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## **Improving Food Security and Empowerment with SSHiNE GIS**

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## **Abstract**

The South Sudan Health, Nutrition, and Empowerment Geographic Information Systems (SSHINE GIS) was developed as an online mapping application that integrates information about health facilities, food distribution, infrastructure, and socioeconomic data. The goal of this system is to improve the health and nutrition of women and children under five years of age within the states of Northern Bahr-el-Ghazal and Warrap in South Sudan. As part of the multidisciplinary approach to develop SSHINE GIS, a comprehensive health facility assessment (HFA) was conducted combining survey data with latitude and longitude coordinates for each identified health facility. Data was analyzed for spatial patterns and results revealed an uneven distribution of health facilities across the region. Majority of health facilities reported high volumes of children diagnosed with malaria, however, less than 40% reported the distribution of insecticide treated bed nets. This paper will describe the methodology and challenges in developing SSHINE GIS web services and discuss the outcome of the project.

**Key Words:** South Sudan Health, Nutrition, and Empowerment (SSHINE) Geographic Information Systems (GIS), Health Facility Assessment

## Introduction

Decades of unstable government rule and internal conflict have prevented the establishment of basic resources including an effective health care system in South Sudan. As a result, the South Sudanese people have experienced some of the worst health outcomes in the world (*Country Cooperation Strategy for WHO and Sudan*, 2009). In addition, many unstable areas lack sustainable food and water resources thus increasing vulnerability to malnutrition. In 2006, a Sudan Household Health Survey conducted by the Ministry of Health (MoH) and the Central Bureau of Statistics (CBS) found a neonatal mortality rate of 52.4 per 1,000 live births, an infant mortality rate of 102.4 per 1,000 live infants, and an under-five mortality rate of 135.3 per 1,000 children; rates approximately 20% higher than northern Sudan statistics (*Sudan Household Health Survey*, 2006). Furthermore, northern and southern Sudan, as a whole, suffers from a maternal mortality rate of 1,107 deaths per 100,000 live births. However, rates in several South Sudan states (i.e. Northern Bahr-el-Ghazal and Warrap) are over twice this rate with more than 2,000 maternal deaths per 100,000 live births (*Sudan Household Health Survey*, 2006). A 2004 UNICEF report stated that a girl born in Southern Sudan has a better chance of dying in pregnancy or childbirth than completing primary school (Kimanzi, 2004).

In 2006, a MoH report (as cited in United States Agency for International Development [USAID], 2007, p. 32) identified 691 health care facilities throughout Southern Sudan. A 2008 report from United States Agency for International Development (USAID) estimated 750 – 800 functional health facilities within the same area (USAID, 2008). Although the actual number of health facilities may vary by source, there is a general consensus that most facilities are usually inadequately staffed, lack proper supplies, and depend highly on the assistance of non-government organizations (NGOs) to function. Furthermore, according to USAID, only 25 – 30% of the Southern Sudanese population has even minimal access to available healthcare services (USAID, 2008). Inadequate and unequally

distributed health care facilities contribute to the continuing cycle of high morbidity and mortality among the population. Unfortunately, efforts to provide underrepresented areas with basic health services have been thwarted by continuing tribal violence and northern hostility. For example, a 2011 attack by the Murle against the Lou Nuer tribe in Uror County (northern Jonglei state) resulted in at least 640 deaths, 861 injured, and 208 missing or kidnapped (*“Hundreds Killed in South Sudan’s Jonglei State,”* 2011). In addition, an estimated 3,421 houses and one international humanitarian medical hospital were burnt during the conflict. Such attacks escalate the public health crisis in this resource-poor region and require increased humanitarian aid, government intervention, and security for future resource development.

The Southern Sudan Health, Nutrition, and Empowerment (SSHINE) project is a two-year collaborative maternal and child health program led by the Adventist Development and Relief Agency (ADRA). The program’s goal is to improve the health and nutrition of vulnerable women and children less than five years of age in the Southern Sudan states of Northern Bahr-el-Ghazal and Warrap. The SSHINE project aims to improve the health and nutrition of this population by accomplishing three strategic objectives: 1) reduce malnutrition in children less than five years of age, 2) decrease prevalence of illness (especially childhood diseases), and 3) enhance women’s household economic empowerment and their leadership role within the community. As a subset of the SSHINE program, the South Sudan Health, Nutrition, and Empowerment Geographic Information System (SSHINE GIS) project was established to help guide SSHINE’s multidisciplinary approach to its three program objectives. Specifically, SSHINE GIS was designed to assist with the field assessment process by conducting a health facility assessment (HFA) survey and creating a system to analyze, store, and share the resulting data with program partners to support the decision making process.

The SSHiNE GIS project uses geospatial technologies to integrate several forms of data (i.e. local healthcare and community based facilities, training and distribution sites, infrastructure, and socioeconomic data) to create a web-based GIS application for the SSHiNE program that provides a virtual platform to share decisive data and geographical maps with partners and stakeholders. This paper will discuss the SSHiNE GIS project as a two-part approach, which includes the health facility assessment process followed by the creation of the web-based GIS application with the ultimate goal of improving health, nutrition, and empowerment for women and children in South Sudan.

### **Methodology**

As part of the multidisciplinary approach to improve health, nutrition, and empowerment for women and children in South Sudan, a HFA was conducted in the two states of Warrap and Northern Bahr-el-Ghazal (Figure 1) to evaluate the capacity of the functioning health facilities. Within these two states, the SSHiNE program focused on ten payams in Northern Bahr-el-Ghazal: Ariath, Ayat East, Bar Mayen, Gomjure Center, Malual East, Malual North, Mariem West, Myocawany, Panthou, and Wathmuok; and nine payams in Warrap: Alek South, Aweeng, Gogrial, Kuac North, Nyang, Toch East, Toch North, Turalei, and Wunrok. All other payams in the two states were eliminated due to security concerns.



*Figure 1: Map of project and assessment areas*

### **Health Facility Assessment Survey**

The HFA survey was created by the partnering team at Johns Hopkins University. This survey was later modified to its final version by the South Sudan field data collection team. The final HFA survey include the following sections: general facility information, staffing information, services, infrastructure, equipment functionality, drug and supply availability, and protocol and documentation review. This paper will only report on results for the services, drug and availability supplies, and protocol and documentation review sections.

**Enumerator training.** Training on the use of field data collection technologies was conducted in August 2011. The training occurred at the South Sudan Hotel compound in Aweil, Northern Bahr-el-Ghazal on August 14 and 15. A total of 12 local MoH workers, or data enumerators, were trained on the principles and practices of conducting HFA surveys using a combination of both electronic and manual methodologies. Each participant was trained on how to use the Trimble Juno ([www.trimble.com](http://www.trimble.com)) field data logger with integrated Global Positioning

Systems (GPS), digital camera, and ArcPad 10 ([www.esri.com/software/arcgis/arcpad](http://www.esri.com/software/arcgis/arcpad)) as the mobile mapping software. A customized ArcPad 10 form was created to collect a selected number of attributes from the HFA survey (date, time, facility identification number, payam name, and county) in addition to the latitude and longitude coordinates, a field for a photo of the facility, the name of the data enumerator, and the date of entry. After this information had been captured, the enumerators were instructed to manually complete the paper-based HFA survey by interviewing the appropriate health facility personnel. It was important for the enumerators to include the health facility identification number on the paper-based surveys so that the data saved on the Trimble Juno units could be linked with the appropriate survey and the data could be digitally merged at a later date.

Enumerators were naturally familiar with the local geography and were able to identify the number and location of the primary health care units (PHCU), primary health care center (PHCC), and hospitals in their MoH service area. Through a verbal report by the health professionals attending the workshop, a total of 62 PHCUs, PHCCs, and hospitals were recorded.

### **HFA Data Collection**

After the training, the 12 enumerators were distributed equally among the two states (six enumerators per state), then divided further into three groups (two enumerators per group) and assigned a varying number of health facilities depending on the size and accessibility of the targeted area. Enumerators were given 10 working days to survey each assigned health facility, however, due to unexpected circumstances; a few surveys were completed after the allotted time frame. Throughout the HFA data collection process, the enumerators were supported by SSHiNE GIS staff. As completed surveys were submitted from the enumerators to the SSHiNE GIS staff, the data was immediately prepared for the web-based GIS application. The HFA survey collection process was completed on August 29.

## **Web-based GIS Application Development**

**Data inventory.** In order to determine the most up-to-date and reliable data and avoid duplicating work, it was essential to evaluate current availability of geospatial data (i.e. geography, demographics, and transportation network) within the project's focus area. An initial inventory of existing data revealed that there was limited up-to-date data and even less geographic-based data available for the country of South Sudan. A basic online search of geographic-based data resulted in two categories availability: 1) data was available as shapefiles and ready for download; or 2) data was referenced in a report or an existing map but not available for download. The later scenario was often the result of a previous organization's effort to create an inventory of all existing datasets within specific regions. All the applicable shapefiles were downloaded and imported into ArcMap 10. Shapefiles were compared against similar datasets from other sources and the most detailed and reliable shapefiles were used to create a basemap of the targeted SSHiNE areas. A map document (.mdx file) was created with country, state, county, and payam polygons; city, town, settlement, and pooling stations points; and road and waterway lines. All attempts to obtain geospatial data from local government sources were unsuccessful.

**HFA data preparation.** A database was created in Microsoft Access 2010 to store the digitized HFA survey responses and merge with the data saved on the Trimble Juno GPA unit. When creating the database, each HFA survey question was assigned an attribute number and coded to fit within the Microsoft Access column title specifications. To identify the specific HFA survey question associated to the attribute number, a codebook was created for reference. All responses on the paper-based HFA survey were manually entered into the Microsoft Access database. When necessary, numerical values were assigned to survey responses (i.e. yes, no responses) for easy identification and analysis. Data from each Trimble Juno Pocket PC unit was imported to the Microsoft Access database and merged with the HFA data based on the assigned facility identification number. After

all information were entered, merged, and organized in the Microsoft Access database; the data was imported into IBM SPSS Statistics 20 and ArcMap 10 for statistical and spatial analysis, respectively. Data was later used to create a web-based map hosted at the following location: <http://maps.llu.edu/SSHINE/>.

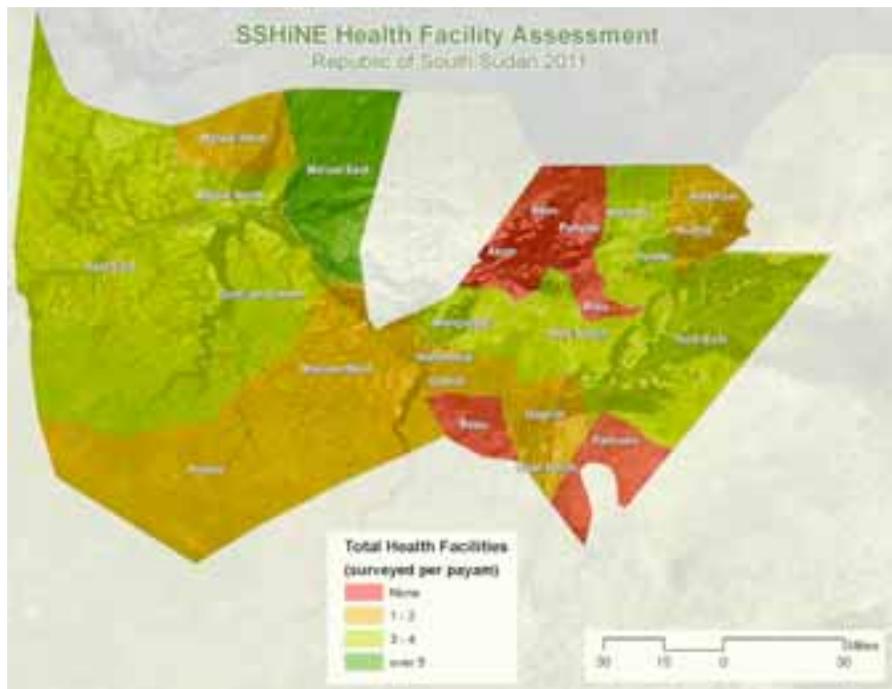
**Web GIS application development.** Using the ArcGIS server, ArcGIS web service was created to publish the ArcMap document. As a first step in the process, a file geodatabase was created to manage the aforementioned datasets including the HFA data. Spatial and attribute indexes were created in the map service for increased speed and performance. The data generated is on a file geodatabase and it is published as web services by an ArcGIS server. The map layout was authored by using ArcMap 10 in a desktop environment. The data generated stands on a file geodatabase and it is published as web services by an ArcGIS server – which resides in a Windows server running Internet Information Services (IIS). To provide a rich user experience, the client application uses Adobe Flash technology to render the map on a web browser. A JavaScript version is being tested to provide map access for a wider range of devices, particularly targeting the ones that will not render Flash objects. To provide a global reach, wider platform compatibility, ease deployment and update, the SSHiNE data maps were created in a context of Web GIS where the maps produced can be available through web pages.

## **Results**

### **Health Facility Assessment**

A sum of 33 PHCUs, 17 PHCCs, and two hospitals (52 facilities total) were surveyed by the enumerators for the SSHiNE GIS project. The number of surveyed health facilities varied across the targeted payams (Figure 2). Thirty health facilities (57.7%) were located in Northern Bahr-el-Ghazal and 22 health facilities (42.3%) were located within Warrap. Gomjure Center and Malual East,

located in Northern Bahr-el-Ghazal, were the payams with the largest number of surveyed facilities (6 health facilities in each payam). Detailed results can be found in Appendix 1.



*Figure 2: Total health facilities surveyed per payam*

**Frequency and type of services.** Surveyed health facilities reported on the frequency of services provided by health facility staff on a daily, weekly, monthly, and quarterly basis, if at all. Acute respiratory infection (ARI) case management was the most common service provided on a daily basis (84%), followed by sick-adult consultations (82%) and identification of malaria and treatment of non-complicated cases (82%), diarrhea case management and treatment (80%), sick child consultations (78%), and treatment of injuries (72%). Refer to Appendix 2 for details.

**Drugs and supply availability.** Surveyed health facilities reported on the quantity and condition of a list of select health care supplies, if available. Among the surveyed health facilities, 94% reported the lack of candles, 90% reported the lack of partographs, and 24% reported an insufficient supply of hand soap or detergent. In addition, among the surveyed health facilities, 86% reported condoms as the most common family planning “drug” consistently available for the past 30

days. The PHCC in Gogrial was the only health facility to report the availability of Lo-Fem, intrauterine devices, or implants as an alternative family planning method. In terms of malaria treatments, 69% of health facilities reported Sulphadoxine with Pyrimethamine/Fansidar, 55% reported doxycycline, and 46% reported Artesunate Combination Therapy with Coartum as essential drugs consistently available for the past 30 days. Less than 35% of surveyed health facilities reported the availability of pediatric anti-malarial preparations. Detailed results for this section of the HFA can be found in Appendix 3.

**Protocol and documentation review.** Surveyed health facilities reported on the total number of deliveries, maternal deaths, and neonatal deaths both in the facility and in the community for the three months prior to the HFA survey. Among these surveyed health facilities, over 50% reported assisting with at least one delivery within the facility over the months of May, June, and July 2011. One or more in-facility maternal deaths were reported by 8% of the health facilities for the month of May and July and reported by 14% for the month of June 2011. Similarly, one or more in-facility neonatal deaths were reported by 8% of the health facilities for the month of May, reported by 16% for the month of June, and reported by 20% for the month of July 2011.

Surveyed health facilities reported malaria, pneumonia, and diarrhea patient cases and treatment numbers in children less than five years of age. Among surveyed health facilities reporting malaria or fever cases in register of children less than five years of age, 100 cases or less were reported by 59% of health facilities in May, 50% in June, and 47% in July 2011. Furthermore, among surveyed health facilities reporting malaria cases of children less than five years of age treated with first line anti-malarial drugs, 100 cases or less were reported by 60% of health facilities in May and June, and 55% in July 2011. Figure 3 represents the geographic location of each surveyed health facility and the number of reported monthly malaria cases in children less than five years of age. See Appendix 4 for detailed results for this section of the HFA.

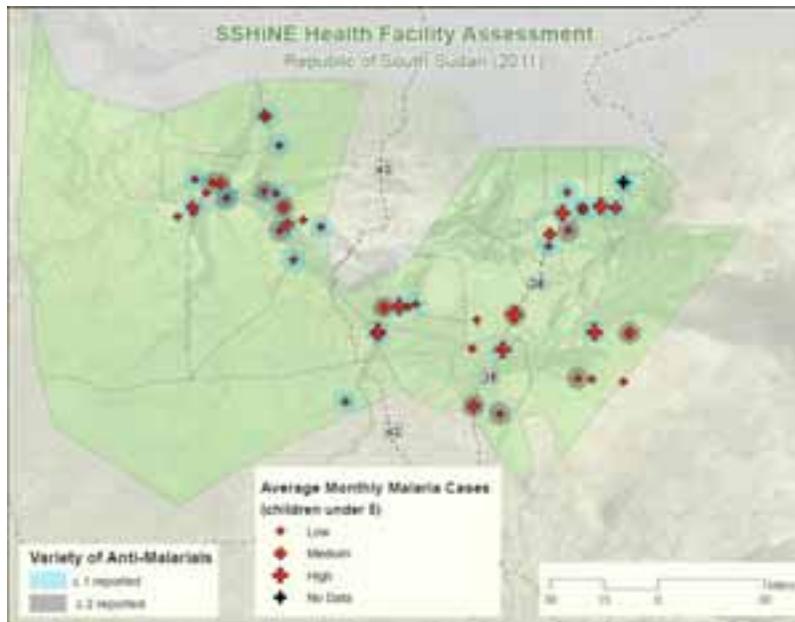


Figure 3: Average monthly malaria cases in children under 5 years of age

### SSHINE GIS Web Application

The data aggregated for the SSHiNE GIS database contains health facilities, training sites, airfields, and other generic supplemental map data, totaling more than 30 layers of map data. Each layer has a corresponding check box that can turn on or off the visibility of the layer in the map. The health facilities, training, pooling stations and airfields layers can show additional data in a popup menu when clicked directly on the representing icon. Additionally, there is the option to dynamically select and search the health facilities layer with capabilities of showing charts from the corresponding data. The National Geographic world map is being used as primary base map because of its appropriate cartography for this project, and as an option, the base map can be changed to show satellite imagery from Esri or BING Hybrid maps.

A widget was created to compare health facilities and/or activities between the different geographic areas. It is also possible to view details of each health facility, such as trained staff, services, hours of operation, a photo of the facility, etc. Additionally, it is also possible to print and save maps or create bookmarks for certain areas for presentation purposes.

## **Discussion**

In the two-part approach, the SSHiNE GIS project completed a HFA field survey followed by the creation of the web-based GIS application. In this first part, the descriptive data revealed a majority of surveyed health facilities to lack essential supplies and pharmaceutical drugs despite the regional need. A majority of surveyed health facilities reported a high volume of malaria in children five years in age and younger, yet few health facilities distributed insecticide treated nets or had an adequate supply of pediatric anti-malarial preparations. The finding of inadequate facilities and high volumes of patients was a theme found across the two states which is consistent with other findings (Carlstrom, 2011; Green, 2012). In the second part, the web-based GIS application created using the collected HFA data proved to be a tool to help analyze, store, and share the resulting data with program partners. These results have made it easier for program leaders to view and understand the current health landscape in South Sudan in a way that will help make mediate critical program decisions.

It is important to note that, during the data collection process, severe weather conditions limited travel between different health facilities and prevented the enumerators from reaching all 62 pre-identified health facilities.

## **Conclusion**

South Sudan is a country that lacks sufficient infrastructure including transportation and healthcare. The new government is in the transition process and international NGOs continue to lead the aid response as an increasing number of communities with an expanding amount of internally displaced individuals seek aid. Limited funds must be utilized to an optimal state to ensure maximum impact. Local health facilities provided organizations with a resource in which to collect unbiased health information regarding the neighboring communities. The current project collected specific health information relevant to SSHiNE's objectives to observe descriptive data on the geographic level and share critical information with program partners through a unique web-based platform. The resulting application will help mitigate funds to the areas in most need to assist with SSHiNE's goals and, ultimately, save lives.

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## **Conflict of Interest Statement**

The authors declare no conflict of interest.

## **Source of Funding**

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## Appendix 1

List of identified health facilities in the SSHiNE program targeted area:

<b>Payam</b>	<b>State</b>	<b>Total PHCU</b>	<b>Total PHCC</b>	<b>Total Hospital</b>	<b>Total Surveyed</b>
Alek South	Warrap	1	1	0	2
Ariath	Northern Bahr-el-Ghazal	3	0	0	3
Aweeng	Warrap	1	2	0	3
Ayat East	Northern Bahr-el-Ghazal	2	1	0	3
Bar Mayen	Northern Bahr-el-Ghazal	0	1	0	1
Gogrial	Warrap	2	1	0	3
Gomjure Center	Northern Bahr-el-Ghazal	4	1	1	6
Kuac North	Warrap	1	1	0	2
Malual East	Northern Bahr-el-Ghazal	5	1	0	6
Malual North	Northern Bahr-el-Ghazal	3	1	0	4
Mariem West	Northern Bahr-el-Ghazal	1	0	0	1
Nyang	Warrap	1	0	0	1
Nyocawany	Northern Bahr-el-Ghazal	1	1	0	2
Panthou	Northern Bahr-el-Ghazal	0	2	0	2
Toch East	Warrap	2	1	0	3
Toch North	Warrap	1	0	0	1
Turalei	Warrap	1	1	1	3
Wathmuok	Northern Bahr-el-Ghazal	2	0	0	2
Wunrok	Warrap	2	2	0	4
<b>Total</b>		<b>33</b>	<b>17</b>	<b>2</b>	<b>52</b>