The Use of Geospatial Technology to Survey Urban Internally Displaced Persons

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Introduction

The Tufts University GIS Center recently partnered with the Feinstein International Center at Tufts University and the Internal Displacement Monitoring Centre (IDMC) to develop techniques to gather information on urban internally displaced persons (IDPs) in conflict-affected countries. Internally displaced persons are "persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalised violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized State border." (IDMC, 2008). Large population migrations of displaced persons to a city stress nearly every area of city's infrastructure and resources. Stress can begin at the local, neighborhood level and can eventually expand to the municipal, state, national, and even regional level. To allocate resources effectively, we must understand the socio-economic background and the spatial distribution of the urban IDPs.

The study conducted household surveys of urban IDPs in Khartoum, Sudan (January 2007); Abidjan, Côte d'Ivoire (May 2007); and Santa Marta, Colombia (February 2008) (see Fig. 1). The survey was conducted by trained local researchers in the official language of the countries and sought to gather socio-economic information on urban IDPs. Khartoum has experienced a significant influx of IDPs largely from the Darfur region of Sudan. In Abidjan, displaced persons have largely fled to the city as a result of the violence and instability from the northern portions of Côte d'Ivoire starting in 2000 and increasing dramatically in 2002. In Santa Marta, displaced persons have been migrating from the rural portions of Colombia since the 1990s largely as a result of conflict between government forces, anti-government insurgents, and paramilitary groups.

Tufts GIS Center utilized geospatial technology in the planning and implementation of the urban surveys. Geospatial technology is technology used in the collection, storage, analysis, and dissemination of geographic information, which in our survey included GIS, GPS, remote sensing, cartography, virtual globe software, printed maps, and database management systems (DBMS). This paper will examine the best practice methods and techniques of utilizing geospatial technology to survey internally displaced persons in the cities of Abidjan, Côte d'Ivoire and Santa Marta, Colombia (see Table 1 for list of geospatial technology used). We first used geospatial technology in the Abidjan survey and then improved many or our methods in the Santa Marta survey. Because of the lack of available data and resources, we used very little spatial technology in the survey of Khartoum.

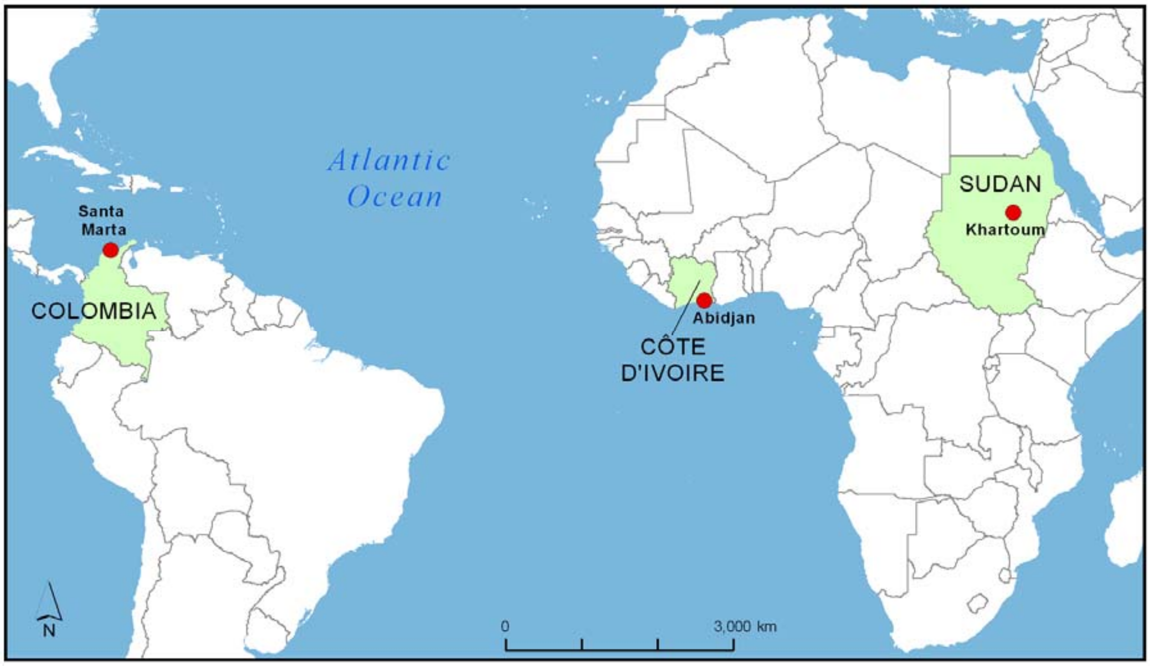

Figure 1. Overview map of cities surveyed.

The survey had two primary objectives (Jacobsen, 2008):

1. Develop a methodology that would allow us to make population estimates of IDPs within the defined urban area
2. Enable a comparison of the demographic and livelihood characteristics of IDPs and Non-IDPs

In order to accomplish these objectives, we used geospatial technology to help answer two fundamental questions:

Where in the cities do we survey?
How do we determine the location of survey respondents?

Locating the survey respondents was critical to understanding the spatial distribution of IDPs within the cities. As a result, we used geospatial technology in three phases of the study: strategic planning for determining where to survey, tactical planning for field data collection, and analyzing the data.

The study faced several challenges in locating and mapping the survey respondents.

1. Logistics
   Navigating an urban terrain can be difficult. Maps often do not exist or are inaccurate or incomplete. Streets are often unmarked, and the winding dirt roads of shanty towns can be disorienting and confusing. Furthermore, some areas are insecure or unsafe.
2. Unavailability of GIS data
   Often the required GIS data does not exist or access is refused by government agencies. In both Abidjan and Santa Marta we had to purchase the necessary data

from a third party vendor and also spend significant time developing/converting data because the national agencies refused to give us the requested datasets.

3. Locating the invisible
   Urban IDPs live alongside the urban poor and economic migrants and intentional seek anonymity for security reasons; they do not want to be seen. Therefore, identifying high density IDP areas can be challenging.

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Software	**Hardware**
ArcGIS http://www.esri.com/	5 Garmin GPSmap 76units
Google Earth (free), requires high speed Internet access http://earth.google.com/products.html	Personal Computer
Hawth's Tools (free) http://www.spatialecology.com/htools/tooldesc.php	Printer with extra printer cartridges
DNR Garmin (free) http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html	Video Projector (not used but recommended)
Arc2Earth http://www.arc2earth.com/default.htm	
MS Access	

Table 1. Geospatial and information technology used.

Strategic Planning Phase

The strategic planning phase consisted of the following:

- Data Acquisition and Development
- Data Modeling and Design
- Sampling Strategy

Data Acquisition and Development

The first step in strategic planning is identifying the spatial data resources needed for the survey. Project researchers wanted a target sample of 1000 households and chose to employ a systematic random sampling technique known as PPS (probability proportional to size). In order to use this technique we needed to acquire detailed census administrative geography boundaries and the accompanying household and population data. These data would become our enumeration areas and allow us to incorporate each city's national census data in the analysis of our survey results. Unfortunately, this type of spatial data is often the most difficult to acquire.

The national statistical agency of Côte d'Ivoire is the Institut National de la Statistique (INS) and for Colombia the Departamento Administrativo Nacional de Estadistica (DANE). These agencies possessed the census geography boundaries we needed for both Abidjan and Santa Marta; however, we could not acquire the data from these agencies within an adequate time frame for the project. Our requests were denied. For Abidjan we were able to acquire a digital map of the *quartier* boundaries (see Fig. 2), so we georeferenced the map and digitized and encoded the *quartier* boundaries. This data conversion effort required around twenty-five hours of technician work. While not an ideal scenario, we absolutely needed these boundaries to be able to use the their national census data at the urban level within a spatial context. For Colombia, we purchased data from a third party vendor that included administrative census geography at the *barrio* level along with streets, hydrography, etc.

In order to see what was on the ground in the selected survey areas of each city, high resolution satellite imagery was necessary to help revise or sampling strategy. Purchasing such imagery was deemed cost prohibitive; however, were were able to instead use the QuickBird imagery available within Google Earth for our study areas. We also acquired street and hydrographic data for both Abidjan and Santa Marta in order to assist with the data collection efforts. Table 2 lists all of the spatial data sources used in the urban IDP surveys.

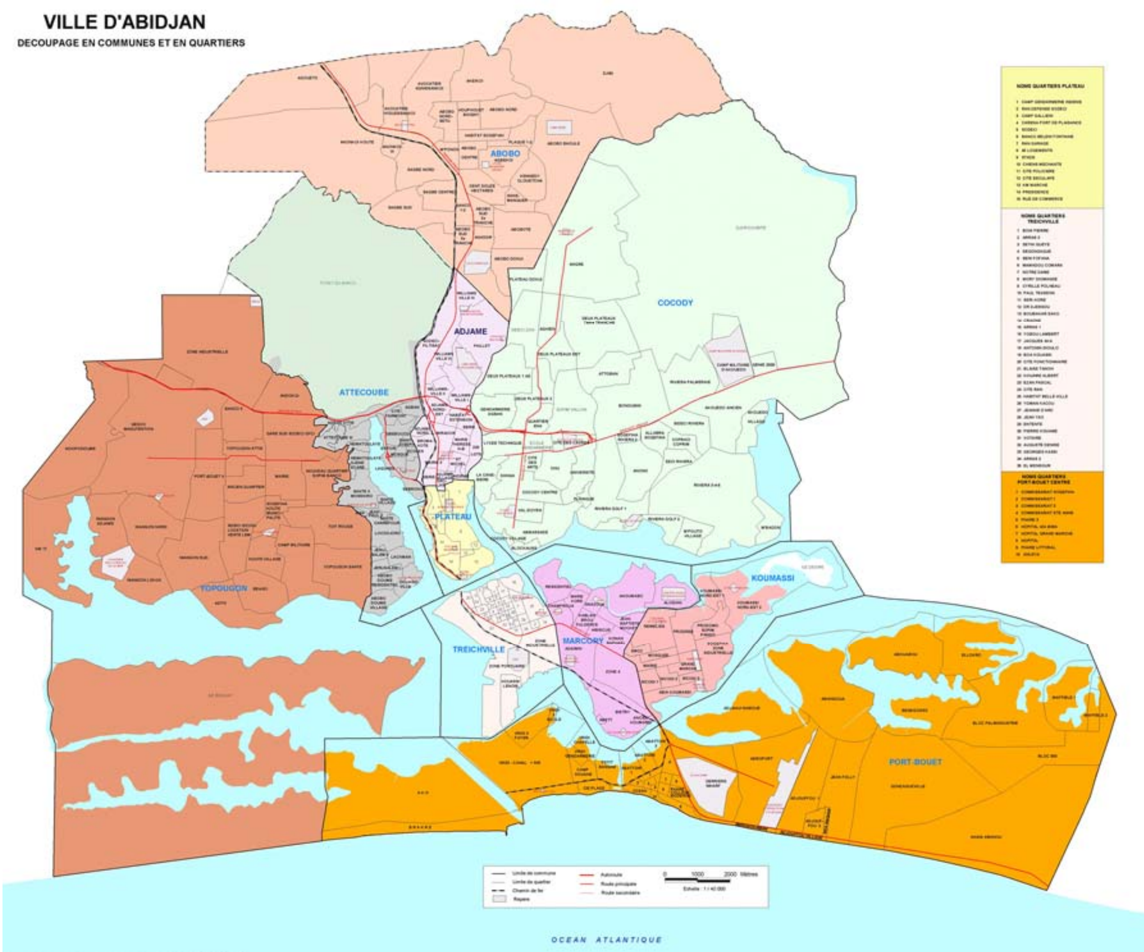

Figure 2. Map of Abidjan *quartier* and *commune* boundaries used for digitizing.

We also needed to record the origins of the IDPs. This required acquiring spatial data such as a gazetteer of populated places or administrative boundaries for municipalities, districts, states, etc. for the entire country. We did not acquire these administrative boundary data for Abidjan prior to the survey, but we did for our third survey in Colombia. Fortunately we were able to acquire the DANE data free of charge from GIST (DANE, 2007). We also used this data as a look-up table directly within our survey questionnaire.

Spatial Data	**Extent**	**Source**
Quartier boundaries	Abidjan	Digitized and derived from Institut National de la Statistique (INS) map
Commune boundaries	Abidjan	UNOSAT
Streets	Abidjan	UNOSAT
Hydrography	Abidjan	UNOSAT
Quickbird imagery	Abidjan	DigitalGlobe via Google Earth
Barrio boundaries	Santa Marta	Geobis International
Streets	Santa Marta	Geobis International
Hydrography	Santa Marta	Geobis International
Quickbird imagery	Santa Marta	DigitalGlobe via Google Earth
Municipios boundaries	Colombia	DANE via GIST
Departamentos boundaries	Colombia	DANE via GIST

Table 2. Spatial datasets used within the IDP surveys.

Data Modeling & Design

The data modeling consisted of structuring and organizing of our survey data in such a way that allowed the integration of the survey questionnaire, GPS data, and GIS data for use within a database management system (DBMS). One of the challenges was to ensure the integration of the geocodes of the surveys. In other words, how do we tie the surveys to their spatial location and store that data for use in a DBMS and GIS?

We utilized two techniques for linking the surveys to their location: recording the enumeration area (*quartier* or *barrio*) code on the survey and recording the GPS coordinates of the location on the survey. For the Abidjan survey, we included a section on the questionnaire for the enumerator to record both the *quatier* number and the higher level geography *commune* number. This allowed us to join the survey data back to the original *quartier* and *commune* boundaries to map the locations of the survey and perform analysis. Essentially we aggregated the survey data by *quartier* (see Fig. 3). While this technique proved successful, we found that it was often difficult for the enumerators to determine the correct enumeration area in which they were surveying. *Quartier* boundaries often coincide with streets, rivers, mountain ranges, etc. Clearly one does not see or encounter an administrative boundary in the real world. In urban settings, many streets or pathways are often unmapped or unmarked, so locating oneself can be quite difficult; it is particularly difficult in shanty areas with dirt roads and trails that are routinely “off the map.” As a result the enumerators can become confused and record the wrong enumeration area number (*quartier* in Abidjan).

In Santa Marta we employed an additional technique to geocode the surveys: Global Positioning System (GPS). GPS turned out to be a very easy way to document the location of the survey respondents. All the enumerator needed to do was take a waypoint and record the positional information. Although there is a positional error of around ten meters with handheld GPS, we found this much more accurate and efficient then solely recording the enumeration area number (*quartier* or *barrio*). In our data model, we included the GPS unit number, waypoint number, and the longitude and latitude in decimal degrees. The concatenation of the GPS unit number with the waypoint number served as the unique identifier for the GPS coordinate. For instance, GPS unit 05 and way point number 006 combined to form the unique identifier 05006. In addition to storing the GPS coordinate in the unit, we also recorded the GPS information on the survey questionnaire. This served two purposes: it served as a back up to the GPS unit, and it ensured that the enumerator took the GPS coordinates for each survey.

Ultimately we found combining the two approaches was most effective. For instance, we recommend recording the administrative/enumeration area(s) (*quartier* and higher level *commune* in Abidjan and *barrio* in Santa Marta) in addition to the GPS information. This allows the data to be easily aggregated by the enumeration area and also point mapped via the GPS coordinates. Furthermore, through a spatial join one can compare the accuracy of the GPS locations with the recorded enumeration area to identify positional and data entry error. The inclusion of both the enumeration area and GPS coordinates in the data model and questionnaire facilitate the locating of the survey respondents and improves the quality assurance/quality control (QA/QC).

We also decided to incorporate the origins of the IDPs in our data model and devised a look-up table to record the information in our DBMS. One crucial piece of information is where in the country the IDPs came from. In the Santa Marta survey, we populated the municipality and district information directly into the data model and questionnaire from our spatial datasets (see Table 3). These data included the unique identifier number for each municipality and district from the GIS. These unique identifiers are often called Place Codes (PCODES) within the field of humanitarian assistance. In our case these unique identifiers were also the same codes used by the Colombian national statistical agency, DANE. As a result, one could easily link the IDP origin data to the GIS and also easily incorporate other DANE data during analysis. Essentially we established referential integrity to the place of origin data. If referential integrity is not established and one allows free entry in the questionnaire, the data become virtually useless. Often many duplicate city/town names occur within one country and the variant spellings due to language and regional differences become difficult to interpret and expensive to reconcile afterwards. When modeled correctly the origin data could be used for various types of analyses. For instance, in a separate survey completed in Kebkabiya and Zalingei, Darfur, the linking of the survey data to a detailed gazetteer allowed us to create density zones of IDP origins (Young & Jacobsen, 2008) (see Fig. 4 & 5). Correctly modeling the data allowed us to perform spatial analysis on displacement distances traveled, ethnicity, and many other socio-economic indicators regarding IDP origins within a spatial context. The development of quality gazetteers of populated places is greatly needed within the field of humanitarian assistance. In short, one needs to include an authority record of cities/towns in the data model with at least one higher level administrative geography dataset (districts, states, etc.) to differentiate individual towns. These gazetteer authority records should also have the unique codes to link to the GIS data.

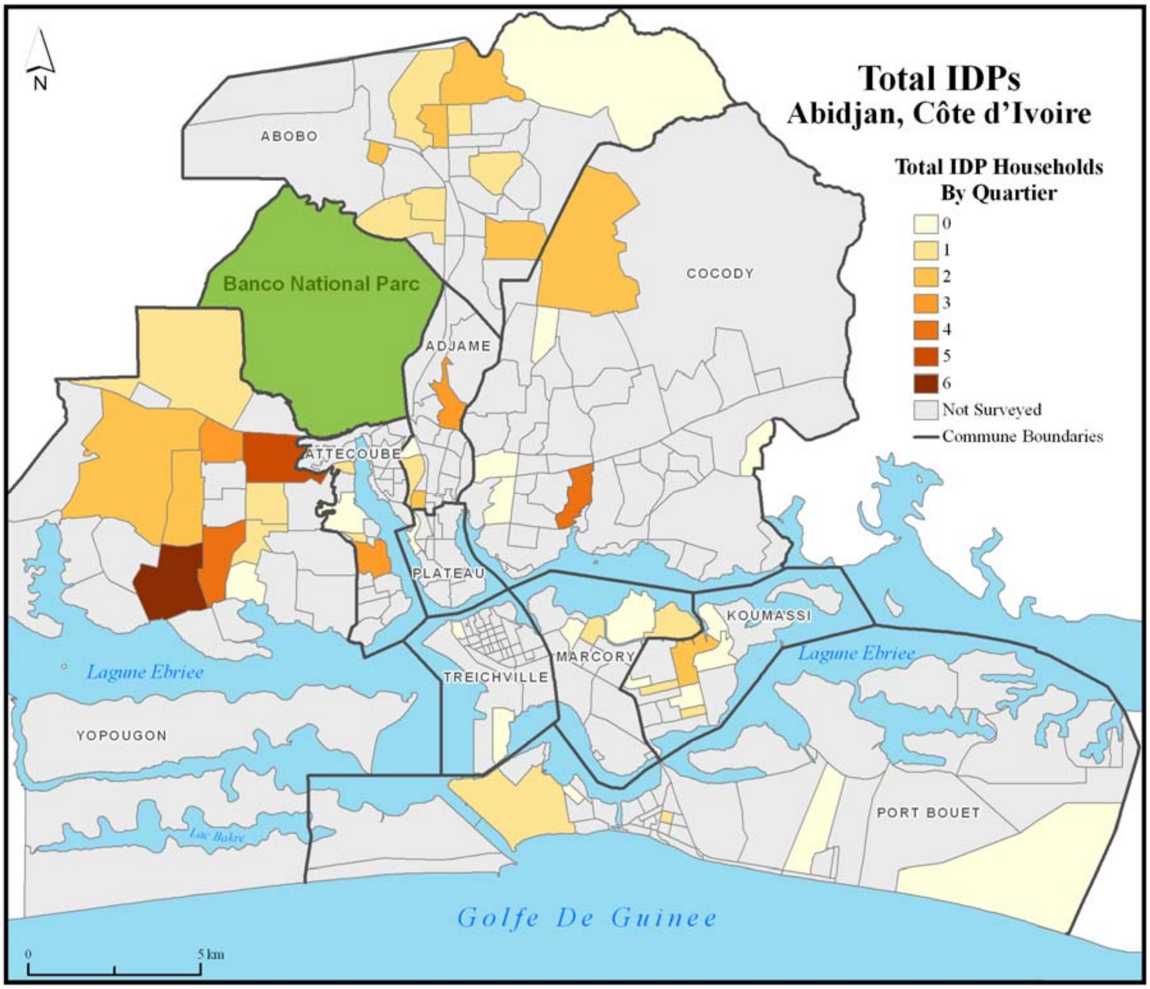

Figure 3. Map of total IDPs identified in Abidjan by *quartier*.

For the survey in Colombia, we developed a data model that incorporated the questionnaire information, survey location, and the origins of the IDPs. We also implemented MS Access as our DBMS both for data entry and storage. The development of a quality data model and DBMS saved significant time both in data entry and in the data post-processing (data cleaning). When compared to the techniques used in the Abidjan survey, I would estimate that we saved 40% in our data entry cost and at least 300-500 hours in data cleaning. It was well worth investing significant time to develop our working data model and database; it provided significant savings to the project and yielded more accurate data.

LA GUAJIRA	44		
Municipio	**Código**	**Municipio**	**Código**
Barrancas	078	Fonseca	279
Dibulla	090	Hatonuevo	378
Distraccion	098	La Jagua del Pilar	420
El Molino	110	Maicao	430

MAGDALENA	47		
Municipio	**Código**	**Municipio**	**Código**
Algarrobo	030	El Banco	245
Aracataca	053	El Pinon	258
Ariguani	058	El Reten	268
Cerro San Antonio	161	Fundacion	288
Chivolo	170	Guamal	318
Cienaga	980	Pedraza	541

Table 3. Survey questionnaire look up table of Colombian municipios and departementos with GIS codes.

Figure 4. Overview of Darfur IDP survey.

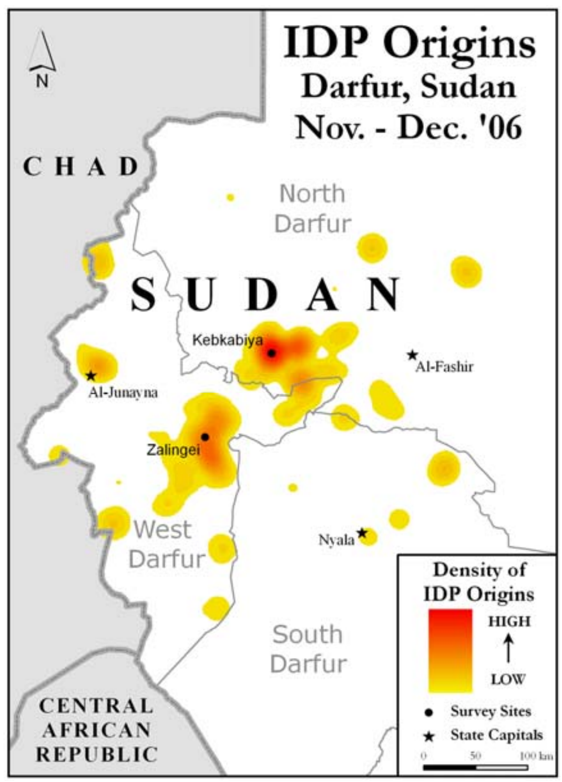

Figure 5. Darfur IDP survey results.

Sampling Strategy

Geospatial technology also proved useful in the development of a two-stage sampling strategy to survey Abidjan and Santa Marta. In the first stage, our goal was to select geographic areas (enumeration areas) to sample in both cities. We joined the household census data from the INS and DANE to the enumeration areas we acquired for both cities (*quartier* in Abidjan and *barrio* in Santa Marta). This provided us with the spatial distribution of household density across the cities. We then employed the systematic random sampling technique PPS to select the appropriate *quartier* and *barrio* for sampling. In Abidjan we selected 50 *quartier* out of 270 and in Santa Marta 49 *barrio* out of 84 (see Fig. 6).

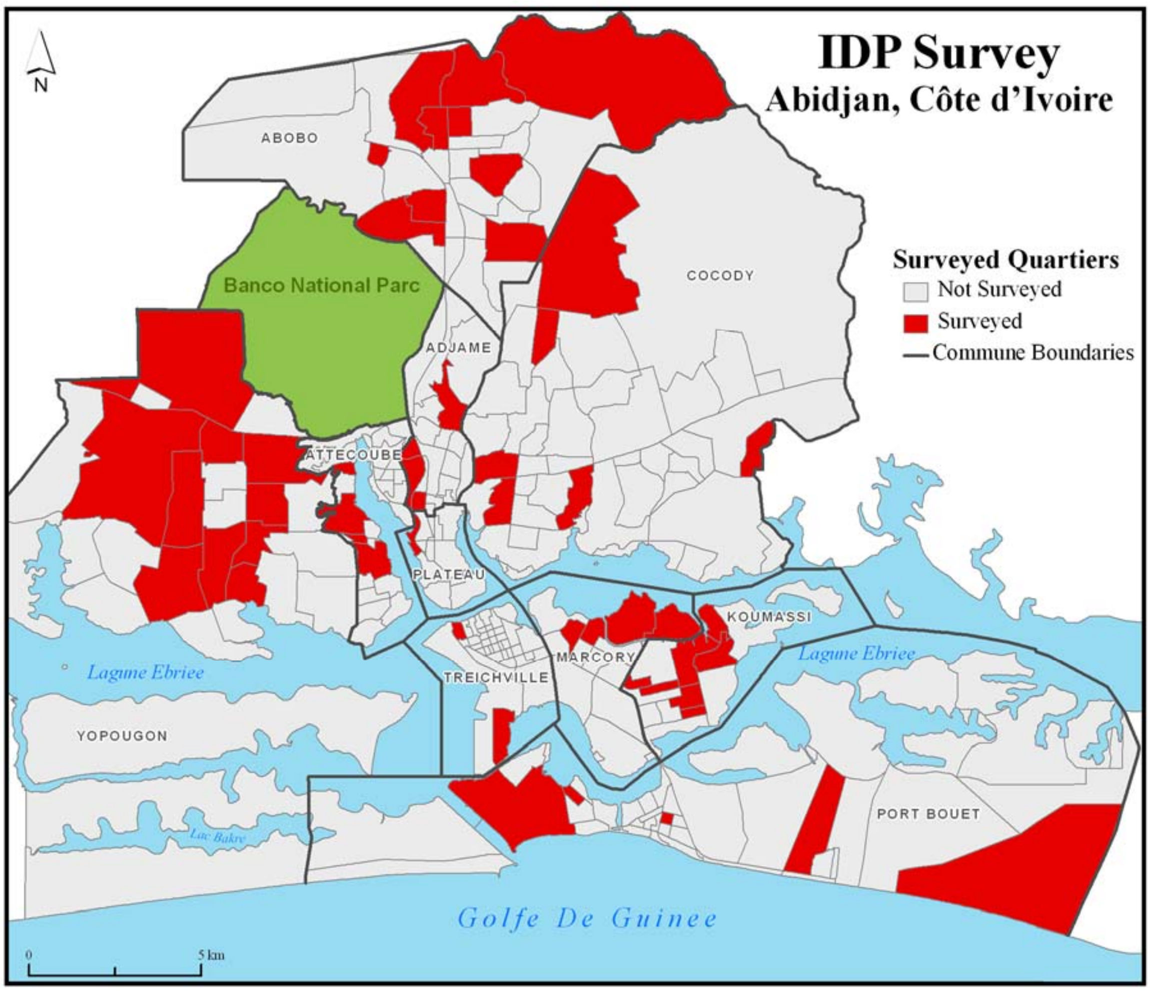

Figure 6. *Quartiers* selected for sampling in Abidjan.

We wanted to weight our survey to sample more in IDP areas, so we worked with local officials on the ground in the cities to review our selected sampling areas and modify the areas covered. Enumeration areas selected for sampling were converted from the ArcGIS format to the Google Earth format, using Arc2Earth extension for ArcGIS. This allowed the local officials to overlay the enumeration areas over Google Earth QuickBird high resolution satellite imagery and identify areas that should or should not be sampled (see Fig. 7). The name of each enumeration area and base demographic information for the local aid workers were also included. Enumerators also ranked each selected enumeration area from low to medium to high IDP density. After their review, we modified our selected enumeration areas to reflect their recommendations. The use of Google Earth in this way proved very successful as we could not afford to purchase the high resolution QuickBird imagery, and Google Earth is also very easy to use. Most of the local reviewers already knew how to use Google Earth, and those who did not learned within about five to ten minutes. Not only could we not afford the imagery to use within GIS software, but there is no way we could have purchased GIS software for the local reviewers and taught them how to use it within such a short period of time. A couple limitations should be noted. We were fortunate that the imagery for our selected cities was loaded into Google Earth; Google Earth still does not provide coverage for much of the world. Satellite imagery can also be obscured by cloud cover, limiting what one can see on the surface of the earth.

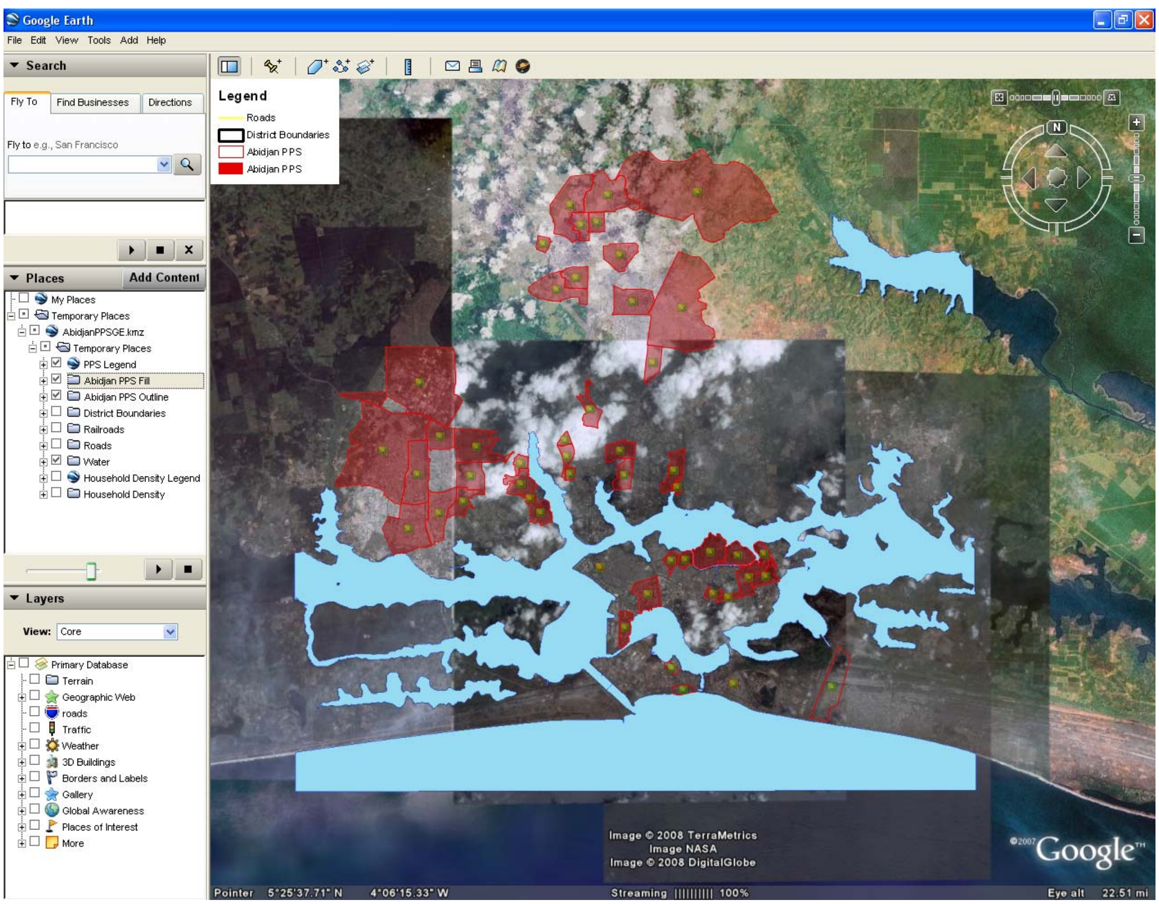

Figure 7. Selected *quartier* in Google Earth for review by Abidjan aid workers.

In the second stage of the sampling, we generated 5 random sample points within each of the selected enumeration area. (see Fig. 9). We used the free Hawth's sampling tool extension for ArcGIS to accomplish this. We then exported the sampling points into Google Earth to overlay over the satellite imagery. We had to manually move some of the points that fell within uninhabited areas such as mountain tops, heavily industrial areas, large farms, etc. We then sent an enumerator to each randomly generated sample point with the selected enumeration areas. At each sample point, the enumerator would randomly survey from 3 to 5 five households. This provided us with our target sample size of around 1000 households.

Tactical Planning and Field Data Collection

The tactical planning phase included the logistics of daily field data collection: determining selected enumeration areas to survey in a given day, planning the travel to the survey locations, and the method of recording the locations of the surveys. We used custom maps, Google Earth, and GPS for these tasks. To begin with, in Santa Marta we generated one large-format planning map (42"x 60") that displayed all the selected enumeration areas, sample points, streets, hydrography, caution areas, and no vehicle zones (see Fig. 8). This map was instrumental in our logistical daily planning both in determining where and how to go, but also in tracking the enumeration areas surveyed.

Figure 8. Santa Marta enumerators planning daily activities using the large planning map.

In Santa Marta, we also created larger scale, detailed daily maps of each enumeration area for each enumerator. These daily maps showed the sample points, streets, hydrography, etc. (see Fig. 9). We developed a template that allowed us the make the maps rapidly every afternoon for use the next day. We encountered a few issues related to making custom maps. For one thing, it required personnel with basic GIS skills and GIS software to generate them. It also required a significant amount of printing. We generated around 4 maps daily of each enumeration area for each member of the interview team amounting to 24 prints a day. As a result we went through a significant amount of paper and a couple ink cartridges. This may seem minor and insignificant; however, when one is on a tight schedule and limited budget, acquiring an ink cartridge rapidly in some locations can be difficult. When one is on a tight budget with limited amount of time, every delay is critical. I recommend bringing a printer and extra cartridges. However, the maps proved incredibly valuable. We did not make the custom daily maps for the Abidjan survey, and the manager of the Abidjan survey confirmed that the maps greatly improved the efficiency of the project and the safety of the enumerators in Santa Marta, Colombia.

We did discover that we needed to provide training on the basics of map reading and map use. In our first outing, several student enumerators became lost or disoriented, even in areas where streets were well marked and on the maps. We trained all of our enumerators, which took about 45 minutes. The training consisted of reading an overview map (inset) to get a sense of the location represented on the map in relation to the greater city area. We also explained how to use cross streets to locate their position on the maps as well as using landmarks such as parks, water bodies, etc. The basics of orientation and scale were covered as well.

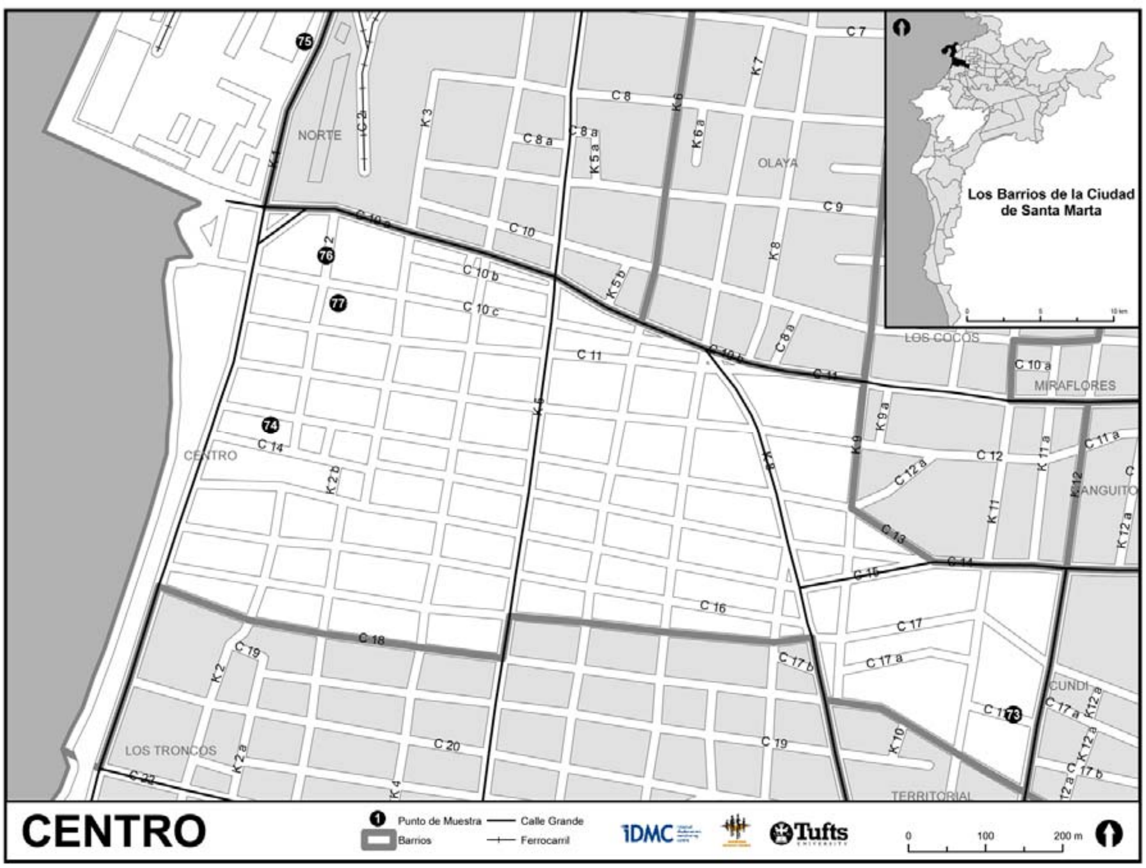

Figure 9. Map of the Centro *barrio* (enumeration area) in Santa Marta depicting random sample points.

For both the Abidjan and Santa Marta surveys we developed a custom Google Earth application to assist in daily tactical planning of field data collection. Much of the mapping data used on our custom daily maps was incomplete or missing, particularly in areas of high IPD density. This is particularly evident in shanty areas where IDPs tend to congregate. The winding dirt roads and paths are rarely depicted or labeled on maps, so the usefulness of our custom daily maps was limited in these areas. To help navigate these "off the map" areas, we loaded our sample points, enumeration areas, streets, and hydrographic data into Google Earth for use by survey staff (see Fig. 10). Through Google Earth they could zoom into unmapped areas and plan their routes, print out of these areas, draw additional streets on their daily maps, etc. The Google Earth application proved essential. Before using Google Earth, we routinely had enumerators become lost in these areas, which resulted in a loss of time, accuracy of the survey, and most importantly could jeopardize the safety of the enumerators.

Figure 10. "Off-the-map-area" in Santa Marta with streets lines depicted in yellow, random sample points as red points, and *barrio* boundaries in red within Google Earth.

We conducted around thirty minutes of tactical and logistical map planning every morning before going out into the field. The planning consisted of consulting the large planning map, the daily enumeration area maps, and the Google Earth application. This map planning saved time and money, improved data collection accuracy, and improved staff security.

The lack of accurate maps and the difficulty in interpreting and reading maps prompted us to use GPS for our data collection. We found that using GPS is much easier than trying to record the location on a map. It takes minimal training and literally consists of pushing a button and writing down a few pieces of information. For this survey, we used Garmin GPSmap 76 handheld units. We decided not to use differential grade GPS because of cost and complexity. The handheld units cost around $160 U.S. each as opposed to $600 to $2,500 for differential grade units. We also did not want our enumerators walking around with expensive equipment. The equipment can easily become lost or stolen, and we did not want to put our enumerators at risk. We also wanted to keep the data collection very simple; conducting an urban IDP survey of an entire city is complex enough as it is. Our GPS technique consisted of the enumerator taking a waypoint and then hand recording the following information on the questionnaire itself: the GPS unit number, waypoint number, and longitude and latitude in decimal degrees. Writing down the GPS information is absolutely essential. It ensures that the step of taking a GPS reading occurs, and it serves as a back up. We did provide about 45 minutes of GPS training and then tested the data collection in a pilot area. We explained the basic principles of GPS and data collection including how to take and delete waypoints, the number of satellites required, factors affecting signal strength such as tree canopy and buildings, etc. We found the GPS training and use much easier than the map use. Common problems we encountered were taking but not actually saving the waypoint and taking accidental waypoints.

A GPS unit going down in the field can be costly. If one is out in the field and has to come back to the office, that can be significant loss of time, particularly when time and money are so limited. For field use, we required that the units be charged every other day, each enumerator always have a spare set of charged batteries, and each team have a car charger. We implemented a checklist everyday before leaving the office for field work. For GPS unit selection, I recommend more affordable handheld units with multi-lingual capabilities and black and white screens to save battery life and reduce cost.

Conclusions

The use of geographic information technology in the urban IDP surveys of Abidjan and Santa Marta was a learning experience for everyone. However, with each successive survey we feel we improved our methods and techniques. The use of geospatial technology adds some cost in personnel, hardware, and data. One must weigh the cost versus the benefit of implementing these technologies. GIS can be expensive, especially when it is implemented poorly. Once improved, our use of geospatial technology reduced the overall cost of the survey while at the same time significantly improved the quality of the data collected. Our use of spatial technology also constituted much more than making maps; we ultimately used GIS as a resource management tool to manage the survey planning, design, data collection, storage, and analysis. The primary limitation implementing the technology was the lack of available and affordable GIS data and personnel. As geographic information technologies become more widespread and available, there is an ever growing demand for improved global spatial data infrastructure. It is still quite difficult to locate and acquire the necessary spatial data.

There is also an ever growing demand for professionals in the field of humanitarian assistance with geospatial skills. Universities and NGOs need to provide more training in spatial information literacy and technology.

In the city of Abidjan, our techniques yielded a conservative estimated IDP population of 299,937 - 440,414 arriving within the last six years, which compares with the estimate from a UNFPA/ENSEA study in 2005 (Jacobsen, 2008). Most IDPs live in the *communes* of Yopougon and Abobo (see Fig. 3), and the highest proportions of ethnicity are the Baoule and Guere. We also have a wealth of spatial referenced quantitative data that can be analyzed to develop a better understanding of the socio-economic and geographic characteristics of urban IDPs. The data can also be used for intervention and service planning and a variety of policy decisions. For Santa Marta, we just completed the survey and are currently processing the data. In the future, we plan to explore the interpolation and spatial distribution of IDP populations throughout the non-surveyed areas within the city as well as automated urban feature extraction from satellite imagery. We would like to also publish a recommended data model for IDP surveys for use by researchers and aid workers.

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Appendix A: The Study Team

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	William Smith
	Bradley Rawson

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Implementing Team in Abidjan

Field Supervision Eric Levron, consultant

Implementing Team in Santa Marta

Field Supervision Eric Levron, consultant