WORKING PAPER

Building a Web-Based Decision Support System

August 2018

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MEASURE Evaluation

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Building a Web-Based Decision Support System

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August 2018

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ABBREVIATIONS

DHS	Demographic and Health Survey(s)
DSS	decision support system(s)
GIS	geographic information system
HMIS	health management information system
PEPFAR	United States President's Emergency Plan for AIDS Relief
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

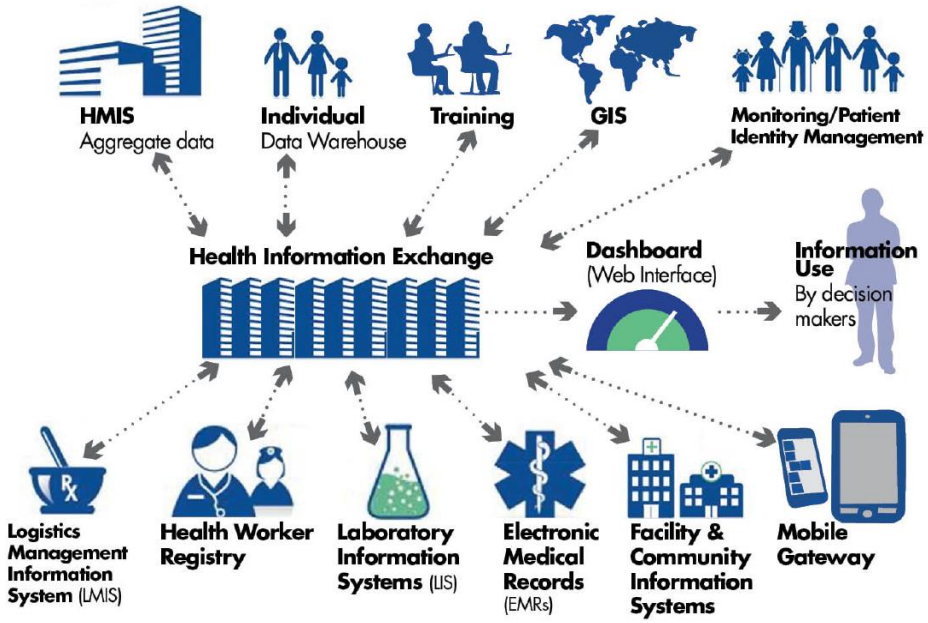
As countries strengthen their data infrastructures, global health professionals increasingly need data from multiple sources for monitoring programs and for preventing and controlling the spread of epidemics. These data sources are routine health information systems (health facility and community-based information systems) and nonroutine sources (household and other population-based surveys, census, civil registration and vital statistics systems, disease surveillance systems, health facility surveys, and administrative data systems). These varied sources of data complement one another, and when combined, improve the data's usefulness.

Before data sources can be linked, they need to be interoperable. To accomplish this, countries are developing health information exchange protocols, also called interoperability layers or health information mediators. Many of the current efforts seek to make patient-level and aggregate data systems interoperable, using health information exchange standards. Examples of aggregate data systems are health management information systems (HMIS), logistics management information systems, and human resource information systems. A feature of some aggregate systems is that they provide web application programming interfaces (APIs), which allow external applications to access data.

To exploit the possibilities of linking multiple data sources, countries are establishing data repositories—also called data warehouses—which bring data sources together and link them through an interoperability layer. Data warehouses are connected to a "health observatory," which is a gateway to health statistics. Health observatories permit access to in-depth analyses of population health and health services at the national, subnational, and district levels. Health observatories can take the form of dashboards, portals, and web interfaces developed for specific stakeholders.

Another component of a health observatory is a decision support system (DSS)—the focus of this paper. A DSS is a tool that brings data together from multiple sources and presents them in innovative visual formats: graphs, spatial analyses, and maps; health sector reports; and other media (Figure 1). A DSS makes health information more readily available, understandable, and, ultimately, more likely to be used by decision makers.

Figure 1. Types of data that can be linked by a decision support system



MEASURE Evaluation—funded by the United States Agency for International Development (USAID)—has supported the development and use of easily accessible, powerful, computerized DSS linked to national health information systems, United States President's Emergency Plan for AIDS Relief (PEPFAR) HIV/AIDS program monitoring systems, and other computerized information systems. We developed a prototype of a web-based DSS tool that links routine, nonroutine, and other data sources. The tool uses web application programming interfaces (APIs) to visualize data captured from the DHIS 2 health information system software platform, Demographic and Health Surveys (DHS), and the Microsoft Access and Excel legacy programs).

Linking multiple data sources is possible only when standard data formats are used. Data sources must have matching key field information for temporal and geographic linkages. This document highlights some of the steps needed to link data sources, with particular focus on the master facility list (MFL), importing from legacy data sources, and connecting to online data sources using web APIs.

Purpose of This Document

This working paper is a companion to MEASURE Evaluation's DSS tool prototype. It explores the process of linking to systems using DHIS 2, DHS data, and the Microsoft Access and Excel legacy programs. It also discusses the graphic and geographic information system (GIS) functionality standards that should be included in a DSS.

INTRODUCTION

For more than 20 years, MEASURE Evaluation (and its predecessor, the EVALUATION Project) supported the development and use of user-friendly, powerful, computerized DSS linked to national health information systems and PEPFAR HIV/AIDS program monitoring systems and other computerized information systems. A DSS provides users with dynamic, multidimensional analysis capabilities (i.e., data triangulation), in which users can visualize temporal and geographic patterns in their data. A DSS allows decision makers to rapidly visualize, graphically, the health indicators collected by the health information system. From a user-friendly interface, the user chooses the level of analysis, the health program, the program-specific indicator, and the type of graphic display desired. Examples of these displays are line graphs for time trends, histograms and thematic maps for geographic comparisons, and pie charts and summary tables.

District health managers and program managers appreciate using DSS as a planning and programming tool for health activities in their districts and programs. The graphics generated by DSS illustrate data at the health facility, district, regional, or national level. Indicators can be examined by administrative level, periodicity, or geographic or reporting source. Users can print or electronically save the output for use in summary reports, documents, and presentations. Summary data can be exported to Excel for analysis.

Early DSS were linked to dBASE III+ databases and developed using the Clipper programming language and data Graphics Extender (dGE) for the creation of time-trend graphs, histograms, and pie charts.

As the ministries of health that were using these early DSS adopted Windows-based systems (using Microsoft Access), they requested assistance from MEASURE Evaluation to develop Windows-based DSS with the graphic capabilities found in DOS-based systems. Using Microsoft Access and the ActiveX object add-ons GraphicsServer and MapObjects LT, MEASURE Evaluation developed a Windows-based DSS that had license-free distribution. In addition to the line graphs, bar graphs, and pie charts found in the DOS-based DSS applications, thematic maps were added. This system was designed to be accessible from the national level to the facility level of a health information system. Its Visual Basic for Applications architecture enables the Windows-based DSS to easily function with almost any Microsoft Access database, and it is scalable to other database platforms. Using simple bar charts, line graphs, tabular reports, and thematic mapping, the DSS translates raw data into easily understood graphics.

Although some of these Windows-based applications are still used today, migration to web-based health information systems is on the rise. To address the demands of this digital revolution, MEASURE Evaluation developed a web-based DSS prototype that has powerful functionality and a user-friendly interface.

MEASURE EVALUATION'S WEB-BASED DSS PROTOTYPE

MEASURE Evaluation had the following goals in developing its DSS prototype:

1. Meet the needs of countries that are migrating legacy databases to web-based data systems.

2. Develop best practices and standards for MFL (i.e., health facility registry) search and analysis functionality.

3. Using web APIs, demonstrate linkages with Internet-based data sources, specifically with data from DHIS 2 and the DHS Program's STATcompiler.

Our prototype is designed to make it easier and quicker to find information, by using the data sources' natural groupings, such as region or district and health program area. For instance, looking through a long list of all health facilities is tedious. It is quicker to drill down, by first selecting the region that contains the facility, then selecting a district from a list of districts in the selected region, and then a facility from a much shorter list of facilities in the selected district. Health program groupings are also used to facilitate the selection of the indicator or data elements for analysis.

The web-based DSS prototype is built in the cloud (i.e., commercial server service) with open-source, freely available web-development tools and applications. The code is written using the PHP (http://php.net/) scripting language, JavaScript (https://www.javascript.com/), MySQL (https://www.mysql.com/) online database, Highcharts (http://www.highcharts.com/) interactive charting and mapping tool, and the Google Maps API (https://developers.google.com/maps/). ADOdb (http://adodb.org), a database extraction layer for PHP, was also used. Data found in DHIS 2 (https://www.dhis2.org/) software are accessed using the DHIS 2 web API, and DHS data are accessed using the DHS web API (http://api.dhsprogram.com). Country boundary layers for DHS data can be downloaded at the DHS Spatial Data Repository (https://spatialdata.dhsprogram.com/home/).

DATA SOURCES FOR DECISION SUPPORT SYSTEMS

"Health information system" is the term used to refer to all health-related data sources in a country, including household and other population-based surveys, census, civil registration and vital statistics systems, disease surveillance systems, routine health facility and community information systems, health facility surveys, and administrative data systems. Some countries are establishing data warehouses and linking these varied sources of data, by using a common identifier for geographic hierarchies or organizational units (e.g., region, district, subdistrict, health facility, and community). Linking many of these sources requires a common MFL, as well as common geographic hierarchies.

The ability to access various data sources within a health information system makes a DSS a powerful tool for analyzing and visualizing data from multiple sources. Because different data sources may each have different structures and formats, it may be necessary to transform the data into standard data structures called tidy data. (Click here for more information about this: https://www.measureevaluation.org/resources/publications/sr-17-142.)

Importing Reference Table Data

The first step in the development of a web-based DSS is to import the necessary reference data needed to populate the dropdown lists that allow users to select the specific criteria for the analysis of their data. Each dropdown list is populated from a reference table. For example, the first dropdown list in a DSS is the list of data sources. The available data sources (e.g., HMIS, DHS, and MFL) are stored in a table that includes a numeric data source identifier field and the data source name. When a data source is selected from the list, the data source identifier can be passed to the next step in the application (i.e., a PHP $_GET parameter).

After selecting a data source, the user selects the level of analysis (e.g., nation, region, district, and health facility). Again, a table with the country's geographic hierarchy that includes a numeric identifier and the hierarchical level is used to populate the dropdown list, and the chosen level's identifier is passed to the web page as a GET parameter. The most commonly used program for storing data is Excel. Although some countries use different programs, many software packages allow for data to be exported as an Excel spreadsheet. When using data in an Excel format, it is important to keep it simple, i.e., keep all data on one tab, with the first row of each column a one-word description that can be used as a field name. The rest of the data is in the corresponding row, with no breaks, subtotals, totals or other calculations. The Excel file is then saved as a CSV file, which can then be imported into the web-based database MySQL, or another web-based database.

Setting up the Master Facility List

Countries need a geographically accurate and complete database of their healthcare facilities. For instance, after the 2010 earthquake, Haiti's national health information system, called S*ystème HSIS*, was the key source of information on health facility locations. The MFL was crucial for the immediate relief effort, and subsequently, for the Haitian Ministry of Health's long-term effort to rebuild the country's health systems (MEASURE Evaluation, n.d.).

Master facility lists, also called health facility registries, are essential to interoperability of numerous data systems needed in the health information system. The MFL enables health facilities to exchange health information with other systems and enables interoperability with the HMIS. Master facility lists are also essential for the interoperability of the aggregate systems, such as the HMIS, supply chain (i.e., logistics management information system), and human resources information system; and they can help integrate parallel disease-specific information systems in the national HMIS. Facility surveys and assessments, such as the Service Availability and Readiness Assessment (SARA), Service Provision Assessment (SPA), Performance of Routine Information System Management (PRISM), and the Routine Data Quality Assessment (RDQA), need updated MFL information, as well. The MFL, when fully functional, allows decision makers in a health ministry and health care community to get a more complete picture of the operations at each facility.

A well-functioning MFL application allows users to download facility data and link them to other data sets. The MFL can also be expanded beyond a list of facilities, by using a unique identifier to include all the hierarchical levels (i.e., organizational units) for a country, including lists of regions, provinces, or states; districts, subdistricts, counties; constituencies; health facilities; and facility type and ownership (public/private) information. As countries improve their facility information, the MFL can also include service and other infrastructure information. The MFL application can then use this additional information about the facility to allow users to search for facilities with certain characteristics.

When developing an MFL, it is important also to establish unique identifiers for each level of the geographic hierarchy (e.g., region, district, and subdistrict). For the DSS, these geographic hierarchies are used to drill down to the selected geographic unit. After the user chooses the first geographic level, the unique identifier is used as a URL parameter that is passed to the web page, and then used to filter the list for the next geographic level. This makes it easier for the user to select a list item, because the lists are much shorter. For instance, the user selects a region from the Region list, and then selects the district from a District list in the selected region.

Ideally, in addition to the Region/District location, the MFL data also contain information about the health facility, such as the facility type, ownership, and geographic coordinates (i.e., latitude and longitude). Countries are also working to add information about the services provided at a facility and the infrastructure (i.e., equipment and resources) available there.

Generally, MFL data are most often available for distribution as an Excel file. The DSS developer can use these Excel data to create the necessary lookup tables for the geographic levels (i.e., region, district, and facility). These tables can then be imported into the MySQL database.

To learn more, review the MFL resource package available at https://wiki.ohie.org/download/attachments/28836615/1-Introduction%20to%20the%20MFL_May.pdf?version=1&modificationDate=1495728412295&api=v2.

Importing Access-Based Legacy HMIS Data

In the 1990s and early 2000s, many countries either updated existing DOS-based applications or built new HMIS applications using Access. The first step needed to use data from these legacy systems in a web-based application is to import the tables into the web-based database. These tables can be exported from Access as delimited text files with a .csv extension, and then imported into MySQL.

In addition to the data tables, reference tables for the different health programs and subprograms (also referred to as "data groups" in DHIS 2 terminology) need to be created. These are used to populate dropdown lists so that the user does not have to scroll through long lists of indicators or data elements. The health program and subprogram tables contain unique identifiers that can be passed as selection and filtering parameters to the DSS web page.

Finally, a metadata table is created that contains the data element or indicator name, program or subprogram identifiers, unique identifier, and field name and table where the data are stored. When the user selects a data element or indicator from the list, the field name and table values in this file are passed to the SQL query that selects the data and is passed to the graphic and geographic display functions.

Training resources on how to import data from an Access database to MySQl are available at

https://dev.mysql.com/doc/connector-odbc/en/connector-odbc-examples-tools-with-access-export.html

Creating Linkages between DHIS 2-Based HMIS Data and Other Data Sources

As countries continue to adopt DHIS 2 as their platform for their national HMIS, there is a growing need to develop linkages between DHIS 2 and other data systems. Many countries are exploring interoperability solutions between DHIS 2 and other databases. Using web APIs, linkages with DHIS 2 data can be used to extract data housed in the DHIS 2 platform for analysis with other applications, such as the web-based DSS. Using the DHIS 2 web APIs, functions are written to populate the necessary dropdown lists to select criteria for analyses. When tables are imported from legacy Access systems to populate the dropdown lists, the DHIS 2 API reference call can be used instead to extract the needed geographic levels (e.g., region, district, and health facility) by selecting from DHIS 2 organizational units, data element groups, and data elements. The DHIS 2 API reference call returns JSON-formatted data, which is transformed into PHP arrays that are used to generate the selected graphs and maps.

The DHIS 2 (https://docs.dhis2.org/) user documentation is a good resource for learning about extracting data from DHIS 2 through web API. For example, the documentation for the DHIS 2 2.26 is available at https://docs.dhis2.org/2.26/en/developer/html/webapi.html.

Importing and Using Demographic and Health Survey Data

The DHS program's household health and population-based survey is an essential data source for understanding population health status and health risks and behaviors. These surveys are vital when civil registration systems and facility reporting systems are not yet fully developed or of low quality.

To further analyze and disseminate DHS results, data found in the DHS final reports is added to the Access-based DSS developed by MEASURE Evaluation. This is a time-consuming process, as each table is extracted from the PDF tables found in the final reports of the various surveys. With the development of the DHS program's STATcompiler, DHS data can be downloaded as Excel files, and easily imported into the DSS. The DHS data tables and field information are added to the DSS metadata table, which allows the selected DHS indicators to be graphed and mapped in the same way as the HMIS fields and indicators.

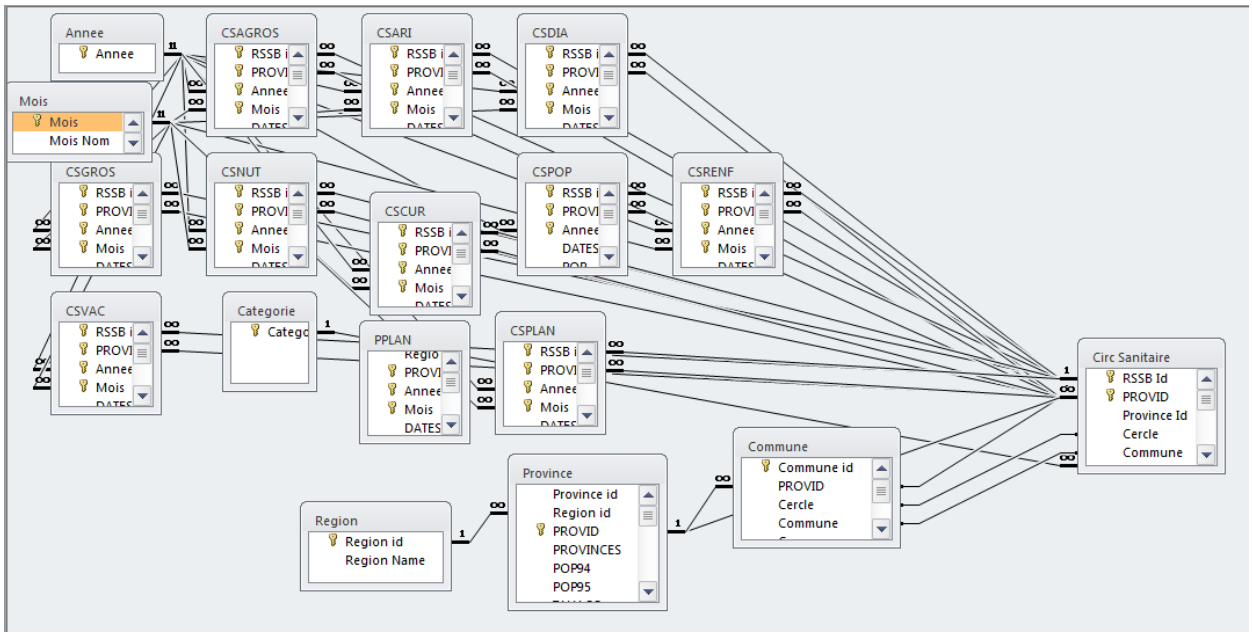
The DHS program has also developed a web API (http://api.dhsprogram.com). This allows access to aggregated DHS indicator data (not just the individual or household data files). Using the API, applications can link to the DHS database and extract JSON-formatted data that can be passed as arrays to populate the DSS graphs and maps. The DHS API uses a unique identifier with a two-character program identifier. For instance, FE is the code for fertility, FP is the code for family planning, and CH is for child health. A four-character code can be used for a subprogram identifier. These codes are used to create the program and subprogram dropdown lists in the DSS.

Creating Reference (Lookup) Tables

The DSS web-based application uses reference, or lookup, tables for every dropdown list, or combobox, used to select criteria for analysis (Figure 2). Each reference table should have the description of the item in the list and a unique identifier. The description is what you would see in the dropdown list, and the unique identifier is the parameter that is passed to the DSS web page. The lookup tables are dependent on the country and the available data sources. Tables can by populated, by importing data from text-delimited or CSV-formatted files, or they can be built dynamically using web APIs.

You can find general guidance on how to create lookup tables in MySQL at https://dev.mysql.com/doc/refman/5.7/en/create-table.html.

Figure 2. Example of reference table linkages



The health facility table (i.e., CircSanitaire) is linked to the geographic hierarchy (i.e., region, province, or commune) and the health services tables (e.g., CSVAC, CSGROS, and CSNUT). The health service tables are also linked to the Year and Month tables (i.e., Annee, Mois).

Organizational Units

Because the web-based DSS supports analysis at all levels of the health system (national, regional, district, and health facility), the simplest system design is to have a reference table for each level of the country's geographic hierarchy. The first level (i.e., Region/State/Province) should have a unique identifier and the name of the region. Other useful fields for GIS mapping would include the longitude and latitude for the geographic polygon's centroid. A zoom value can also be included; this is useful when regions vary in size. Small regions use a larger zoom factor than larger regions when displaying the map on the web page.

The next level, District/County, contains the name, a unique identifier, and the unique identifier of the Region/State level in which it is located. Thus, each level would, at a minimum, have a name and unique identifier, as well as a unique identifier for the geographic area where it is located.

Master Facility List Reference Subgroups

Reference subgroups of the MFL are created using information available for health facilities. For instance, the facility type and owner are common to many of the health facility lists that are currently available. The more information there is about the facility, the more powerful the MFL analysis and search functionality can be. Therefore, countries should consider including information on the services and infrastructures available for each facility. This allows the facility search feature in the DSS to identify facilities based on a broad range of features.

DHIS 2 Reference Groups

Reference groups for DHIS 2 can by generated dynamically using the DHIS 2 web APIs. The DHIS 2 organizational units have a unique eleven-character code of letters and numbers. The orgUnit table contains a record for the country, and the country orgUnitID is the parentID for the regional level. For example, the orgUnitID for the region is the parentID for the district.

Demographic and Health Survey Reference Tables

DHS data are not stored in the MySQL database, but there are several reference tables that allow the user to select the program, subprogram, and indicator for analysis. These tables are imported by accessing the list of indicators from the DHS API link, and then extracting and creating the program and subprogram table; each has a unique identifier. The subprogram includes the program's identifier, and the indicator table includes the program and subprogram indicator. When an indicator is selected, the specific indicator ID is passed to the DHS API and JSON-formatted data is returned.

Another parameter that must be added to the DHS API call string is the desired year of the survey. These codes are saved in a DHS Year reference table and are used to populate the DHS API call string. When an indicator is selected, all available data for the country is downloaded in JSON format and used to populate a MySQL table. The appropriate data is then automatically extracted based on the selection criteria for the graph or map.

Two other reference tables are needed to handle the subdivisions found in the DHS data: By Variables and Characteristics. By Variables include different ways the indicator may be calculated. For instance, one By Variable is whether the indicator was calculated using the three years preceding the survey or the five years preceding the survey. Characteristics are different subgroups, such as region, education level, residence, and age group, that may be listed for certain indicators. The different characteristics found in the summary tables are also available through the API. Reference tables for By Variable and Characteristics are needed to populate the dropdown lists in the DSS. These reference tables are updated dynamically with calls to the DHS API.

User Interface

The website program code is written in PHP scripting language, a common open-source programming language used for website development. It is used in combination with MySQL, an open source, relational database management system that uses structured query language. This combination allows for the development of a dynamic, data-driven user interface. The web page uses a series of comboboxes, or dropdown lists. The user makes a selection from the first combobox (Data Source), and this reloads the web page with the added parameter. This triggers the visibility of the second combobox (Level). Different data sources can have different levels. For instance, an HMIS might have Nation, Region, District and Health Facility levels, while the DHS has only Nation and Region levels. After selecting the level of analysis, the selection process continues with the selection of the program, or indicator group. Finally, the desired indicator or data element is selected and the buttons for different graphical analyses will appear. These buttons may differ for different data sources. An HMIS may have monthly or quarterly graphs, while DHS will have only annual graphs (i.e., graphs that show data for the years when the surveys were conducted).

Graphics and Mapping Development

The graphs and maps use JavaScript code in combination with PHP and MySQL. The static aspects of the code use JavaScript, while the dynamic features use PHP and MySQL to load data into the necessary arrays for the graphs and maps. Graphs use the Highcharts Java Script Library, which is freely available for nonprofits, and the maps use the Google Maps API.

The GIS administrative boundary files used by the web-based DSS are in GeoJSON format. These were created from the original ESRI shapefiles using the open source GIS application QGIS (https://qgis.org/en/site/). It is imperative that the unique identifier for the map file geographic boundary polygons (region or district) match the unique identifier for the corresponding geographic unit in the DSS database.

The DHS program's Spatial Data Repository has shapefiles for each country that correspond to the level of aggregation used in a survey. Shapefiles can be downloaded from the Spatial Data Repository for both the most recent survey and for historical surveys.

Country Prototype Examples

The web-based DSS prototype has been configured with various country data systems. At this time, none of the prototypes represent official data for the country. They are rather meant to be illustrative of the potential functionality of a web-based DSS. Table 1 shows the features that are currently available for each instance of the prototype.

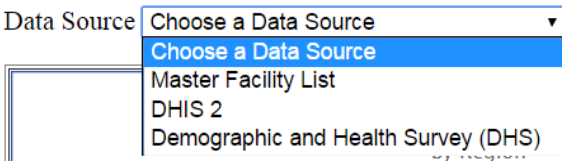
Table 1. Country-specific features available in web-based decision support systems

Country	Website Link	Available Features
Sierra Leone (using DHIS 2's Demo data	http://za-esi.net/SLDSS/SLDSS.htm	• MFL • Links to DHIS 2 • Links to DHS
Côte d'Ivoire	http://snisnet.net/CIDSS/CIDSS.htm	• MFL • Links to DHS API • Imported health system Strengthening data
Niger	http://snisnet.net/NIDSS/NIDSS.htm	• MFL • Imported SNIS data • Links to DHS
Nigeria	http://dssbase.net/NGMFL/NGMFL.html	• MFL • Imported TSHIP Project LQAS Survey data • Links to DHS
Namibia	http://za-esi.net/NaDSS.htm	• MFL • Links to DHS
Madagascar	http://snisnet.net/MDDSS/MDDSS.htm	• MFL • Links to DHS

Health Facility Dashboard

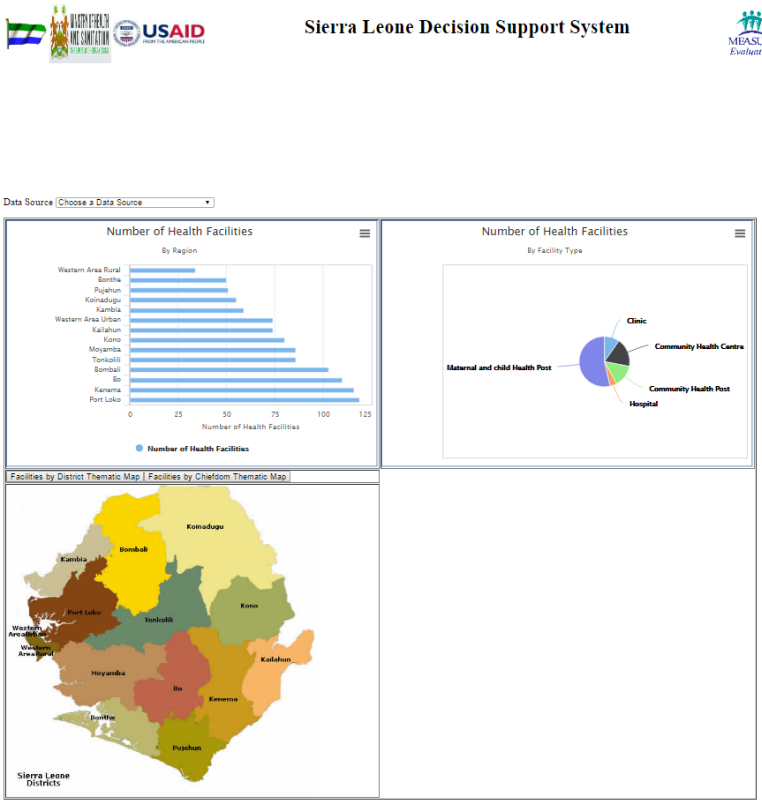
In the Sierra Leone example of the web-based DSS (Figure 3), there is a dropdown box from which the user can choose a data source. The Data Source dropdown list allows the user to choose the desired data source for visualization.

Figure 3. Example of a data source dropdown box



The dashboard has a bar chart of the number of facilities by first-level administrative level, a pie chart showing the number of facilities by facility type, and thematic maps with buttons to show the number of facilities by first- or second-level administrative levels (Figure 4).

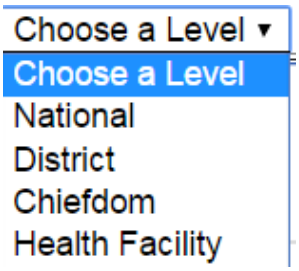
Figure 4. Example of a dashboard



Master Facility List

Using the same Sierra Leone example, after choosing MFL from the Data Source dropdown list, the user then chooses a level of analysis from the Level dropdown list (Figure 5).

Figure 5. Example of Level dropdown list



Following the selection of the level, the user may use other available criteria to select a subset of the facilities. Currently, countries typically have facility type and ownership information available, but as countries expand the breadth of information collected in the MFL, additional information on services provided and infrastructures available can be added to the selection criteria. The user can also click buttons to generate maps of the selected facilities or export a CSV file containing the list of facilities. If the Subnational level is selected, then heirarchical dropdown lists allow users to drill down to select a level of analysis. The following image shows a specific facility, Dia Chp, being selected (Figure 6).

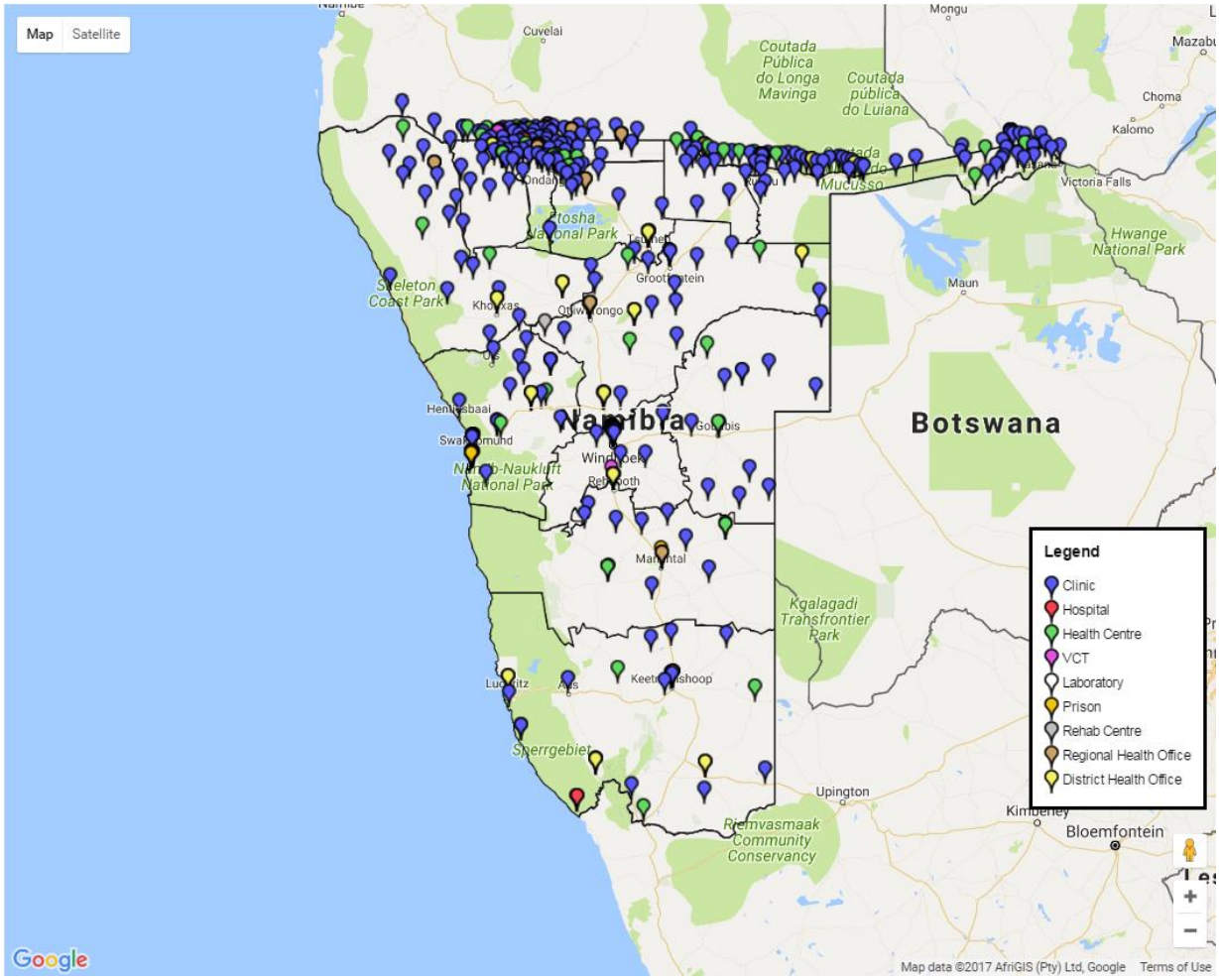
Figure 6. Example of selections for a health facility

Data Source: Master Facility List | Level: Health Facility | District: Kailahun | Chiefdom: Kissi Kama | Facility: Dia Chp
Facility Type: Choose Facility Type | Facility Owner: Choose Facility Owner
Map View | Download Data

Facility ID	Facility Name	Facility Type	District	Chiefdom	Owner	Longitude	Latitude
245	Dia Chp	Community Health Post	Kailahun	Kissi Kama	Government	-10.409266	8.384603

Users can choose to map all the health facilities (i.e., those with geo-coordinates) in a country, or a subset of facilities based on their chosen criteria. The following map shows all health facilities in Namibia (Figure 7).

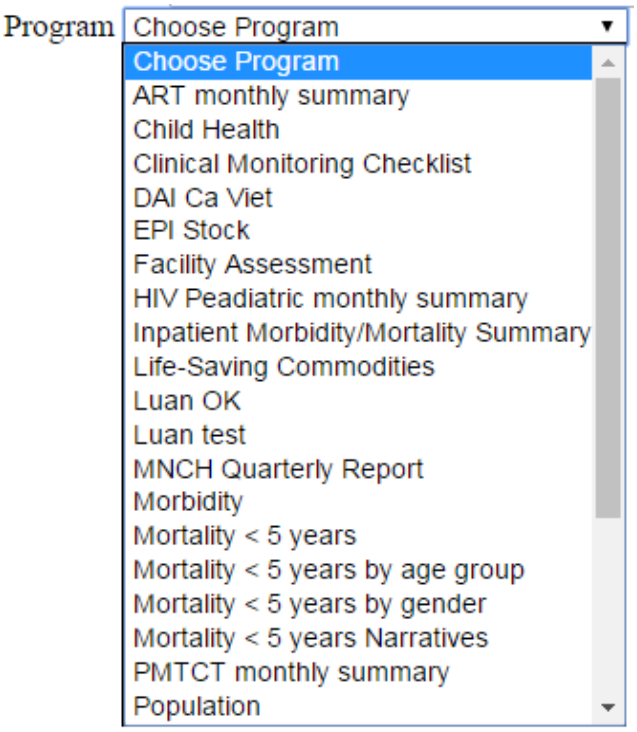
Figure 7. Map of health facilities in Namibia



DHIS 2 and HMIS Data

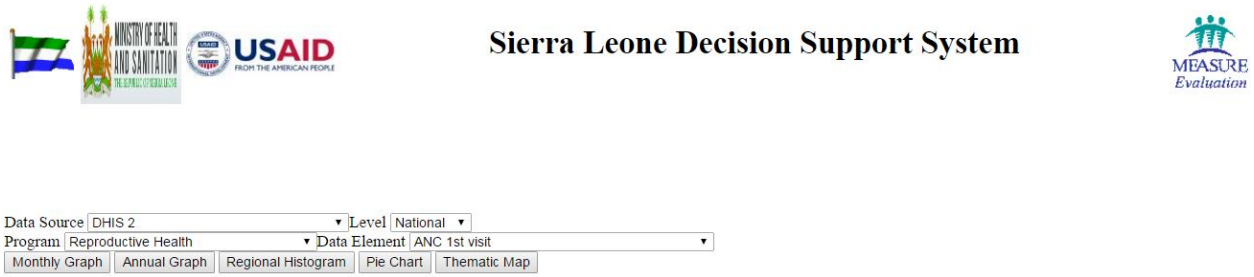
For countries managing their HMIS data using DHIS 2, the data can be selected from the dropdown Data Sources "combobox." The user can then choose the appropriate level (National, Region, District, and Health Facility) for the desired analysis. Next, from a list of health programs found in the countries' health information system, the user can select the desired Program/Subprogram, for example, for analysis (Figure 8).

Figure 8. Example of Program dropdown combobox



Finally, a number of graphic and mapping options can be selected, as shown in Figure 9 below.

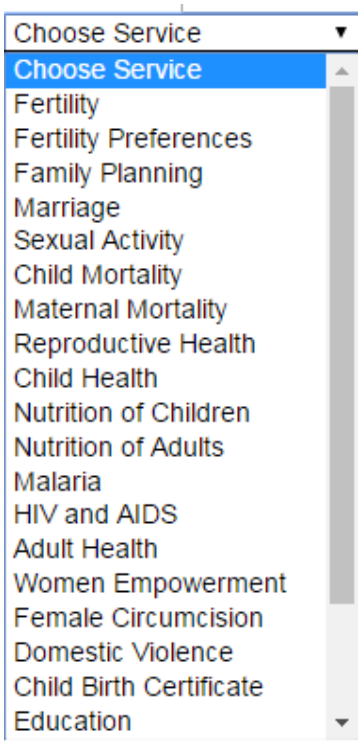
Figure 9. Example of graphic and mapping options



Demographic and Health Surveys

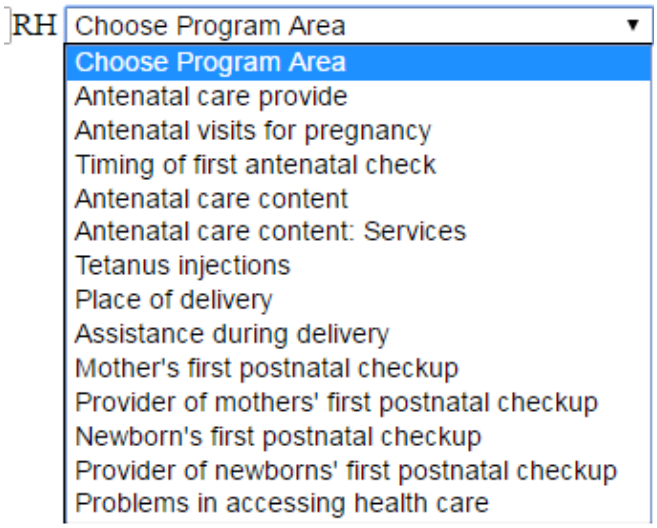
When DHS is chosen as the Data Source, only National and Regional options are available as levels. This is one of the limitations of survey data. The sample size of the survey determines the reliability of the estimate, and usually DHS data is reliable only down to the first administrative level. After selecting a level, a list of DHS program areas will appear as shown in the Figure 10.

Figure 10. Example of dropdown list for DHS program areas



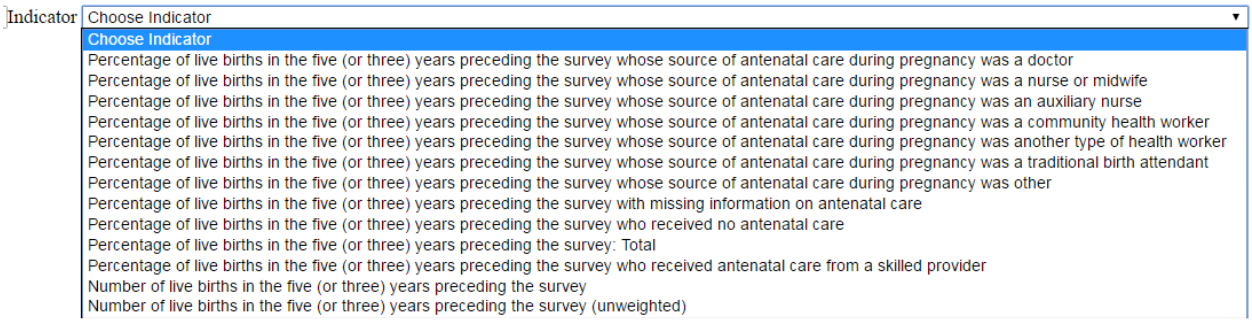
Several DHS Programs/Services are further subdivided. For instance, Reproductive Health has the following subcategories shown in Figure 11 below:

Figure 11. Example of DHS Reproductive Health subcategory dropdown list



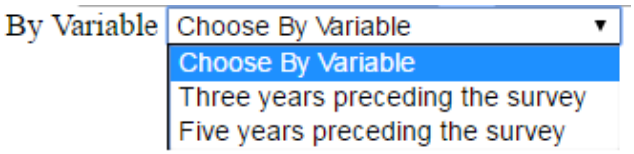
Once the program area is selected, the user can select the desired indicator from a list of indicators for the chosen program area (Figure 12).

Figure 12. Example of Indicator dropdown list



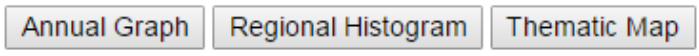
For some DHS indicators, there are different estimates, or By Variables, for the three- and five-year periods preceding the survey (Figure 13).

Figure 13. Example of By Variable dropdown list for DHS indicators



After selecting the By Variable, the desired graphic and mapping option can be selected from a list of options (Figure 14).

Figure 14. Example of By Variable graphic and mapping options

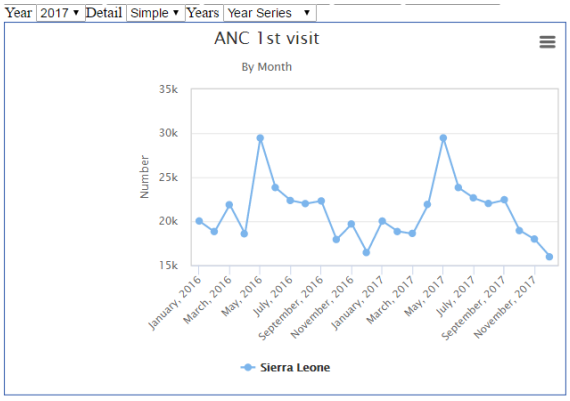


Graph and Map Options

Monthly and Quarterly Time-Trend Graphs

Monthly and quarterly time-trend graphs are currently available for DHIS 2 and HMIS data. After choosing the Monthly/Quarterly Graph option, dropdown lists allow the user to further specify where one year or multiple years can be graphed (Figure 15).

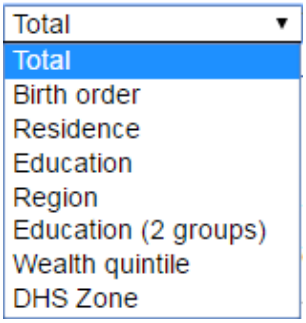
Figure 15. Examples of time-trend graph options



Annual Time-Trend Graphs

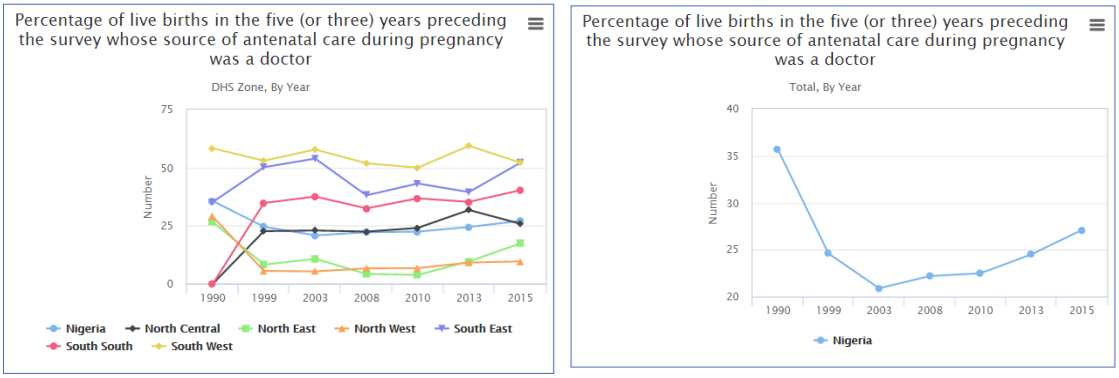
Annual time-trend graphs can be displayed for the total value of the indicator or by subgroups. For instance, the user can choose a graph with a single line for the values of the indicator at the National level, or with detail, i.e., where there is a time trend line for each region. Demographic and health survey data can also display indicators by characteristic, as shown in Figure 16.

Figure 16. Example of indicator characteristics dropdown list for DHS survey data



Due to sample size considerations, subnational groupings of data differ across survey years. Some surveys may not have the same geographical regions as others. Thus, DHS Zone was added as a category to account for those differences. Examples of annual time-trend graphs are presented in Figure 17.

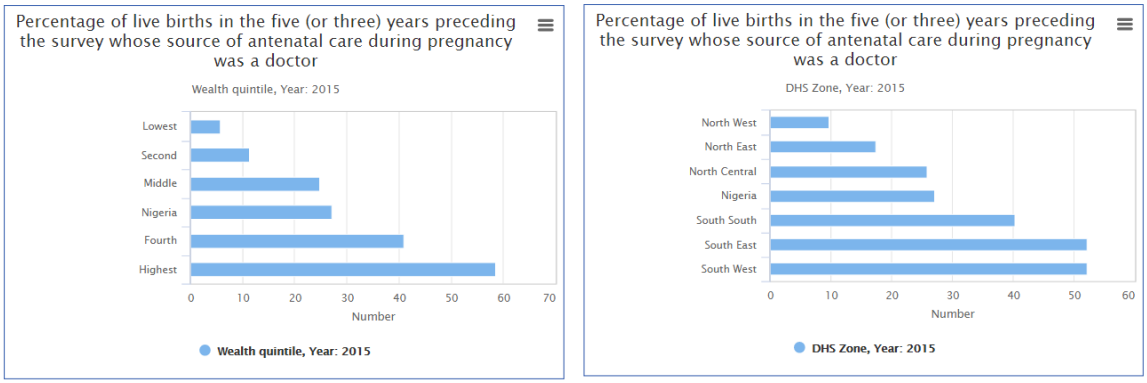
Figure 17. Examples of annual time-trend graphs



Regional Comparisons

Regional comparison bar charts show a bar for each administrative level below the selected level, or by selected DHS characteristic as show in Figure 18.

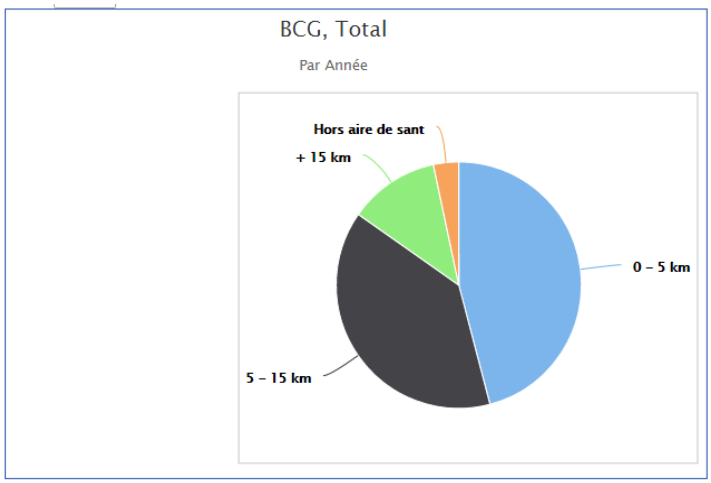
Figure 18. Example of comparison bar charts for administrative levels



Pie Charts

Pie charts are available only for indicators where the subgroups add up to 100. The pie chart below (Figure 19) is an example from the Niger HMIS, called SNIS, web-based DSS.

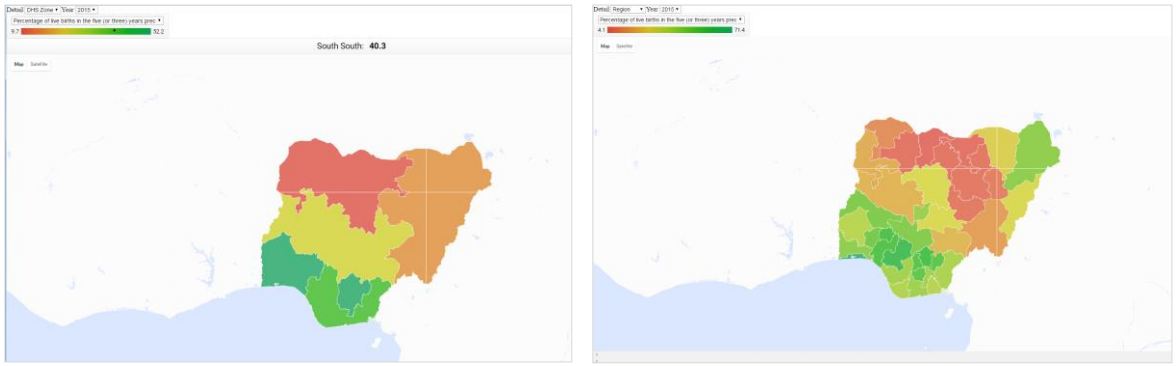
Figure 19. Example of pie chart



Thematic Maps

Thematic maps can be generated for any indicator or data element. The user can zoom in and out and hover over the map to display the name of the region under the cursor. There is also a dropdown list on DHS maps to show region or DHS zones (Figure 20).

Figure 20. Example of thematic map



The Niger DSS allows for drilling down where the National level shows either regional or district thematic maps, and the District level shows commune level maps.

RECOMMENDATIONS

As countries improve their health information systems and strengthen their data sources, they need to ensure that data sources are standardized and formatted so they can be linked and made interoperable. This process should place special focus on the MFL, which is essential for linking data sources; the MFL must be publicly available to facilitate the standardization process. As several online health information systems are using web APIs, the library of web API functions in the prototype DSS tool needs to be expanded to fully exploit the complexity of the underlying data sources.

There is also scope to add other graphic analyses and improve the mapping capabilities of the DSS. Of particular value to countries and other DSS users are planned additions of multiple indicator graphs and heat maps. Functionalities enabling analysis of gender and health system strengthening indicators have also been proposed, because of their great value.

CONCLUSION

Decision support systems, such as the prototype developed by MEASURE Evaluation, are capable of linking many diverse data sources and are powerful but user-friendly tools to analyze data. As data sources are strengthened and more become available, we must ensure that they are interoperable. The MFL is the most important data source, because it enables the linking of data sources. For this reason, it requires special focus. The DSS offers robust information to decision makers for monitoring programs and preventing and controlling the spread of epidemics.

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