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Applying Geospatial Tools to Rugg's Staircase Method for Monitoring and Evaluation: MEASURE Evaluation's Case Studies

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Carolina Population Center
University of North Carolina at Chapel Hill
400 Meadowmont Village Circle, 3rd Floor
Chapel Hill, North Carolina 27517
Phone: 919-445-9350
measure@unc.edu

www.cpc.unc.edu/measure

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Applying geospatial tools to Rugg's staircase method for monitoring and evaluation: MEASURE Evaluation's case studies

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2014

Background

Geographic Information Systems (GIS) and Geospatial analysis (GSA) are useful tools for Monitoring and Evaluation (M&E) in global health and development systems since most issues regarding public health services are interrelated with their geographic location. Spatially informed analysis can be used to: 1) prepare, focus, monitor and evaluate interventions; 2) identify the spatial distribution of diseases and their evolution in space and time; 3) assess community health needs, resource allocations and gaps in services; 4) detect populations at risk, risk factors and epidemics; 5) manage health administration such as supplies, human resources, service locations; and 6) create visual displays to disseminate public health information (Kandwal, 2009; Nash, 2009; Noor, 2004). Moreover, geospatial data are generally collected during interventions and M&E would benefit from the utilization of this data in GSAs.

This paper seeks to illustrate the important role geospatial analysis can have on M&E. We move beyond the hypothetical scenarios that have been previously used in the literature and discuss specific, real world examples of how geospatial tools, methods and techniques have been used to support M&E. The examples in this paper are from HIV/AIDS prevention activities associated with the MEASURE Evaluation project and are conceptualized within the Rugg et al eight-step M&E framework (Rugg, 2004). MEASURE Evaluation is a United States Agency for International Development (USAID) funded cooperative agreement that builds M&E capacity in countries throughout the world. Geospatial methods are one of the tools employed by MEASURE Evaluation.

In the past many barriers kept geospatial tools such as GIS from being utilized in the M&E of global public health interventions. Geospatial analyses required high performance computers, specialized training and expensive software. Additionally, spatial data sets needed for analyses were rare. In recent years, GIS has become more accessible through the availability of free, easier to use software that can be run on standard computers (MEASURE, 2012). Furthermore, the necessary geographic data has become more widely available (Tatem 2012). As geospatial tools have become more accessible there has been a growing recognition of the value of GIS techniques to strengthen M&E. Nonetheless, there are few published studies on the use of geospatial tools in the context of M&E of global public health interventions. Those studies which do exist have generally presented the value of GIS by providing hypothetical examples. In 2002, Renger et al. published a peer-reviewed technical article on the use of GIS in M&E for evaluators with little knowledge of GIS (Renger, 2002). A more recent paper from Azzam (Azzam 2013) discusses the history of GIS, provides an overview of current geospatial techniques, and demonstrates through a hypothetical example how GIS can support program development and evaluation at all stages.

Rugg's framework has been widely promoted by the Joint United Nations Programme on HIV/AIDS for the M&E of global public health intervention (UNAIDS, 2010). This method provides a solid guideline for thorough examination of each step of the M&E process from hypothesis generation to programmatic activities, final outcomes and overall effects. Rugg's framework is sometimes known as the "stairstep model" because there are 8 stages and it is often presented graphically as a staircase (see Figure 1). Each step addresses a specific step in an intervention and the basic questions relevant to that stage, such as "What is the nature and magnitude of the problem?" or "Are interventions working or making a difference?" (Rugg, 2004; UNAIDS, 2010; MEASURE, 2014b).

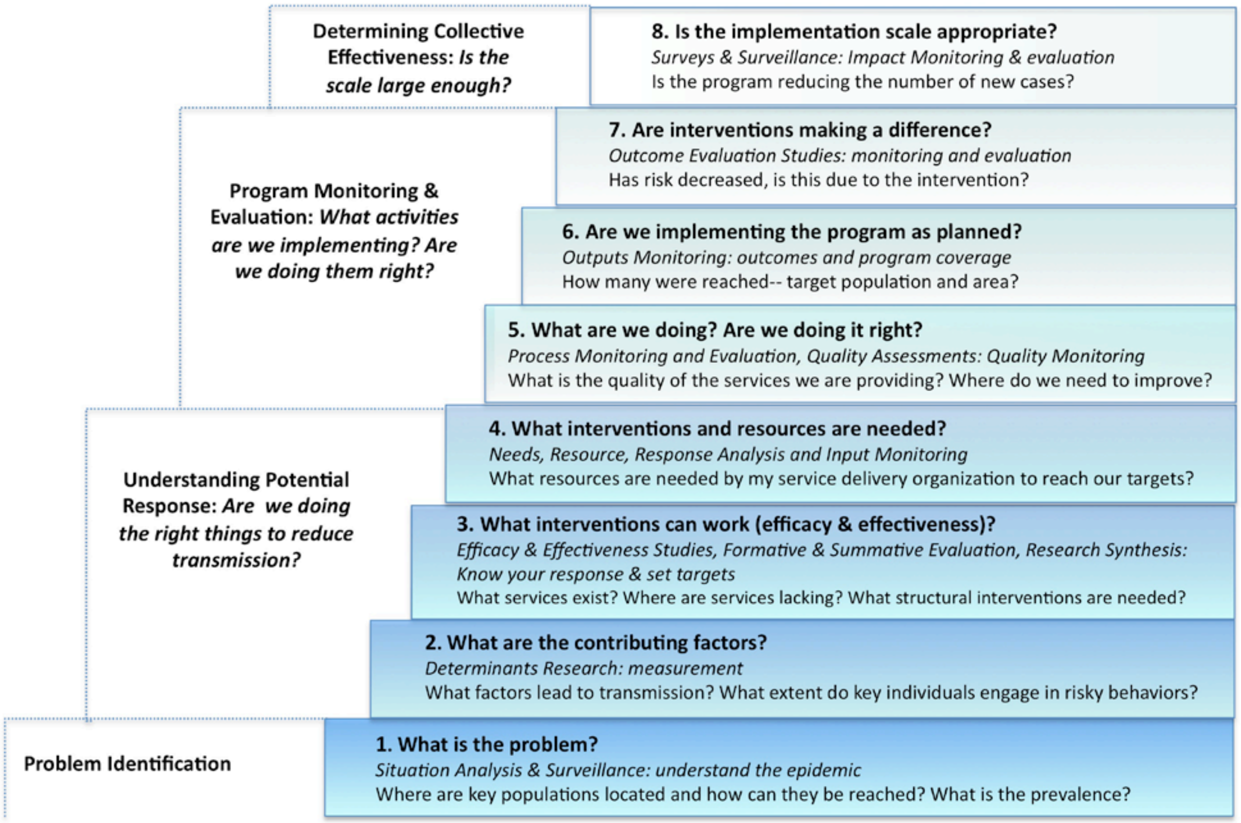

Figure 1: Adapted from Rugg's 8 step framework for M&E (Rugg, 2004; UNAIDS, 2010; MEASURE, 2014b)

There are opportunities for GIS to support each stage of Rugg's eight-step framework shown in Figure 1. In the first step, geospatial analyses can be leveraged to identify problems and trends such as hotspots of infection and inappropriately distributed services. GIS can manage and integrate multiple contextual datasets and programmatic data allowing context to be incorporated into the second step analyses. Contributing factors such as geographic location and determinants for the outcome such as population density and access to services can be identified. To illustrate, in a study by Nash in 2009 geospatial tools were used to link population, HIV/AIDS prevalence, and the number of patients newly initiating Anti-RetoViral Treatments (Nash, 2009). For phases three and four, GIS' ability to link and display contextual data can again be leveraged to locate interventions and select intervention methods. In the remaining steps (5-8), the effectiveness of the intervention is assessed. Geospatial analyses can improve analysis in these steps through spatial and statistical analyses and visual displays such as maps. For example, Manne et al. (2012) demonstrated through the use of the geostatistical clustering metric Getis-Ord Gi(*)d that changes in spraying periods would achieve stronger results for the vector control of Chagas Disease in Guatemala (Manne, 2012). In another study by Noor, 2004 a geospatial analysis method, kriging was conducted with Kenyan health management information system data finding imperfect datasets with missing data and be reliably predicted using appropriate geostatistical techniques (MEASURE, 2014b; Noor, 2004).

This paper presents three case studies from MEASURE Evaluation's activities (see Table 1) demonstrating the utility of GIS for six of Rugg's steps, though GIS can play an important role in all eight steps. In the first case study, MEASURE Evaluation with support from the U.S. President's Emergency Plan for AIDS Relief and USAID collaborated with Rwanda's Ministry of Health (MOH). Rugg's logical framework was used to guide stakeholders to create geospatial analyses to support planning, implementation and monitoring of programmatic goals and activities. The primary objectives for the National HIV plan are the reduction of HIV incidence by 50%, decreases in morbidity and mortality due to HIV and increasing the quality of life of those affected by or living with HIV. Female sex workers, serodiscordant couples and children were selected as the priority groups. Key programmatic activities include mobile testing, health care provider training, increased provision of health insurance and reproductive services. Program outcomes are reductions in risky sexual activities, and thus reduction in HIV transmission.

The second and third cases studies are in Tanzania and Jamaica where MEASURE worked with local partners implementing programs based on the Priorities for Local AIDS Control Efforts (PLACE) method. The PLACE method is designed to control and abate HIV/AIDS prevalence by identifying and explaining HIV transmission patterns (Weir, 2002, Weir, 2003, Weir, 2004; Weir, 2005; Van Damme, 2012). In the PLACE method geospatial data and analyses are a key component in visualizing programmatic coverage, distribution of resources and gaps in services. The PLACE program is implemented in regions with consistently elevated HIV prevalence where previous interventions have shown a highly targeted approach may be more effective than previously implemented regional approaches. In addition to implementing the PLACE method, geospatial analyses were used in Jamaica's St. James parish for a Randomized Control Trial of the PLACE method.

Table 1: Overview of MEASURE Evaluation Projects that show how GIS can support Rugg's stairstep M&E

Case Study	Objective
Rwanda National HIV Prevention Plan Evaluation	Support Rwanda Ministry of Health in their preparation for 2015 evaluation of National HIV Prevention Plan
Tanzania HIV Program Evaluation	Identify location of HIV hotspots and mapping of prevention services in Iringa district
Jamaica PLACE Study	Identify HIV transmission patterns in Jamaica

<u>Rugg's stairstep GIS implementation examples:</u>

<u>Step One: What is the Problem?</u>

For Rugg's first stairstep, simple GIS maps can be utilized to view pertinent information about a particular feature, such as a district or facility or to create basic maps of site locations. Maps are also an effective medium to identify the spatial distribution of targeted populations and the patterns of prevalence.

In Tanzania and Jamaica, locations where MEASURE implemented the PLACE program, Rugg's Step One was similarly implemented. Key informants including local business owners, governmental and health officials and AIDS committee members were asked to identify high-risk locations such as clubs, schools and hotels. Interview questions included where do the following targeted populations go to seek new sex partners and engage in sexual activities or inject intravenous drugs: 1) young women and older men; 2) sex workers; 3) men who have sex with men; 4) migratory workers and 5) military service members. Locations were listed until no new sites were identified. Next, sexual and injecting drug use network sites were categorized according to the number of times they were identified in interviews. Handheld GPS devices were then taken to these locations to record their coordinates (aerial photographs and hand-drawn maps can also be used and then digitized in GIS). Maps were then created of the most high-risk locations for HIV transmission (see Figure 2 for an illustrative example using fabricated data) according to the total times sites were identified in interviews. The maps show there are clusters of areas with multiple high-risk sites and areas with primarily low-risk sites.

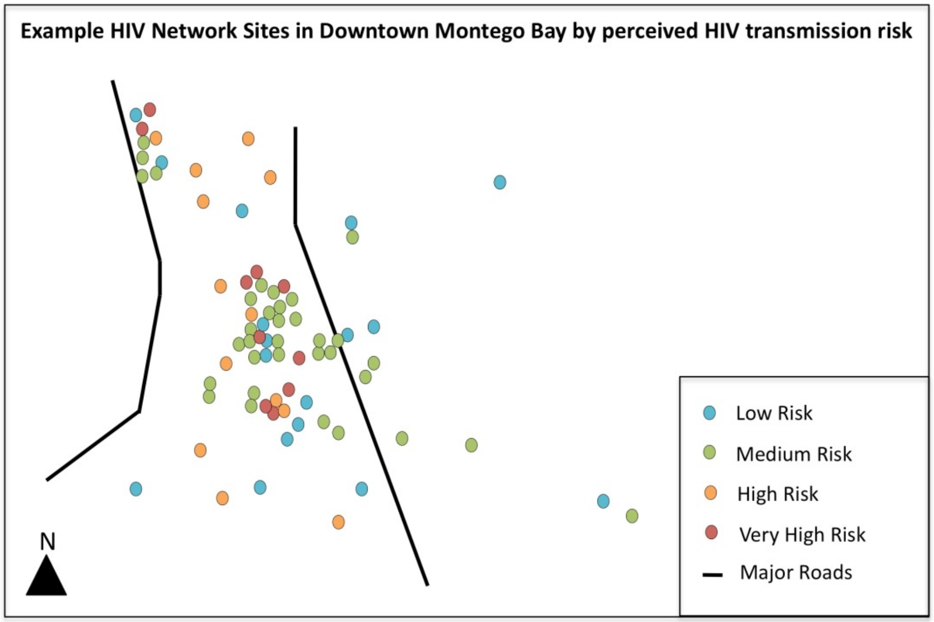

Figure 2: Example Sites for a PLACE study

In Rwanda Demographic and Health Surveys (DHS), the National AIDS Control Commission, TRACnet (an organization created by the Rwandan MOH and Research AIDS Center to collect, store and manage data) and the Youth Behavioral Surveillance Survey datasets were compiled. The free and open-source program QGIS 1.7.0 (Quantum GIS Development Team, 2004) software was used to georeference (e.g. code with geographic data such as latitude and longitude coordinates) these datasets and create a series of choropleth maps of priority groups and their HIV incidence. Choropleth maps are a simple visualization of univariate change over a selected geographic region, such as HIV prevalence by youth (shown in Figure 3), population density, male to female ratios, average years of education or per-capita income.

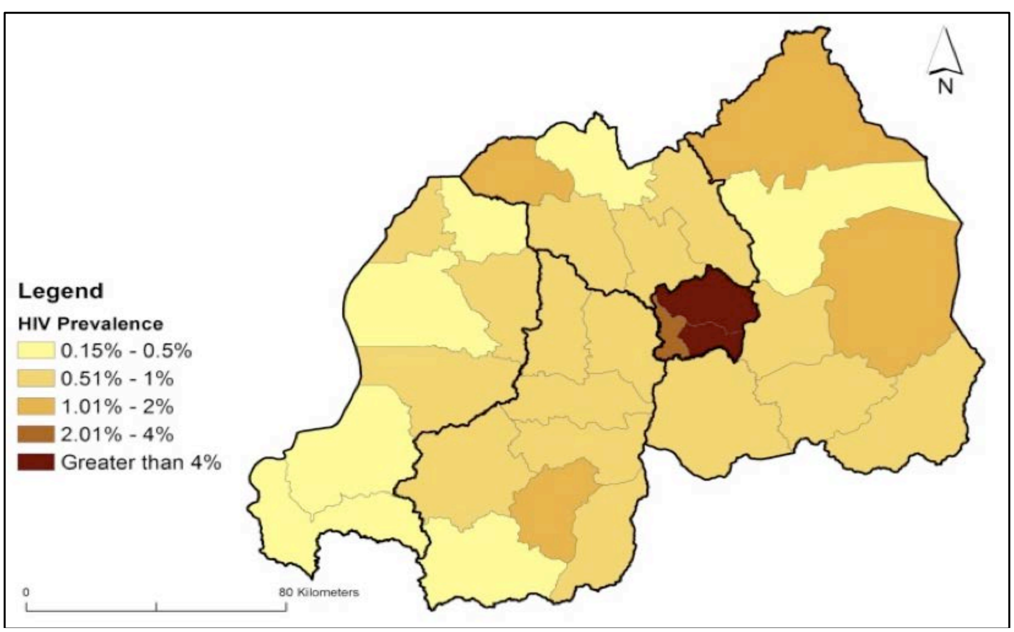

Figure 3: Overall prevalence of HIV among youth in Rwanda by District

Step Two: What are the Determining Factors?

Linking health outcomes (e.g. disease incidence, prevalence, transmission rates) to contextual data (e.g. poverty, education level, income, population) is the key activity for Rugg's Step 2. Data on contextual factors affecting interventions are rarely found in one dataset, thus multiple contextual datasets must be managed and integrated with programmatic data. Breaking down such data silos and simply managing the data necessary can be challenging without a framework to guide the collection, joining and management of the data. Geospatial tools such as GIS are often thought of as a map-making applications, however their real power is their ability to manage and link multiple data sets using spatial context. GIS uses unique geographic identifiers such as district or city names to effectively connect datasets and easily manage complex data linkages. Once data is linked, the spatial distribution of multiple contextual factors and outcomes can be quickly and easily analyzed and displayed in a real-world context for evidence based decision-making (MEASURE, 2012; MEASURE, 2014a, MEASURE,2014b).

In Rwanda, facility data was geographically linked to governmental districts. This allowed for the production of outcome-based maps by a given district, province or health care facility. Geospatial analyses were used to identify the populations; which would have the greatest impact on HIV prevalence reduction. To do this, contextual factors such as population and gender were linked to district level HIV prevalence and then summarized using GIS. This basic analysis showed HIV prevalence is higher among young women than young men in all provinces. Next, analyses from the Rwandan Ministry of Health's Demographic Health Surveys (DHS) found unmet family planning needs for women increase with poverty and reduced education. To identify areas with the highest unmet needs, GIS was used to link DHS Family Planning and education data with the National Institute of Statistics of Rwanda's poverty data. Figure 4 shows women outside of the city of Kigali have lower education levels and greater poverty than women inside the city, thus the highest unmet need. To highlight these areas, color-coded circles showing intensity of unmet need were added to the map (MEASURE, 2014c).

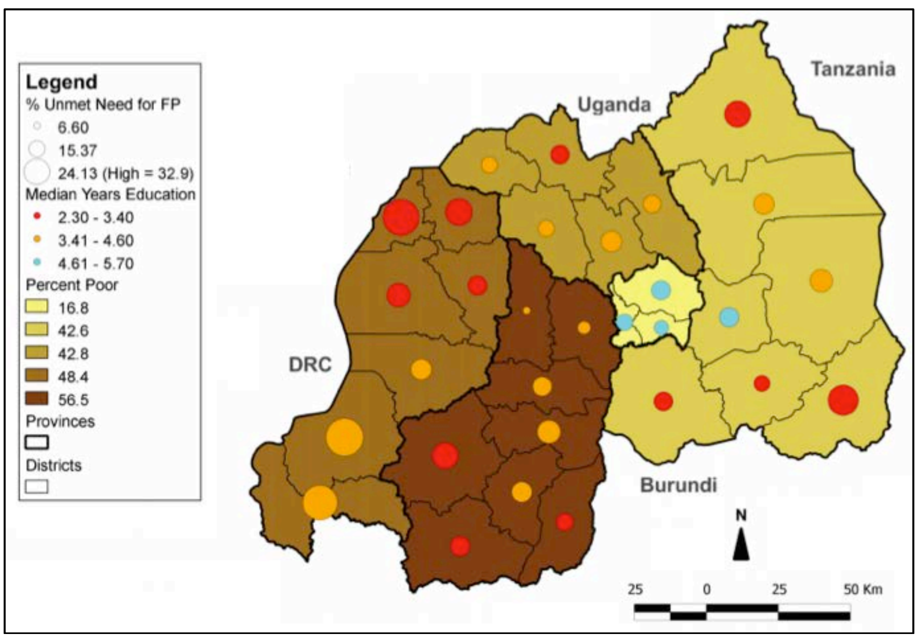

Figure 4. Rwanda Unmet Need for Family Planning among Women Age 15-49 vs. Educational Attainment by Women and Poverty (MEASURE, 2014c.)

In Tanzania and Jamaica for Rugg's Step Two, determinants that increase transmission and services available (or lack thereof) were recorded at each site HIV transmission site. Data collected included: a) type of venue, b) condom availability, c) number of staff, d) maximum occupancy, e) patron demographics (ratio of female to male, sexual orientation, age, employment status, residence, etc.), f) regular patrons, g) evidence of AIDS prevention programs and h) whether partners are met. At the most high risk sites, teams were also sent to conduct HIV and STI testing and interview targeted populations such as sex workers.

Step Three: What interventions can work?

Access to and distribution of services have an inherent relationship to geographic location. Human populations, health problems and facilities are usually unevenly distributed in space (Kandwal, 2009; Nash, 2009) and understanding not only the geographic distribution but the context of the surrounding areas can be a vital component to understanding health issues. The ability of GIS to store and input spatial data, to conduct multi-faceted analyses and output numeric and visual results has been recognized as a considerable decision making tool in creating public health goals and identifying the scale of disparity in a population's access to health care (Noor, 2004). These analyses can identify patterns in the data, such as coverage of general or specific health services in relation to need, access (e.g. distance to major roadways) and how service programs are related to communities, to one another, and to the larger health infrastructure. Furthermore, GIS data can be quickly updated to highlight areas of concern and once an infrastructure has been created, it can easily be converted to surveillance of other outcomes (Srivastava, 2009)**.**

Simple analyses can be utilized to identify coverage patterns: areas of overlapping services, and gaps in service. In Rwanda gaps in coverage were determined by creating a map with the districts and health facilities. A buffer analysis was then performed on the health facilities to determine overlapping coverage and identify areas without coverage. Figure 5 shows there is inequality of distribution of services, where some areas have multiple facilities clustered together (shown as red circles) and other regions do not have any accessible service coverage. To increase coverage, some facilities could be moved to locations without coverage, or new facilities could be opened in locations without coverage.

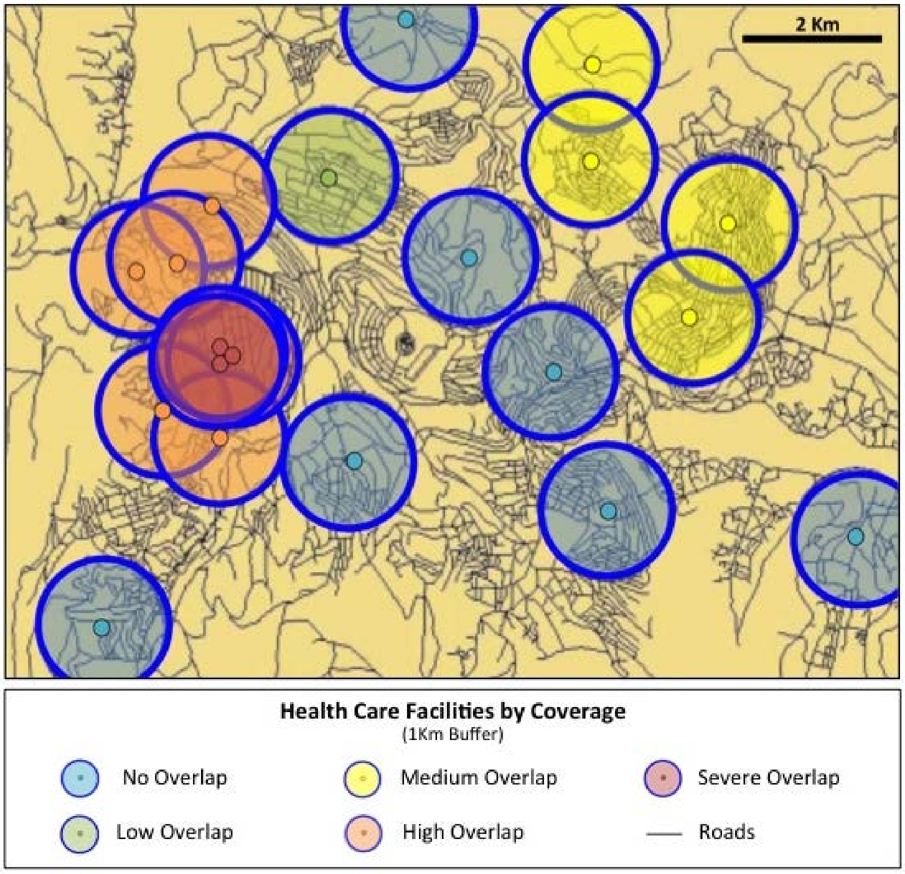

Figure 5. QGIS Hypothetical Catchment Areas for Health Facilities in Kigali, Rwanda Using Circular Buffers with a 1-Km Radius (MEASURE, 2012)

In Jamaica and Tanzania, high-risk venues were categorized by availability of condoms shown in Figure 6. The map shows most sexual network sites are not providing condoms. Furthermore, there does not seem to be a unique pattern or clustering of condom availability, contrarily, the there is widespread unavailability of condoms at sites. These maps were then used to ensure condom delivery services go to the correct locations. The maps were also shared with local stakeholders to help inform action plans for districts to respond to site behaviors and services.

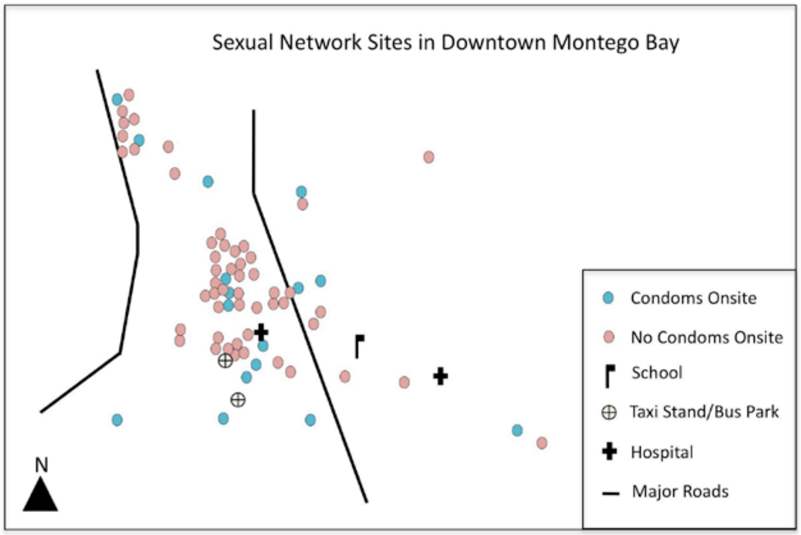

Figure 6: Sexual Network Sites in St. James Parish categorized by type and condom availability

Step Four: What interventions and resources are needed?

For programs to be successful, underserved areas and sub-groups must be identified. Interventions must then be implemented in locations where the need is the highest and target populations can most easily be impacted. GSAs serve an important role in categorizing areas and specific sites so programs can efficiently implement interventions and distribute resources.

The use of family planning services is a decision made in the context of societal and cultural norms and access to basic needs such as food and water. In this context, food security data can facilitate programmatic understanding of family planning needs and support integrating interventions. For example, interventions can be designed to concurrently address food security issues and unmet family planning needs. To further understand areas of unmet need and determine interventions and resources needed in Rwanda, a GIS analysis linked unmet need for family planning to women's food insecurity and nutrition (see Figure 7). Overall, this analysis demonstrated a low association between food security, nutrition and unmet Family Planning needs. The map also shows high food insecurity and low nutrition is more prevalent in the southern districts of Rwanda, while unmet Family Planning need is highest in the districts along Rwanda's borders.

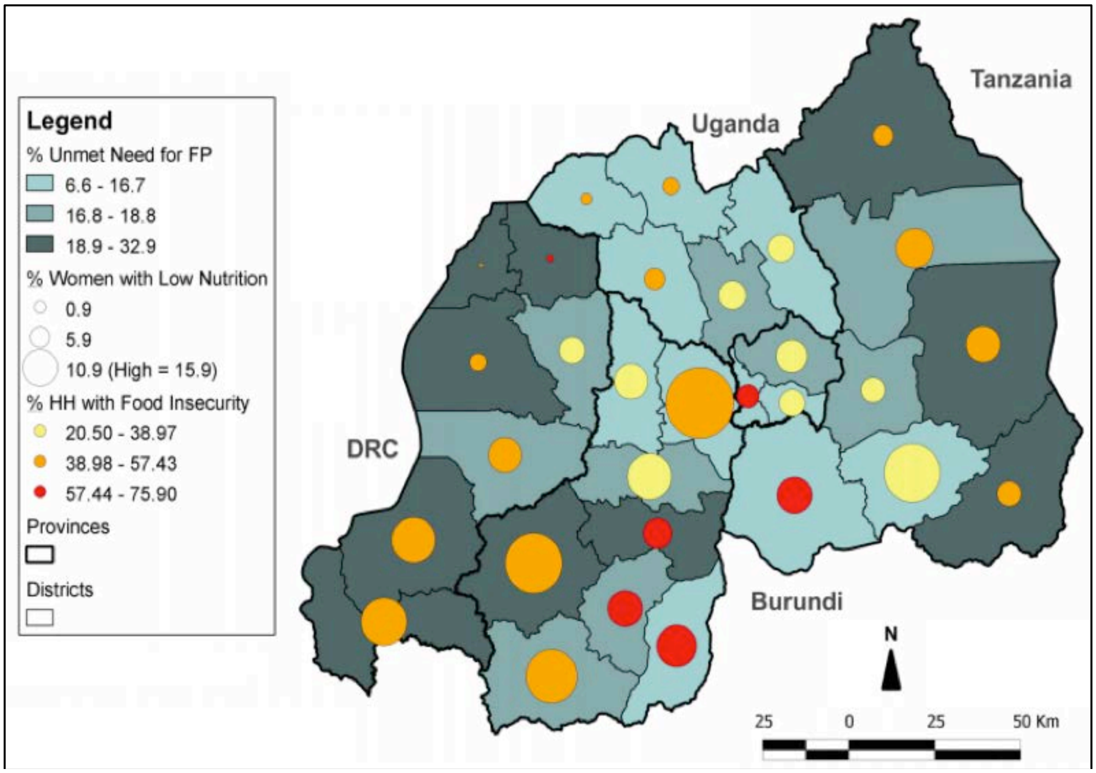

Figure 7: 2010 Unmet Need for Family Planning among Married Women Age 15-49 vs. Low Nutrition among Women Age 15-49 (BMI < 18.5) and Food Insecurity in Households from Sept 2007-February 2008 in Rwanda (MEASURE, 2014c)

Step Five: What are we doing, are we doing it right?

Knowing where interventions and programs are is a key part of being able to understand what is being done and whether it is being done correctly. The most obvious role for GIS in this step is through its ability to produce maps of intervention locations, however the tool can help answer this question even if no map is produced. It is possible in a GIS to link programmatic data using geography; the resulting data can be linked to other contextual data to provide a comprehensive picture of an area and its interventions.

As discussed earlier, using GPS devices and paper maps, MEASURE Evaluation in conjunction with implementers in Iringa Region of Tanzania interviewed key local informants to identify the location of HIV transmission hotspots as well as the reach of United States Government (USG) supported implementing partners' efforts (e.g. prevention of mother to child transmission, male circumcision, voluntary counseling and testing, care and treatment, home-based care, and orphans and vulnerable children services) (MEASURE, 2002). After being uploaded or digitized using GIS, this information was linked to the reported number of people receiving prevention services per USG program and overlaid to identify coverage patterns, areas of overlapping services, and gaps in service. In general services were concentrated along major roads or in high-population areas. Similar services from different facilities tended to overlap in urban areas. Reach for prevention of mother to child transmission programs was extensive, while treatment and voluntary counseling and testing services were concentrated in the more densely populated areas. By identifying transmission hotspots and existing services these maps provide insight for planning and managing prevention and treatment services.

In Rwanda, data on Family Planning services implemented by the USAID DELIVER PROJECT was linked to the existing Rwandan Health Management Information System (HMIS) (See Figure 8). These data sets were easily connected through matching district geographic identifiers. Using GIS, Family Planning services were summarized for each district as couple years protection (CYP). CYP is measure of provision of health services, such as condom distribution multiplied by a conversion factor to estimate the amount of time a couple will be protected by the commodities distributed by the center. More details can be found in the report (MEASURE, 2014c) but geospatial tools identified inconsistencies across geographic regions in the relationship between CYP and family planning distribution. The maps can serve to assist decision makers better answer the question raised in Step 5 “What are we doing?” by providing maps showing FP use as well as “Are we doing it right?” by producing maps that showed instances where CYP did not match family planning uptake.

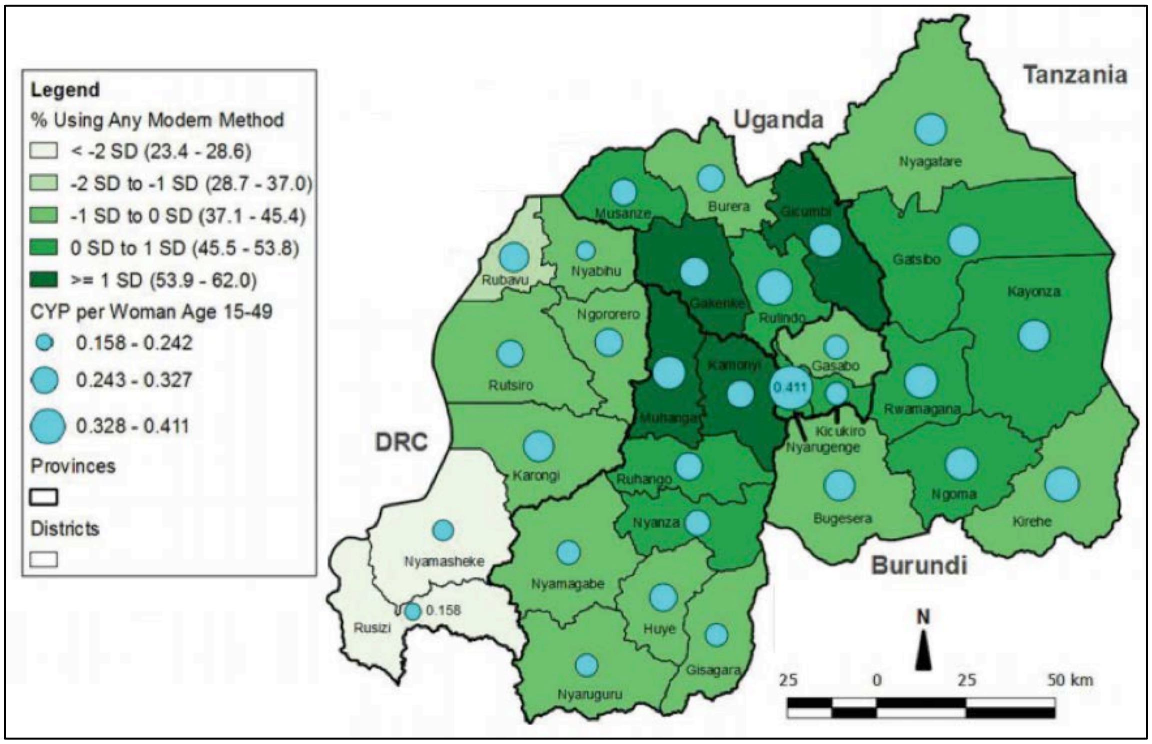

Figure 8: Rwanda by District: Percentage of Married Women Age 15-49 Using Any Modern Method of Contraception vs Couple Years of Protection from Modern Contraception Methods Normalized by Estimation District Population for Women Age 15-49 (MEASURE, 2014c)

7: Are Interventions Making a Difference?

In Rugg’s Step 7, the effect of the intervention on disease risk is evaluated. GIS can be used to conduct all analyses for Step 7, or as a stepping stone to reduce geographic bias in an evaluation. For example, GIS can be used for the simple selection of geographic clusters for case and control clusters to ensure the comparability of the case and control sites. Or in a more comprehensive analysis as was conducted by Manne, 2012 in a retrospective analysis of vector control efforts in the fight against Chagas Disease in Guatemala. Using the geostatistical clustering metric Getis-Ord Gi(*)d, Manne demonstrated the interventions achieved declines in infections and changes in spraying periods would achieve even stronger results (Manne, 2012).

At MEASURE Evaluation, geospatial analysis was an important part in evaluating the effect of the PLACE program on decreasing the spread of HIV in potential high transmission areas in Kingston, Jamaica (Figueroa, 2010). As mentioned previously, locations that were considered potential high transmission sites (bars, hotels, clubs, etc.)

were mapped. Next, GIS was used to classify each site as intervention or control (Figueroa, 2010). Intervention sites received additional condoms and other materials promoting safe-sex. Mapping was an important part of site selection because it helped identify locations with the highest risk behavior and ensure the selection of the control and intervention sites were not geographically biased.

Conclusion

The strengths of geospatial tools are well suited for M&E, regardless of the M&E approach used, and can be useful in mitigating a particular M&E method's inherent weakness. For each step of Rugg's framework, GIS has the ability to produce maps and data products and the creation of links between discrete data sets to facilitate evaluation. This paper has presented examples that highlight the role GIS can play in several of Rugg's steps.

For many users, GIS is seen as purely a mapping tool and this capability by itself would make GIS a valuable M&E tool. Maps are an effective medium to present the complex data collected during the M&E process. GIS can facilitate M&E at the planning stages of an intervention, during the monitoring stage and during the evaluation stage. Prior to the onset of the intervention, geospatial tools and data can help with selection of intervention populations. During the monitoring and evaluation phase, data from the program can be mapped, linked with other data and analyzed using spatial analysis techniques. Arguably though, the most useful contribution to M&E that geospatial tools can make is the technology's ability to manage data and make linkages through the use of a common geography. It is these capabilities that make it such an effective tool for M&E.

We believe GIS' role in M&E will also rapidly increase in importance with the availability of the software and data. However it is important to stress that GIS can't just magically fit into an M&E environment, accordingly we present the following recommendations for use of geospatial tools:

1) **Include geographic identifiers in programmatic data** – in order to use data in a GIS, it must have a link to geography. This can be something as simple as district or community name or could be coordinates collected using GPS receivers or from a digital globe such as Google Earth.
2) **Adhere to data standards for both geographic identifiers and programmatic data**. Many countries have standardized unique identifiers and spellings of geographic features in their country. Following these standards will make it easier to link datasets. Programmatic data should follow relevant standards for metadata, indicator selections and other key factors.
3) **Be open** – Making programmatic data widely available, makes it easier to employ that data in other evaluations. There are confidentiality and security issues that must be considered, however the growth of the open data movement offers promise to M&E.
4) **Build organizational capacity to use GIS first:** Before asking stakeholders to share data, it is critical they have the necessary skills to use GIS technology, and their own data, within their own organizations. Ensuring the training has a practical use builds ownership and supports effective data-sharing.
5) **Develop a strong logic framework:** Linking data through GIS is feasible without a logic frame. However, a robust logic frame is critical to ensure a clear linkage between program activities and the output and outcomes indicators associated with these program activities. It is essential that GIS users not only understand GIS technology, applications, and use, but also the need for a sound logic framework to justify the data linkage--as well as how to use linked data to support decision-making
6) **Continue to build the evidence base:** More research and better data are needed to improve understanding of the drivers of risk for vulnerable populations. For instance, all women aged 15 to 24 are not uniformly at risk for HIV infection, and further research is needed to understand the specific characteristics and risk behaviors to effectively target these women with prevention interventions. Similarly, serodiscordant couples may need different approaches, depending on which partner is

infected. In addition, more data are needed on such marginalized groups as men who have sex with men (MSM) to develop appropriate programs and activities and ensure adequate coverage of these populations.

While the growing complexity of the public health environment may complicate M&E, it also provides an opportunity to create more effective assessments. The increased number of programs also corresponds to an increased availability of data and as a result there is generally more data available at both the programmatic level as well as the contextual level to support M&E. Effective M&E in such an environment requires tools, methods and techniques that can effectively manage the complexity. Geospatial tools such as geographic information systems (GIS) offer the ability to manage these complex data environments and facilitate their analysis to support M&E. We believe there is an opportunity to use these tools to support M&E of public health programs that is not fully being taken advantage of. M&E practitioners may not be aware of the potential strengths of geospatial tools and conversely, GIS professionals may not be aware of the potential that exists to apply their tools in support of M&E in the global public health environment.

References

1. *Creating spatially defined databases for equitable health service planning in low-income countries: the example of Kenya.* A.M Noor, P.W Gikandi, S.I Hay, R.O Muga, R.W Snow.2004. Acta Tropica. V91:3
2. *Health GIS and HIV/AIDS studies: Perspective and retrospective.* Rashmi Kandwal, P.K. Garg, R.D. Garg. Journal of Biomedical Informatics. V42:4. 2009.
3. Identification of malaria hot spots for focused intervention in tribal state of India: a GIS based approach. Aruna Srivastava**,** BN Nagpal**,** PL Joshi**,** JC Paliwal**,** AP Dash. *International Journal of Health Geographics* 2009, 8:30.
4. *Strategies for More Effective Monitoring and Evaluation Systems in HIV Programmatic Scale-Up in Resource-Limited Settings: Implications for Health Systems Strengthening.* Nash, Denis, Elul, Batya, Rabkin, Miriam, Tun, May, Saito, Suzue, Becker, Mark, Nuwagaba-Biribonwoha, Harriet. 2009. JAIDS Journal of Acquired Immune Deficiency Syndromes.
5. Weir, S. S., et al. "A pilot study of a rapid assessment method to identify places for AIDS prevention in Cape Town, South Africa." *Sexually Transmitted Infections* 78.suppl 1 (2002): i106-i113.
6. Weir, Sharon S., et al. "From people to places: focusing AIDS prevention efforts where it matters most." *Aids* 17.6 (2003): 895-903.
7. Weir, S. S., et al. "Where the action is: monitoring local trends in sexual behaviour." *Sexually transmitted infections* 80.suppl 2 (2004): ii63-ii68.
8. Weir, S. S., J. Tate, and S. B. Hileman. "Priorities for local AIDS control efforts: a manual for implementing the PLACE method." *Chapel Hill, NC: Carolina Population Center* (2005).
9. Van Damme, Lut, et al. "Preexposure prophylaxis for HIV infection among African women." *New England Journal of Medicine* 367.5 (2012): 411-422.
10. Rugg, Deborah, et al. "Global advances in monitoring and evaluation of HIV/AIDS: from AIDS case reporting to program improvement." *New Directions for Evaluation* 2004.103 (2004): 33-48.
11. "Quantum GIS Development Team (2004). Quantum GIS Geographic Information System 2.0. Open Source Geospatial Foundation Project. http://qgis.osgeo.org.
12. MEASURE 2012 GIS Data Linking to Enhance Multi-sectoral Decision Making for Family Planning and Reproductive Health http://www.cpc.unc.edu/measure/publications/sr-12-74
13. Figueroa, J. Peter, et al. "The challenge of promoting safe sex at sites where persons meet new sex partners in Jamaica: results of the Kingston PLACE randomized controlled trial." *Tropical Medicine & International Health* 15.8 (2010): 945-954.

14. *Triatomine Infestation in Guatemala: Spatial Assessment after Two Rounds of Vector Control*. Manne, Nakagawa, Yamagata, Goehler, Brownstein and Castro. Am. J. Trop. Med. Hyg., 86(3), 2012, pp. 446–454
15. MEASURE *Evaluation* Bulletin. Number 4, 2002. Using the PLACE Method to Monitor AIDS Prevention Programs at the District Level in Tanzania *Tanzania PLACE Study Group*.
16. Tatem, Andrew J., et al. "Mapping populations at risk: improving spatial demographic data for infectious disease modeling and metric derivation." *Popul Health Metr* 10.8 (2012).
17. Renger, Ralph, et al. "Geographic information systems (GIS) as an evaluation tool." *American Journal of Evaluation* 23.4 (2002): 469-479.
18. Wakode, Hemant Balwant, et al. "Morphometric analysis of the upper catchment of Kosi River using GIS techniques." *Arabian Journal of Geosciences* 6.2 (2013): 395-408.
19. MEASURE. 2014a. MEASURE Evaluation Capability Statement: Geographic Information Systems for Developing and Maintaining Master Facility Lists. Accessed at: http://www.cpc.unc.edu/measure/publications/fs-14-134b. Last accessed 9/2/14.
20. MEASURE. 2014b. Mapping Community-Based Global Health Programs: A Reference Guide for Community-Based Practitioners. Accessed at: http://www.cpc.unc.edu/measure/publications/ms-13-76. Last accessed 9/2/14.
21. MEASURE. 2014c. GIS and HIV: Linking HIV Databases in Rwanda. A Case Study. Accessed at: http://www.cpc.unc.edu/measure/publications/sr-14-86 . Last accessed 9/2/14.

22. Basic Terminology and Frameworks for Monitoring and Evaluation. UNAIDS. 2010. Accessed at: http://www.unaids.org/en/media/unaids/contentassets/documents/document/2010/7_1-Basic-Terminology-and-Frameworks-MEF.pdf. Last accessed 9/2/14

MEASURE Evaluation

Carolina Population Center
400 Meadowmont Village Circle, 3rd Floor
Chapel Hill, NC 27517

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