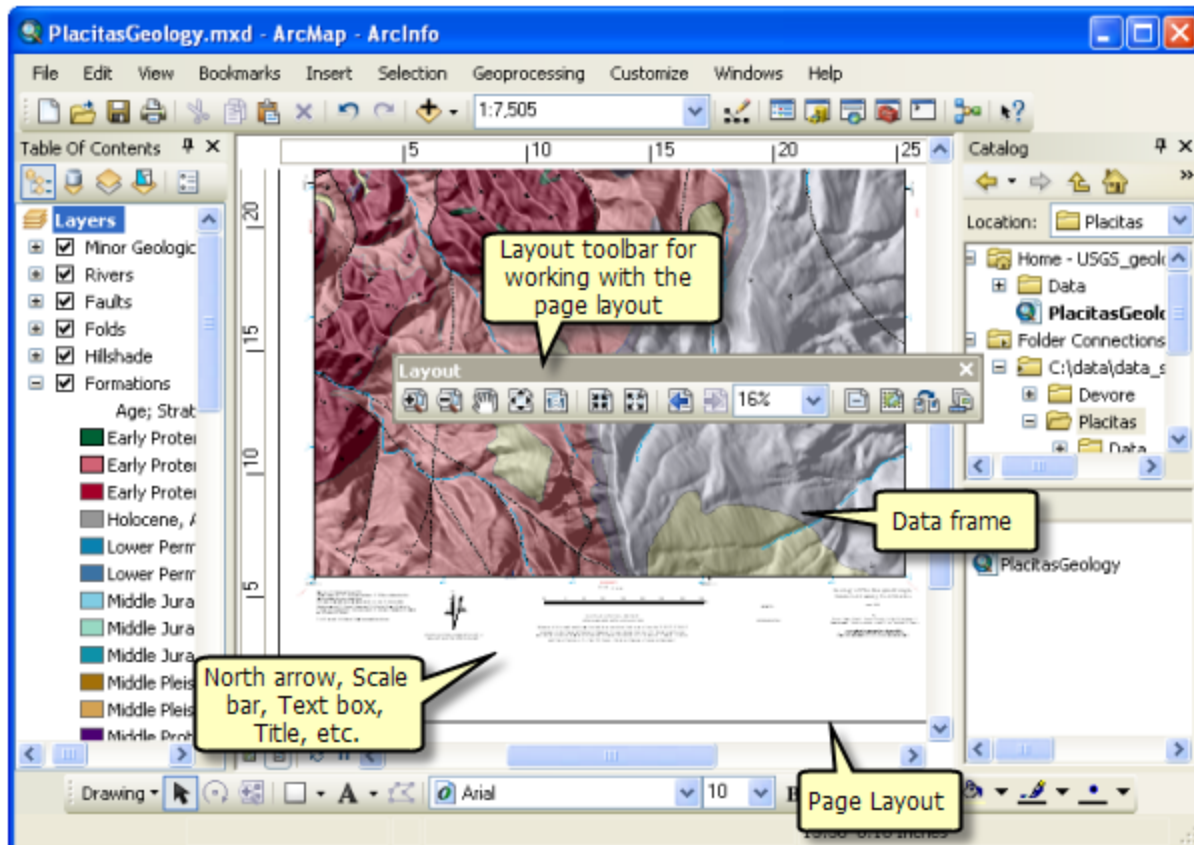


Figure 10: An overview of the ArcMap layout window showing toolbars, layers, symbology, and selected cartographic elements such as scale bar, north arrow, and legend.

QGIS for Use Case 3.2

Functionality:

- Full functionality is provided at each step – options for the themes: color, fill type, dot density, chart (bar, pie), proportional symbol and value labels.
- *Limitations:* None identified.

Ease of Use:

- The process is straightforward, efficient, and well documented.
- *Weaknesses:* None identified.

DevInfo for Use Case 3.2

Functionality:

- Requires that all data be uploaded into the Data Manager.

- Very good to excellent functionality at each step – had the same symbology options as ArcGIS for a single variable.
- **Limitations:** Provides fewer classification schemes (no quantiles), and no ability to use dot density or proportional symbols or charts on map.

Ease of Use:

- As stated in Use Case 3.1, DevInfo is quite user-friendly for data entry staff once it is set up, but there is a bit more of a learning process involved in customized database creation, and it is recommended that the DevInfo team be contacted if you wish to customize the application to work with your own shapefiles.

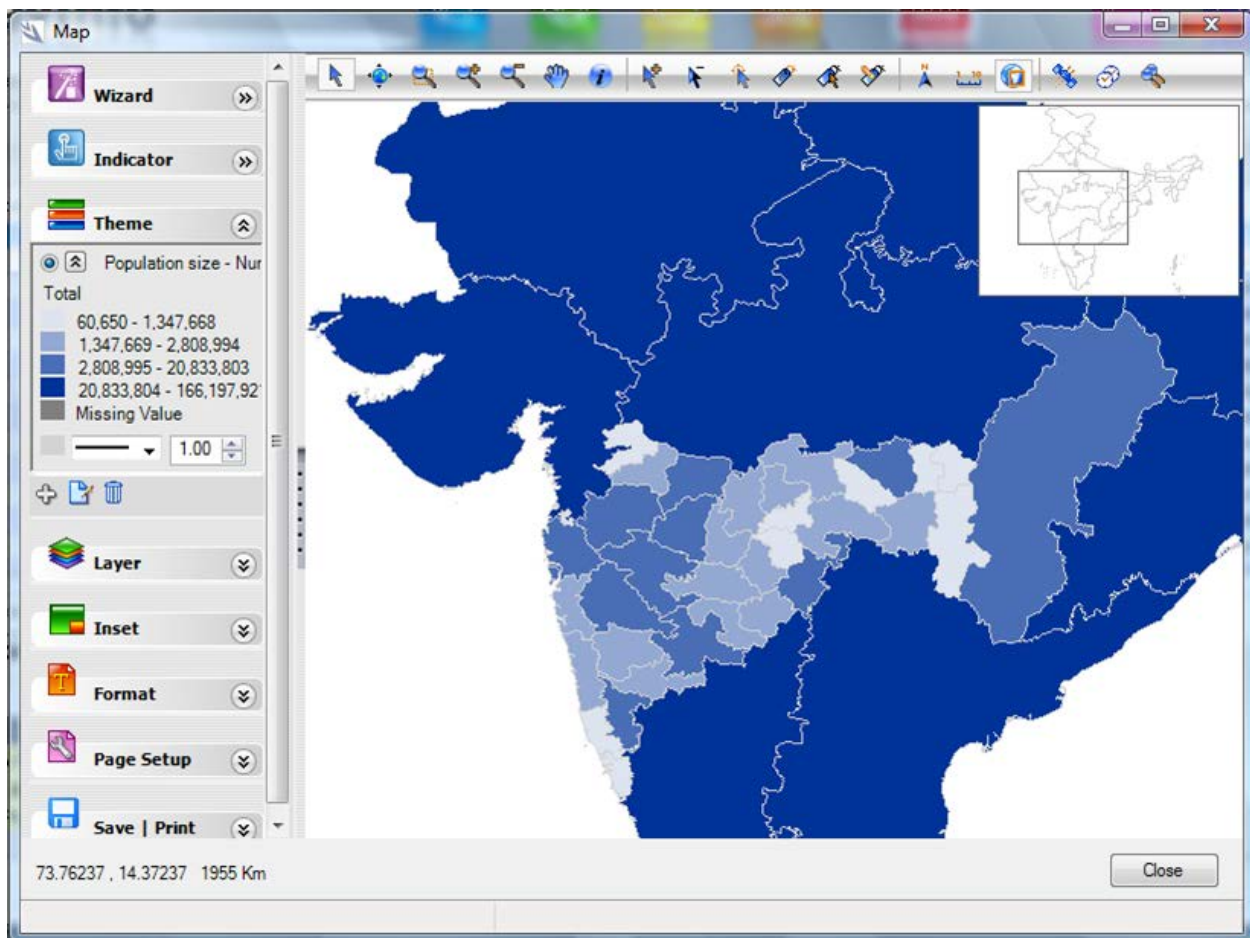


Figure 11: Choropleth map produced in DevInfo by classing a single variable.

Epi Info for Use Case 3.2

Functionality:

- Limitations not apparent when working with a single variable.
- **Limitations:** Fewer symbology options (no diagram overlays).

Ease of Use:

- The process is straightforward, efficient, and well documented.
- *Weaknesses:* None identified.

Google for Use Case 3.2

Functionality:

- Ability to categorize data once it is in the correct format and fusion table is properly linked to the map.
- **Limitations:** Limited data classification schemes. No legend generation. Only one variable can be mapped at a time. No template capability. Map can be published to the Web but printing capabilities are limited to those of the browser.

Ease of Use:

- Fusion Tables documentation is somewhat limited, although there are user forums that can be searched online.
- Terminology is somewhat obscure (e.g., data classes are referred to as “buckets”).

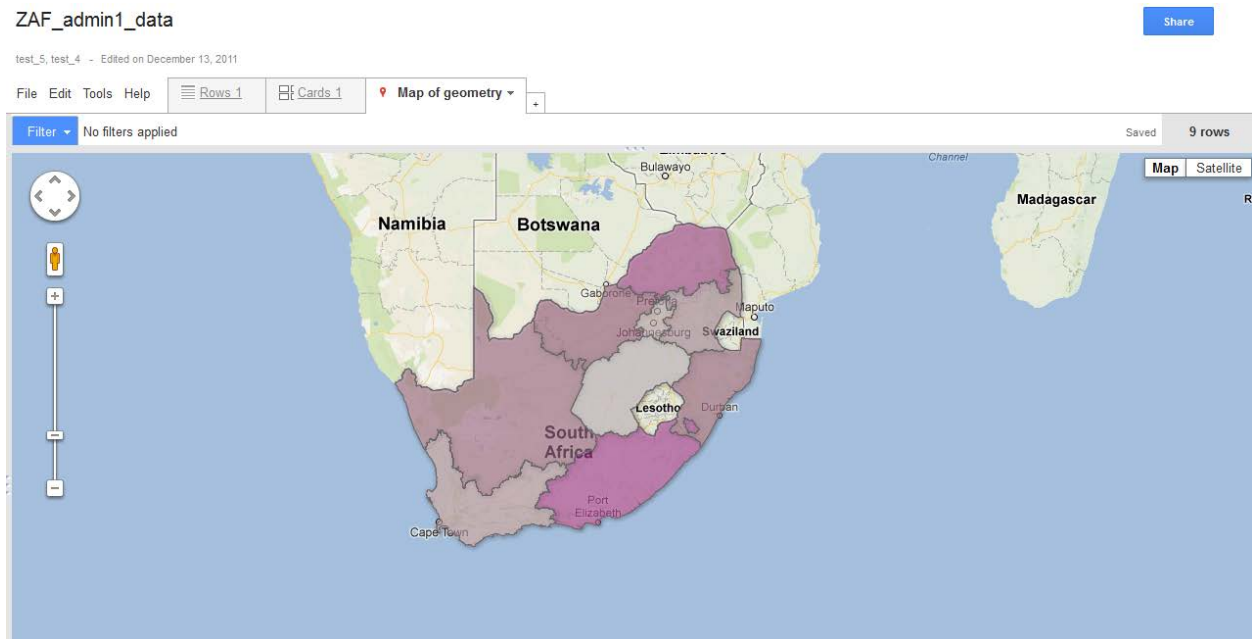


Figure 12: Classed and shaded variable in Google Maps.

Table 13 provides a list of steps involved in Use Case 3.3.

Table 13: Use Case 3.3 Steps

<p>Use Case 3.3: Generate maps plotting multiple area-based variables (the number orphans served by the types of services received: education, nutrition support, psychosocial support, housing, and medical services, and the total number of orphans in the region):</p> <ol style="list-style-type: none"> six choropleth maps, each displaying two variables (one for each service, depicting total number of orphans by region as a color theme and each service represented as a proportional symbol, hatch, dot density or bar chart); a choropleth map of the total number of orphans served by region and an accompanying bar chart (or table) with the number of orphans; and a single map with number of orphans as the color theme and a bar chart over each region showing number of orphans served by service type. 	
3.3.1	Classify attribute values into value ranges.
3.3.2	Represent value ranges with different colors, fill patterns, symbol size, dot density and charts for two or more variables.
3.3.3	Label features with choice of variables stored in attribute table.
3.3.4	Create table or chart summarizing data.
3.3.5	Display table or chart in the map layout.
3.3.6	Create customizable map layout for export or printing.
3.3.7	Save map template to streamline periodic reporting.

Results Overview: The applications differ substantially in their ability to display two or more variables simultaneously and the ease with which they produce tables and graphs. Only ArcGIS can currently produce the full range of outputs (under other circumstances, i.e. with other variables, DevInfo and QGIS would be able to produce the full range of outputs). DevInfo can display up to five variables simultaneously (five themes: color, fill, dot density, proportional symbol, and bar chart); while in addition to those five, QGIS can display additional variables within pie charts and bar graphs as diagram overlays.

ArcGIS for Use Case 3.3

Functionality:

- Produces the full range of desired outputs.
- *Limitations:* none identified.

Ease of Use:

- Process is straightforward, efficient, and well documented.
- *Weaknesses:* None identified.

Functionality:

- Has three options of chart displays on top of choropleth map: pie charts, which worked as expected; bar charts, shown in figure 13; and proportional symbols.
- Map projects can be created and updated for periodic reports.
- *Limitations:* Some functionality requires use of plugins to accomplish; a third-party software that can edit scalable vector graphics is required for legend generation or symbol editing; and knowledge of map scale and projection is required in order to adjust properly the size display of charts, which is based on the map scale.

Ease of Use: Process can be cumbersome, especially with regard to producing charts on maps.

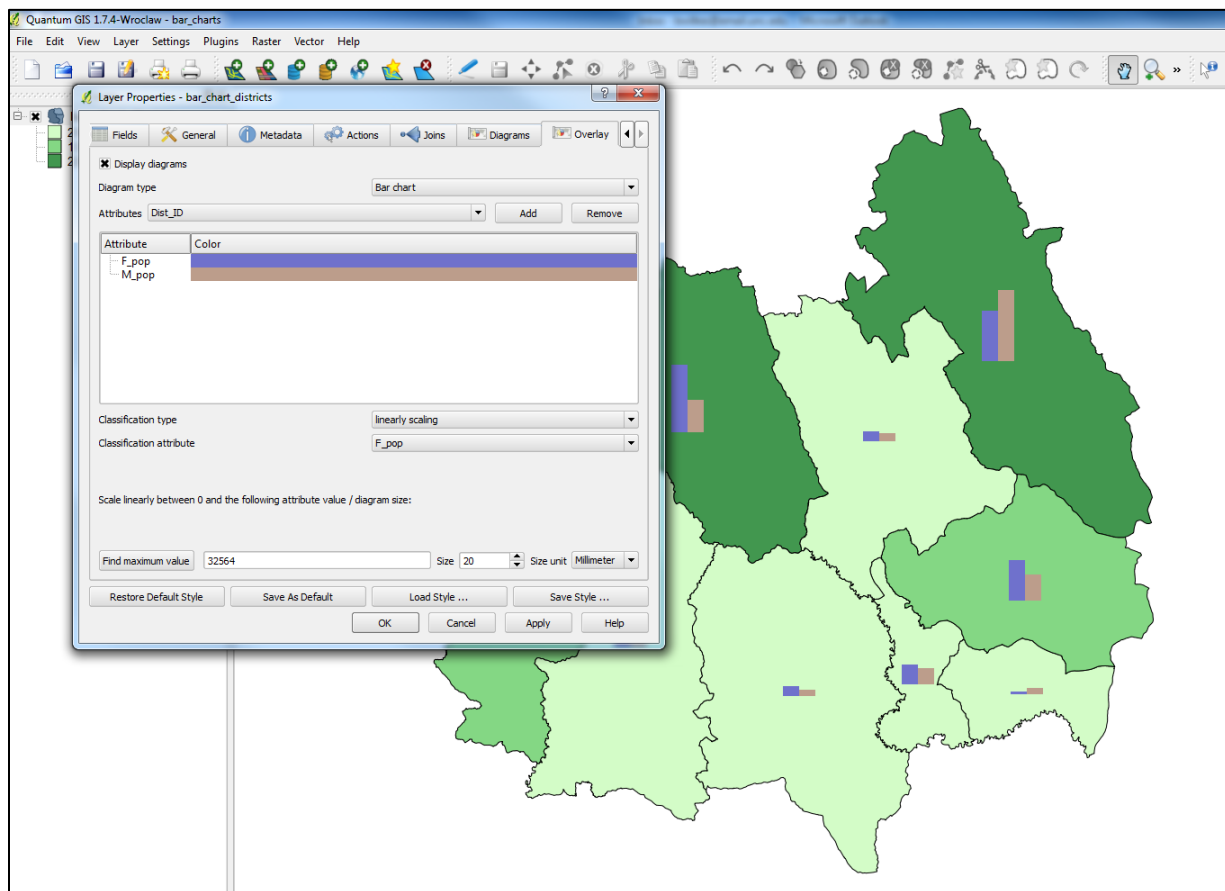


Figure 13: Bar charts page in QGIS.

Functionality:

- Can produce a) or b) but not c).
- *Limitations:* Bar charts limited to displaying one attribute at a time.

Ease of Use:

- Process is straightforward, efficient, and well documented.
- Especially easy to generate, move between, and customize presentation quality maps, tables and charts.
- *Weaknesses:* None identified.

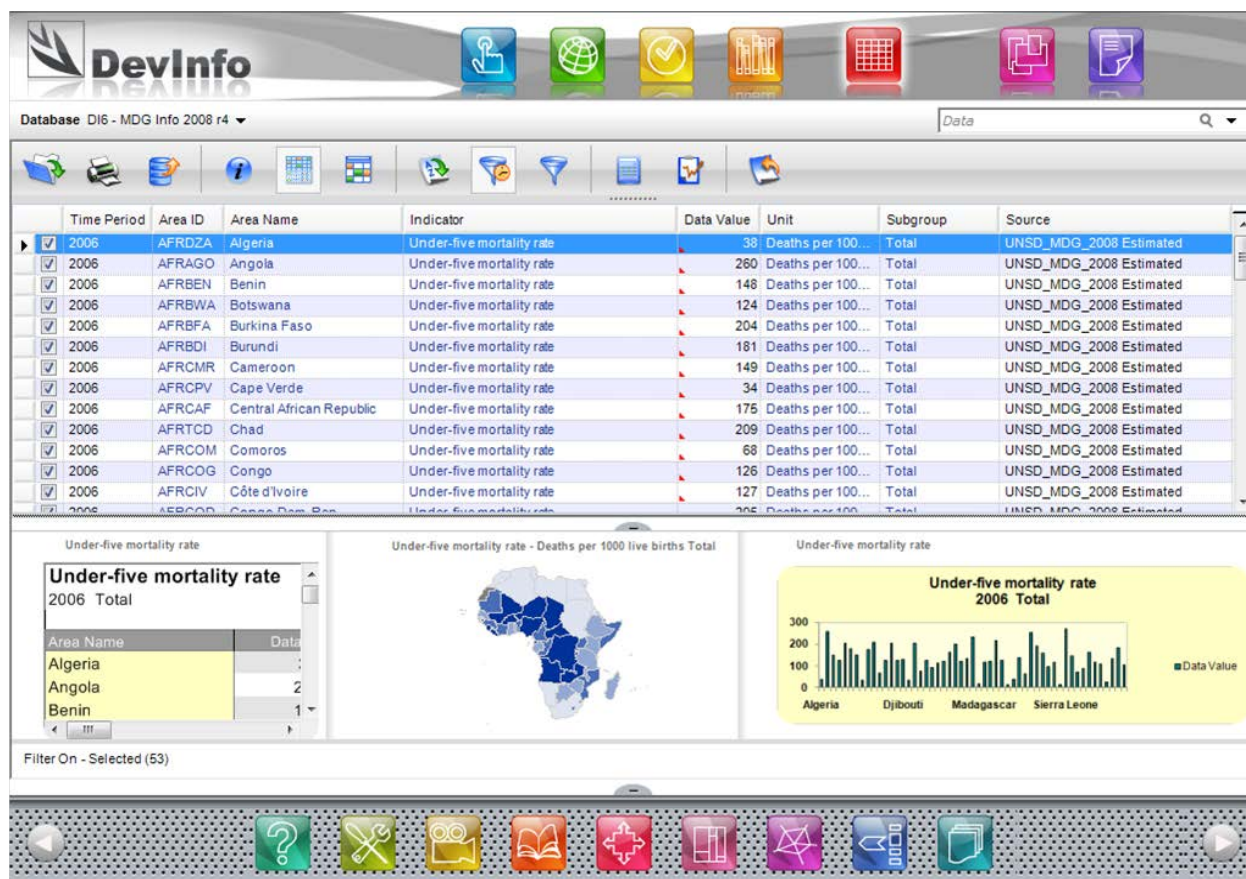


Figure 14: Table, map, and graph views for a single variable in DevInfo.

Epi Info for Use Case 3.3

Functionality:

- Can produce a) or b) but not c).
- *Limitations:* Limited symbology, only choropleth, dot density and proportional symbol and can only display a single variable at a time, with the exception that it can overlay case-based data over a choropleth map.

Ease of Use:

- Production of tables is straightforward and well-documented

- *Weaknesses:* Slightly inefficient, user must switch between Analysis and Epi Map, graphing feature non-intuitive and not particularly well documented.

Figure 15 shows a choropleth map in Epi Info.

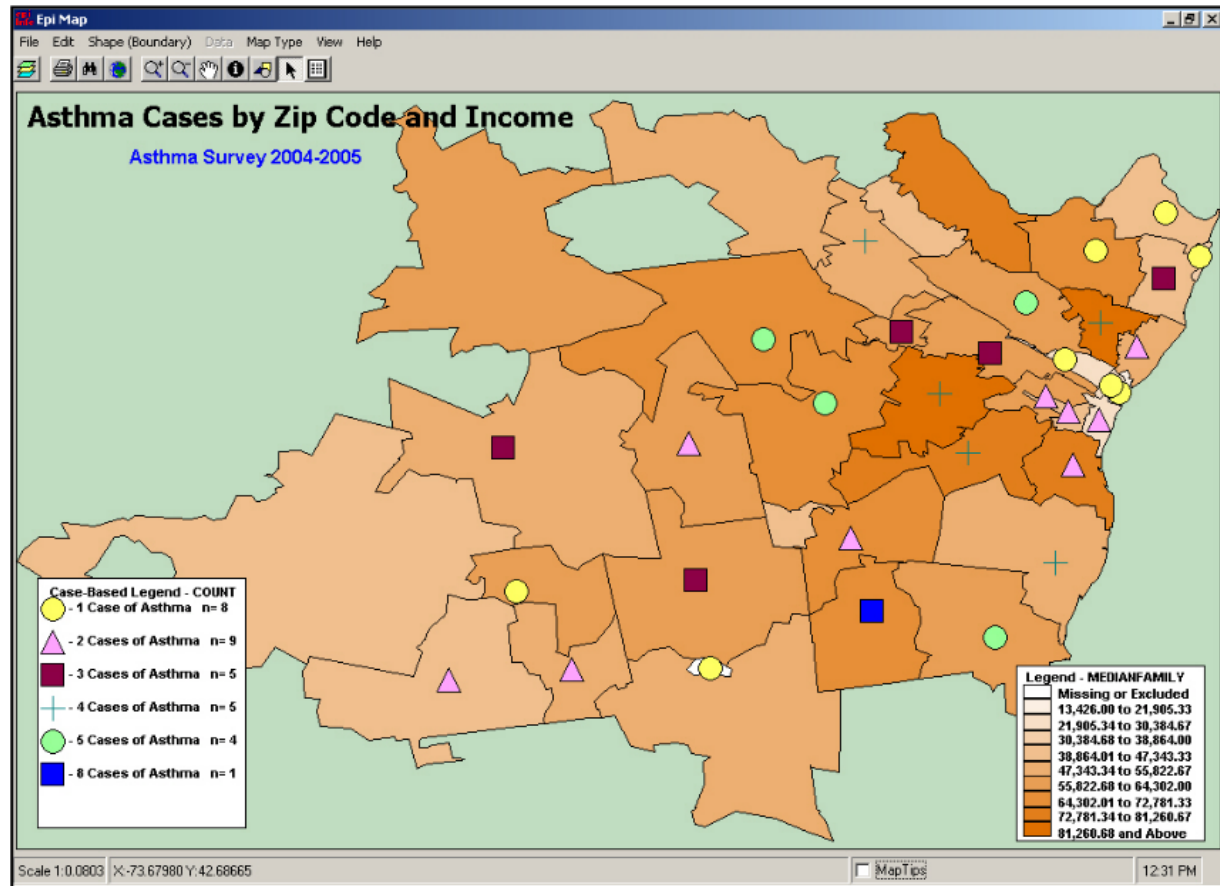


Figure 15: Example of a choropleth map with another variable used to create a symbol overlay, with legend and title are also displayed.

Google for Use Case 3.3

Functionality:

- Multiple variables cannot be displayed simultaneously on one map, unless KML overlays are created in a separate program and displayed in Google Maps or Google Earth.

- Google Chart Tools can be used to create graphs in formats that will display in most browsers (i.e. SVG or VML) but you must be willing to write some code to handle the input data (see <https://developers.google.com/chart>).
- A single choropleth map can be produced using data in Fusion Tables, but a legend cannot be added to a map. The E2G tool⁸ can produce a choropleth map and a legend. Several choropleth maps can also be loaded in at once to Google Earth and toggled on and off for comparison purposes.
- *Limitations:* Each map can only display one variable at a time.

Ease of Use:

- Loading data to Fusion Tables for mapping to Google Maps can be cumbersome, although data entry through Microsoft Excel (to the E2G tool) for mapping in Google Earth is straightforward. In either case, you must have a file available with needed subcountry boundaries.⁹
- *Weaknesses:* Data setup can be cumbersome in Google Maps. Google can only display one geographic area at a time, requiring toggling for multiple map layer viewing.

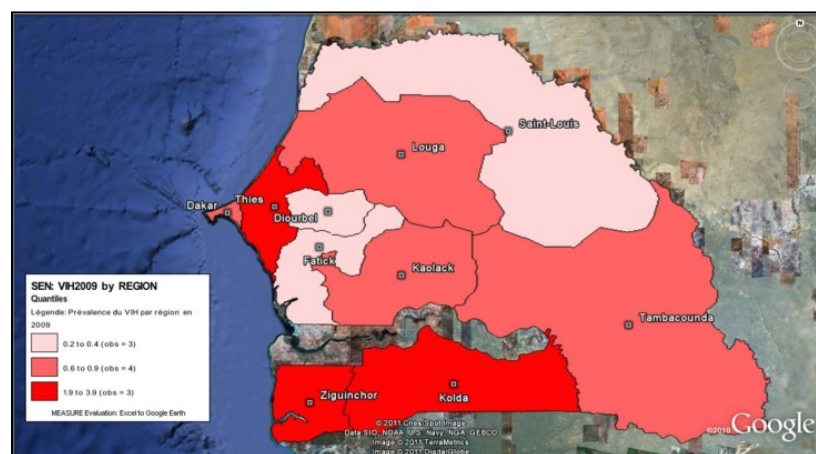


Figure 15: Example of a single-variable choropleth map in Google Earth, produced using the E2G tool.

⁸ E2G stands for Excel to Google Earth, a free tool produced by and available from MEASURE Evaluation. The tool is a Macro that runs in Microsoft Excel and requires the use of both Microsoft Excel and Google Earth software. See <http://www.cpc.unc.edu/measure/tools/monitoring-evaluation-systems/e2g> for more information.

⁹ There are currently sub-country administrative level boundaries available for 40 different countries. These are included with the full E2G download, or can be selected individually for separate download.

Table 14 provides a list of steps involved in Use Case 3.3.

Table 14: Use Case 3.4 Steps

<p>Use Case 3.4: A time series of the Child Status Index (a composite index calculated based on a number of attributes) by region. Multiple approaches for displaying data:</p> <ol style="list-style-type: none"> create a map for each time period that can be displayed side by side (or using inset images); create a map with an accompanying chart showing change over time by region; and create a map with line chart diagram overlays. 	
3.4.1	Create a user defined calculation to calculate the Child Status Index based on separate indicator values.
3.4.2	Create a time series of a single area-based indicator using inset images showing side-by-side comparison in the printed map layout.
3.4.3	Create a chart summarizing changes over time by region.
3.4.4	Display chart in map layout.
3.4.4	Create a map displaying change over time with a line chart diagram overlay.

Results Overview: The applications differ substantially in their ability to display time series data – especially when there have been changes in the administrative boundaries over the period covered in the report - and the ease with which they produce tables and graphs. DevInfo is particularly strong at displaying time series data.

ArcGIS for Use Case 3.4

Functionality:

- Full functionality at each step is provided.
- Can produce the full range of desired outputs.
- *Limitations:* None identified.

Ease of Use:

- The process is straightforward and well documented.
- *Weaknesses:* Comparatively less efficient than DevInfo. The user must create multiple data frames – a matter of copying and pasting the files and then switching field being displayed to a different year. If the administrative boundaries have changed, the correct boundary map can be shown for each time period, but the user must be aware of the changes, and have access to both shapefiles.

QGIS for Use Case 3.4

Functionality:

- Can produce the outputs for approaches (a) and (c), with diagram overlays.
- *Limitations:* Cannot produce the graphs for (b).

Ease of Use: Existing functionality is similar to ArcGIS to use.

DevInfo for Use Case 3.4

Functionality:

- Provides full functionality at each step.
- Produces the full range of desired outputs.
- A time period is associated with administrative boundary maps in the database.
- **Limitations:** None identified.

Ease of Use:

- Process is straightforward, extremely efficient, and well documented.
- The application automatically pulls all the data between the to-and-from dates and generates multiple data frames (one for each time period for which data were collected).
- User can easily create temporal animations; table, chart and graph automatically generated when the user runs the query.
- If administrative boundaries have changed over the period of the query, the correct boundary map is shown for each time period.
- **Weaknesses:** Slightly awkward in the initial set up of the calculation.

Epi Info for Use Case 3.4

Functionality:

- Can produce outputs (a) and (b) but not (c).
- CSI is calculated in the Analysis module, graphing also done in the Analysis module.
- **Limitations:** No diagram overlays.

Ease of Use:

- The user must produce a map for each time period, save it as a bitmap and then it can be made smaller and included as an inset in the current time period map.
- **Weaknesses:** Among software compared, this is the least efficient for producing multiple images; graphing tool is not intuitive.

Google for Use Case 3.4

Functionality:

- Map production requires use of Google Fusion Tables and graph production also requires Google Chart Tools (see Use Case 3.3).
- The E2G tool is a simpler way to produce a map that includes a legend and labels.

- Both uses can only generate a single map at a time; each map must then be exported and/or printed in order to be viewed either side-by-side; or they can then be loaded into one screen view and then toggled on and off, with either the Google Earth satellite view or Google Maps base map used as a visual reference.
- (C) is not possible with either tool.
- *Limitations:* Requires generation and management of multiple maps. Legend generation and label display are limited. Setup for graph generation is somewhat cumbersome, and graphs cannot be displayed on maps.

Ease of Use:

- Requires some familiarity with Google Charts and Google Fusion Tables and/or Microsoft Excel.
- Base data are built into the display and can serve as a valuable visual reference.
- Graphing tools are separate from map generation and somewhat cumbersome.
- *Weaknesses:* No ability to display multiple maps and graphs at once without generating and exporting one at a time.

Use Case 4: Develop a Targeted Approach to Fighting Malaria

Background: The Regional Health Department (RHD) plans to implement an indoor residual spray campaign targeting high-risk households in areas where malaria is endemic and there are high rates of transmission. Because pesticide is expensive and has health risks associated with its use, the health department plans to target the areas that are at highest risk and needs to estimate how much spray will be needed to conduct the campaign.

The RHD plans to use GIS to:

- identify local hot spots, where high rates of malaria transmission are occurring (the disease surveillance system currently provides a list of health facilities treating malaria in the last year and the number of cases encountered at each);
- evaluate whether the malaria occurring in a given region is likely to be endemic or the result of an outbreak; and
- target the IRS to high-risk households.¹⁰

Table 15 provides a summary of how the five GIS tools performed.

Table 15: Use Case 4 Summary of Functionality and Ease of Use for Five Programs Evaluated

	ArcGIS	QGIS	DevInfo	Epi Info	Google
<i>Functionality</i>					
Case 4.1: Generate a map of incidence of Malaria by health facility.	●	●	◐	○	○
Case 4.2: Create a map or series of maps with graphs showing trends over time.	●	◐	●	◐	◐
Case 4.3: Create a risk map of households in the target area.	●	●	○	○	◐
Case 4.4: Create a map of the treated houses.	●	●	○	◐	◐
<i>Ease of Use</i>					
Case 4.1: Generate a map of incidence of Malaria by health facility.	●	●	◐	○	○
Case 4.2: Create a map or series of maps with graphs showing trends over time.	●	●	●	◐	◐
Case 4.3: Create a risk map of households in the target area.	●	●	○	○	◐
Case 4.4: Create a map of the treated houses.	●	●	○	◐	◐

- ● **Robust:** Exceptional compared to other software.
- ◐ **Acceptable:** Average compared to other software.
- ○ **Lacking:** Capabilities don't exist or poor compared to other software.

¹⁰ A number of risk models of malaria transmission have been proposed. The following have all been proposed as risk factors: elevation, Normalized Difference Vegetation Index (NDVI) value, average rainfall, certain land cover types, presence of existing cases, and blood parasite levels.

Table 16 provides a list of steps involved in Use Case 4.1.

Table 16: Use Case 4.1 Steps

<i>Use Case 4.1: Generate a map of incidence of malaria by health facility.</i>	
4.1.1	Classify attribute values into ranges.
4.1.2	Represent each range of values with graduated symbols.
4.1.3	Label features with choice of values stored in attribute table.
4.1.4	Complete the map layout with a north arrow, scale bar, legend, title, and neat line.
4.1.5	Save map layout for export or printing.
4.1.6	Save as a template to streamline periodic reporting.

Results Overview: While Use Case 4.1 is based on points rather than polygons, all evaluated software offer the same functionality as described previously for Use Case 3.2.

Table 17 provides a list of steps involved in Use Case 4.2.

Table 17 Use Case 4.2 Steps

<i>Use Case 4.2: Create a map or series of maps with graphs showing the trend of disease over time.</i>	
4.2.1	Create a time series of maps giving a side-by-side comparison.
4.2.2	Create a series of charts summarizing changes over time by health facility.
4.2.3	Create a map of health facilities with a line chart diagram overlay for each facility showing change over time.

Results Overview: While Use Case 4.1 is based on points rather than polygons, all evaluated programs offer the same functionality as described for Use Case 3.4.

Table 18 provides a list of steps involved in Use Case 4.3.

Table 18 Use Case 4.3 Steps

<i>Use Case 4.3: Create a risk map of households in the target area.</i>	
4.3.1	Use georeferenced image as base layer to digitize areas of interest (polygons).
4.3.2	Classify polygons according to whether they are low (1), moderate (2), or high (3) risk in each layer.
4.3.3	Use classified digitized layer as base layer. Create a new point based layer of houses assigning an attribute of the 'risk' score based on location.

Results Overview: The evaluated applications differed substantially in capacity to handle the individual tasks. ArcGIS and QGIS are capable of performing all tasks required. DevInfo and Epi Info are not capable of the tasks. Google's tools provide some limited functionality.

ArcGIS for Use Case 4.3

Functionality:

- Full functionality at each step.
- *Limitations*: None identified.

Ease of Use:

- Process straightforward, efficient, and well documented.
- *Weaknesses*: None identified.

QGIS for Use Case 4.3

Functionality: Functionally equivalent to ArcGIS.

DevInfo for Use Case 4.3

Functionality: None.

Epi Info for Use Case 4.3

Functionality: None.

Google for Use Case 4.3

Functionality:

- Google Earth provides excellent base information in the form of up-to-date, high-resolution imagery for most areas around the world.
- Google Map provides excellent base map data for many areas as well. Points can be digitized directly on-screen or imported from a field-based GPS unit. Polygons can be digitized on-screen and classified by hand.
- *Limitations*: Points within polygons must be identified by hand (visually) — there is no known algorithm for this computation.

Ease of Use:

- Straightforward, efficient, and well-documented.
- *Weaknesses*: Road networks are incomplete or out-of-date in some areas in Google Maps. Resolution of imagery in Google Earth is sometimes inadequate at certain scales. Administrative boundaries in Google Maps and in Google Earth are not always accurate.

Table 19 provides a list of steps involved in Use Case 4.4.

Table 19 Use Case 4.4 Steps

<i>Use Case 4.4: Create a map of the treated houses.</i>	
4.4.1	Download GPS data into system.
4.4.2	Create and populate a new attribute ("Treated Y/N").

ArcGIS for Use Case 4.4

Functionality:

- Full functionality is provided at each step.
- Produces the full range of desired outputs.
- *Limitations:* None identified.

Ease of Use:

- Process straightforward, efficient, and well documented.
- Imported point file must be saved separately as a geodatabase or shapefile before it can be populated with attribute data.
- *Weaknesses:* Data must be downloaded from GPS unit using third-party software. Software imports converted data files only.

DevInfo for Use Case 4.4

Functionality: None.

Epi Info for Use Case 4.4

Functionality:

- Full functionality at each step.
- Produces the full range of desired outputs.
- *Limitations:* None identified.

Ease of Use:

- Process straightforward, efficient, and well documented.
- *Weaknesses:* None identified.

Google for Use Case 4.4

Functionality:

- Full functionality available.
- Base imagery provides a way to quickly and easily check for stray points/errors in data collection.
- *Limitations:* None identified.

Ease of Use:

- Straightforward, efficient, and well-documented.
- *Weaknesses:* None identified.

QGIS for Use Case 4.4

Functionally:

- Equivalent to ArcGIS.

Ease of Use:

- Process is straightforward, efficient, and well documented.
- *Weaknesses:* None identified.

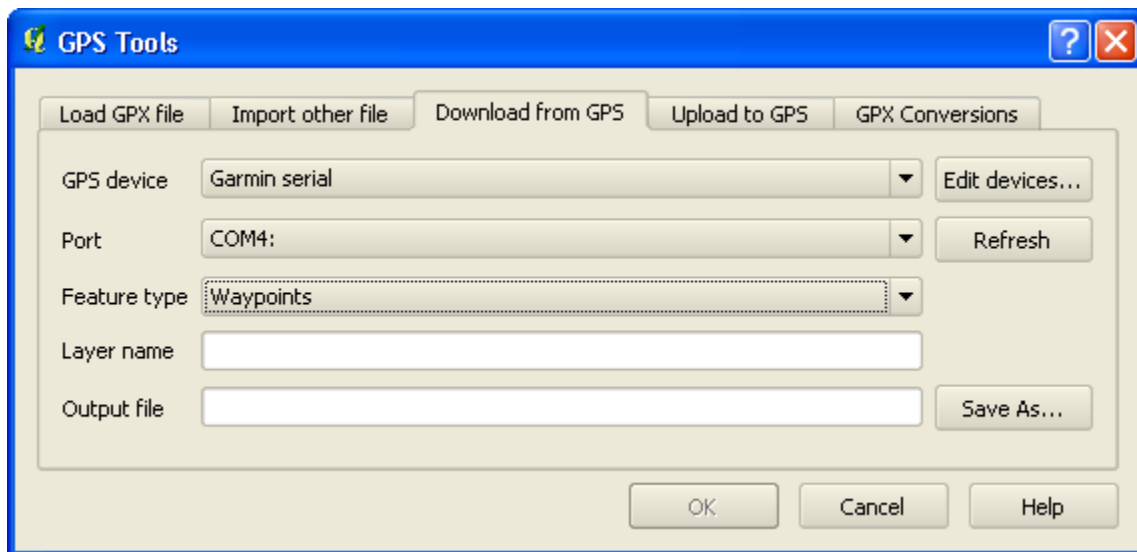


Figure 16: The GPS Tools dialog box in QGIS.

Conclusion

No matter what the use case, selecting software is nearly always a trade-off between features and ease of use. GIS and mapping software packages are no exception. Global public health professionals have available to them a wide range of options that make it possible to understand public health issues and plan and evaluate programs.

Users of any software package may encounter difficulties with certain tasks. A mapping software package can be especially difficult for new users, as it often enforces rigid data structure requirements, can frequently use terminology that is unfamiliar to non-mapmakers, and can require users to be aware of highly technical knowledge, such as projections and datums.

The core GIS/mapping functionality required for public health is currently available, most of it for free, within a range of applications. In reviewing a representative sample of GIS/mapping software packages, it became apparent that functionality was not lacking. In fact, most of the software packages contained most or all of the functionality required; the larger issue was that the software interfaces were often not intuitively constructed for public health professionals who may have little or no training in GIS or other mapping software.

ArcGIS and QGIS, for example, are extremely powerful and flexible, but are designed as full-functionality toolboxes that lack a specific focus on public health. As a result, the learning curve can be substantial. DevInfo and Epi Info provide interfaces that are much more targeted toward public health professionals — and therefore give them the ability to visualize thematic maps of different indicators based on health-specific workflows — but they are more limited in GIS and mapping capabilities and for some use cases pose ease-of-use obstacles based on underlying architectural decisions. Google's tools offer a variety of base data and basic display functionality that is user-friendly and valuable to public health professionals. Other related tools such as Fusion Tables and the Excel to Google Earth (E2G) tool do provide additional data classing and overlay options. But the Google tools lack in-product analysis options, such as buffer creation/dissolving, point-in-polygon location, and basic spatial statistics.

Not all tools are equally well suited for every task and the average user could benefit from using them in combination with each other. Developers could help increase the uptake of GIS in the field of public health by adding functionality to the existing public health applications with which most users are familiar (such as DevInfo or Epi Info) and by creating public health interfaces that guide users more intuitively through common public health tasks. In addition, public health users would benefit from stand-alone databases with data collection and reporting templates that are designed for public health applications and that can be accessed using ArcGIS and QGIS.

A summary of the features and ease of use for the five software programs evaluated is provided in table 20:

Table 20: Ease of Use for Five Programs Evaluated

	ArcGIS	QGIS	DevInfo	Epi Info	Google
<i>Functionality</i>					
1 Evaluate health care access	●	●	○	○	●
2 Target an HIV/AIDS prevention program	●	●	●	●	●
3 Develop and evaluate an OVC program rollout	●	●	●	●	●
4 Develop a targeted approach to righting malaria	●	●	○	●	●
<i>Ease of Use</i>					
1 Evaluate health care access	●	●	○	○	●
2 Target an HIV/AIDS prevention program	●	●	●	●	○
3 Develop and evaluate an OVC program rollout	●	●	●	●	●
4 Develop a targeted approach to righting malaria	●	●	○	●	●

- **Robust:** Exceptional compared to other software.
- **Acceptable:** Average compared to other software.
- **Lacking:** Capabilities don't exist or poor compared to other software.

Appendix A: Downloading and Background Information on ArcGIS, QGIS, Epi Info, DevInfo, and Google's Mapping Tools; Other Tools

Esri Arc Family of Products: ArcInfo, ArcMap, ArcCatalog, ArcView

The current version, ArcGIS 10, runs on a Windows operating system and is available for a free 60-day trial and purchase from:

<http://www.esri.com/software/arcgis/arcgis10/trial.html>

ArcGIS is used by a wide range of industries including business, defense and intelligence, education, government, environmental resources, transportation, among others in addition to health and human services. Its greatest strengths are its power, its flexibility and Esri's commitment to customer service and support. Its greatest challenge is that it can be overwhelming for the novice public health user, or even quite a practiced one.

ArcGIS 10 is a Windows-based suite of powerful and flexible geographic information system (GIS) software products available at several licensing levels. (All components are installed on the system, with only those that are licensed being made functional.) Extensions can be purchased separately to increase the functionality of ArcGIS.

- **ArcReader** is included in all ArcGIS packages and is available for free download. It allows one to view and query existing maps created with the other Arc products.
- **ArcGIS Explorer** is a 3D GIS viewer included in all ArcGIS packages and is available for free download.
- **ArcView** is the entry level of licensing offered. It includes ArcReader, ArcExplorer, ArcMap (the application used to view, edit and query geospatial data, and create maps) and ArcCatalog (the data management application, used to browse data sets and files on one's computer, database, or other sources).¹¹ It allows one to view spatial data, create layered maps, and perform basic spatial analysis. Some of the ArcToolbox¹² applications are available as add-ons;
- **ArcEditor** is the mid-level software suite. In addition to the functionality of ArcView, It provides tools for the creation of map and spatial data used in GIS, including the ability of editing geodatabase files and data, multiuser geodatabase editing, versioning, raster

¹¹ In addition to showing what data are available, ArcCatalog also allows users to create personal geodatabases and preview the data on a map. ArcCatalog also provides the ability to view and manage metadata for spatial datasets.

¹² The ArcToolbox contains a number of software extensions to provide added functionality including geoprocessing, data conversion, and analysis tools, and also supports batch processing for frequently repeated tasks.

data editing and vectorization, advanced vector data editing, managing coverages, coordinate geometry (COGO), and editing geometric networks. ArcEditor is not intended for advanced spatial analysis. Some of the ArcToolbox applications are available as add-ons.

- **ArcInfo** is the highest level of ArcGIS licensing available. It contains the full ArcToolbox providing increased capability in the areas of spatial analysis, geoprocessing, data management, and others. It allows users the most flexibility and control in "all aspects of data building, modeling, analysis, and map display."
- **ArcGIS Mobile** and **ArcPad** are products designed for mobile devices. ArcGIS Mobile is a software development kit for developers to use to create applications for mobile devices, such as smart phones or tablet personal computers (PCs). If connected to the Internet, mobile applications can connect to ArcGIS Server to access or update data. ArcGIS Mobile is only available at the Enterprise level.

Esri offers **ArcWeb Services**, a hosted GIS that provides geographic web services (W3C/SOAP and others) to web browsers and other Internet-enabled technology.

ArcGIS Online is a free web application that allows sharing and search of geographic information, as well as content published by Esri, ArcGIS users, and other authoritative data providers. It allows users to create and join groups, and control access to items shared publicly or within groups.

DevInfo 6.0 and 7.0

DevInfo 6.0 is available for free download at:

<http://www.devinfo.org>

The software runs on Windows operating system and there is a Web-based version of the software, known as DevInfo 7.

DevInfo is not designed to be a stand-alone GIS. To utilize shapefiles within DevInfo, they must have a specific field titled "ID_" and "NAME_" in their .dbf files. The "ID_" field is the basis for defining the association between the area defined in the database and the shapefile geometry. Another GIS program is needed to convert shapefiles from other sources to project the files in the appropriate coordinate system and add columns with area IDs in the standard DevInfo format. Also it lacks the full analytical capabilities of more powerful applications.

The DevInfo initiative has developed a number of customized data visualization applications such as:

- CME Info, which allows users to generate estimate graphs on child mortality indicators.
- MICS Compiler, which provides easy access to viewing data on key indicators collected through UNICEF's Multiple Indicator Cluster Surveys.
- Di Analyzer, which allows users to view and present data in animated scatter plots to explore trends over time.

- CensusInfo is an innovative and flexible database technology for the dissemination of population and housing census results.
- EmergencyInfo is a powerful decision support system, based on DevInfo database technology that helps people to respond better in emergency situations.
- Polio Communication Info is a DevInfo 6.0 adaptation launched jointly by the Government of India and UNICEF intended to monitor and track polio eradication programs in Northern India.¹³

Epi-Info 6 and 7

The examples in this document use Epi-Info 6. Epi-Info 7, which has additional mapping capabilities, was released after Epi-Info 6 testing was conducted for this document. Epi-Info 6 and 7 are produced by CDC and run on the Windows operating system. They are available for free download at:

<http://wwwn.cdc.gov/Epi Info/>

Also on the CDC Web site is an active forum dedicated to Epi Info (<http://forums.myeinfo.info/>). Epi Info delivers core ad-hoc epidemiologic functionality without the complexity or expense of large, enterprise applications. The user can run the application from a universal serial bus (USB) thumb drive and, potentially, on hand-held devices such as smart phones, personal digital assistants (PDAs), and tablet PCs.

Epi Info has a data entry dashboard that allows data collectors to receive immediate statistical feedback after entering case data.

Epi Info consists of five core modules: Make View, Enter Data, Analysis, Epi Map, and Epi Report. Each module has stand-alone capabilities; however, using them for one project from start to finish adds functionality and efficiency:

- **Make View** is the questionnaire or survey designer, and the entry point for setting up the database. The Make View module is based on Microsoft Access' Form Design View and, through it, the user generates an .mdb file.
- **Enter Data** automatically creates the database from the questionnaire in MakeView. Users enter data, modify existing data, or search for records.
- **Analysis** is a statistical toolbox that provides the user with many ways to transform data and perform statistical evaluations, particularly those relevant to epidemiology. Not only does Epi Info make it easy to run fairly complex statistical procedures, the tutorial provides clear, relevant examples and explains why they would be of interest to the public health professional. The ability to easily recode, aggregate and summarize data gives Epi Info the ability to manage data associated with individual patients or participants. The other systems

¹³ See <http://en.wikipedia.org/wiki/DevInfo>, accessed April 20, 2011.

that include a database component (DevInfo and Health Mapper) record outcomes on data that has been previously aggregated, while Epi Info supports collection of data at the level of the individual.

- **Epi Map** is primarily a map viewer built around software from Esri, it can be used to generate choropleth, case-based and point maps; includes limited capabilities in creating and editing shapefiles (Epi Map can be used to generate Points can also have labels applied to them during creation); but does not include tools for spatial analysis, limited symbology and limited classifications.
- **Epi Report** is a user-friendly tool to create professional custom reports that include results from the Analysis output. Epi Report can combine Analysis output with data from Enter as well as other sources such as Access or SQL Server. When generating reports, queries are applied to the specified data sources, and the latest information is extracted and displayed.

Quantum GIS 1.7

QGIS runs on a variety of operating systems including Mac OS X, Linux, UNIX, and Microsoft Windows. It is available for download here:

<http://www.qgis.org/wiki/Download>

It can be considered a GIS since it provides the ability to manage data and layers and to perform a variety of spatial analysis functions.

In addition to its core functionalities, users have created specialized software plug-ins to address specific needs. Public health users may find plug-ins provide valuable functionality for tasks such as calculating service areas, network analysis and density calculations.

Similar to ArcGIS in both appearance and functionality, it is a powerful GIS. It provides the geoprocessing and geoeediting tools that allow users to create and modify shapefiles, rasters and many of the same spatial analysis tools which are provided by the Spatial Analyst toolbox in ArcGIS. One drawback to QGIS is official documentation is poor and not always updated to reflect changes in the software. The “Help Contents” takes the user to a developer guide with step-by-step instructions for how to build QGIS from source code, but does not answer simple questions about how to use features. While the official user manual can be disorganized, tutorials are being developed by some QGIS users. Unfortunately, many tutorials are not stored on a centralized repository and require Web searches to find. These tutorials can be valuable when current; however, unless regularly updated, they can become out of date quickly as new versions of the software introduce new features or change existing functionality.

Google’s free mapping tools (Google Maps and Google Earth) are available at:

maps.google.com

earth.google.com

Google Maps and Google Earth are not true GIS products; they simply allow basic data visualization and distance measurements on top of freely provided base data and base imagery. But, mostly due to the free and up-to-date nature of this base data and imagery, these tools can be quite useful.

Google Fusion Tables is a useful Google product that allows for import of spreadsheet data to Google's online data service (called Google Drive) and a variety of visualizations of that data from within Google Maps. It is available at:

tables.googlelabs.com

This Excel to Google Earth tool was created by MEASURE Evaluation to allow users to map data from Microsoft Excel in Google Earth for over 40 countries at the first and second level administrative levels. Google Earth is a free digital globe program from Google. The advantage with E2G is that it is free and easy to use. However, E2G is limited to producing maps of just one variable. Because of this limitation, it is technically not a GIS, but it does provide users with a free, easy to use solution for producing maps of their data. There are tutorials and video screencasts on YouTube to help users learn the software. E2G is available at:

<http://www.cpc.unc.edu/measure/e2g>

Other Free Mapping Programs

Other programs deserving mention but not fully evaluated in the current analysis include: GRASS, DIVA, OpenGeoDa, and DHIS2.

DIVA GIS is a GIS program for mapping and geographic data analysis. It is particularly useful for mapping and analyzing biodiversity data, such as the distribution of species, or other 'point-distributions'. Grids (raster files) are central to the analytical capabilities of DIVA-GIS. It also reads and writes standard data formats such as Esri shapefiles and image files that can be displayed but not used for analysis, such as an aerial photo or satellite image. DIVA-GIS supports three image formats: TIFF, JPEG, and mrSID. The diva.org website has many resources including links to freely available data and training materials.

<http://www.diva-gis.org>

GRASS (Geographic Resources Analysis Support System) is used for data management, image processing, graphics production, spatial modeling, and visualization of many types of data. GRASS is an official project of the [Open Source Geospatial Foundation](http://www.osgeo.org). GRASS is currently used in academic and commercial settings around the world, as well as many U.S. government agencies and environmental consulting companies. There is a GRASS plug-in for QGIS. GRASS is available at:

[http:// grass.osgeo.org](http://grass.osgeo.org)

OpenGeoDa has a focus on spatial analysis and exploratory data analysis. It allows the user to see data in tables, charts and maps. It offers several spatial analysis methods to help with spatial regression and clustering. While it provides robust spatial analysis options, its ability to produce publication quality maps is limited. It is available at:

<http://geodacenter.asu.edu/ogeoda>

DHIS2 is a free and open source platform for collection, validation, analysis and presentation of data. It is designed to work within a national public health system. DHIS2 provides robust data analysis and mapping capabilities. However it is not well-suited as a stand-alone mapping program. Most who implement this system use programmers to help customize the tool to their needs. It is available at:

<http://dhis2.org>

Appendix B: Resources

Online Resources

This section includes Web-based tools, data sources, online tutorials, and other resources.

AidData provides subnational level, geocoded aid data. AidData has collaborated with the World Bank Institute, African Development Bank, Malawi Ministry of Finance, and Climate Change and African Political Stability Program (CCAPS) at the University of Texas to map projects from over 30 donors in Malawi, and World Bank/African Development Bank projects in up to 144 countries. Data can be subset by sector.

<http://www.aiddata.org>

DevInfo training resources are at:

http://www.devinfo.org/di_training.html

Epi Info community is at:

<http://cms.myeqi.info/>

Geocommons is a Web-based mapping tool that allows the user to upload and display their own data or search the data repository. Limited cartographic tools similar to Epi Info, it can only display one or two area or point-based variables. Currently no geoprocessing tools

<http://geocommons.com/>

Global Health eLearning Center, developed by USAID's Bureau for Global Health, provides technical information for global health professionals. It has a series of courses on using GIS for public health. Certificate programs are available.

<http://www.globalhealthlearning.org/>

HIV Spatial Data Repository provides HIV data for over 50 countries aided by the U.S. President's Emergency Plan for AIDS Relief and others. The data come from MEASURE DHS (Demographic and Health Surveys) and from the US Census Bureau.

<http://www.hivspatialdata.net/>

Malaria Atlas Project is a spatial database of linked information based on medical intelligence and satellite-derived climate data to constrain the limits of malaria transmission and the largest ever archive of community-based estimates of parasite prevalence:

<http://www.map.ox.ac.uk/>

TerraViva is a free Global Data Viewer produced by ISciences and the National Aeronautics and Space Administration's Socioeconomic Data and Applications Center, operated by Center for International Earth Science Information Network at Columbia University.

<http://www.terraviva.net/>

A You Tube Video on using the TerraViva Viewer is available at:

<http://www.youtube.com/watch?v=GYvNvzk2q6s>

WHO Global Health Atlas is a global online atlas of infectious diseases, building on the features of the Health Mapper. Over 300 indicators for more than 20 infectious diseases of major public health concern are included in the database. In a single electronic platform, the Atlas is bringing together for analysis and comparison standardized data and statistics for individual diseases and indicators at country, regional, and global levels. The analysis and interpretation of data are further supported through information on demography, socioeconomic conditions, and environmental factors. Maps are used to display data on the prevalence of individual diseases, the location of at-risk populations and vector habitats, and patterns of antimicrobial drug resistance. It is available at:

http://www.who.int/health_mapping/tools/globalatlas/en/index.html

Other Links

Other useful Web resources include the following.

CDC WONDER databases are available at:

<http://wonder.cdc.gov/>

CDC Epi Info resources are at:

http://www.cdc.gov/Epi_Info/maps.htm

Geographical Information Systems for Public Health is available at:

https://practice.sph.umich.edu/micphp/files/GIS_course_index.php

IMMPACT's Global Positioning System (GPS) User Manual is at:

http://www.abdn.ac.uk/immpact/resources/gis/downloads/Venture_GPS_manual20050727.doc

IMMPACT's Basic Guide to GPS Data Management in Epi Info 6.4 is at:

http://www.abdn.ac.uk/immpact/resources/gis/downloads/IMMPACT_Basic_Guide_to_GPS_data_management_in_Epi_Info_2020050719.doc

MEASURE Evaluation GIS resources are available at:

<http://www.cpc.unc.edu/measure/our-work/gis>

U.S. Geological Survey resources are available at:

<http://seamless.usgs.gov/>

World Health Organization mapping resources are available at:

http://www.who.int/health_mapping/en/

World Health Organization health facility locations are available at:

<http://apps.who.int/geonetwork/srv/en/main.search> (health facility locations)

Resources Using Mapping/GIS:

The following list is provided as a jumping off point, and not meant to be in any way comprehensive. Additional resources can be found elsewhere, including the **Esri GIS** bibliography, a good resource for articles featuring GIS:

<http://training.esri.com/campus/library/bibliography>

Healthcare Access, Participatory GIS and General Interest, enabling methods for community health mapping in developing countries:

<http://www.ij-healthgeographics.com/content/9/1/56>

Participatory GIS mapping and population estimation in a city in Sierra Leone, use of GIS for planning HIV prevention interventions for high-risk youths, describes the process and problems of data acquisition, analysis, and mapping in the development of structural interventions, demonstrating how program planners can use this technology to inform and improve planning decisions:

<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2040351/>