GEOGRAPHIC DATA TO SUPPORT INTERNATIONAL AID AND RELIEF: FROM GIS TO CROWDSOURCING IN A COMPLEX ORGANIZATIONAL CONTEXT

by

SHADROCK LEE ROBERTS

(Under the Direction of MARGUERITE MADDEN)

ABSTRACT

This dissertation explores how geographic data are created to support, or as part of, projects within the field of international relief and aid. Specifically, it examines the use of traditional geographic information systems (GIS) and documents the first use of crowdsourcing by the U.S. Agency for International Development to explore the values and challenges of different modes of production. This work also details common organizational contexts encountered while working in international relief and aid: this context exerts a significant influence on how geographic data are produced, managed, and distributed yet is rarely examined in literature regarding GIS for relief and aid projects.

INDEX WORDS: Relief, Aid, Humanitarian, International Development, GIS, remote sensing, geography, geographic data, crowdsourcing

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2016

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December 2016

DEDICATION

First and foremost, this one is for the Original and Expanded Master Cluster. Working in nebulous organizational environments and deep within the machine of bureaucracy can be absolutely soul destroying if you don't have support: you guys were always there when I needed a hand, a scene, or a contact. Thank you.

I would also like to dedicate this work to the many tireless volunteers who have assisted me and many other humanitarian practitioners with their dedication, innovation, and energy. Volunteering during the 2010 Haiti Earthquake was a life changing experience on many levels and in the "crisis mapping community" I found people who have become friends and colleagues. The first forum at which I was able to talk about my work was the International Conference of Crisis Mappers and I will be forever grateful for that opportunity. My research and projects have also benefitted greatly from the following volunteer organizations: the Standby Task Force, GISCorps, and the OpenStreetMap community with support from the Humanitarian OpenStreetMap Team.

Finally, I dedicate this to my dear friends, without whom none of this would have ever happened: for years of couch surfing, this is the best I have to offer. I hope it was worth it!

ACKNOWLEDGEMENTS

The best piece of advice I can give any prospective PhD is to find the right advisor. I have been very lucky to have Dr. Marguerite Madden fill that role. She has been consistently supportive of me as a student, which is something that is much less common than you might expect. She and Dr. Tommy Jordan also afforded me every opportunity to find applied work opportunities during the early phases of my PhD, for which I am very grateful.

Several individuals in the U.S. government have been particularly important for this dissertation. Dr. Jim Holt validated the potential of this research early on by granting me a fellowship at the Centers for Disease Control and Prevention, which was an enormous influence and springboard for my work. Also at the CDC, Carl Kinkade offered very useful insight to GIS for international relief and my good friend and colleague Ryan Lash has been an insightful and hard working collaborator for many years. At the U.S. State Department I owe Dr. Lee Schwartz, Dr. (!) Josh Campbell, and Benson Wilder and enormous debt of gratitude for their support and collaboration. At USAID I would like to thank Alex Dagan, who hired me (for better and for worse!) to help guide the GeoCenter as a model for improving development. Carrie Stokes, who now directs the GeoCenter, has been a long-time advocate for geography in development and was a wonderful boss. Also at the GeoCenter I would like to thank Chad Blevins for taking many of my initial pilot projects and guiding them to full-blown programs (even though it means much more work for him). Patrick Gault is an extremely thoughtful analyst whose ability to translate the concept of GIS into a useful training tool for non-geographers is nothing short of extraordinary. My colleagues Ben Swartley and Stephanie Grosser were brilliant co-leads for the crowdsourcing project highlighted in this research: thank you for being willing to take a chance on that project and giving so much of yourselves to it. Al Gembara, Amy Noreuil, and Karl Wurster were huge supporters of GIS and my many conversations with them about how GIS, analysis and open data should be part of international aid were particularly illuminating. I would be remiss if I did not salute the national and international staff in many USAID missions who are the backbone of GIS at the agency.

I have had the pleasure of working with several individuals from the United Nations. Andrej Verity is one of the most supportive and practical supporters of innovation in relief and aid that I know of. His observations about organizations and his technical understanding of data and analytics often help steer my thinking. Likewise, Lars Bromley has been indispensible for thinking through what it takes to build a truly sustainable pipeline for remote sensing. My thanks also go out to Helena Puig Larrauri, Maximo Halty, and Margunn Indreboe who have implemented GIS in some of the most difficult situations on Earth. The ability to work with them on a variety of projects was critical to informing my research and professional practice.

While there can be a divide between academics and practitioners, I have had the incredible pleasure of working with several individuals who are equally effective as both: Drs. Ed Carr, Brent McCusker, Patricia Solis, Jen Ziemke, and Scira Menoni, Nuala Cowen, and Richard Hinton have influenced my work through both their research and their applied projects.

Finally, Patrick Meier, Erica Hagen, John Crowley, Robert Soden, Sara-Jayne Terp, Michelle Hamilton-Page, and Adin Mbuh have all been brilliant colleagues, co-workers, partners, and generally wonderful to work with. I thank them for their time and thoughtfulness.

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LIST OF ABBREVIATIONS

ARC	American Red Cross
BFR	Boulder Flood Relief
CDC	Centers for Disease Control and Prevention
DCA	Development Credit Authority (office within USAID)
DoD	Department of Defense
ECG	emergent citizen groups
ESRI	Environmental Systems Research Institute (software manufacturer)
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
GAO	Government Accountability Office
GEOBIA	Geographic object-based image analysis
GIS	Geographic information systems
GNS	National Geospatial Intelligence Agencies GEOnet Names Server
GPS	Global Positioning Systems
GSA	General Services Administration
HIU	Humanitarian Information Unit (office within the U.S. State Department)
HOT	Humanitarian OpenStreetMap Team
IATI	International Aid Transparency Initiative
ICT	Information and communication technologies
ICT4D	Information and communication technologies for development
IT	Information Technology (department in an organization)
LULCC	Land use and land cover change

NDA	Non-disclosure agreement
NDVI	Normalized difference vegetation index
NGA	National Geospatial-Intelligence Agency
NGO	Non governmental organization
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OMB	White House Office of Management and Budget
OSM	OpenStreetMap
PCA	Principal component analysis
QA/QC	Quality assurance / quality control
S&T	Science and Technology (office within USAID)
SBTF	Standby Task Force
SoW	Scope of work
U.S.	United States
USAID	United States Agency for International Development
USB	Universal Serial Bus (portable external computer drives)
USG	U.S. Government (used to denote all governmental agencies collectively)
USGS	U.S. Geological Survey
UN	United Nations
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
VGI	Volunteered geographic information
VHR	Very high resolution (satellite imagery)
VTC	Volunteer technical communities

CHAPTER 1

INTRODUCTION

International relief and aid is primarily concerned with combatting poverty and alleviating the suffering associated with disasters or civil strife at a global scale. And the scale is truly massive: in 2015 more than 65 million people, or one person in 113, were displaced from their homes by conflict and persecution [*UNHCR*, 2016] and over 800 million people live in "extreme poverty" or less than $1.25 per day [*UNDP*, 2015].

Although international relief and aid is understood in a variety of ideologically framed ways these broad goals are a constant and geography is often cited as a critical component to the undertaking of these efforts. The role of geographic data is critical for both the logistics and delivery of aid [*Voigt et al*. 2005; *National Research Council* 2007b; *Hiltz et al.* 2010; *Soden et al.* 2014] and providing substantive knowledge to improve the structure of these interventions [*National Research Council*, 2007a; *Keola et al.*, 2015; *Richmond et al.*, 2015]. Indeed, geospatial data was specifically identified as a critical aspect of monitoring progress for the Millennium Development Goals: the global commitment to quantified targets for addressing extreme poverty [*UNDP*, 2015]. Seen in this light, geographic data can literally be a matter of life and death. Understanding how they are produced to support, and as a part of, international relief and aid activities is critical in improving aid effectiveness

This dissertation documents the modes of production for geographic data in international relief and aid programs at a moment in history when alternative modes of production became not only possible, but had considerable impact on the field of practice. The research began as I started my PhD program in 2009, using traditional geographic information systems (GIS) to produce conduct research into refugee camp enumeration. The following year, during the 2010 earthquake in Haiti, I became part of a new wave of individuals working to produce geographic information for response to natural disasters, humanitarian crisis, and international development. I entered this rapidly evolving community of practice – most commonly referred to as "crisis mapping" [*Ziemke*, 2012] – as both researcher and practitioner and focus, in this work, primarily on my experiences over a period of 5 years, starting in 2011 and ending in 2015.

Foundations for Examining Knowledge Production in International Aid & Relief

Research regarding the production of knowledge and information in international aid can truly said to have its beginning in the 1980s, when critics began deconstructing the discourse that was produced by and related to international relief and aid efforts. Sen's [1981] criticism of concepts such as "famine" and how a discourse of food production – rather than access or market policy – impacted the response to it is considered a benchmark in critical studies of aid. During the 1990s a sharper focus of discourse produced by the "development apparatus" showed how it came to shape thinking about the "third world", and established conceptual frameworks about international aid even while poverty and hunger became widespread [*Escobar*, 2011]. These critiques eventually led large international aid organizations to a "knowledge for development" vision in the early 2000s whose primary output was wider dissemination of reports and data upon which their policies were crafted. However, this vision is criticized for assuming that poor nations and their own incredible variety of institutions, cultures, and histories will readily absorb the type of "foreign aid knowledge" produced by these aid organizations [*Easterly*, 2006].

The early 2000s also saw an enormous increase in the application of information and communication technologies (ICTs) in international relief. The use of ICTs for development –

known colloquially as "ICT4D" – saw increasing examination of the technology being used and the concepts surrounding it. For some, the prominent discourse about information and technology was mystifying, granting it "transcendent powers" that undermine the need for sustained analysis about how institutions and their policies shape civil society [*Russill*, 2008]. For others, the operational aspects of the technology became a focal point in an attempt to assess the usefulness of them for supporting international relief when applied in practice, rather than drawing conclusions from a theoretical understanding of the potential benefits they may provide [*Hiltz et al.*, 2010].

Knowledge is increasingly seen as critical to international aid as a form of competitive advantage to improve performance, measure results, and provide greater transparency [*Ramalingam*, 2013]. Since 2010, a steady trend in creating open data for international aid has helped highlight the complexity of how information flows in international aid [*Smith and Reilly*, 2013]. Attempts to present a more precise description of the "industrial development complex" (*Norris*, citied in *Roberts*, 2014) and examine how information and knowledge flows between the actors of which it is composed has been undertaken to provide critical geographical understanding of development capital [*Roberts*, 2014].

Yet even as these investigations of knowledge production in international relief continue to evolve their conceptual scale is relatively broad. While researchers like Sen and Escobar elucidate how knowledge is produced and Roberts and Ramalingam uncover complexity in the networks it moves among, very little work has been done to detail precisely the process by which a specific data set, or a particular analysis, is created. Moreover, existing work that relies heavily on case studies at a time when alternative modes of data and knowledge production are more prevalent avoids critical self-reflection. The advent of "crowdsourcing" – a process through which data can be created by enlisting a wide variety of people considered non-experts via the Internet – has generated research seeking to build linkages with diverse geographic scholarship and the role of crowdsourcing for geographic knowledge production [*Sui et al.*, 2013] and begun to closely examine the motivations of the volunteers or "crowd" [*Burns*, 2015] yet detailed organizational ethnographies remain rare. Research that does examine a range of specific projects using crowdsourcing for relief and aid – also known as "crisis mapping" or "digital humanitarianism" [*Meier*, 2015] remains somewhat evangelistic and lacks detail concerning the institutional environments, personal relationships, and strategies that may have led to the rise of crisis mapping and allow it to continue. I find the state of research around crowdsourcing and crisis mapping in the realm of aid and relief eerily reminiscent of that concerning GIS in the 1990s and this work is an attempt to ensure, as Pickles [1995] urged, that the discourse surrounding GIS was adequately situated within an analysis of the networks of power and systems of practices in which it operated and partially constituted.

Objective of the Dissertation & the Research Context

This work is an attempt to provide a detailed view of how geographic information is being created by aid practitioners at a key point in the history of international aid. Driven by a desire to create applied research that can inform practice I focused my research around two primary questions:

- How is geographic data created for international aid and relief? What are the methods, but also the institutional context for creating useful geographic data in this context? What makes it "useful"?
- Is crowdsourcing a viable option for the creation of geographic data in international aid? Does it add value or present specific challenges?

To answer these questions, specific objectives were required and include:

- Examining a specific example of GIS in relief and aid to provide the technical foundation necessary to create a replicable analytical product to inform decision making and examine the degree to which GIS alone – as a replacement to field work or other forms of data collection – is useful.
- Implementing GIS analysis "in the field" or relief and aid: putting research into action to better understand how geographic data and knowledge function within the organizations that implement aid projects.
- Implementing alternative modes of production for geographic data – such as crowdsourcing as a comparison to understand if or how they may differ from traditional GIS.
- Engaging with range of practitioners to unpack how they understand crowdsourcing and the potential pitfalls or advantages it may present.

I chart the evolution of my work as a geographer within the field of international aid utilizing both traditional and alternative modes of production while producing geographic data or managing projects whose primary output was geographic data. When taken as a whole, this document captures a particular period in the history of geography that has deeper implications for understanding the role of geographic data in the aid sector as seen from across three distinct organizational landscapes:

The Organizational Context of the Research

As the nation's health protection agency, the Centers for Disease Control and Prevention (CDC), conducts science, provides health information and responds to health threats in the U.S. and abroad by supporting ministries of health, and international public health organizations. The

CDC is unique among the organizations encountered during my research in that it both implements relief and aid projects and conducts science. My research at the CDC was conducted as part of the Oak Ridge Institute for Science and Education (ORISE) Fellowship program for the Division of Adult and Community Health, which contributes to research about the application of GIS for chronic disease prevention and health promotion. As an ORISE fellow I explored the use of remote sensing for refugee enumeration to support the Immigrant, Refugee, and Migrant Health Branch. The research environment at CDC is robust and much of it is aimed at developing and testing effective disease prevention, control, and health promotion programs.

Thanks, in part to my experience at the CDC, I was hired at the U.S. Agency for International Development (USAID) to help found a "Geocenter" that would promote traditional GIS and new innovations in data creation and analysis to support the creation and assessment of USAID funded programs as part of its newly created "Office of Science and Technology (S&T)." USAID is the primary U.S. government agency responsible for administering civilian international aid and it provides financial assistance to organizations, local non-governmental organizations (NGO), and international NGOs to support international relief and international development. It is the largest bilateral development donor in the world. USAID can also provide technical assistance in the form of consulting, training, scholarships, construction, and commodities, etc. but these are mostly contracted by USAID and provided in-kind to recipients. While USAID once housed research capacity, a shifting political climate saw this capacity practically erased as agency staff was cut and remaining operations became more focused on outsourcing the work of designing and implementing international aid and relief programs [*Stanger*, 2009]. USAID supports research through financial assistance and S&T specifically has leveraged a variety of fellowship programs to introduce researchers to its ranks, yet the primary point of engagement is one of policy creation and the both "science" and "technology" are continuously referenced in uncritical terms [*McCusker*, 2015]. During my time at USAID I worked with a wide variety of geographic analysts across the U.S. Government and those involved with providing support for both aid and relief programs. I was also seconded to the United Nations Development Programme (UNDP) to support the replication of a "Crisis Recovery Mapping and Analysis" project that had begun in Sudan and was being piloted in Central Africa. Through this work and my work at USAID, I began to regularly interact with United Nations staff at a variety of different agencies and coordinate around the themes of geographic data and analysis.

After three years working at USAID, I now work at Ushahidi: a non-profit based in Nairobi, Kenya. Ushahidi views itself as a software company and focuses on the creation of open-source software to collect, map, and visualize crowdsourced data, it also manages a variety of programs to implement the use of its software or foster new technology to support formal and informal efforts related to international relief and aid. The programming at Ushahidi is made possible through a variety of funding sources, including USAID. My role at the company is largely centered on creating programs that leverage the use of Ushahidi software in relief and aid projects.

While the three organizational environments all have different missions, they are all actors in international relief and aid that create or fund the creation of geographic data. I observed several similarities among them with regards to how geographic data are created, most of which are never presented in literature related to GIS in international aid. This dissertation provides an in-depth view of this process.

A Note on Terminology

Throughout the period of study my I was engaged in a variety of projects in what I refer to as "international relief" or "international aid." In our current international system and the literature regarding it there are sometimes distinctions to be made between the two such as "crisis response", "humanitarian response", "disaster assistance", "economic development", and "international development" to name only a few. To great extent these terms are important due to the network of governmental and non-governmental organizations that have been created to implement various forms of international aid and that are governed by political mandates that stipulate very specific contexts for intervention. Some organizations, such as USAID engage in development programming and disaster assistance, with different parts of the agency handling specific events in accordance with a specific mandate. The UN is another large bureaucratic entity under which several agencies that respond to various forms of international assistance are grouped. At the broadest conceptual level all of this work is related, as illustrated by the "disaster cycle." While several different models of this cycle exist, almost all of them include four basic phases: mitigation, preparedness, response, and recovery [*Hiltz et al.*, 2010]. Both mitigation and preparedness sometimes fall under "international development" activities such as capacity building but can also be found under projects aimed to improve crisis or humanitarian response specifically. Similarly, long-term recovery can be considered both disaster response and "development" and in the literature examining this vast array of activities one will find almost infinite configurations of terms and ideas depending on the specificity of the research. I am interested in capturing and examining the broader phenomena of how geographic information is created and managed in organizations and communities of practice that operate across these categories. I have therefore chosen the terms international relief and aid to compass both humanitarian assistance for "natural" and man-made disasters – generally considered "relief" – and long term economic development, which is broadly referred to as "aid."

Structure and Methodology

The structure of this dissertation follows various stages of geographic production that I was involved in as a relief and aid practitioner. This began with a focus on what type of existing GIS analysis would be appropriate for a given aid problem or challenge and evolved into a preoccupation with the organizational context required to enact such an analysis. Looking outside the realm of "traditional" GIS and embracing alternative modes of production, such as crowdsourcing, I began to explore the validity that new modes of production for geographic might have and their implications for the community of practice. I also explore how the projects I was involved with during the study period were perceived and described by others within the field of international aid.

Structure of the Dissertation

This dissertation contains seven chapters that are outlined below. Chapters 2, 4, and 5 are in manuscript form while chapters 3, an addendum to 4, and 6 are more reflective chapters written to be the "connective tissue" between each of the manuscripts to show how they are both part of a larger portrait of geographic data creation as applied to aid and my personal journey as a practitioner.

This chapter provides an introduction to the goals of the dissertation, outlines methodological approaches, and provides a foundational overview of research that examines knowledge, data, and information management in international aid and relief broadly. Chapter 2 is in manuscript form and uses quantitative methods and GIS to explore the application of remote sensing to refugee enumeration. It focuses on the creation and evaluation of a specific remote sensing method. Beyond its value in contributing to technical literature it serves an important example of "traditional" geographic data production in international relief, which is contrasted with the alternative methods of geographic data production outlined in chapters 4 and 5. Using the example set forth in chapter 2, the third chapter begins to describe the type of organizational landscape common for those working in international relief and aid. I unpack the difficulty of performing "traditional GIS" as a practitioner and establish the logic for examining alternative modes of data production. Chapter 4 is in manuscript form and documents a crowdsourcing project to process geographic data collected as part of an international aid project. While the approach of crowdsourcing was conducted in a participatory manner, and could be considered alternative to the traditional methods outlined in chapter 2, it follows a traditional quantitative approach to assess the effectiveness of the project. Included in chapter 4 is a section critically reflects on how the project was perceived and discussed in the community of practice. It raises questions about the meaning of adopting it as a method for geographic data creation in international aid. Chapter 5 is presented in manuscript form and draws on both personal experience and a variety of case studies conducted by colleagues in the community of practice to address the questions raised in chapter 4.

Research Methods & Data

This dissertation examines international aid projects in which the author was a key actor, often in the role of a lead analyst or project manager. Its scholarly contribution lies in presenting a real-world case study and natural experiment in improving the availability, type, and quality of geographic data used to support international aid and relief interventions. Taken as a whole, the dissertation is rooted in action research, which refers to the conjunction of three elements: action, research, and participation and is primarily concerned with collaborative investigation and practical intervention for social change [*Greenwood and Levin*, 2007]. For this dissertation, "action" refers to my professional engagement as a practitioner and participation is the ongoing discussion about geographic data in international aid by the community of practice and, specifically for the crowdsourcing project outlined in chapter 4, a group of online volunteers who make up part of this community. Others have promoted an increased engagement between researchers and policy makers and, as McCusker explains:

> "Given the fact that so many different individuals with vastly different agendas shape and reshape policy, largely anonymously, it can be difficult to discern what actually happens "on the inside." Taking time to engage with and understand some of the internal dynamics helps explain what appear to be contradictory or inexplicable policies. Second, building alliances with like-minded individuals within the policy community is critical to understanding how the given agency or department works. This helps identify not only needs, but also pressure points where policy changes can be attempted." [*McCusker*, 2015:195]

Several methods and approaches were used to accomplish the research at hand. Both chapters 2 and 4 relied on traditional methods of GIS or data analysis, including machine processing and error assessment. Chapter 2 makes use of various forms of remotely sensed imagery and existing GIS data sets that are detailed in the chapter. Similarly, the data and processing methods used for the crowdsourcing project in Chapter 4 are detailed within the chapter.

To more broadly examine the organizational contexts in which geographic data are created for international aid and relief I relied on an ethnographic approach as participant and observer. While the ethnographic approach has been useful in studying the recipients or "beneficiaries" – a term now disparaged by practitioners – of international aid and relief [see *Hyndman* 2000; *Horst* 2006; *Hammett, Twyman, and Graham* 2014 for examples] it remains less used as a tool to examine processes from within organizations that implement it: "despite the fundamental role of agencies in the delivery of aid, there are very few examples of empirical work on organizational issues" [*Ramalingam*, 2013:75].

Throughout the period of study, I maintained a series of field notes including both practical information required to see various analysis and projects to fruition and observations regarding the organizational context and social relations in which the analysis or project was embedded. Originally designed as a practical, source of information to facilitate the implementation of my work, over time these became a record of cultural knowledge about working in a particular place and time and presented a picture of my lived experience. A wide range of other documents including shared project documents, case studies, and research published by my colleagues added to this record. While the notes were often composed contemporaneously, they were more carefully examined in retrospect in an "experiential style." The process of writing ethnographic field notes encompasses a wide range of approaches and there is no one perfect method [*Emerson et al.*, 2011] and the shift from the techniques-oriented methods of remote sensing to those of ethnography were difficult. Because much of this reflective work has been done in retrospect I have focused on phenomena that were consistently present in my experience, across a range of contexts, and aggregated them to discover broad themes. I have done my best to carefully understand all documents at my disposal and, in many ways, consider this research ongoing: for I am still trying to understand many of the experiences that I lived through.

Ethics and Reflection on the Position of the Researcher

While the research presented here is not "human subject research" examining, as it does, various types of data creation, it nevertheless required my interaction with wide variety of individuals and reliance on volunteers to help create data. Be this as it may, any research – and perhaps especially research about international aid and relief – is constructed in specific social contexts for particular purposes and within these contexts are a myriad of power dynamics. Thus,

> "An ethical researcher should, in addition to being mindful of the standard twin goals of validity and reliability, be context-sensitive, honest, and 'up front' about her/his own interests and how the research and kinds of relationships s/he has with members of the research(ed)" community. [Brydon, 2006:28]"

Reflecting on my own position as a researcher and member of a community of practice is a vital part of ethical research. Throughout the period of study I made my role as a "PhD student researching geographic data in international aid and relief" explicit to the community of practice of which I am a part. It is part of my professional biography and, indeed, one of the reasons that I was first hired at USAID. I found that being associated with such a major development agency significantly enhanced my access to a variety of individuals, data, and organizational processes that I would likely have not had access to had my only institutional connection to the subject been my university. This being said, much of my work experience fell under a variety of policies that governed the type of information I was allowed to collect and share publicly, primarily in the form of non-disclosure agreements (NDA) and classification of information. The NDA I was subject to are legal contracts that outline how access to confidential material, knowledge, or information may be shared or restricted third parties. In each NDA I have been a signatory to, I have outlined my role as a researcher and negotiated for the right to document my work for the purposes of published research. This, however, did not apply to classified information: any material that the governmental bodies with whom I worked considered sensitive. In these cases, classified material is restricted by law and covered in Executive Order 13526 by the President of the United States. No classified information has been recorded as part of this research.

The crowdsourcing project detailed in chapter 4 required gathering a crowd of volunteers for assistance. While my goal was to conduct action research that might change policy within

USAID, I was also under tremendous pressure to conduct an "innovative" project that would be well received by my superiors. Likewise, many "digital volunteers" who support international relief and aid projects negotiate their own knowledge politics to demonstrate their value to intended audiences [*Burns*, 2014]. Success was therefore in the interest of most stakeholders in the project. I have done my best to reflect critically on what this event meant in chapter 5 and what the greater implications for crowdsourcing in aid and relief might be in chapter 6. Moreover, the inclusion of a large volunteer force to help produce the data I was examining required additional steps to ensure transparency "up front" about the organizational relationships created to implement the project. The participatory nature of the project prompted USAID to require an ethics review and informed consent by participants as stipulated by the agency's General Counsel. To ensure the project was in compliance with U.S. law that governs volunteer labor, quality and handling of information, several steps were put into place and are detailed in the chapter. The project was designed in close collaboration with volunteers and USAID's general counsel and included memorandums of understanding for volunteer groups and individual consent agreement for individual volunteers. The final results were shared publicly in an online forum to ensure maximum accessibility for stakeholders and allowed an active question and answer session: an archive of the webcast remains online for public access [*Wilson Center*, 2012]. Additionally, an "after action" meeting was conducted with the primary volunteer groups to ensure that all stakeholders felt that the project was carried out in an ethical manner.

Finally, many of my colleagues also fill a dual role as researcher/practitioner and publish on projects that I have been involved in [*Campbell*, 2015], actively helped shape or manage [*Meier*, 2015]; and what meaning these projects might have [*Crowley*, 2013]. This body of work helps to inform my own field notes and perceptions recorded throughout the period of study.

Chapter 5 makes extensive use of these documents by comparing case studies written by members of the community of practice during the study period. These works were all created to be part of the public record and this dissertation can be seen as engaging with this explicitly public dialogue.

CHAPTER 2

EXPLORING A HYBRID APPROACH TO REMOTE SENSING-BASED POPULATION ESTIMATES IN PROTRACTED REFUGEE SITUATIONS [1]

[1] Shadrock Roberts, James Holt, Minho Kim, Marguerite Madden, Submitted to *Professional Geographer*, 3/21/13

Abstract

This study employs geographic object-based image analysis (GEOBIA) for feature extraction of dwelling units from high-resolution satellite imagery in the Kakuma refugee camp in Kenya. We found that land cover transition complicates remote sensing population estimates in this case and that, while remote sensing can be a tool for accurately defining zones of building density, the relationship between population density and building density in protracted refugee camps merits further research. Finally, we suggest a hybrid approach employing remote sensing as a tool for guiding field work towards the most efficient opportunities in data collection rather than simply as stand-alone alternative.

Introduction

Obtaining refugee camp population estimates is crucial for planning adequate aid delivery and for creating baseline data by which important health indicators can be calculated [*CDC-MMWR* 1992; *Depoortere and Brown* 2006]. Settlement information has also proven useful in assessing health risks and managing plans for public health concerns [*Tatem et al.* 2004]. Underestimating the population in need can lead to undesirable outcomes and exacerbate already tenuous situations, while overestimation may result in inefficient resource allocation in which valuable supplies and support go unused at the expense of populations in need elsewhere. The accuracy and timeliness of population estimates can be a matter of life and death for those affected by a humanitarian emergency. Moreover, these baseline population data remain important for planning purposes and estimating future needs because these camps can easily grow well beyond the limits of their supporting infrastructure and present significant management challenges.

Previous studies have validated the use of remote sensing in determining refugee camp area [*Bjorgo* 2000; *Madden and Ross* 2009] and population estimation [*Giada et al.* 2003]. The conventional practice for population estimates entails extracting dwelling units from very high resolution (VHR) satellite imagery – a ground sampling distance of 1 to 4 m – and using previously obtained occupancy rates of the dwellings to calculate the total camp population [*Giada et al.* 2003; *Kranz et al.* 2010; *Tiede and Lang* 2010].

Challenges in field-based population estimates

The quadrat sampling method is a conventional technique whereby ground-based teams delineate the boundaries of the camp on a map, and then adds another layer to the map containing a grid of cells (a quadrat) that cover the total area of the camp. Sample cells are chosen randomly from the quadrat and the individuals within the dwelling units in that cell are counted. This occupancy rate is then used to extrapolate the total population by the total camp area [*Brown et al.* 2001]. Global Positioning Systems (GPS) and geographic information systems (GIS) have been adopted to facilitate this method [*Kaiser et al.* 2003]. However, this method assumes homogeneity among cells within the sample frame itself, which is unlikely, and Grais et al. [2006] suggests developing new tools or methods to provide an empirical approach to defining areas of differing population density within camps.

In protracted refugee situations – defined as 25,000 or more people living in exile for more than five years in a developing country [*UNHCR* 2006] – other forms of enumeration such as head-counts are accompanied by social challenges. While aid agencies require accurate population numbers for logistics purposes, justification of expenditures to funders, and to prioritize humanitarian intervention, refugee livelihood strategies may involve tactics that inflate population data in order to survive in camps [*Kibreab* 2004; *Gale* 2006]. Ethnographic studies in refugee camps note that the tension surrounding head-counts can be a cause of subversion [*Kibreab* 2004] and lead to significant backlash from camp inhabitants who are frustrated by the manner in which headcounts are carried out [*Hyndman* 2000]. The fact that refugee camps can exist for such a long period of time while remaining spaces of risk for natural hazards such as flooding, ongoing sites of conflict, and health problems due to overcrowding or inconsistency in the delivery of aid, underscores the critical need for timely population data to respond to, or mitigate, these challenges.

Remote sensing in humanitarian operations

Interest in remote sensing as an assessment method has increased as VHR satellite imagery became commercially available. Bjorgo [2001] illustrated several examples in which humanitarian operations information needs could be met with remote sensing including: camp planning, monitoring, environmental assessments, and environmental conservation and development. While the use of optical satellites to gather data has its limitations, including obscurity due to clouds or ground cover, it also presents a method of data collection when situations on the ground prevent field teams from accessing the site in question. This approach has been employed for monitoring, identification, and documentation of human rights violations [see *Kuehn* 2009].

Research in humanitarian remote sensing often focuses on the opportunity it presents for population estimation [*National Research Council* 2007b]. One key advantage of the remote sensing method may be to monitor growth in protracted refugee situations and provide ongoing estimates when a dwelling occupancy rate has already been derived.

While the studies described above demonstrate the utility of remote sensing for rapid population estimates in some refugees camps, land use and land cover change (LULCC) in protracted refugee situations may complicate remotely sensed dwelling counts. Over time, additional structures are often constructed that: 1) may be miscounted as dwelling units and inflate population estimates, 2) consist of natural materials that are difficult to distinguish from surrounding ground features, and 3) alter the pattern of dwelling unit arrangement from regular and evenly spaced to an irregular settlement pattern.

Our study explores the use of VHR satellite imagery for refugee population estimation by performing dwelling extraction and population estimates in a protracted refugee camp with a variety of land cover, dwelling types, and settlement patterns. Additionally, we discuss the use of geographic object-based image analysis (GEOBIA), a contextual method of image processing that is especially suitable for extracting dwelling units from VHR images [*Kim et al.* 2011a]. We also investigate the utility of remote sensing in population estimates that rely on occupancy rates determined by field surveys, which are capable of producing their own population estimate. Based on our findings, we propose a hybrid approach in which remotely sensed imagery would serve an important role in the creation of the sampling frame to be used by a field team, thus improving the timeliness and accuracy of population estimates in protracted refugee situations.

Addressing feature extraction with GEOBIA

Field survey methods conclude that the physical structure of residence is a conceptually appropriate unit for population estimates [*Grais et al.* 2006], and research has focused on the development of extraction methods of dwelling units within refugee camps [*Giada et al.* 2003; *Kim et al.* 2011a]. GEOBIA has gained much interest as an effective feature extraction method and an alternative to conventional pixel-based image analysis approaches, considered to have some limitations with VHR satellite imagery. Fine spatial resolution images and increased spectral variation within the same ground features, so-called within-class spectral variation, decreases the performance of conventional pixel-based classifications [*Schiewe et al.* 2001; *Alpin* 2003; *Kim et al.* 2011b]. GEOBIA approaches are based on image segmentation that groups individual pixels into image objects (segments or geo-objects) that are hierarchically classified using heuristic rule sets, ancillary data, and fuzzy logic [*Burnett and Blaschke 2003*; *Yu et al*. 2006]. In this way, GEOBIA emulates human interpreters' ability to employ spectral, spatial (e.g., area and shape index), and contextual (e.g., topological relationship) information associated with image objects in classification and extraction of ground features [*Hay and Castilla* 2008; *Madden et al.* 2009]. Moreover, GEOBIA produces vector polygons that can be directly utilized for GIS analysis [*Blaschke* 2003; *Castilla et al.* 2008; *Kim et al.* 2010].

Study Area and Data

The Kakuma refugee camp is a protracted refugee situation that is located in northwestern Kenya (see fig. 2.1). The arid climate and paucity of ground cover in northwestern Kenya offer an optimal environment for using satellite imagery. Due to availability of suitable imagery and data, we were able to compile a comprehensive GIS that was not available for other refugee camps. Established in 1992, Kakuma has grown to comprise three camps (I, II, III) referred to collectively here as "Kakuma." Each camp is subdivided into zones, which in turn are divided into groups or "blocks." An additional camp, Kakuma IV, was created during 2002 – 2003 to shelter refugees awaiting transfer or resettlement. While Kakuma IV has since been largely evacuated, it serves as a valuable example of how camp dwelling construction and surrounding features change over time. Kakuma's population can fluctuate significantly based on the influx of refugees from regional conflicts or transfers between camps [*Ohta* 2005]. Data received from the UNHCR showed that an estimated 95,242 people were living in Kakuma in 2006 and it remains one of the largest refugee camps in the world.

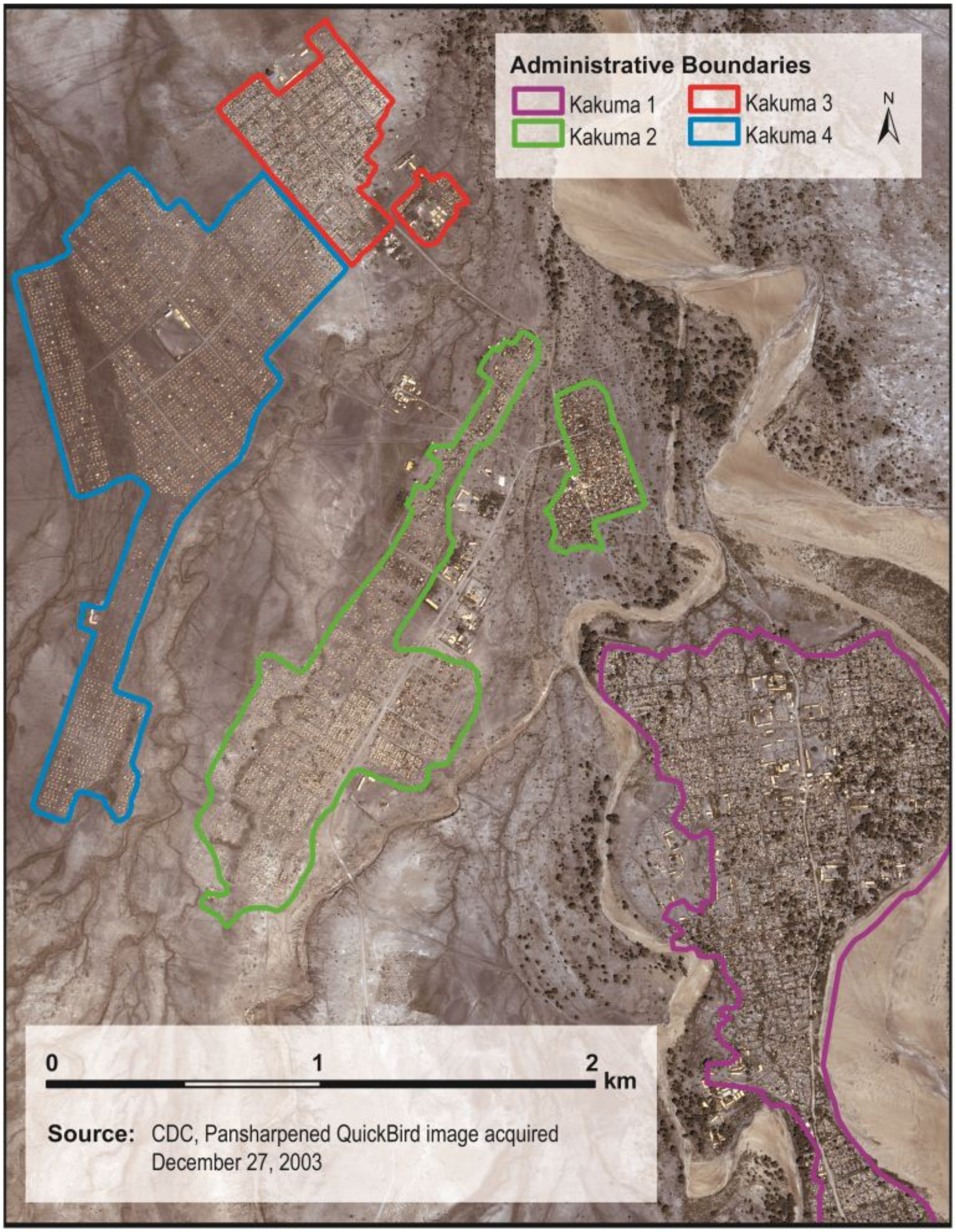

Figure 2.1: *Map of Kakuma Refguee Camp Sections.*

The Kakuma camp was selected as a study site because it contains both established, long-term areas of settlement that have taken on a more organic settlement pattern over time and areas of relatively new development, which retain a very clear, gridded layout. Comparing these areas allows for a better assessment of remotely sensed population estimates in a variety of conditions.

GIS and VHR Imagery

A comprehensive data set was compiled from work completed by the Centers for Disease Control and Prevention (CDC) and the UNHCR in 2003. A VHR QuickBird image acquired the same year on December was delivered to CDC from the National Geospatial-Intelligence Agency. An additional QuickBird image acquired January 14, 2007 was used to better understand how camp features change over time. The QuickBird satellite has a spatial resolution of 0.61m in the panchromatic band and 2.40m in spectral bands: Blue (430 - 545 nanometers), Green (466 - 620 nanometers), Red (590 - 710 nanometers), Near-infra red (715 - 918 nanometers). It is the highest resolution imagery publically available for the time period of the study.

Administrative divisions within the camp and population estimates from the UNHCR refugee registration database for 2003 were supplied by the UNHCR. The database records new arrivals at UNHCR camps or offices. Over time, refugees are asked to re-register in order to update the database to reflect births and deaths in a camp since the last update. Although refugee registration databases may contain some error due to the challenges listed previously, it represents the most comprehensive data available to refugee camp managers. Thus, combining these data with the complimentary results of remote sensing becomes important: hybrid methods can both improve the accuracy and timeliness of these data. In addition, CDC provided dwelling unit points from a pixel-based dwelling unit extraction performed in 2003.

Methods

QuickBird satellite images and population information were compiled in ArcGIS 9.3 (Environmental Systems Research Institute, Redlands, CA) and were used to identify areas of consistent and varying dwelling unit density. The population figures provided by the UNHCR and the dwelling unit points provided by CDC were used to check accuracies of dwelling unit extraction and population estimation results.

The QuickBird imagery contained panchromatic and multispectral bands. We conducted pansharpening using the High Pass filter technique for its ability to produce pansharepened images with high spectral quality, compared with the original multispectral imagery [*Gankofner et al.* 2008; *Kim et al.* 2011b]. All the subsequent processes were performed with the pansharpened images. Visual interpretation of the imagery suggested differences in building density and pattern between distinct sections of the camp. Therefore, we created a randomly-placed quadrat of 250 x 250 meter grid cells over the image and selected one representative cell for manual interpretation of dwelling units within low, medium, and high/mixed population density areas. The size of the grid cells was determined to ensure that several cells would encompass at least one block within each cell and allow for the suggested 25m x 25m cells used by field teams conducting population estimates [*Brown et al.* 2001] to nest within them. The manually-counted dwelling units were compared with the UNHCR population estimate, which was taken from the refugee registration database that the agency uses to record refugees living in the camp. The high/mixed density cell contained 373 buildings, the medium 241, and the low 190 (fig. 2.2), which supports the axiom that higher population density is accompanied by an increase in dwelling units. The manually-interpreted dwelling data layer, combined with the

UNHCR population estimate, was used as a reference for comparison of GEOBIA feature extraction results.

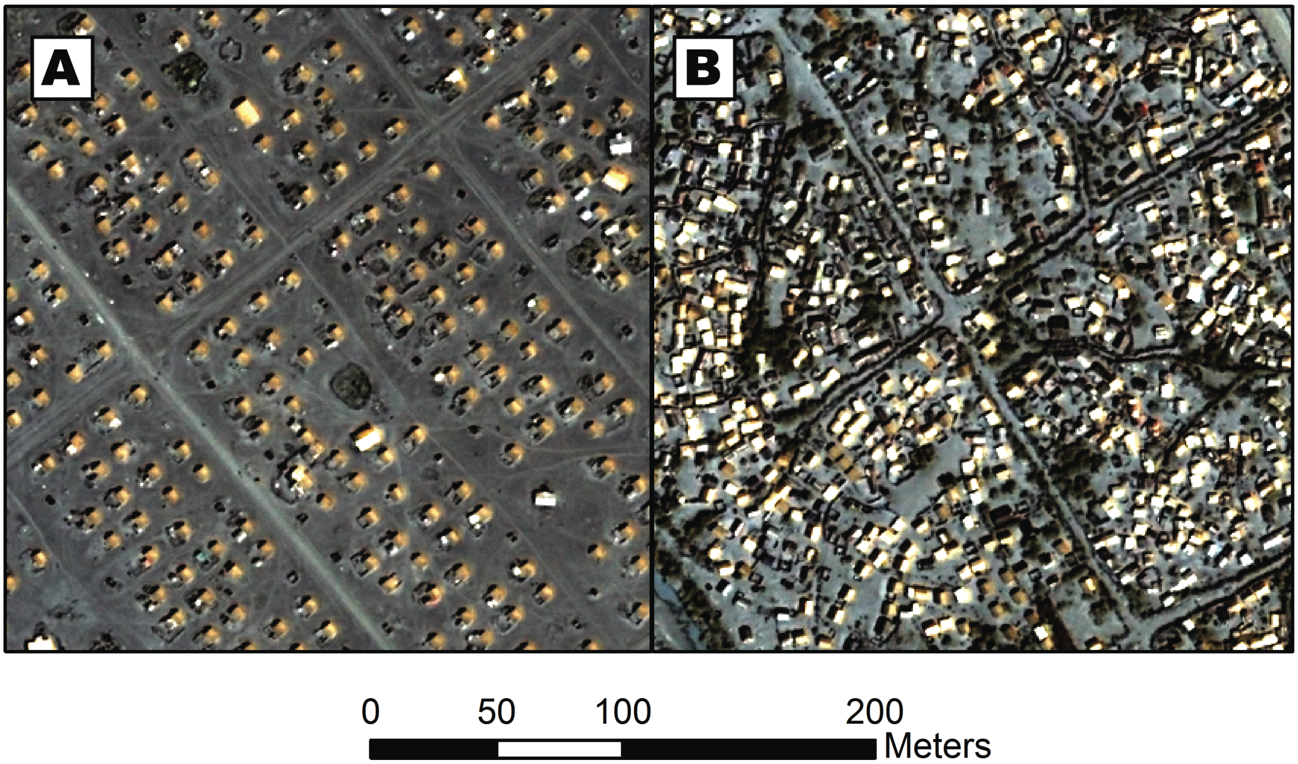

Figure 2.2: *Representative low-density in Kakuma IV (A) and high-density Kakuma I (B) sample areas.*

Dwelling extraction in protracted refugee camps

We utilized GEOBIA in Definiens Developer 7.0 software (Trimble, Sunnyvale, CA) to extract dwelling units of refugee camps from the imagery. To determine the optimal scale factor for segmentation in Definiens, a total of fifty (50) randomly selected dwelling units across Kakuma were manually digitized from the imagery using ArcGIS to formulate descriptive statistics relating to their size. Administrative boundary shapefiles obtained from CDC and

UNHCR were used to rule out blocks containing administrative buildings. The mean area of a dwelling unit was 31 m^2 (range 14.0 – 83.0 m^2; standard deviation 14.5 m^2). This is logical considering that the international standards by which Kakuma is constructed call for an overall shelter area, garden plot, and footpaths to be approximately 45 m^2 [Sphere 2004]. Outliers could be attributed to incorrect identification of a dwelling unit versus an administrative unit or outbuildings or to identifying several buildings as one.

A series of image segmentation was performed using multiresolution segmentation, in Definiens, with the following scale parameters: 10, 20, 30, 40, and 50. The scale parameter is an abstract value that determines the size of individual image objects based on spectral and shape heterogeneity and it is considered to play an important role in deciding the quality of image segmentation and influencing object-based image classification/extraction results [*Dorren, et al.* 2003; *Kim et al.* 2009; *Kim et al.* 2010; *Kim et al.* 2011c].

Our segmentation results were overlaid with the manually-digitized dwelling units to judge segmentation quality as the least number of segments (image objects) and as the closest fit of segment shape to dwelling unit outline (fig 2.3). We found that a scale parameter of ten (10) closely delineated dwelling units. To further calibrate the scale factor, segmentation was performed again at scale factor intervals of one starting at five (5) and ending with fifteen (15). A scale factor of ten (10) again proved optimal for extracting dwelling units in Kakuma.

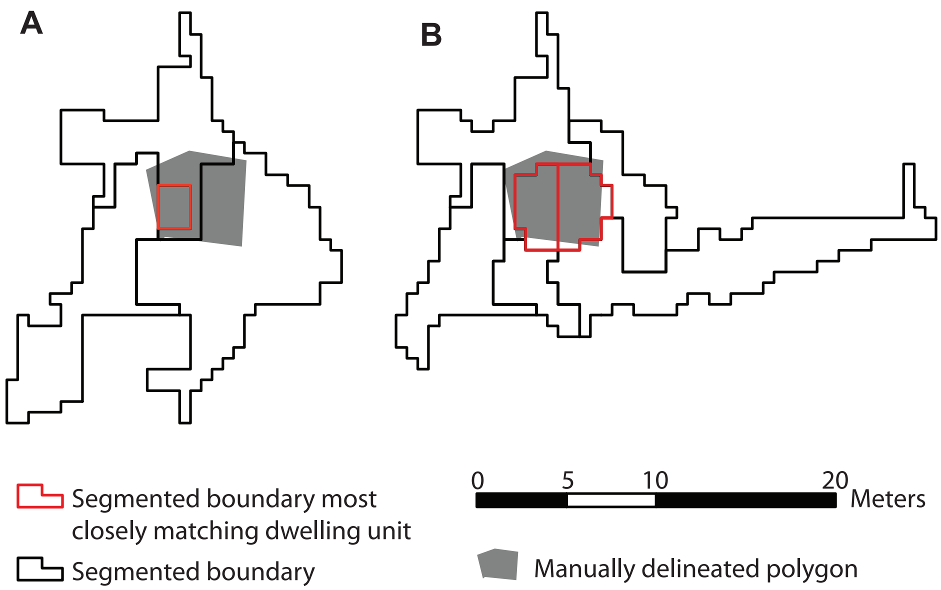

Figure 2.3: *Comparison of segmentation objects overlaid with a digitized dwelling unit: scale factor 10 without PCA3 (A) and with PCA3 (B).*

Our initial segmentation results, however, did not delineate metal-roofed units as a single image object, instead separating them into two objects along their sun-side and shade-side aspects. Image processing techniques, including morphological operations and principal component analysis (PCA), have been used to derive additional input data to separate buildings from non-buildings in refugee camps based using GEOBIA [*Giada et al.* 2003]. Kim et al. [2011a] found that a principal component (PC) image could produce enhanced segmentation quality for metal-roofed buildings. In this study, PCA was conducted with the four spectral bands of the QuickBird image to delineate the footprint of the buildings without being affected by shadow. PCA image 3 revealed well-defined building footprints (fig. 2.4) and was introduced as an additional layer for image segmentation to produce more enhanced image objects and greatly improve the segmented object output for buildings.

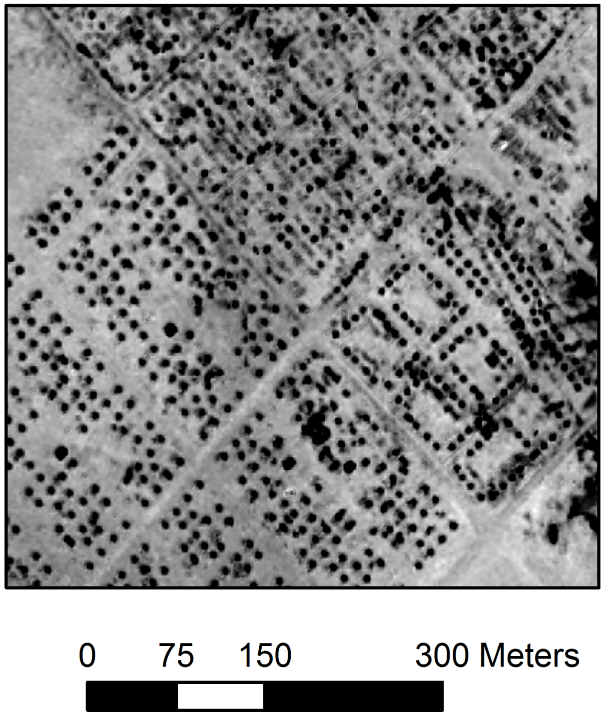

Figure 2.4: *Comparison of segmentation objects overlaid with a digitized dwelling unit: scale factor 10 without PCA3 (A) and with PCA3 (B).*

The PCA image 3 also introduced some confusion between the high spectral reflectance values for metal rooftops and those of vegetation. Following standard image processing practices [*Lillesand et al.* 2008] the reflectance values were recalibrated to radiance values using data from the provider [*Krause* 2003] and a normalized difference vegetation index (NDVI) was created and introduced to separate vegetation from dwelling units.

Results for Dwelling Extraction and Population Estimates

Our population estimates for Kakuma III and IV began with dwelling unit extraction using the following process in Definiens Developer. The first step consisted of classification based on PCA image 3 and NDVI. Since our goal was the enumeration of dwelling units, all land cover classes except dwelling units were collapsed. Our training samples consisted of 10 metal rooftops randomly selected from throughout this section of the camp and forty (40) additional random samples from the combined, non-dwelling unit, classes. This yielded very high accuracy in Kakuma IV where low-density dwellings are roofed with metal and are evenly spaced (Table 1).

Table 2.1*: Error matrix for Kakuma IV. Overall Accuracy is 98%*

	Metal Roof Dwelling Units	Other	Row Total	User's Accuracy (%)
Metal Roof Dwelling Units	70	*4*	**74**	**94%**
Other	*0*	183	**183**	**100%**
Column total	**70**	**187**	**257**	
Producer's Accuracy (%)	**100%**	**98%**		

Kakuma III, on the other hand, is characterized by dwelling units constructed from vegetation that is indicative of its longer history as a place of residence. A visual inspection revealed that very few non-metal-roofed dwelling units in Kakuma III had been identified. For the second step of classification in Definiens Developer, the classification scheme was expanded to include non-metal-roofed dwelling units, and the sunlit aspects of these dwellings were carefully examined to determine where their spectral signatures overlapped with other classes. Using the "Sample Editor" window in Definiens Developer, we compared spectral signatures of sample dwelling units and surrounding objects with similar spectral signatures. By observing the averages and ranges of these signatures, we identified radiance values that occurred most frequently for dwelling units but were not present in the other objects sampled. The following radiance values were selected from each band to indicate "non-metal-roofed dwelling units": In the green band, <48 but >53; in the red band <42 but >46; and in the near infrared band <45 but >50. The blue band was not used since it is the most susceptible to scattering.

Additionally a new layer was created by performing a non-directional edge-enhancement using a Sobel filter in ERDAS Imagine and added to the Definiens workflow. This gave better definition to non-metal-roofed dwellings and contributed to greater contrast between the aspects of their roofs that were reflecting sunlight in a similar way to background soil. Metal-roofed buildings were masked out using the first step classification, a spatial definition was used to exclude any object, such as what might have been administrative buildings, greater than 60 m^2 from the dwelling unit class, and administrative shapefiles were used to exclude any objects beyond the camp boundaries.

Trial and error revealed that several thousand points would be needed to begin an assessment of all the whole area. Therefore, 4 blocks were randomly chosen and, within them, 300 random points were generated using a GIS. In ArcGIS points were symbolized at 10 points in size and any object that intersected them was counted. In cases where more than one point touched the same object only one point was used (that with the centroid closest to the objects centroid). Where points overlapped on “non objects” the first point encountered was deleted. This yielded a classification with an overall accuracy of 83% for Kakuma III (Table 2) and was used in combination with the results of the first stage classification in Kakuma IV for the population estimate.

Table 2.2: *Error matrix for Kakuma III. Overall accuracy: 83%*

	Metal Roof Dwelling Units	**Non-Metal Roof Dwelling Units**	**Other**	Row Total	User's Accuracy (%)
Metal Roof Dwelling Units	*26*	0	0	**26**	100
Non-Metal Roof Dwelling Units	3	*39*	3	**45**	86
Other	4	18	*74*	**96**	
Column total	**33**	**57**	**77**	*167*	
Producer's Accuracy (%)	78	68			

Population Estimates for Kakuma III and IV

We extracted a total of 4,015 dwelling units from Kakuma III and IV. Using the mean occupancy rate per dwelling of five, the number provided by CDC, the total population for this area was estimated to be 20,075. While CDC's 2003 pixel-based dwelling count did not provide an accuracy assessment, the two (2) results are strikingly close: 4,280 dwellings extracted for a population of 21,400: a difference of 5 percent. Our results, therefore, support the capability of GEOBIA methods to extract and enumerate dwelling units accurately.

While the CDC data contained a total population estimate for both Kakuma III and IV, the UNHCR refugee registration database only contained data for Kakuma III. Therefore, a dwelling-unit-based population estimate also was conducted exclusively in Kakuma III for comparison with these population figures. The number of dwellings extracted from Kakuma III was 1,130 and using the occupancy rate listed above, the total population would be 5,650, compared to the UNHCR population of 4,644. The overestimation of almost 22 percent from the remote sensing-based technique suggests protracted refugee situations present specific challenges in dwelling unit extraction due to dwelling units being constructed from local vegetation. While this does not dismiss the use of remote sensing in these cases, it does illustrate the need for more robust methodological approaches to distinguish and understand ground features in protracted camps. Furthermore, overestimation resulting from the remotely sensed estimate also implies that not all objects identified as dwellings actually house occupants.

In Kakuma III, the discrepancy between our dwelling-based estimate and the UNHCR population database suggests that refugee registration may provide better estimates despite concerns of overestimation from refugee reported figures. Our findings also suggest that the use of GEOBIA with VHR imagery requires additional processing steps. In cases where building units are roofed with vegetative material, the use of non-spectral information is valuable since other forms of data such as PCA, NDVI, edge matching, or other operations can help to define the targeted object. Giada et al. [2003] and Kim et al. [2011a] suggest morphological operations, which seek to understand the structure or form of an object by identifying boundaries within an image, as an additional source of data.

Discussion: LULCC as a Challenge for Population Estimates in Protracted Refugee Camps

A visual assessment of the QuickBird images revealed a stark difference in dwelling unit patterns and texture between the older, and more populated, sections of Kakuma versus the more recently constructed sections containing fewer, and more regularly spaced, dwelling units. However, the texture of the image is related to other features also, such as fences or outbuildings that have origins dependent upon the relative ages of different sections of the camp, as refugees construct more structures or additions to dwelling units over time (personal communication: John Marinos, UNHCR, 23 June 2009). During the acquisition periods of the two QuickBird images, Kakuma IV was the newest extension of the camp and had regularly spaced, low-density dwellings units. Kakuma I, however, had higher density and greater variation in buildings and their spatial arrangements. This change can be seen by comparing QuickBird images of Kakuma IV in 2003 and 2007 (fig. 2.5). The initial gridded arrangment of buildings clearly takes on a more organic form over time. Furthermore, the 2007 image shows that individual dwelling units become part of clusters of structures with additional constructed boundaries.

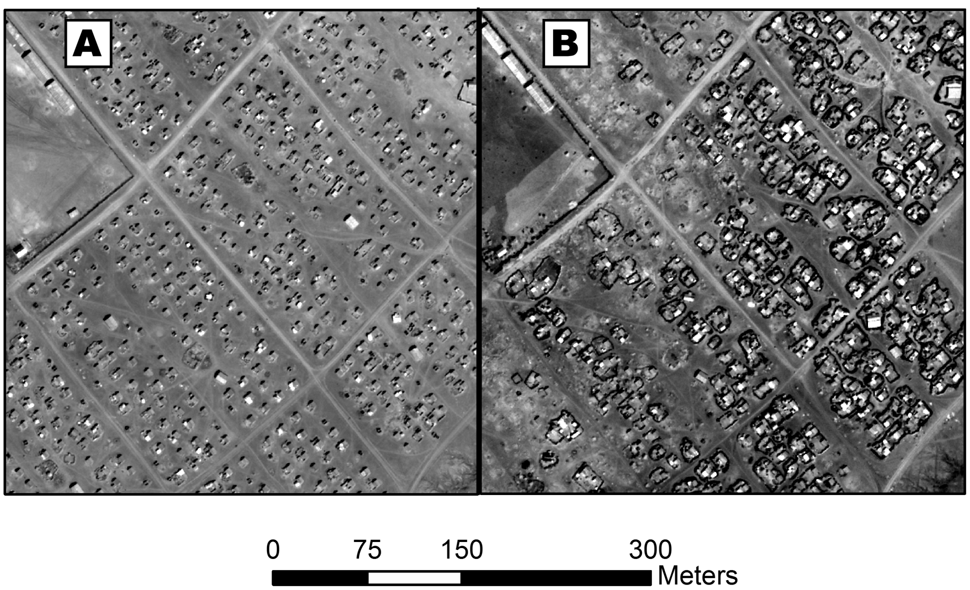

Figure 2.5: *Changing settlement patterns in the low density area of Kakuma IV between 2003 (A) and 2007 (B).*

Ethnographic studies have noted that refugees often re-create former dwelling unit patterns and layouts with whatever material is available at hand, thus changing the original camp layout–planned by the aid agency managing the camp–over time [*Hyndman* 2000; *Agier* 2008]. In Kakuma, many dwelling units have a tin roof (part of the material issued by the managing aid agency) that gives these dwelling units a distinctive spectral signature. However, additional built features such as fences, ancillary structures, and dwelling unit extensions are often constructed from local vegetation and may have significant spectral overlap with other vegetative features. This is important because these additions and structures can easily be confused with dwelling units and can inflate dwelling-based counts, as was the case in our initial test sites where spectral bands were used for GEOBIA segmentation. Automated classification in the newer, low-density area was nearly perfect. Where manual interpretation had identified 195 buildings, automated GEOBIA methods identified 196 buildings.

In the older, high-density area of Kakuma I, however, segmentation and classification were considerably more difficult owing to the greater complexity of ground features and did not yield any useful result (fig. 2.6). While our initial classification, using spectral bands, clearly distinguished dwelling units constructed with metal roofs, dwelling units made from local vegetation could not be separated from structures such as fences or ancillary buildings. Furthermore, viewing the image in a false color composite using the near infrared band (760–900 nanometers) suggests that some structures, especially fences and barriers, are created using living vegetation; causing considerable confusion between the vegetation used as a building material and surrounding vegetation.

The extra stages necessary for classification of non-metal roofs demonstrates that LULCC–specifically that of the built environment–complicates dwelling unit extraction in protracted refugee situations. The relationship between building density and population density also becomes less certain as non-metal roofs may indicate ancillary structures that do not house refugees. While software classifiers in Definiens Developer could be further calibrated to more accurately extract the footprint of a given class of buildings by employing spatial parameters to distinguish building types at a very fine scale, ground truth occupancy data would still be required to confirm that the building is a dwelling and not an ancillary structure. Therefore, the spatial, physical, and temporal nature of a refugee camp must be considered before an accurate population estimate can be derived from imagery alone.

Figure 2.6: *GEOBIA results in low density Kakuma IV (A) and high density Kakuma I (B) areas.*

Borrowing Hybrid Methods from Urban Geography

While remote sensing population estimates based on GEOBIA provide a high degree of accuracy in refugee camps composed of evenly spaced dwelling units built with materials that have distinct spectral characteristics, LULCC in protracted refugee situations can reduce accuracy. However, the fusion of remote sensing and field-based methods provides a possible solution to this problem. This would reposition remote sensing as a tool for supporting efficient field data collection, rather than an alternative to it.

Urban geographers have long taken advantage of remote sensing's synoptic capability to investigate population distribution and density [e.g. *Tobler* 1969]. The imagery can clearly reveal urban spatial arrangements such as zones of housing type (e.g. low-density residential) and the distribution of land occupation, which can be used to make indirect estimates of population [Lo 2003]. Furthermore, remotely sensed imagery coupled with complementary qualitative data can reveal a great deal about the underlying dynamics of, and relationship between, population change and landuse/land cover [*Entwisle et al.* 1998].

Baudot [2001] used these strengths to estimate the populations of rapidly growing cities in developing countries. His three-step method draws on the ability of remote sensing to guide field work towards opportunities for more efficient data collection [*Paul* 1984], and to augment population studies when used in conjunction with conventional field survey methods [*Hardin et al.* 2007].

Baudot employed 10 meter resolution Satellite Pour l'Observation de la Terre (SPOT) imagery to 1) classify density zones; 2) obtain dwelling counts within these zones with large-scale imagery; 3) tailor a ground survey based on these results; and 4) extrapolate the population from the combined data. This allows remote sensing to play an active role in two key procedures of the rapid population estimation process: delineating the boundaries of camp or settlement areas, which is the first step in any assessment [*Brown et al.* 2001; *Kaiser et al.* 2003] but can be problematic for field teams [*Grais et al.* 2006]; and defining zones of varying population density that can be used to create the sample frame to ensure greater accuracy. While it is theoretically possible to define density zones on the ground, the ability to do this rapidly and empirically is an area of concern due to its subjective nature [*Brown et al.* 2001]. To further investigate this relationship in Kakuma, a quadrat of 25m by 25m cells was laid over the QuickBird image and ten cells were selected at random for a building density count. Kakuma IV averaged 5.3 buildings per cell while Kakuma III averaged 2.7. This supports the fact that satellite imagery can reveal a difference in the density of features, thus improving the sampling frame for field-based methods. Once density zones and occupancy rates are established, they could be used over time to estimate populations more accurately. Kranz et al. [2010] found that dwelling density zones were useful for assessing refugee camp growth in Sudan, even if the exact number of occupants per dwelling were unknown.

Camps such as Kakuma would be well-suited to this method because their population, layout, infrastructure, and socio-economic characteristics generally fit the UN Centre for Human Settlements definition of an urban area [*Montclos and Kagwanja* 2000]. To borrow Montclos and Kagwanja's [2000:220] term, they can therefore be viewed as refugee "camp-towns" and are a conceptually appropriate site for the use of a population estimation method developed in an urban context. Indeed, analogies are often made between protracted refugee camps and urban forms [*Agier* 2008] and can resemble highly concentrated, and problematic, "desert cities" [*Hyndman* 2000].

A combination of remote sensing and field survey methods could extend the use of dwelling count and zonal population methods found in urban geography [*Lo* 2006; *Hardin et al.* 2007] to a refugee camp to resolve issues of population density and distribution that pose problems in conventional methods [*Brown et al.* 2001; *Kaiser et al.* 2003; *Grais et al.* 2006].

Conclusion

Our research contributes to a growing body of work on the use of remote sensing in the management of refugee populations. This study demonstrates that while VHR satellite imagery and GEOBIA extraction methods have a high accuracy rate in some cases, LULCC in protracted refugee situations can complicate dwelling unit extraction and the associated population estimate. Therefore, the physical and temporal aspects of the camp must be carefully considered and addressed before an estimate is performed.

VHR satellite imagery is capable of revealing differences in refugee camp building density, and we propose that methods for urban population estimates may provide a model for a hybrid method of remote sensing and fieldwork. Our results also urge caution regarding the relationship between population and building densities. Although our findings indicated that this axiom was appropriate in the more recently established Kakuma IV site, it may not be applicable to refugee camps where land cover change has occurred, such as in Kakuma I and III.

Overall, our results suggest that population estimates relying exclusively on remote sensing or field surveys will have weaknesses that may be mitigated by a hybrid approach combining the two. Because dwelling unit occupancy rates cannot be determined through remotely sensed imagery, a field survey is necessary to acquire these data. When field surveys can be carried out, they typically derive the population of the entire camp. In this case, remote sensing may serve as a useful adjunct to validate the ground survey, but it may also be seen as unnecessary. Therefore, one challenge for remote sensing in humanitarian operations is to improve the speed or accuracy of current methods and add value to them while avoiding unnecessary duplication of effort.

The ability of remote sensing to reveal changes in dwelling unit density can guide fieldwork towards more efficient opportunities in data collection. Further research concerning dwelling unit extraction in protracted refugee situations, occupancy and structure rates per household, and integration of remotely sensed and field-based methods is necessary to improve the accuracy and timeliness of remotely sensed population estimates in protracted refugee situations.

CHAPTER 3

THE WISDOM OF CROWDS: THE CHANGING LANDSCAPE OF GIS IN INTERNATIONAL AID

Introduction

The previous chapter illustrates the prevailing view, in academic literature, of how geographic information is created and moves through the humanitarian sector. In this case remote sensing is seen as a quantitative approach that can improve the delivery of international aid and development interventions. While important, this view nevertheless misses the broader organizational context that GIS and remote sensing exist within and which has a profound impact on how this information is created or used. This context is made up of the physical infrastructure upon which any computing depends; the policies that govern this infrastructure, the people who interact with it, and the data which moves through it; and the social relations that enforce adherence to, or to help circumnavigate, the limits of this context.

This chapter records the organizational and political context that I was confronted with as I began work with USAID to establish the Geocenter. The objective of this chapter is to detail the types of challenges that exist for GIS analysts implementing GIS "in the field" of relief and aid. Indeed, these challenges are what shifted my research away from traditional GIS and remote sensing towards crowdsourcing. It acts as a bridge between the quantitative case studies of chapters 2 and 4 to provide a more complete understanding of how geographic data and knowledge were viewed and managed within the organizations that implement aid projects.

Feral Databases & Heterogeneous Assemblages: the organizational aspects of geographic information in the international aid industry

Perhaps the biggest shock I encountered upon entering the field of practice was the tremendously uncertain access to computing infrastructure. Large humanitarian organizations are composed of an array of divisions, bureaus, offices, and centers that grow, shrink, disappear, and spring up in accordance with the political and financial climate of a particular time. At USAID, I was hired as the lead GIS analyst in the Agency's new office of "Science and Technology (S&T)." Far from the cutting edge office I envisioned – and that such a name implies – my first day found me sitting in a dis-used closet that once held a large filing cabinet with a desk and chair that had clearly been salvaged from the demise of another office. I was provided with a small, out of date personal computer with no GIS software installed. I had no Internet access. This situation was not unique to me and during the period of study I found similar situations in most agencies that I visited: GIS positions were often tenuous, housed in ad-hoc environments – or very modest ones – and were given little in the way of resources.

By contrast, IT departments were well-funded and staffed: largely because they also controlled all other computing systems upon which an entire organization depended: Internet access, networks containing shared files, licensing of software and operating systems for all computers, etc. Interactions between the central IT department of a given organization and GIS officers, or others whose primary tasks involved the retrieval, storage, and management of data via the Internet ranged from collegial to hostile but were often fraught with a certain tension about the control of digital services. In highly regulated environments, such as USAID, GIS officers often asked for access or permission to use open-source GIS software, which was easier to maintain cost less than the typical enterprise software provided by companies such as ESRI.

The approval process for this requires a considerable investment of time: often demanding that an applicant provide written justification, present at several meetings, and complete additional administrative tasks.

At first these interactions mystified me. I couldn't understand why one part of an organizational entity would prevent another from quickly and easily adopting money saving software that was tailored to the specificities of their stated work. Over time, however, a picture emerged of a changing technocratic landscape in which the heads of IT departments had risen to organizational prominence by controlling the financial mechanisms and relationships with software vendors. As the capability of Internet technologies continued to expand, project managers, analysts, or simply enterprising individuals who were frustrated with what they perceived to be the slow pace of the IT department or by lack of funds in general, began to use technologies outside their organization's control in order to accomplish their tasks. Online tools like Google Drive (https://www.google.com/drive) and DropBox (https://www.dropbox.com) facilitated the sharing of documents with those outside of an organization and the plethora of other online tools such as CartoDB (https://carto.com), Mapbox (https://www.mapbox.com), Ushahidi (https://www.ushahidi.com), or Tableau (https://public.tableau.com/s) greatly improved the ability of a GIS analyst to perform analysis and publish data online and outside the control of a given organization.

When presenting a pilot project or a new idea, it was not uncommon for GIS analysts to present a live demonstration using software, that was not approved by their organization, in order to show that they were able to complete a project in the same amount of time that it would take to start the administrative procedure necessary for software to be approved. On several occasions I was encouraged to do this in order to "show the Administrator [the head of the USAID] that we move faster than them [the IT department].” The general attitude among analysts who were seated in offices outside of the main IT branch of an organization was that the IT staff are the “guys who set up your phone and give you an e-mail address and now think they’re the guardians of all technology.”

Most of the analysts I worked with during the period of study had created their own databases or information management systems: commonly consisting of shared files and spreadsheets or word documents to act as a catalogue. These “work arounds” were generally accessible to other members of the same team, such as a group of analysts, but undiscoverable to the rest of the agency. As a result, geographic information was often fractured and invisible except by the maintenance of personal relationships with those who maintained these islands of information. The technologist Vinay Gupta [2015] offers one of the most succinct descriptions of this phenomenon. He explains that at the heart of all large – especially governmental – organizations exists a central database that is built to securely hold data and information: it is not built to be good at sharing or exchanging information. Anything that can be represented within the data schema of this database is “institutional reality.” Anything that cannot be or is not held within this database is generally housed in improvisational spreadsheets elsewhere – sometimes referred to as “feral databases” – and represent things that the main data core cannot. All organizational wisdom is trying to migrate into this big data core and these feral databases are not legible to the institution. I would add that information that is not legible to the institution is generally not considered “wisdom” – to borrow Gupta’s term – by virtue of the fact that they are not legible. This begins a cycle of them being further marginalized from the administrative processes that might bring them into wider circulation through things like approved software.

The integration of remote sensing data into this context is difficult. While most employees of humanitarian organizations understand the concept of remote sensing by exposure to such common tools as Google Earth, the notion that a remote sensing image contains digital numbers corresponding to the electromagnetic spectrum or that vectors can be derived from them is not a well-understood process. There is generally no good system for acquiring, cataloguing, and managing remote sensing data and, because it tends to require significant computing space and power to process – as well as further specialized software to analyze – its use is often limited by the context described above.

Further complicating this landscape is the dense network of associated organizations that receive funding from USAID to carry out development or humanitarian interventions. As Susan Roberts [*2*014] describes, USAID is a "donor organization" whose chief administrative functions are development policy and subcontracting organizations to implement it. Roberts' conceptual network for a critical study of development assistance theorizes it as "working through complex and unstable networks; as constantly shifting and blurring relationships comprising a heterogeneous assemblage." The exact number of organizations that USAID funds is nearly impossible to calculate as many primary contractors will, in turn, further sub-contract aspects of a given contract or grant to other organizations. As an agency, USAID has historically shown weak oversight capacity regarding contractors [*GAO*, 2011, 2012]. As within a singular development or humanitarian organization, each of these contractors or sub-contractors use, and sometime develop, a wide variety of approaches to information management and it is exceedingly rare that two organizations can easily share information across organizational lines by any other means than "sneaker net" – the use of USB keys or external hard drives carried by analysts to one another because large attachments are often not possible or blocked by various security firewalls. As part of their work, each of these organizations is often charged with some form of data collection about project implementation but this is overwhelmingly with the intent to account for the funds disbursed and not with an explicit goal to perform geographic analysis. This heterogeneous assemblage is often absent from a body of research that is often much more focused on highly specific technical pursuits, such as the extraction of features from imagery as described in chapter 2. The field of disaster research has generally done a better job of unpacking the context of data in humanitarian events, with the relatively recent recognition that studies should emphasize "the importance of assessing the usefulness of new information systems for supporting emergency preparedness and response, when applied in practice, rather than just drawing conclusions from a theoretical understanding of the potential benefits of new technology. [*Hiltz et al.*, 2010]" In general, however, the organizational and management issues are not part of a concerted research agenda and, as a result, there is a still a large gap in our understanding the organizational context that affects how international development and humanitarian aid is carried out [*Ramalingam*, 2013].

A Caricature of GIS: mapping for results

The informational environment found across the development and humanitarian sector makes any exchange of digital assets difficult and was consistent across organizations and countries throughout the period of study. By extension, the *creation* of digital assets, such as a database of where an agency is intervening or funding intervention, is equally marred in a context of fragmented technological solutions to real or perceived organizational issues. For GIS and program officers at USAID this was highlighted by increasingly strident demands for the Agency to create "maps" about where it was working in order to be more transparent and with a strong eye towards improved efficiency.

The impetus for this appeared to have originated with a project of the World Bank called "Mapping for Results" which presented an online map of various projects; available in its current iteration at http://maps.worldbank.org. Mapping for Results received considerable attention during a time when the U.S. congress was finding it increasingly difficult to track information about where U.S. development interventions were happening. The reality of data and information management systems balkanized by organizational politics was nothing new to many and accounts of it had been captured in journalistic and biographic portrayals of the aid industry [*Maren*, 1997; *Van Buren*, 2011; *Katz*, 2013]. However, upper-level policy analysts and decision makers seemed consistently surprised to hear this was the case. More often than not, they assumed that the same "systems" that allowed for organizational necessities such as financial reporting, automatically would also allow for spatial analysis. Mapping for results, contrary to popular assumptions of the time, was not the product of pre-meditated data collection with a specific goal in mind, but a manual effort on the part a large group of students and staff to manually geo-code World Bank documents that contained a common spatial attribute and which were created as the part of projects

It is, even with the benefit of considerable reflection, difficult to accurately describe the incredible pressure created – and often exerted on analysts – by this mismatch of expectations at the highest level of an agency and the digital infrastructure at its lowest. It was rare that a middle manager or executive could quickly and easily grasp the basics of data collection. I am speaking here of simply the act of transferring digital information: more conceptual issues around data collection, such as the problematic aspects of geographic scale, were simply incomprehensible to most individuals.

While at USAID, S&T was often visited by the head of USAID who was intent on developing a system of capturing highly detailed geographic data about the location of USAID programs similar to that of Mapping for Results. Indeed, this may have been the impetus for starting the Geocenter. In a press release for the launch of the Geocenter, the Administrator explained that:

> "The launch of the center is the first key step in enabling anyone in the world to visit a GIS map, click on a country, understand where all of our projects are, what they're doing, and the kinds of results they're getting…" [*USAID*, 2011]

Discussions at the time framed this system as feeding into a traditional GIS in which the locations of aid interventions could be combined with other geographic data to create substantive knowledge about improving development. This was all part of the rhetoric about a "data-driven" approach to international aid that was prominent then, and now. The system, then, would communicate to users precisely where US foreign aid dollars were being spent. The creation of this system encompassed enormous conceptual challenges (what defines the bounds of something like a nationwide agricultural project: what scale should it be mapped at?); data collection challenges (working in extremely difficult field environments without electricity, access to the Internet, or to where most USAID staff could not travel due to safety issues); challenges in geo-visualization (should a reforestation program be represented as a point or as a polygon describing the area of the intervention intended to effect or should it be aggregated and assigned to an administrative boundary?); technological issues (how would all of these data be collected, standardized, and delivered?); and a myriad of other challenges that are well established throughout the history of geographic literature. However, very little time or cognitive energy was allotted to address such issues.

One anecdote that accurately illustrates how this organizational context played out personally came while preparing to brief the Administrator on potential solutions that could be implemented. Shortly before the scheduled meeting, an aide arrived to inform me that I that I would "have 2-3 minutes to present… maybe, like, two PowerPoint slides before the Administrator starts interrupting to ask questions." It was for this reason that my team had worked for weeks to "get everyone on the same page" about the challenges we faced and create a catchphrase that would convey something about them. In this case the catchphrase was, "You have a data problem, not a mapping problem." Continuously returning to this refrain was referred to as "staying on message." The implied goal of staying on this particular message was not to resolve the problem, but to shift the expectation that S&T would respond to this particular request.

It was clear during the brief meeting that none of the decision makers present at the meeting accurately grasped the complex nature of the request. Attempts to bring even a baseline understanding of what could be done to meet the request were almost continually interrupted by a variety of advisors who made tangential technical references such as, "couldn't we do this in Google Earth?" The meeting ended with the Administrator's parting comment, "I still want my web map." I have witnessed scenes like this play out numerous times at different scales and they are commonly compared by GIS officers or similarly placed technical personnel across a variety of organizations. The appearance of new popular terms such as "social media" and "big data" often added to the confusion as they were introduced during meetings about how to best "map where we work" and they were often conflated with the concept of GIS.

At the time of writing, USAID does publish a "web map" of "projects " at http://map.usaid.gov. A cursory investigation of the data provided shows that only top-level information, such as the name of the project, the overall budget, and a brief summary, are presented. The cartography employed uses icons to display these projects at the national level: a multitude of activities that make up these projects, such as the construction of a school or the location of a training program, are not represented.

The Wisdom of Crowds

The difficulties of data sharing about what was happening where, both internally and externally, limited organizational resources, and an intense pressure to show the value of GIS in particular and various forms of scientific analysis in general, lead geographers or analysts in some organizations to find alternative methods of conducting their work. This was the case for myself at USAID but also for colleagues at other organizations. During the period of study one approach that was of considerable interest was "crowdsourcing": a process through which data can be created by enlisting a wide variety of people considered non-experts via the Internet. Crowdsourcing has been touted as a way to leverage society's increasing "cognitive surplus" – or leisure time often spent online – towards projects of civic value [*Shirky*, 2010].

The prodigious output of crowdsourcing projects has received considerable attention in political and academic circles: specifically the use of OpenStreetMap to provide open vector data and Ushahidi to provide citizen generated reports during the 2010 response to Haiti were often held up as examples [*Heipke*, 2010; *Liu and Palen*, 2010; *Neis and Zielstra*, 2014; *Goodchild*, 2015]. These efforts caught the imagination of executive leadership in many organizations whose rhetoric included the need to "innovate" in the international aid industry.

The question that arose was whether the use of online tools – outside the bounds of an organization – and the mass coordination of individuals – also outside the bounds of an organization – could effectively be used to circumvent the existing information landscape. To test this question, I set out to conduct USAID's first use of crowdsourcing. If successful, such a project could have substantive value by creating new data, political value in the terms of transparency and public outreach, and set a precedent for a solution to what was often described as a dysfunctional environment for information management and sharing.

CHAPTER 4

CROWDSOURCING TO

GEOCODE DEVELOPMENT CREDIT AUTHORITY DATA: A CASE STUDY [2]

[2] Shadrock Roberts, Stephanie Grosser, D. Ben Swartley, 2012. *U.S. Agency for International Development*. USAID Document ID: PN-ADY-964

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Abstract

This report for the United States Agency for International Development details the first use of crowdsourcing by USAID to produce geographic data. It outlines the technical, organizational, and legal aspects of conducting such a project. The report also provides insight to behavior of online volunteers – or "the crowd" – and a detailed accuracy assessment of the resulting dataset.

The objective of this chapter is to explore the implementation of crowdsourcing for geographic data to understand if or how it may differ from traditional GIS in the realm of relief and aid. The project detailed here put research into action to better understand how different types of geographic data can be created within the organizations that implement aid projects and the degree to which crowdsourcing is a viable approach. It also set precedent within an aid agency that has allowed others to continue the use of crowdsourcing to produce geographic data. At the end of this chapter is a coda, not published in the original report, which offers a critical reflection of how the project was received and interpreted in the months that followed. This, more nuanced view of the crowdsourcing project, informed thoughts about how this method might add value or present specific challenges in relief and aid organizations.

Introduction and Background

On June 1, 2012, USAID launched its first crowdsourcing event to create and map data about one of the agency's development programs. At that time, no one predicted that all records would be completed in just 16 hours – a full 44 hours earlier than expected, which is precisely what happened. By leveraging partnerships, volunteers, other federal agencies, and the private sector, the entire project was completed at no cost. Our hope is that the case study will provide others in government with information and guidance to move forward with their own crowdsourcing projects. Whether the intent is opening data, increased engagement, or improved services, agencies must embrace new technologies that can bring citizens closer to their government.

USAID's GeoCenter, working in cooperation with the Agency's Development Credit Authority (DCA), identified a global USAID dataset of approximately 117,000 records that could be mapped and made open to the public. Significant data cleanup – detailed below – was necessary before this was possible. USAID utilized a crowdsourcing solution for the data cleanup that had three primary advantages for the Agency:

- Substantive Impacts: The data describe the locations of loans made by private banks in developing countries through a USAID risk-sharing guarantee program. Making the data publicly available can lead to a variety of important analyses.
- Transparency Impacts: USAID is working to make more of its data publicly available. By doing so, the public can make significant and creative contributions to how USAID does business.
- Establishing cutting-edge methods for data processing: This is the first time that USAID has used crowdsourcing for help processing its data. This project serves as an example for future public engagement.

Prior to this event, the DCA database could only be mapped at the national level despite the existence of a very large amount of additional geographic data that has been collected since the inception of the program. At the national level, the entire data set can be mapped with an accuracy of 100 percent. The goal of this project was to add value to the data set by allowing users to map or query data at a finer level of granularity.

USAID partnered with federal colleagues in the Department of Defense (DoD) and General Services Administration (GSA), Socrata and Esri in the private sector, and the online volunteer communities – known more specifically as volunteer technical communities (VTCs) – of the Standby Task Force and GISCorps. In the end, these partnerships allowed USAID to automate geocoding processes that refined 66,917 records at 64 percent accuracy while a crowdsourcing process refined an additional 7,085 records at 85 percent accuracy. Our results confirm that crowdsourcing and using volunteered data can, indeed, be more accurate than other processes and establishes a promising precedent for future projects.

The reliability of crowdsourced and volunteered geographic information has been a persistent focus of research on the topic [*Elwood*, 2008a; *Haklay*, 2010; *Goodchild and Li*, 2012]. As this research notes, there is no reason to, *a priori*, suspect that these data are any less reliable than so called "authoritative data." As is true with any innovation, this project was a learning experience. Listed below are improvements and recommendations for any public sector, development, or humanitarian agency that would like to pursue a crowdsourcing path to data processing and public engagement.

- Agencies should involve their General Counsel from the outset to ensure that the project does not raise any legal issues and/or violate any policies/regulations. Every attempt should be made to disclose the nature of the data that volunteers are working on and ensure that they understand the purpose of the project. If certain information cannot be disclosed, these parameters need to be defined at the beginning of the project. When possible, a forum should be provided for questions to be answered to more completely engage volunteers in the goal of the project.

- Crowdsourcing a task should be understood as a project – like any other – that requires both management and a considerable amount of communication among partners to ensure a mutually beneficial experience and positive outcomes. Any organization that is planning to engage with crowdsourcing or VTCs regularly should build this management capacity into its organization. For USAID, I was able to fill this roll having previously been a member of several VTC.
- Agencies organizing crowdsourcing events should work closely with volunteer coordinators to provide the most appropriate guidance, for example by using several types of media (documents, videos, online chatting) to maximize volunteers' time.
- It is essential to have consistent and dedicated support for all technological aspects of such a project. All applications should be sufficiently tested to ensure that they can support more volunteers than expected.
- Development and humanitarian mapping projects would benefit from greater investment in existing initiatives to create and maintain updated, open, global boundary sets such as the United Nation's Second Administrative Level Boundaries or the United Nation's Food and Agriculture Organization's Global Administrative Unit Layers.
- Likewise, development and humanitarian mapping projects would benefit from greater investment in the National Geospatial Intelligence Agencies GEOnet Names Server (GNS) database in terms of content and usability.

This case study is meant to help individuals inside government looking to engage the public in new ways, and to individuals outside government hoping to understand some of the challenges and limitations the government faces in opening data. Ultimately taking risks with projects such as this one is key to helping all parties achieve more in a smarter, more collaborative way.

The Concept

Crowdsourcing is a relatively new phenomenon that has evolved significantly due to the emergence of Web 2.0 technologies that facilitate assimilating several small contributions into a larger effort. Crowdsourcing and associated themes rose to the forefront of the humanitarian and development context during the 2010 earthquake in Haiti. This was perhaps most visible in the "Ushahidi Haiti Project" through which the local population used text messaging to send requests for help. These requests were then translated, triaged, and geo-referenced by online volunteers to create an online map that gave an overview of needs for aid and relief assistance as expressed by the affected population.

Since then, the information landscape has continued to evolve. The humanitarian and development sector has identified innovative ways to incorporate new data and methods into well-established work flows, and leaders within "the crowd" have begun to formalize relationships and methodologies. While still nascent, increased public participation using new technology presents a shift in how the U.S. Government engages with its citizens and how citizens can participate in and direct their government.

The use of crowdsourcing for humanitarian or development interventions has spurred a lively debate about the attendant advantages and disadvantages of this approach including – justifiably –many questions surrounding data quality, security, and usability. Our experience will show that these questions were confidently addressed through careful planning and extensive dialogue with our partners. In addition to the substantive impact of having a clean dataset and map to release publicly, USAID was eager to explore this new way to engage with interested individuals anticipating that we would identify further applications of this methodology to further our work.

What is Crowdsourcing?

The neologism "Crowdsourcing" first appeared in 2006 to describe the phenomena whereby tasks are outsourced to a distributed group of people or "crowd" who is generally considered to be made up of non- experts and is further differentiated from formal, organized groups such as paid employees by their distributed nature [Howe, 2006]. However, no set definition yet exists since it can be used to describe a wide group of activities that take on different forms. Reviewing the definitions currently in use, Estellés and González [2012] propose the following:

> "Crowdsourcing is a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task. The undertaking of the task, of variable complexity and modularity, and in which the crowd should participate bringing their work, money, knowledge and/or experience, always entails mutual benefit. The user will receive the satisfaction of a given type of need, be it economic, social recognition, self-esteem, or the development of individual skills, while the crowdsourcer will obtain and utilize to their advantage that what the user has brought to the venture, whose form will depend on the type of activity undertaken."

Who was the "USAID Crowd?"

A common question regarding crowdsourcing is who, exactly, makes up "the Crowd?" Put most simply, the Crowd will be composed of individuals who are interested in the task at hand. Because most crowdsourcing involves access to a computer, Internet, and potential mobile devices you can begin to infer certain characteristics about members of the Crowd (e.g. those with access and capacity to use these tools).

Because this project demanded the ability to quickly and thoroughly investigate partial or problematic locational data, USAID chose to partner with online volunteer communities –

known more specifically as volunteer technical communities (VTCs) – to form the nucleus of the crowd while also soliciting general public engagement through various social media platforms such as Facebook and Twitter, and raising the awareness of this groundbreaking initiative. This had the benefit of ensuring that a minimum level of capacity for the task would exist in the Crowd while, at the same time, providing any interested individual with an opportunity to get involved. The two VTCs that partnered with USAID on this project were the Standby Task Force (SBTF) and GISCorps.

The Data and the Goal

The Development Credit Authority

All of the data used in this project came from USAID's Development Credit Authority (DCA). Through DCA, USAID issues partial credit guarantees to encourage lending to underserved sectors and entrepreneurs in developing countries. USAID typically shares fifty percent of any defaults as a result of the targeted lending with the financial institution.

Since DCA was established in 1999, more than 300 guarantees have been established with private financial institutions in developing countries. Over the years, up to $2.3 billion in local capital has been made available for 117,000 entrepreneurs in all sectors. The default rate is just 1.64 percent across the portfolio, proving the profitability and creditworthiness of these new sectors and borrowers. USAID has only paid out $8.6 million in claims, while collecting $10.6 million in fees, for billions of private capital mobilized.

Initial Data Release: DCA Guarantees

In December 2011, DCA released data on its 300 active and expired guarantees. The released dataset showed all partial credit guarantees that USAID has issued since DCA was founded in 1999. The spreadsheet detailed the full facility size of each guarantee, how much was lent under each guarantee, the status of the guarantee (i.e., active or expired), how much in claims the bank submitted due to losses it incurred for loans placed under the guarantee, which sectors each guarantee covered, and how many loans were placed under coverage of the guarantee. Since then, USAID has received requests from partners and the public asking for the Agency to release additional data from the program.

Releasing Additional Data: Loan Information

In 2012, DCA decided to map its reach and impact, and release that information to the public, to improve programming and analysis of its work. To map activities more precisely than the country level, USAID needed to release information related to each individual loan for all active and expired guarantees. While the first dataset contained 314 guarantee records, the second data set contained 117,000 loan records. Previously, loan records were primarily used by USAID to ensure that banks were making loans to the correctly targeted sectors as per the guarantee agreement. By performing in-person audits of the transaction records, USAID staff was able to confirm financial institutions were inputting accurate data into the Credit Management System, and could therefore pay claims related to those loans. The Credit Management System is an online database where USAID's financial partners input data regarding the loans they make against USAID guarantee agreements. USAID loan data has never been analyzed outside of the Agency and its independent evaluators.

The Goal: Potential impacts for Opening the Data

There are several substantive impacts that USAID foresees with the release of this data.

Better Serving Entrepreneurs: By creating a map that shows where there is available financing, USAID is making it easier for entrepreneurs to see where they could qualify for local financing. In addition, organizations working to help certain groups of entrepreneurs around the world access financing can take advantage of the USAID guarantee map to connect their networks with available financing. While the map does not list bank names or contact information, it provides a contact e-mail address (DevelopmentCredit@usaid.gov) so individuals can connect with local banks via USAID staff.

Targeted Lending: Visualizing loan data on a map can change the way USAID's in-country Missions plan for future guarantees. Guarantees are often targeted outside of capital cities or in certain regions of a developing country. By seeing where the loans are concentrated, USAID Missions can better analyze if the guarantees are fully reaching the targeted regions. In addition, the maps allow USAID to overlay additional open data sets on the USAID map. By adding a layer of open World Bank data on financial inclusion USAID can quickly see where needs and intervention align.

Analyzing Transnational Impact: For the first time, USAID loans can be easily analyzed across country borders. For example, if the map shows that in one country a region has all of its loans going toward agriculture but a bordering region in another country has all of its loans going toward infrastructure, it may suggest the need for future collaboration between USAID Missions. Without this type of analysis, USAID Missions in one country wouldn't have time to analyze the location of all loans for guarantees in surrounding countries.

Improved Partnerships: While USAID and other donors often try to collaborate to maximize impact; there is no overall database of active guarantees offered by all development agencies. By making accessible the map service layers, other donors can compare or even overlay their guarantee data to identify opportunities to increase collaboration.

Finding a Solution

USAID performed an initial analysis to look for patterns that would inhibit or allow a crowdsourced approach and conducted basic tests involving the number of records that an individual could process during a crowdsourcing event. It quickly became evident that manually processing 117,000 records would be a task that would require even several hundred volunteers, months to accomplish due to the amount of time it would take a volunteer to process one record. However, a majority of the records contained information regarding the first administrative unit of that country (or "Admin1"), which in the United States is the state level. Indeed, this was the only information given for records in certain countries. Based on this, Admin1 became the minimum mapping unit of the processed dataset, with finer scale resolution (place name) included as an ancillary benefit where possible.

Although the idea of crowdsourcing the geo-tagging of the DCA database was present from early on, USAID considered traditional approaches such as using existing labor or contractors. Each approach was evaluated on the basis of practicality, reliability, and cost. In the end, our approach was a hybrid method that involved contributions from other federal partners, private industry, and both the interested public and volunteer online communities that made up the Crowd.

The Problem: Non-Standard Location Information

The DCA database was originally structured to capture information regarding the amount, sector, and purpose of each loan as per the guarantee agreement and paid less attention to the geographic specificity of each loan. Users who entered data were given a single field marked "City/Region" and all geographic information was stored as free-form text in a single column in the database.

Typically databases have detailed geographic information collected in separate fields that are machine readable. The DCA database, on the other hand, did not separate these fields. Moreover there was no standardization given for how to enter various pieces of information (e.g. spelling of place names, abbreviations to use, separation of discreet pieces of information by commas). This unstructured, non-standard input method translated into a column of information that contained some, partial, geographic information but that could not be automated for mapping. Because the problem originated with a database that was poorly structured to capture geographic information our first task was to rectify this.

Fixing the Database

The DCA database has now been updated to have partners input location information into three separate fields: national, Admin1, and a populated place, which is generally the name of a village, town, or city. In order to keep the database standardized, the fields are linked to an external gazetteer, or geographical directory (GNS).

Whole-of-Government Approach

USAID staff take seriously the President's commitment to a "whole-of-government" approach to solving our country's challenges. Working with U.S. Government partners in the Department of Defense (DoD) USAID developed a basic automated process that standardized and searched the text in each record for any identifying features in the National Geospatial Intelligence Agency's (NGA) online gazetteer "GNS Names Server." Because the national scale information was correct, the automated process searched only for matches within that country. In cases were a place name was found, this was added to the record and used to generate both the Admin1 information and populate latitude and longitude based on the geographic center of that place: also known as a centroid.

Roughly 70,000 records could be automated to derive the needed Admin1 information and an additional 42,238 records contained no sub-national geographic information whatsoever. These records can only be mapped at the national level. The 9,616 remaining records, which contained the most problematic and partial geographic data, required human processing.

Bringing in the Crowd

After thoroughly and carefully conceptualizing the remaining problem, it was determined that crowdsourcing would be the best approach to move forward. USAID would present the Crowd with a clearly defined, bounded task that could be completed in approximately 15 minutes per record. As the project methodology developed, USAID conducted a series of tests using the evolving work flow and small groups of volunteers. One early test showed that volunteers grew frustrated by processing multiple entries with duplicate geographic information. Based on this, and with the help of the DoD, USAID developed a method of pre-processing whereby multiple, duplicate, entries, were collapsed into a single, "parent" entry to be given to the Crowd. The parent entry then would be used to populate its associated duplicate records.

In sum, the final, hybrid approach was a mixture of automated processes and crowdsourcing. Pre-processing involved stripping potentially sensitive data from the entire dataset, using the automated process to generate Admin1 and place name information where possible, and group multiple entries of duplicate information into a single record.

The Platform

Once USAID decided to move forward with a crowdsourcing solution, the Agency needed to identify an appropriate platform to enable the Crowd to view and edit the data. Internal market research turned up the following options:

1. Building a crowdsourcing platform for USAID to host similar projects in the future. This way the Agency would be able to build and cultivate an interested community within an engagement platform.
2. Using an existing tested platform on the market, for example, Amazon's Mechanical Turk.
3. Utilize a pre-existing government option. USAID discovered that Data.gov has the potential to be a platform for crowdsourcing. Data.gov currently hosts data in order to increase transparency with the public. This platform is already built and paid for by the General Services Administration (GSA) and is available for all U.S. Government (USG) agencies to use. By uploading the dataset as "private", then inviting the crowd to access it, the platform could be used at no cost.

Besides cost and utilizing pre-existing platforms, USAID also had to decide to either give volunteers a form where they would only see one record at a time, or give volunteers access to a spreadsheet to view multiple records at a time and have access to all records they previously geocoded. Ultimately a spreadsheet format, available through Data.gov , made more sense so people could reference records they had already completed or make corrections to past records if necessary.

For other Agencies interested in emulating this process, it should be noted that the setup for the USAID crowdsourcing application that connected to the Data.gov site was a one-off proof of concept and not a permanent part of the Data.gov contract.

Policy Issues & Necessary Clearances

When thinking through using crowdsourcing to process or edit previously non-public government information some initial flags were raised:

- Whether the government may use crowdsourcing and sponsor hackathon type events;
- Which steps the government must follow to use volunteers;
- What non-public information the government is able to release; and
- How to ensure data processed by external volunteers meets the Information Quality Act Compliance.

Using Crowdsourcing in the Government

The White House Office of Management and Budget (OMB) published a Technology Neutrality memo in January 2011 stating that, "...agencies should analyze alternatives that include proprietary, open source, and mixed source technologies. This allows the Government to pursue the best strategy to meet its particular needs."

Even before the OMB memo was published, other Agencies were utilizing crowdsourcing. For example, since 1999, the U.S. Geological Survey (USGS) Earthquake Hazards Program has used the "Did You Feel It?" Internet questionnaire to collect information about shaking intensity and damage from the Crowd. This qualitative crisis information from the public turned into quantitative metrics that fed into the other USGS earthquake products for emergency response purposes. More information can be found at: http://earthquake.usgs.gov/research/dyfi.

Similarly, in 2010, the Federal Communications Commission (FCC) used crowdsourcing to help populate the National Broadband Map (http://www.broadbandmap.gov/). The FCC provided the public with a mobile application to test and report their speeds, which were then used to populate the broadband map.

Finally, at the same time that USAID launched this project, the U.S. Department of State's Humanitarian Information Unit, launched an experiment to map roads and footpaths in 10 refugee camps that contain a population of over 600,000 people to better support humanitarian response and logistics. As with the USAID effort, they partnered with a well-known VTC – the Humanitarian OpenStreetmap Team – and the general public who spent 48 hours tracing satellite imagery to generate the maps. This short list is by no means exhaustive but illustrates the point that these new methods have already made an important contribution to the U.S. Government.

Free labor

It is within USAID's purview to accept gratuitous services if they are other than those performed by a U.S. Government employee as part of his or her scope of work. Assuming that is the case, the Agency could accept gratuitous labor after receipt of a written affirmation from those providing the services (prior to them doing the service) that:

- They understand they have no employment relationship with USAID or USG;
- They understand and affirm that they will receive no compensation; and
- They waive any and all claims against the USG with respect to the services being provided.

Because the project was taken on by the USAID team in addition to their regular duties, USAID's Development Credit Authority did not have the time or resources to go through 100,000 records for the purpose of geocoding the data. In order to use volunteer labor, USAID included the language above in the crowdsourcing application that every volunteer checked off prior to seeing any data.

Non-Disclosure Act Compliance

USAID's Development Credit Authority has partnerships with private financial institutions in developing countries. Due to the Non-Disclosure Act, the U.S. Government is not legally allowed to release private financial data of these partners. Therefore USAID deleted all private and strategic information prior to releasing the data. More specifically, USAID deleted columns including bank names, borrower names, borrower business names, borrower business asset size, interest rates charged to the borrowers, purpose of the loan, fees charged to the banks, and whether or not each individual borrower defaulted on his/her loan. Items remaining in the dataset includes the location of each transaction at the state level, and where possible at the city level, the sector of each loan, the amount of each loan in U.S. dollars, the gender of the borrower, whether the loan went to a first-time borrower, the currency of the loan since USAID guarantees both local currency and U.S. dollars, and which records were geo-tagged by the crowd.

Releasing Publicly Identifiable Information

For privacy reasons, USAID wanted to ensure that a business supported by a DCA guarantee could not be identified based on the data USAID released. Therefore prior to the crowdsourcing event, USAID partnered with the DoD to remove all exact addresses from the records. This was achieved by replacing all numeric data with a pound symbol ("#") throughout the database. However, concern remained that in some rural areas of certain countries even a single street name could be used to identify the one business on that street. Therefore USAID decided to take additional precautions.

First, all non-location columns were deleted from the Crowd's dataset so they would not have access to any additional information about each client. Then USAID took the additional precaution of not disclosing what the data represented to the crowd. Instead of telling volunteers the data represented loans to businesses, they were told that they were geocoding "certain USAID economic growth data." That way even if a business was identified due to a street that only had one business in a rural area, volunteers would not know anything about the USAID project the business was involved in. After the crowdsourcing event, the non-location columns were merged back into the dataset.

Next, in the final dataset released to the public, all specific addresses were removed, such as street names and street numbers, and USAID only released place names such as towns or villages where possible associated with each record. This is so the public would not be able to identify a specific business that benefited from a guarantee without the borrower's and bank's permission.

Finally, USAID was initially planning on releasing the original location field without numbers to the public in case anyone wanted to perform their own quality control/quality assurance on the records the crowd completed. However, to fully protect the clients, USAID ultimately deleted the original location field from the released dataset and instead released only the parsed out place name (i.e. nearest town, village, city, administrative unit, etc. to the address of the loan) and Admin1 name (i.e. state).

Information Quality Act Compliance

Federal agencies are required to comply with the Information Quality Act (Section 515 of P.L. 106-554) by maximizing the quality, objectivity, utility, and integrity of the information they disseminate. USAID ensured that the plan to use volunteers to improve the data using the Data.gov platform would comply with the Information Quality Act. During the crowdsourcing project, the data being worked on was visible only to the volunteers and was not publicly disseminated to non-volunteers. For the success of the project it was critical that I, and my colleagues, worked within the confines of the Information Quality Act with the Data.gov Program Management Office (PMO) in the U.S. General Services Administration (GSA). In the end, it was determined that there was not an Information Quality Act prohibition on using volunteers to reformat the data used in the project as long as USAID was able certify that the resulting information complies with the Information Quality Act and internal USAID procedures for assuring the quality of the information disseminated to the public.

Workflow

The Crowd's Task

As mentioned previously, the DCA database is structured in such a way that all geographic information is stored in a single field (labeled "City/Region" in the original database and later changed to "Original Location" for processing) and not standardized across all records (see example below): sometimes the city is given, sometimes a street address, and sometimes only the first administrative (or "state") level is provided. This is essentially a manual data entry problem: the data had to be broken out into different fields to be mapped at the lowest level of granularity across all records. Once parsed out, the place name would be used to capture the first administrative level unit by using a gazetteer such as GNS.

Because a DCA record often contains an Admin1 name and a city/town name within the Original Location field, it was recognized as feasible to develop an automated process that used a computer script to parse out the Admin1 name and/or place names and validate them against an authoritative database. The script first looked for matches for place names and Admin1 names against the NGA database. If no match was found, the text of Original Location was input to the Google Geocoding API to see if it would return an Admin1 name that was valid in the GNS database. The roughly 10,000 remaining records – representing the most complex and/or partial data would require human processing by way of the Crowd.

The Crowd's task was to mine the data for clues to the appropriate Admin1 and "place name" or name of a populated area or feature that would allow a volunteer to determine the

Admin1. Volunteers, therefore, would be given the country name and the "Original Location" (known in the original DCA database as "City/Region") with the task of deriving the Admin1 name, the Admin1 Code (based on international standards to eliminate problems of transliteration between disparate language), and place name if possible. Because of incomplete data, not all records could be processed and it was important to allow volunteers to flag such records as "bad data."

Table 4.1: *The "original location" column would be mined/parsed in to the proceeding columns and the status updated accordingly:*

Status	Country	Original Location	Admin 1	Admin 1 Code	place name
Assigned	Vietnam	Mac Thi Buoi Vinh Tuy Ward, Hai Ba Trung Dist Ha Noi Viet Nam			
Assigned	Haiti	Port au prince			
Assigned	Haiti	Sud			
Assigned	Paraguay	### calle, campo ####			

Table 4.2: *Thus the entries become…*

Status	Country	Original Location	Admin 1	Admin 1 Code	place name
Completed	Vietnam	Mac Thi Buoi Vinh Tuy Ward, Hai Ba Trung Dist	**Ha Noi**	**VM44**	Ha Noi
Completed	Haiti	Port au prince	**Ouest**	**HA11**	Port au prince
Completed	Haiti	Sud	Sud	**HA12**	
Bad Data	Paraguay	### calle, campo ####			

Assembling the Crowd

Reaching out to Volunteer Technical Communities (VTCs)

Because the primary task of the project was to mine geographic information and prepare the data to be mapped, USAID partnered with VTCs known for their capacity in this domain.

The Standby Task Force (SBTF) - http://blog.standbytaskforce.com: Launched in 2010, the SBTF has roots in the ad-hoc groups of tech-savvy volunteers who had begun to engage the humanitarian sector around mapping, information management, and other technical challenges. The goal of the SBTF is to harness the power of ad-hoc volunteers "into a flexible, trained and prepared network ready to deploy." The main objective of SBTF, and its 855 members, is to assist "affected communities through co-operation with local and international responders." To this end, capacity building for SBTF volunteers is paramount and supported by dialogue and coordination with other tech and crisis mapping volunteer efforts. SBTF members sign a code of conduct that is based on best practices in the field, including the Code of Conduct of the International Red Cross and Red Crescent Movement and NGOs in Disaster Relief and the United Nation's Office for the Coordination of Humanitarian Affairs (OCHA) Principles of Humanitarian Information Management and Exchange.

As an experienced member of SBTF who has participated in previous deployments I had built trust with several key points of contact and understood both the culture of the organization and its methods. Questions of motivation and trust can figure prominently in discussions between large governmental, humanitarian, or development agencies and VTCs especially when processing or collecting sensitive data. In this instance a common trust had already been well established. Using this as a point of departure allowed both groups to focus all of their energy on achieving the best results possible.

GISCorps: http://giscorps.org: Founded in 2003, GISCorps grew out of The Urban and Regional Information Systems Association (URISA: a nonprofit association of professionals using Geographic Information Systems or "GIS") and other information technologies to solve challenges in government agencies and departments. GISCorps coordinates short-term, volunteer based GIS services to underprivileged communities by deploying any number of its 2,672 members. GISCorps specifically aims to help improve the quality of life by engaging in projects that support humanitarian relief and encourage/foster economic development. GISCorps members sign a code of conduct that fully incorporates URISA's GIS Code of Ethics adding specific obligations for Volunteers, Project Sponsors, Donors, and GISCorps Administrators.

Drafting the Scope of Work to Deploy VTCs

Both partner VTCs have gone to great lengths to streamline requests for their services in the most professional manner possible. An online "request for activation" form can be found on both organizations' web sites. Requests are generally reviewed and responses generated within 24 hours. For this project the response from both organizations came within minutes. The request process is the important first step in defining the scope of work (SoW) for the project. The SoW is important for three primary reasons:

- Volunteer coordinators need to understand, precisely, the demands of the project to allocate appropriate resources and budget their management time.
- Well-defined tasks are more achievable than vague, partial notions: both SBTF and GISCorps place an emphasis on after-action review to learn from the project and to better prepare for the next.
- The above points mitigate volunteer frustration and provide a more rewarding experience.

For this project, USAID drafted a two-page, online document that explained, as precisely as possible, the task at hand. This document, along with the request for activation, became the starting point for a series of e-mails and calls between VTCs and USAID to further refine the SoWs and collaborate on how best to engage the public.

Marketing the Crowdsourcing Event to Potential Volunteers

USAID framed the message around this being a first-of-its-kind opportunity to engage with the Agency on its pilot crowdsourcing event to geo-tag and release economic growth data. While USAID utilized listservs and social media to publicize the event, half of volunteers came from established volunteer communities interested in geographic information and data. By partnering with the Standby Task Force and GIS Corps, the Agency had an automatic pool of thousands of internationally-based and interested volunteers eager to work on international development data with the government.

The primary webpage USAID used to talk about the event was a Facebook event page. The page can still be accessed at http://www.facebook.com/events/395012370542862/. One hundred ninety-one individuals signed up for the event on Facebook. This forum provided a platform to send volunteers quick informal updates about the project. During the week of the event, the USAID DCA Facebook page reached 4,200 people. The page had a 15 percent increase in "likes" in the two months preceding the event, increasing from 522 to 599.

USAID also set up an open data listserv so people could sign up to receive updates about the event straight to their inbox. 121 people signed up for the listserv and received notifications through the list about the launch of the event and a summary of what happened after the event concluded. To engage more people, USAID sent Twitter updates about the event using the hashtag #USAIDCrowd. The hashtag was widely used by the volunteers, interested observers, and other U.S. Government agencies and officials. Two months before the event @USAID_Credit had 830 followers and by June 1st (the starting point for the event) it had surpassed 1000 for the first time, a 20 percent increase.

In order to inform people beyond social media, USAID sent out a press release about the event, which can be found in the appendix of this report. USAID also presented and disseminated information about the event through USAID's University Engagement group. USAID invited other Government Agencies to participate by presenting at the White House Open Data working group meeting. Finally, a crowdsourcing blog post was published on USAID's Impact Blog to call attention to what the Agency was doing before the event.

USAID's partners were instrumental in getting the word out by blogging and tweeting to their followers, putting out their own press releases, and mobilizing their volunteers online.

Implementing the Crowdsourcing Event

The event was organized in four stages, each having its own unique characteristics in terms of the partners involved, data quality assurance and quality control (QA/QC) methods, technical challenges, and outputs. The overall workflow was designed to capitalize on each partners' strengths to achieve the best possible outcome. The stages, described in detail below, were pre-event, Phase 1 (data mining and cleaning using the Crowd), Phase 2 (data cleanup and mapping), and Phase 3 (independent accuracy assessment of Phase 1).

Pre-Event: Partners involved - DoD, Standby Task Force, GISCorps, Data.gov , Socrata, Esri.

This stage was entirely focused on planning. For the VTCs this meant refining the SoW, preparing resources, and test-runs of the workflow (discussed in Phase 1). Both VTCs spent considerable time communicating the established tasks to volunteers. This included creating detailed instructions for volunteers, establishing means of communication, scheduling, etc. For

SBTF this included ensuring continuous, around-the-clock management of a globally distributed volunteer network. USAID was closely involved in this effort, continually refining technical documents for volunteer use, coordinating marketing strategies, and replicating the use of SBTF communications strategies, such as using Google documents and Skype chat channels, for the general public.

One important aspect of the pre-event planning was asking volunteers to indicate their intended level of participation. Volunteer coordinators used this information to allocate appropriate management resources while USAID used the figures to gauge the likelihood of completion. Both SBTF and GISCorps kept their own, internal, "sign-up" lists for this purpose while USAID used DCA's Facebook web page to gather this information.

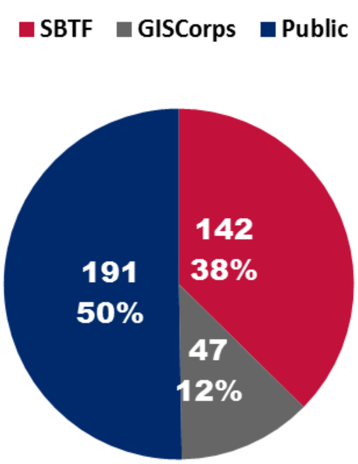

Figure 4.1: *Anticipated Volunteer Participation by Affiliation: "Public" data comes from the DCA Facebook page, which likely included volunteers from each of the other groups.*

It was during this time that volunteer management decisions were made regarding Phase 1. Because maintaining crowd motivation and input was critical for the envisioned three-day period there was considerable discussion about how best to handle a "crowd" of two VTCs and an unknown number of volunteers from the general public. Phases 2 and 3 were less of a concern since they consisted of a small, self-directed team. It was initially decided that SBTF volunteer coordinators would focus primarily on managing SBTF volunteers while USAID would manage GIS Corps staff and non-affiliated members from the general public. However, SBTF volunteer coordinators eventually went on to assist in the management of all volunteers in Phase 1.

During this time USAID also worked closely with Data.gov , Socrata, and Esri regarding the web applications that were developed for the project. Socrata, the contractor for Data.gov, undertook the design of a custom application that allowed for the use of Data.gov as a platform for the tabular data editing and generation. This considerably extended the capabilities of Data.gov that previously solely acted as a platform for data *viewing*. The Socrata application allowed users to check out up to ten individual records from the database at a time for processing. Using Data.gov ’s spreadsheet, the application captured the volunteers e-mail, time of check-out, and presented the user with the necessary fields for filling in Admin1 names, codes, and place names. The application further allowed users to flag "bad data": meaning that the geographic information provided was simply not good enough to permit that user properly geocode the record. USAID worked closely with the DoD regarding technical issues such as the necessary elimination of sensitive data discussed previously. The DoD also performed data cleanup that was necessary to ensure consistency within the dataset and all instances of certain text occurrences (e.g. "P-A-P" "Port au Prince," "Port-Au-Prince," etc.) were standardized.

USAID initially wanted volunteers to use GNS as the primary tool for searching text within the original geographic information and establishing a first administrative unit match. However, initial user testing found that the user interface for this database was problematic because it did not return the Admin1 code alongside the Admin1 name in search results. In general, volunteers did not find it to be as user friendly or extensive as other online tools. With this in mind, USAID also partnered with Esri, a mapping software company, to develop a custom web map application on Esri's ArcGIS Online platform that allowed users to easily and quickly find administrative names and codes with the click of a mouse. The properties and capability of this geocoding tool can be found at: www.arcgis.com/home/item.html?id=991a730ac41248428b48584ccf77b583.

Phase 1: Crowdsourcing - Partners involved: SBTF, GISCorps, Socrata, Esri.

Phase 1 was the most visible stage of the event. In order to coordinate and manage volunteers, USAID adopted the SBTF model including:

- A publicly available, online, Google document that detailed instructions and included screenshots of the applications and a log for frequently asked questions.
- A dedicated chat room using the freely available commercial software Skype. The chat room acted as a "call center" where volunteers could receive real-time instructions, advice, and ask questions. This is a highly social environment and a great number of volunteers used it: SBTF reports that 85 percent of their volunteers actively used the Skype chat room. The chat room becomes a space for sharing information - especially when certain volunteers have regional expertise - and relieving tension by interacting with other volunteers.

Moreover, USAID and the VTCs actively promoted the event and kept volunteers motivated with updates via the use of social networking tools (e.g. Twitter and Facebook) and regular e-mails. As a result of careful planning, Phase 1, which was scheduled to take place over a period of 60 hours (from noon on June 1 until midnight on June 3) was completed in roughly 16 hours with most records having been completed by 3 a.m. (Eastern Daylight Time) at which time the application crashed. When the application came back online, it took only another hour to complete all records.

In all, 145 volunteers took part in geocoding at least one record. While more had signed up to participate, because the event finished so early many volunteers never had the chance to clean records.

Phase: 1 Quality Assurance/Quality Control (QA/QC)

To participate, volunteers had to register an account on Data.gov, which was then linked to each record they geocoded. By linking records to volunteers at the individual level, USAID staff members were able to perform "spot checks" during the crowdsourcing event to look for anomalies in how the Crowd was entering data. If it was determined that any individual volunteer was incorrectly - whether purposefully or not - entering bad data, that volunteer could be contacted directly or their records could be redacted from the final product. It should be noted that at no time did USAID staff detect any suspicious activity. There were some initial mistakes made by volunteers that were rectified by communicating, en masse, the problem via the volunteer coordinators.

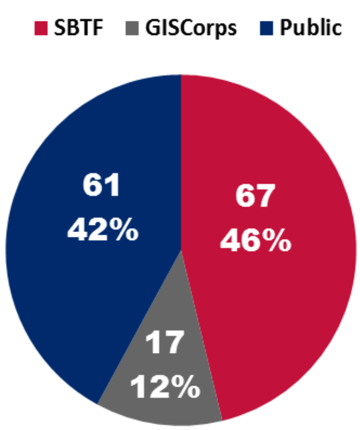

Figure 4.2: *Phase 1 volunteer participation by affiliation. Data are only for Phase 1 and do not reflect GISCorps volunteers for Phases 2 and 3, nor represent those volunteers who had signed up to work but could not due to early completion of the project.*

Phase 2: Data Processing and Mapping - Partners involved: DoD and GISCorps

This phase was largely designed to adjust for any problems in Phase 1 and to begin mapping the data. A small number of records (69) remained “assigned” but had not been completed. This is likely due to a bug in the application or problems while the application crashed. USAID had initially worked with GISCorps to ensure that a small team of volunteers was available in the event that all records were not completed during the two and half day Phase 1. This team was, instead, activated to complete the 69 remaining records. Once these records were finished, they were delivered to the DoD who played an important role by populating duplicate records based on the “parent” record that was given to the crowd. This essentially involved identifying multiple records with duplicate data information in the “original location” field. These records were then given a unique identifier and only one of them was given to the Crowd. The processed records would then be used to populate the necessary information for the duplicates.

It was also during this stage that initial data was processed concerning crowd performance. Records were sorted by volunteer using only a randomly assigned number, and then volunteer affiliation, to compare the intensity with which each group performed in Phase 1.

The volunteer data confirm an axiom for crowdsourcing that a small portion of the crowd is generally responsible for disproportionate share of the work (fig. 4.3). Volunteers from SBTF consistently processed records at a greater intensity. The social nature of volunteering, which was enhanced by using Skype chat rooms, likely contributed to increased productivity across all affiliations. It is possible that some GISCorps or SBTF volunteers were counted as “public” volunteers since these metrics were taken from VTC volunteer e-mail lists and volunteers may have used alternative e-mail addresses.

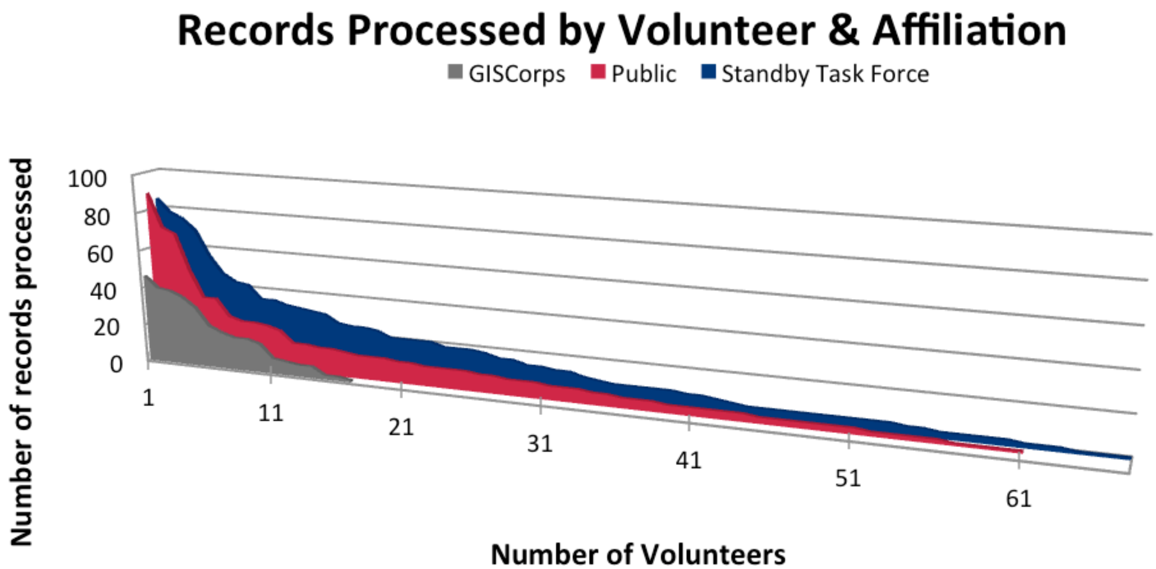

Figure 4.3: *Number of records processed by volunteer affiliation*

Phase 2: Quality Assurance and Quality Control (QA/QC)

Both USAID and the DoD reviewed the data to look for any anomalies or patterns that might indicate systematic error. This included an automated process that checked Admin1 codes in each record against the country designation in the record to ensure that all reported administrative units were indeed located in that country. USAID staff found 66 records that had not been completed correctly but the error was largely due to slight deviations in transcriptions when Admin1 codes were entered. These records were easily corrected. In all, 2,312 records were processed by the crowd, of which 480 (20 percent) were labeled as “bad data” and could not be mapped below the national level.

During phase 2, preliminary QA/QC was performed by comparing a set of 400 records that were processed using both crowd and automated processing. Of the 400 records used, the crowd labeled 12 of them as “bad data.” When comparing the remaining 388 there was agreement in 61 percent of the records for the administrative code (237 agreed, 151 disagreed) and 49 percent for the name of an administrative unit. The difference in agreement between Admin1 codes and names is likely due to small differences in input, including diacritical marks for pronunciation. It was for this reason that Admin1 codes were used as the basis for mapping. At first this finding was confusing because it did not communicate as much as a more disparate finding (e.g. only ten percent agreement or 90 percent agreement) might have, however, it would later confirm a greater than expected discrepancy between the accuracy of the automated and crowdsourced data. It also highlights the very subjective nature of the process and underscores the need for multiple methods for assessing the quality of the data.

Phase 3: Accuracy Assessment - Partners involved: GISCorps

To better understand the limitations of the data provided at the sub-national level, USAID asked the GISCorps to perform an independent accuracy assessment of the data. As geographic data is increasingly produced by, collected from, or processed by 'non-experts' the question of assessing the accuracy of these data has become a focus in scientific literature [*Goodchild & Li*, 2012; *Haklay*, 2010; *Elwood*, 2008a]. Following Congalton [2004], accuracy assessments are important for the following reasons:

- It provides a method of self-evaluation to learn from mistakes;
- It allows for comparison of the two geocoding methods quantitatively; and
- It better positions the final products to be used in decision-making processes where understanding the accuracy of the data is critical.

It is important to judge the relative accuracy of each data set independent of the other because volunteers had records containing much less, or much more difficult, geographic information than was available for the automated process.

Phase 3 Design

Phase 3 volunteers were tasked with creating a Quality Control (QC) dataset of high-quality geolocated records with which to do an accuracy assessment of the automated and crowdsourcing methods of geolocation. A random sample of records was drawn from both datasets; 382 records were drawn from the automated database, and 322 records were drawn from the Crowdsourcing database. These sample sizes were chosen to ensure that sample estimates would correctly represent population metrics.

The seventeen Phase 3 participants were selected from among highly-experienced GIS professionals in GISCorps; participants had an average of eight years of GIS experience. In addition to professional experience, participants were chosen who had experience in this specific geolocating process: of these participants, 13 had taken part in previous phases. In addition, participants were preferentially assigned records for countries in which they had personal experience, or spoke the language of the country. Participants were instructed to geolocate records with the greatest possible care, since their results were to be considered true and accurate. Phase 3 participants used the same geolocating resources as were used for Phases 1 and 2. Participants were not exposed to the earlier automated or crowdsourced results for geolocated records, so as to not bias their determinations. Participants were asked to quantify the difficulty and certainty of their determinations based on a one to five point scale. For example, a difficulty rank of one indicated that correctly spelled city/town name and Admin1 name were present in "Original Location" data, while a difficulty rank of five indicated that neither city/town name or Admin1 name were present and had to be inferred. A certainty rank of five indicated that the volunteer was completely sure of the Admin1 assignment, while a certainty rank of one indicated that the assigned Admin1 name was a best guess.

Phase 3 Results

Accuracy of results was calculated by comparing the resulting Admin1 Codes with the previously determined Admin1 Codes. The Codes were used rather than the Admin1 Names, because there is some variation in the spelling of Admin1 Names among the three geolocation resources. The Automated method was found to be 64 percent accurate, while the Crowdsourcing method was found to be 85 percent accurate.

Automated Method Details

Of the 382 records in the QC dataset for the automated method, 136 were in disagreement with the automated method results. The median certainty rating of records in the QC database (the degree to which volunteers were sure of their assignments) was five: the highest rating of certainty. It is therefore highly certain that the automated method results were inaccurate for these records. The median difficulty ranking of records in the QC dataset was two, which indicates that the "Original Location" field contained a valid Admin1 name or City/Town name, but that these valid values may have been difficult to parse out from among a long string of data. There were two records where the automated method accomplished a geolocation, but our experts were not able to do so.

These results suggest that the automated method script might be re-evaluated and improved by examination of the 137 records where invalid assignments were made. Many of the invalid assignment records contained a complex series of words in the "Original Location" field, for example:

> "LAMREUNG PERUM DAMAI LESATARI, DESA LAMREUNG, KEC. DARUL IMARAH-ACEH BESAR NAD"

A quite sophisticated logic might be needed to find the correct keywords for deciphering this location. In other cases the "Original Location" was not as complex, but the Automated method was too simplistic in its evaluation; for example for the "Original Location" of: "# DE JUNIO Y CALDERON ANTIGUA BAHIA", the Automated method recognized the word "Bahia" as a valid Admin1 Name, while the expert discovered that Antigua Bahia is the name of a neighborhood in the city of Guayaquil in the Canton Guayaquil Admin1 unit.

Crowdsourcing Method Details

Of the 322 records in the QC dataset for the crowdsourcing method, 46 were in disagreement with the crowdsourcing results. The median certainty rating of records in the QC database (the degree to which volunteers were sure of their assignments was four (the second-highest rating of certainty), so the experts were only slightly less certain of their designations than they were for the automated method dataset. This is to be expected, since these records were more complex to evaluate (as suggested by the fact that the automated method was unable to find matches). Surprisingly, however, the median difficulty ranking of records in the QC dataset was two, the same as for the automated records, which indicates that the "Original Location" field contained a valid Admin1 name or City/Town name, but that it takes some degree of sophistication by the experts to find these correct key words.

There were 63 records in the crowdsourcing QC dataset that the experts were not able to geolocate. Of these, 27 were geolocated by the crowd, which suggests that the phase 1 participants, in their zeal for success or inexperience, might have produced a result where one was not warranted. This may indicate that for best results, expert volunteers are needed.

Of the 46 inaccurate records, 15 mismatches were due simply to transcription errors; for example, where an Admin1 Code of "11" was typed instead of the correct code of "TZ11" (the country code was omitted). These errors are quite easy to fix by visual inspection of the database.

After correction of these errors, the accuracy rate of the crowdsourcing method improved from 85 percent to 90 percent.

Phase 3 Summary

The high accuracy rate for crowdsourcing method is a promising indicator of the quality of crowdsourced data, especially when experienced professional volunteers are recruited. The smaller accuracy rate for the automated method suggests that sophisticated algorithms need to be developed to impart a higher degree of intelligence to the computer – one way to develop this machine intelligence is through a QC check such as that done here where mismatches can be examined to capture the human thought process.

Following spot-checks during Phase 1 and the completed accuracy assessment in Phase 3, it was determined that, overall, the crowd performed very well with a high degree of reliability and only a small number of records were corrected.

Published Maps & Data

Determining what to map

As noted earlier, the goal of the project was to achieve a greater resolution than the national scale, which was the only level at which the data could be mapped. It was determined that Admin1 would be the minimum mapping unit but that, where possible, “place name” level data would be provided. This means that the dataset works at three geographic scales: national, first-administrative unit, and place name. The data are complete at the national level but become progressively less so at lower levels. After final processing, the first administrative unit was identified for 76,263 records, or 65 percent of the final dataset. Since some records are available at a finer or coarser geographic resolution, both “Place Name” and “Admin1 columns” are included in the released dataset.

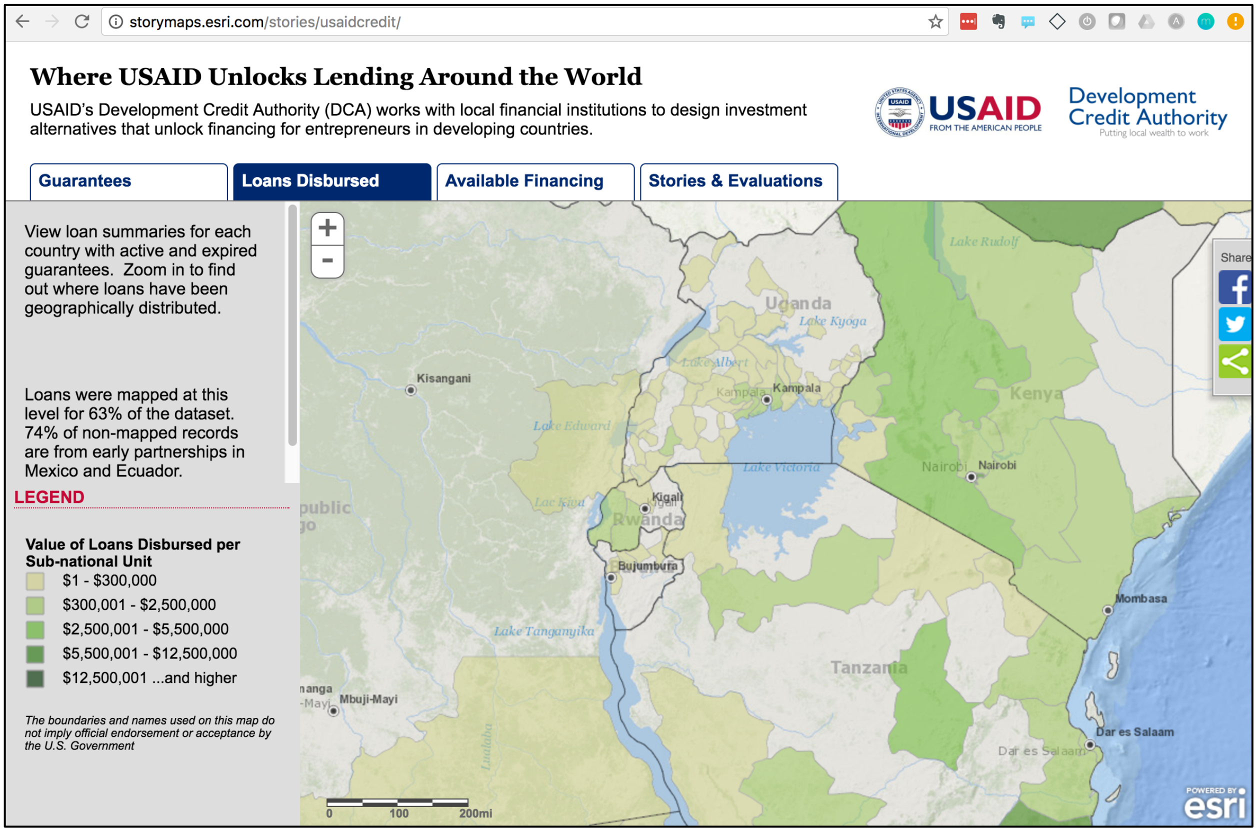

Figure 4.4: Final data published as an interactive, online map. This screenshot displays data at the first administrative level in eastern Africa.

Adopting the IATI Standard

The International Aid Transparency Initiative (IATI) aims to make information about foreign assistance spending easier to find, use and compare [*IATI*, 2012]. To this end, there exists a set of geographic precision codes that can be used with point data (http://iatistandard.org/codelists/geographical_precision). These codes are a valuable international standard that allows data to be compared across entities such as the World Bank, whose "Mapping for Results" uses this standard [*World Bank*, 2012]. However, using a fixed point, rather than an administrative area polygon, presents certain geographic challenges such as not accurately capturing the geographic extent of an activity.

While the web-maps that USAID created for public viewing display all data within aggregated administrative polygons, we have included centroid point data for all records in the transactions data set available on Data.gov and denoted each with the most appropriate IATI precision code.

Geographic and Licensing Issues of Using Admin1

The difficulty with maintaining a global database of internal boundaries is that a) these boundaries are the purview of individual countries and b) these boundaries can and do change. Boundaries or names used are not necessarily authoritative. While several open administrative boundary sets are available online, United Nation's Second Administrative Level Boundaries, or the United Nation's Food and Agriculture Organization's Global Administrative Unit Layers, they are often incomplete and not regularly updated.

The DCA map uses a U.S. Government created global data set of Admin1 units that contains both open and commercial purchased products that are protected by license. While the results derived from these boundaries are public, USAID cannot share the commercially protected shapefiles that contain each boundary's geometry.

The combination of Admin1 codes and names in the open data set can be used with open or commercial boundary sets acquired by the user to create new maps. Additionally, by providing centroid locations for all records and adopting the IAIT precision codes, users can alternatively choose to view the data as point locations instead of administrative units.

Summary & Lessons Learned

Prior to this event, the DCA database could only be mapped at the national level despite the existence of a very large amount of additional geographic data. While the entire data set can still be mapped at the national level with an accuracy of 100 percent value has been added to the data set by automated geocoding processes that refined 69,038 records at 64 percent accuracy and crowdsourcing process refined an additional 9,616 records at 85 percent accuracy, detailed in in the following table.

Table 4.3: *Accuracy Assessment*

Processing Method	Records Processed	Records Mapped at Admin1	Accuracy at Admin1
Automated	107,391	69,038	64%
Crowdsourcing	9, 607	7,225	85%
Total	116,998	76,263	

This provides the public with some options for using the data set at a finer geographic scale. Moreover, the process itself broke new ground by engaging the public, for the first time, in processing to map and open USAID data. The project attracted the attention of more than 300 volunteers worldwide, 145 of whom far exceeded all expectation by finishing their portion of the processing in roughly 16 hours: less than one-third of the time anticipated for this task. The additional 155 volunteers who had signed up to help on Saturday and Sunday logged in to find the project had completed before they were able to geocode any records.

DCA increased Twitter followers by 20 percent and Facebook friends by 15 percent during the preparation and launch of the crowdsourcing event. Moreover, the project created a strong relationship with two vibrant VTCs and was completed without any expenditure. As is true with any innovation, this project was a learning experience. Listed below are improvements and recommendations for any governmental, development, or humanitarian agency that would like to pursue an exciting new path to data processing and public engagement.

Policy Issues

Initially USAID was going to message the event around the impact of the data. However, in order to protect the borrower's personal information, USAID delayed disclosing details concerning the exact nature of the data to the crowd until after the data-processing was closed. There was concern that this would have a negative impact on the amount of volunteers and, indeed, some volunteers would have preferred to more clearly understand both the nature of the data and the final intent. While USAID was ultimately able to garner sufficient interest and participation for the event even with the more generic messaging, it is preferable that there be full public disclosure about the data prior to any crowdsourcing event.

Recommendations:

Agencies should involve their General Counsel from the outset to ensure that the project does not violate any regulations. Every attempt should be made to disclose the nature of the data that volunteers are working on and ensure that they understand the purpose of the project. If certain information cannot be disclosed, define these parameters at the beginning of the project. When possible provide a forum for volunteer questions to be answered and more completely engage volunteers in the goal of the project.

Reach-back to Crowd

Crowdsourcing often requires performance by a large group of individuals who are working remotely without any direct contact with the project convener. VTCs should be viewed no differently than any business partner: all parties are working toward a shared goal with limited resources. In both cases communication is paramount. Interacting with volunteer coordinators preceding and during the crowdsourcing event required a significant amount of time. This was time well spent as it involved continually refining workflow and communications and preparing trial runs of the workflow and applications. Any crowdsourcing project should include adequate time for this critical interaction. VTC coordinators must fully understand the task, workflow, and potential pitfalls that volunteers can encounter to best assist them during the project. Greater time spent preparing will directly maximize the efficiency of the volunteer's time.

Recommendations:

The Crowd is a resource and crowdsourcing should be understood as a project – like any other – that requires both adequate time dedicated to management and a considerable amount of communication between partners to ensure a mutually beneficial experience and positive outcomes. Any organization that is planning to engage with crowdsourcing or VTCs regularly should build this management capacity into their organization.

Operationalizing a Crowdsourcing Event

A simplified set of instructions would have enhanced the crowdsourcing event, and increased the likelihood that volunteers read the instructions fully. Additionally, a short online video showing volunteers the workflow and helping them understand what they were supposed to do would have been helpful. However having run through two trial runs and gaining volunteer leads to help run the Skype channels proved invaluable. Allowing volunteers to be able to choose which country they wanted to work on would enable individuals with a familiarity with a certain country to better complete those tasks.

The event would have also benefited from having volunteers use one gazetteer rather than searching among a wide range of online gazetteers. This would have helped to standardize the updated database and released data. Taking this a step further, ideally USAID, Socrata, and Esri would have linked the Data.gov dataset to the Esri USAID crowdsourcing application so when a volunteer identified a location, with one click the Admin1 name and code could be filled in within the dataset.

Finally, our Socrata application became overwhelmed with traffic and crashed at several points, causing some volunteer frustration. Although many volunteers are used to working in technically challenging conditions, every effort should be made to mitigate technical problems. In this case, Socrata's volunteer support was excellent, but was operating on a time-zone different from some volunteers and could not provide around-the-clock-coverage. Aside from load-related issues, the application also had bugs – most notably for the registration process – that had to be addressed on more than one occasion.

Recommendations:

- Work closely with volunteer coordinators to provide the most appropriate guidance to volunteers: use several types of media (documents, videos, etc.) to maximize volunteer's time.
- It is essential to have consistent and dedicated support for all technological aspects of such a project. Sufficiently test all applications to ensure that they can support more volunteers than you expect. This minimized volunteer frustration and time lost due to crashes.

Publishing Maps & Data

This project did not have access to a global administrative data set that is regularly maintained and that could be distributed publicly. Thus, USAID was unable to make the admin1 polygon shapefiles publically available as a service. Another challenge was that the GNS database did not contain information for some countries. This information had to be created individually and documented.

Recommendations:

- Development and humanitarian mapping projects would benefit from greater investment in existing initiatives to create and maintain updated, open, global boundary sets such as the United Nation's Second Administrative Level Boundaries (http://www.unsalb.org), or the United Nation's Food and Agriculture Organization's Global Administrative Unit Layers (www.fao.org/geonetwork/srv/en/metadata.show?id=12691).
- Likewise, development and humanitarian mapping projects would benefit from greater investment in the GNS database in terms of content and usability.

Conclusion

Throughout the Obama Administration there has been a commitment to make the government more transparent. This pilot USAID project sought to find the most efficient way to go about this process by utilizing existing platforms, new and existing partnerships, and online volunteer communities. Though crowdsourcing has been used by other U.S. Government agencies, this was the first time USAID utilized crowdsourcing to process Agency data and the first time Data.gov was used as a crowdsourcing platform anywhere in government. In effect, the Agency worked to blaze a trail to make these processes easier for others in government. The project has the potential to encourage more Agencies to publish more data in a cost-free manner and engage an interested and experienced public directly in U.S. Government work. This "data-as-dialogue" has transformative power not only for data processing, but also building greater awareness of USAID's mission, goals, and work.

Coda: better understanding crowdsourcing in international aid[1]

Groups within and outside of USAID broadly considered the crowdsourcing project to be a success. The approach I employed was seen to have the benefit of working as a form of public outreach and was also perceived as “innovative” by many observers: from academic researchers [*Eggers and Macmillan*, 2013], commercial producers of widely used GIS software [*Richardson*, 2012], and the popular press. The project was also featured by the global campaign for aid transparency, “Publish What you Fund”, which publishes an aid transparency index and advocates at the highest levels of government throughout the world for development agencies to be more forthcoming with data about their operations and projects. While USAID had fared somewhat poorly on Publish What you Fund’s annual transparency report cards, compared to other wealthy donor nations, the crowdsourcing project was seized upon with great interest and specifically cited in the 2012 report card as tangible proof that the agency, and the United States government in general, were taking bold strides towards transparency and open data [*Publish What You Fund,* 2012].

I conducted a cursory internal analysis to quantify the amount of public interest in the project by comparing web page views of the section of the USAID website devoted to the project to all other pages throughout the remainder of calendar year 2012. The analysis found that the number of unique page views placed the project in the top 3 percent of most-viewed web pages, with many of the remaining 3 percent being pages devoted to job announcements and information for becoming a contractor or grantee of USAID. It was also notable that users, on average, spent over 8 minutes on the web page. This is more than the average for any other page, which was slightly over two minutes. While it is possible that a user may spend longer on a

[1] This section did not appear in the published report.

website they do not understand – using the time to find their way around – it is most common that a user who is unhappy with the layout or content of a webpage will spend very little time viewing: often as little as thirty seconds.

I found it strange that, despite receiving such attention, I was almost never asked if any substantive knowledge was produced as a result of *analyzing* the data. Moreover, the topic of who was consuming the data almost never came up. I did provide one example of an online visualization created by an unknown analyst to view the data in subsequent presentations I gave about the project, but no other examples followed. It appeared that the primary value of the project had largely been its public appeal couched, as it was, in the language of public participation. I found this ironic considering the volunteers were not given a complete explanation about the project until its conclusion. Still the process had worked: it had created geographic data in a context where data creation was difficult and sharing often stymied. A variety of other questions began to develop around the theme of crowdsourcing geographic data for the aid industry:

- Could crowdsourcing be consistently deployed? This was one of the most frequently asked questions by those in charge of logistics and 'in the field' operations. They were often less concerned with extremely precise measures of accuracy and more interested in whether the process could be relied upon repeatedly.
- What types of data could be created? How might the data be used? The example of the Development Credit Authority had been chosen because it was not a live crisis situation, in which the introduction of new ideas is almost impossible

because aid industry professionals are focusing on carrying out activities that have been planned in advance and unfold in accordance to well established protocols.

- Was it really a “solution” to a dysfunctional information landscape or was it just re-creating the same problems?
- Was it really new? Were there historical examples of outsiders engaging to create data to respond to humanitarian events?

Based on my interaction with the “crowd” it appeared that there was a genuine space for exchange and participation and I began to see VGI as a convening tool for the various stakeholders in a given humanitarian event. But what might this look like? This public visibility and perceived political value was accompanied by a measure of freedom to pursue further ‘innovative’ projects. Several other crowdsourcing projects were beginning to happen throughout my community of practice and it became clear that I was part of a broader push in the field to both surmount data creation and sharing challenges, but also provide the opportunity of more inclusive data and knowledge creation. Some of these projects I was actively supporting and others I was only tangentially involved in. I was able to use this position, however, to observe several projects to try and answer these questions.

CHAPTER 5

UNDERSTANDING CROWDSOURCING AND VOLUNTEER ENGAGEMENT: CASE STUDIES FOR HURRICANES, DATA PROCESSING, AND FLOODS [4]

[4] Shadrock Roberts, Tiernan Doyle, 2016. Submitted to *American Geophysical Union*, 10/20/16

Abstract

Crowdsourcing is a method for data collection that involves obtaining data from a large number of individuals via the Internet and is one method for supporting information needs in disaster response. However, this phenomenon is often misunderstood or underutilized by traditional humanitarian agencies. Through a survey of current research on crowdsourcing in disasters, and our experience as practitioners, we unpack the concept of crowdsourcing and situate it in a broader history of volunteer engagement. We survey the current state of literature and present five case studies on crowdsourcing for disasters, with an emphasis on flooding and water events, and draw on our own experiences to investigate the concept of crowdsourcing to identify and describe different formulations of "crowd" and emphasize the volunteerism that underpins most crowdsourcing efforts. We examine the role of engagement with the crowd versus passive data collection to more precisely understand its relationship to data quality. Finally we outline key concepts to consider for crowdsourcing and how each contributes to better engagement with the crowd and results in better data for decision-making.

Introduction

Over the last five years the idea of "crowdsourcing" as a method for data collection during disasters has gone from esoteric, to disruptive, to a buzzword used to inject a sense of "innovation" to a project. Crowdsourcing is most commonly understood as the process by which information is obtained or digital tasks are broken up and completed by a number of people who are generally not considered "experts", typically via the Internet in the form of a large, open, call. Initially coined in the technology magazine *Wired* [*Howe*, 2006] to describe an innovative approach emerging in the technology sector, "crowdsourcing" captured the attention of the international community during the 2010 Haiti earthquake where it became a method to gather a wide variety of data related to the earthquake. At the same time, the sudden addition of thousands of virtual volunteers and overwhelming amounts of data in unorthodox formats created confusion for established modes of humanitarian data production and positioned proponents of crowdsourcing as both a potential threat and a welcome revolution to individuals within the humanitarian industry [*Harvard Humanitarian Initiative*, 2011].

The results of this nexus of technology and collective action have evolved in a variety of ways: previously nebulous groups of volunteers have become highly organized and structured themselves with clear lines of communication and some traditional humanitarian organizations have begun to incorporate various forms of crowdsourcing into their operations or experiment with it. Despite the recognition of the opportunities for disaster response that lie latent in the use of both technology and aggregated data, we have found that crowdsourcing and, perhaps more importantly, the various forms by which "non-experts" convene around data creation and sharing during disasters remain underutilized by traditional organizations responsible for disaster response. This overview presents a summary of literature on crowdsourcing in natural disasters – with a focus on flooding and storm surge events – as a step towards best practices.

We draw on our experience as practitioners working within traditional humanitarian organizations and community-based flood relief organizations to situate crowdsourcing in a longer history of citizen engagement and collective action that are critical for effective disaster response and post-disaster recovery. This chapter also examines the role of engagement with the crowd and its constituent volunteers to facilitate greater inclusivity in decision-making and improve the quality of data collected. We present several case studies that illustrate the value of crowdsourcing but also the considerations required to ensure its effective integration to disaster response. Finally, we outline key concepts to consider for crowdsourcing and how each contributes to better engagement with the crowd and improved data collection during disasters.

Understanding Crowdsourcing

Defining "the Crowd"

In our experience, "crowdsourcing" is a term that is only partially understood by those who manage response to natural disasters and is often viewed with a range of pre-conceived notions from extreme distrust to panacea. At its root, any crowd is composed of individuals and how you understand and build relationships with them or "the crowd" to which they belong will have direct impacts on how you are able to leverage the phenomena of crowdsourcing. Put more succinctly, "people's motivations to contribute information have implications for its credibility" [*Flanagin and Metzger*, 2008] and both accuracy and level of engagement can vary depending on the type of data being collected and their interest in the problem for which they are being collected [See et al. 2013, Swain et al. 2015]. This being said, there is no a priori reason to doubt that the quality of crowdsourced data or information can be good: in some cases – notably in the creation of geographic data – it can rival the quality of data created by commercial or governmental organizations [*Haklay* et al., 2010].

The term "crowdsourcing" originally described a company or institution outsourcing a function once performed by employees to a large, undefined network of people, but has since been used to refer to a wide variety of data creation practices in which those contributing have varying degrees of engagement, motivations, or awareness. In some cases, "crowdsourcing" is the act of harvesting data (often via social media) from a large network of individuals who share information for personal reasons and not as part of a collective action [see Cobb et al., 2014; Herfort et al., 2014] while in other cases it may describe focused collective action to support disaster response for a specific event [see Shahid and Elbanna, 2015]. Some literature uses the term "microtasking" and implies that this is a more structured form of crowdsourcing involving defined workflows and Internet platforms designed to maximize time and efficiency on specific tasks [*Morris et al.*, 2012]. However, microtasking appears to have its roots in crowdsourcing tasks done in exchange for pay by individuals in low-income countries [*Grant*, 2010; *Gino and Staats*, 2012] and although the term appears in conjunction with crowdsourcing in studies about its role in disaster response [*Meier*, 2013] a precise definition of how it relates to, or is different from, other forms of "crowdsourcing" done with specific online platforms remains unclear. The broadness of these terms, therefore, may obscure important details for those who want to operationalize crowdsourcing during floods or other natural disasters. Following [*Estellés-Arolas and González-Ladrón-de-Guevara*, 2012] we use it here to describe, "a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task." The participants from the crowd are fundamentally a volunteer group that is part of an active engagement process in disaster response and we encourage a view of crowdsourcing as a form of collective action.

The Many Faces of the Crowd

Although crowdsourcing is a relatively new phenomenon, the formation of new social relationships to meet the unique demands of a disaster is not new. In order to more clearly understand what crowdsourcing is, we situate it within the historical context of volunteerism related to disasters. Writing in 1985, [*Stallings and Quarantelli*, 1985] describe "emergent citizen groups" (ECG) during disasters. These ECG are loosely organized, tend to have a flat hierarchy, exist for short periods of time, and are composed by a core of continuing members with other individuals participating irregularly (Ibid). These characteristics are strikingly similar to certain group formations of crowdsourcing with the notable exception that ECG have historically defined as those directly affected by, or closest in proximity to, natural disasters.

The phenomenon of crowdsourcing in natural disasters is related to that of ECG. The evolution of technology has resulted in Internet communication technologies (ICT) that have lowered the traditional costs and barriers of social activities such as communicating to large audiences and connecting with others who have similar interests. This, in turn, makes it easier to organize groups of individuals and take collective action on issues that they care about, whether formally or informally [*Shirky*, 2008]. When seen in this light, crowdsourcing combines the motives of ECG with a greater capacity to collect, analyze, and disseminate information via technology. In the humanitarian sector, concerned individuals can now formulate new social relationships and approaches to data collection, analysis, and dissemination during natural disasters, often challenging the status quo of information management [*Meier*, 2015; *Crowley*, 2013; *Liu and Palen*, 2010].

The group formation of these individuals can take many forms. In recent years, the term "Volunteer and technical communities" (VTC) has been applied to volunteer-based communities – usually with some defined leadership – who apply their technical skills to support formal responders to natural disasters [*Waldman et al.*, 2013]. VTC may convene entirely online or be represented by an individual or team at the site of natural disaster. The online network of individuals who support the work of VTC or engage in other forms of crisis or natural disaster response using online tools are sometimes referred to as "digital humanitarians" [*Meier*, 2015], digital humanitarian organizations [*Crowley*, 2013] or "Crisis Mappers" – so named after an annual conference at which many of these new concepts were presented and new networks formed (www.CrisisMappers.net) [*Ziemke*, 2012]. Therefore, crowdsourcing can involve loosely affiliated individuals or highly organized groups; community-based organizations or pools of global volunteers who may never meet in person; and groups who self organize to complete a specific action on their own or those who actively support existing forms of disaster response. Their common characteristics are a strong sense of volunteerism and access to technology that enables them to engage with the humanitarian sector in new ways.

Trusting the Crowd: the role of engagement for better data

Current research regarding crowdsourcing for natural disasters often suggests or investigates its usefulness for situational awareness and, whether implicitly or explicitly, the degree to which it may contain geographical information. In a recent review [*Horita et al.*, 2013] found that the research regarding volunteered geographic information (VGI) in disasters focused primarily on its use during the response phase and that floods and fires were the most common disasters in which it was used. The practice of large groups of volunteers using online mapping tools to create new data has been labeled: neogeography [*Turner*, 2006] volunteered geographic information [*Goodchild*, 2007], or crowdmapping [*Shahid and Elbanna*, 2015] and several research agendas for VGI and crowdsourced data have been suggested [*Elwood*, 2008b, *Zhao and Zhu*, 2014].

The main issues raised concerning the use of VGI are credibility, reliability and quality [*Flanagin and Metzger*, 2008] because they are produced by non-experts in a context that differs significantly from the highly structured format in which "expert" data are created. Understanding the true value of crowdsourced data may be difficult due to its inherent heterogeneity and attendant absence of systematic, "professional" standards [*Feick and Roche*, 2013]. At the same time, several studies have shown that crowdsourced data are credible, reliable, and of generally high quality in a variety of contexts. [*Haklay et al.,* 2010] found that the spatial accuracy of crowdsourced geographic data was comparable to that generated by governmental authorities. The U.S. Government has crowdsourced reports of seismic activity to such great affect that it is considered a "valuable new data resource for both qualitative and quantitative earthquake studies and has the potential to address some longstanding controversies in earthquake science" [*Atkinson and Wald*, 2007] and provides a real-time earthquake detection system [*Liu*, 2014]. Several other reviews of crowdsourced data in practice suggest the promise it holds for environmental monitoring [*Wiggins and Crowston*, 2011; *See et al.*, 2013] and creating geographic data [*Neis and Zielstra*, 2014] and in a review of crowdsourced data relating to wildfire outbreaks, [*Goodchild and Glennon*, 2010] found that the benefits of these data can outweigh the risks.

Similarly, the case studies below show various measures for assessing the relative quality or value of crowdsourced information. However, we feel that absolute measures of credibility, reliability, and quality are inappropriate outside of specific contexts in which crowdsourced data may be created. Like [*Feick and Roche*, 2013] we argue that the socio-technological processes that permit individuals and groups, who may not otherwise interact, to create these types of data offer value in themselves. We see the engagement between the crowd and the end-user or requestor who may initiate a crowdsourcing activity as a critical space for exchange that can both foster greater inclusivity at the same time that it provides more "useful" data.

In the domain of disaster risk reduction, there is an emerging view of knowledge as a convening tool that can allow different stakeholders to build common understanding or risk and the way to cope with it. Like Menoni et al. [2015] we believe that co-production of knowledge should "enhance the cooperation and the coordination capacity among different stakeholders and social groups, particularly when they are working in the same geographical context on the same problems." The role then, of a motivated crowd – or group of volunteers – is a key variable to success [*Gouveia and Fonseca*, 2008; *Swain et al.*, 2015] and it is "critical that the crowd is treated as a partner in the crowdsourcing initiative, and the needs, aspirations, and motivations of the crowd must remain an important consideration" [*Zhao and Zhu*, 2014].

As crowdsourcing works on multiple scales and is not limited to specific types of tools, it can be difficult for informal and non-traditional responders to collect and distribute data in ways that are recognized as authoritative or accurate. Grass-roots responders must negotiate the paradox that their work relies on multiple forms of knowledge "but at the same time must tame them and abstract from them" to align with those pre-existing needs and information management structures of formal responders [*Burns*, 2014].

Recognizing that grassroots groups, especially ECGs, will often emerge during a disaster in order to meet a specific need is a first step towards allowing them to function as spontaneous subject matter experts. Both collecting and dispersing data from the affected population, these groups often possess insider knowledge for specific aspects of a disaster as well as access to communication channels and informal networks that may be more effective than official systems during a disruptive event. Emergent groups can rapidly increase the capacity of formal responders by identifying local resource channels and volunteers and have the potential to provide specialized knowledge derived directly from affected populations. As such, they can simultaneously model effective methods of data acquisition for often highly disparate communities and model service delivery to the affected population.

Several efforts exist to focus and streamline crowdsourcing by establishing volunteer networks and formalizing their crowdsourcing practices and protocols. Both Liu [2014] and

Crowley [2013] examine several of these networks including the Standby Task Force (http://blog.standbytaskforce.com), Humanitarian OpenStreetMap Team, or “HOT” (https://hotosm.org), Humanity Road (http://humanityroad.org) and the consortium of similar organizations known as the Digital Humanitarian Network (http://digitalhumanitarians.com), which organizes disaster simulations to streamline collaboration among groups and regularly publishes guidance for both VTC who would like to support traditional disaster responders [*Waldman et al.*, 2013] and for formal humanitarian organizations would like to better understand crowdsourcing [*Capelo et al.*, 2012]. As traditional disaster response organizations engage with crowdsourcing and, specifically, these emerging groups, the way in which crowdsourcing becomes a way to negotiate social and political processes around knowledge production will become increasingly important to improving future forms of engagement [*Burns*, 2014]. Already, we are seeing that this interaction can and does influence both institutional practice and the behavior of these groups [*Shahid and Elbanna*, 2015] and understanding this engagement as a dynamic relationship is an important step in building true participation as well as receiving data that are an appropriate fit for the task at hand.

Case Studies

The cases presented here are classified by three variables: event type, typology of data processing, and applicable phase in the disaster cycle, the last two being linked. Literature about the disaster management process identifies various phases, almost all of which include four basic phases: mitigation, preparedness, response, and recovery [*Hiltz et al.*, 2010]. Different types of information will be required at different phases of response. For example baseline data and development of scenarios are required for mitigation and preparedness while damage assessments will be required for response. While crowdsourcing activities have most often been studied during a response to a disaster [*Horita et al.*, 2013], the case studies presented here highlight the use of crowdsourcing in various phases of the disaster management cycle. Finally, these cases illustrate the need for building relationships with the "crowd" and creating partnerships, versus only focusing on the outputs of the "crowd" as a passive generator of data, thus situating crowdsourcing in the context of understanding volunteer engagement and community building.

Table 6.1: *Case studies categorized by event type, crowd activity, and disaster phase.*

Section & Case Study	Event Type	Data Processing	Applicable Phase in Disaster Cycle
Sec. 3.1.1 **FEMA damage assessments during Hurricane Sandy**	Hurricane	Damage assessment	Response
Sec. 3.1.2 **American Red Cross damage assessments during Typhoon Haiyan**	Typhoon	Damage assessment	Response
Sec. 3.2.1 **Crowdsourcing baseline data creation for the U.S. Department of State**	Multiple	Baseline data creation	Multiple
Sec. 3.2.2 **Data Processing for USAID**	Economic Development	Baseline data creation / Data processing	Mitigation / Recovery
Sec. 3.4 **Floods and ECG: the case of Boulder Flood Relief**	Flood	Operational data collection and response coordination.	Response / Recovery

Crowdsourcing Damage Assessments

A damage assessment is a preliminary onsite evaluation that captures the extent and cause of damage in the aftermath of a disaster. Assessments are often the first step in formulating response and relief operations such as evacuation, search and rescue, and shelter. Both of these cases were in response to cyclones and used crowdsourcing to produce data and analysis for damage assessments during the response phase of the disaster cycle.

FEMA damage assessments during Hurricane Sandy

In the wake of Hurricane Sandy's landfall on the Eastern seaboard of the USA in 2012, the U.S. Federal Emergency Management Agency (FEMA), used crowdsourcing to evaluate more than 35,000 GPS-tagged aerial photographs of damage-affected areas to aggregate geo-located data for situational awareness. FEMA working with HOT and the VTC GISCorps employed crowdsourcing as a method to evaluate and rate the level of damage shown in the images via an online system that allowed for three broad ratings: little/no damage; medium damage; or heavy damage. The after-action assessment of this effort used inter-volunteer agreement as a metric for evaluating accuracy. This is common in crowdsourced tasks when the "correct" answer is not known and is predicated on Linus's law that, if there is a large amount of agreement concerning a judgment from multiple volunteers, then it is likely that the shared judgment is the correct one [*Haklay et al.,* 2010].

The analysis was restricted to 17,070 images that had been rated by three or more volunteers. In these cases the crowd had majority agreement on 93.54% of the images. Additionally, 720 images believed to be the most difficult to rate were also rated by 11 experts from GISCorps using the same process for comparison. Experts generally agreed about how to rate these, more difficult, images: 81% had a agreement among the experts, compared to just

37% for public volunteers, showing that the volunteers were not as accurate (in terms of inter-annotator agreement) for these images. The biggest divergence of expert opinion from the crowd was on images that the crowd deemed little/no damage but which the experts said showed medium damage. In broad strokes, this matches the findings of the crowdsourcing damage assessment conducted by the American Red Cross (section 3.1.2) and suggests that crowdsourcing may not be an ideal method for damage assessments due to the subtle distinctions that might not be apparent to an untrained eye. This being said, the report also describes the role that image quality plays in aerial image interpretation and suggests that the crowd would likely learn from better and more frequent interaction with experts during rating process.

American Red Cross damage assessments during Typhoon Haiyan (Yolanda)

In 2013, the deadliest Philippine typhoon on record killed at least 6,300 people: it was one of the strongest tropical cyclones ever recorded and devastated portions of Southeast Asia. During the response to Typhoon Haiyan (also known as Yolanda) the American Red Cross (ARC) led a crowdsourcing effort to move beyond the geographic base data typically collected by crowdsourcing such streets, houses, farms and create information about building-level damage in areas affected by natural disasters [*ARC*, 2014]. For this effort ARC choose to use OpenStreetMap (OSM), which is most commonly understood as a free online map of the world. It is, however, a combination of elements: a database of geographic data; a website to display portions of the database; and a variety of tools that allow users to interact with the database to download, add, or edit portions of it. It is also a global community that interacts via various web-based communication channels in-person for conferences or activities that facilitate adding to the database. More than just an online map, OSM is a "multi-faceted project that enables distributed work around a common product." [*Soden and Palen*, 2014].

The use of OSM as a spatial data infrastructure for base vector data derived from satellite imagery during disasters is becoming increasingly common [*Crowley,* 2013; *Soden et al*., 2014] [*Campbell*, 2015]. This is due, in large part, to HOT, which emerged out of the response to the 2010 Haiti earthquake specifically to lead crowdsourcing efforts using OSM. HOT combines both globally distributed and localized work for different aspects of data creation and advancement of the social practices that surround the use of OSM [*Soden and Palen*, 2014].

Together, ARC and HOT tasked the crowd with tracing satellite imagery made available via the U.S. State Department's Humanitarian Information Unit to conduct a damage assessment in 6 coastal, urban municipalities: Carles, Medellin, San Remigio, Bogo, Daanbatayaan, and Tacloban. Instructions to volunteers were communicated via existing OSM wikis; list-servs; and the effort was widely disseminated via social media. To test the validity of the damage assessment, paid enumerators assessed building damage of 1,343 structures, in the field, in randomly selected municipalities that were most highly affected by the typhoon. The results show that the crowd did a "reasonably good job of identifying affected buildings but overestimated the number of buildings completely destroyed by the typhoon and underestimated the number of buildings that were majorly damaged." ARC found that the quality of the imagery directly affected the crowd's ability to perform the assessment especially because the orthographic nature of the imagery might conceal "partial" damage to the sides or insides of buildings. Furthermore imagery interpretation by the crowd was likely affected by three factors.

1. The resolution of the imagery used was too low to allow the crowd to reliably differentiate between destroyed and merely damaged buildings. In this case World View imagery with panchromatic resolution of 0.46 meters and multispectral resolution of 1.84 was used. Volunteers were provided with pansharpened, orthorectified imagery served

via a tiled map service that sends a compressed image file such as a .jpeg or .png that can be directly read by OSM editing software but does not allow volunteers to access the underlying digital numbers associated with each pixel. For a comprehensive look at this process see Cambell [2016].

2. Buildings with major damage in particular may be mistaken for destroyed; habitable buildings with heavily damaged roofs can appear destroyed at a 1 square meter pixel resolution.
3. The time required to plan and implement ground truthing allowed for repairs and reconstruction to have taken place on some structures.

The inability of the crowd to more accurately infer damage from remotely sensed imagery shouldn't be surprising considering the manual interpretation of it is considered both a "science and art" that takes time and experience to perform well [*Lillesand et al*., 2008]. Moreover, existing literature regarding the spatial accuracy of crowdsourced data in OSM suggest that volunteers do very well when identifying easily distinguishable objects. In other words, while OSM may not be the best method for collecting damage assessments, it remains useful for the collection of baseline geographic data. Indeed, ARC suggests that greater investment in baseline geographic data, specifically detailed building data layers within OSM prior to disasters, would improve facilitate the crowd's ability to spot missing or damaged buildings.

Finally, this case study lauds the "the continued responsiveness and diligence of the crowd", which mapped and validated an entire municipality within 48 hours upon receiving the request. It's noticeable that this occurred three weeks after Typhoon Haiyan made landfall when media attention of the typhoon was minimal and public interest had faded. In our experience, formal response organizations are often skeptical that volunteer efforts are a reliable enough workforce to merit any organizational investment in crowdsourcing but this case shows otherwise.

Working the Crowd for Baseline Data Collection and Processing

While crowdsourcing during the response phase of the disaster cycle is most prevalent in literature, it is important to consider how it might be used during the less acute phases. The length of time required to build appropriate relationship with a given body of volunteers may be better matched to mitigation and preparedness phases. The cases listed below show the value of crowdsourcing for the creation of baseline data or data processing and provide examples that could be applied to a variety of event types.

Crowdsourcing baseline data creation for the U.S. Department of State

The increasing value of OSM as resource, tool, and work force to create geographic data during disasters, and the consistent need to create baseline data before disaster strikes – especially in areas at high risk of disasters – led to an initiative of the U.S. State Department's Humanitarian Information Unit (HIU) known as MapGive whose purpose is to increase the amount of free and open geographic data. MapGive combines the "cognitive surplus" [*Shirky*, 2010] of volunteers with the power of the U.S. Government to provide updated high-resolution commercial satellite imagery to volunteers for vetted humanitarian purposes. MapGive has been used in several major disasters and confirms that crowdsourcing is a sustainable resource.

Launched in 2014, MapGive is one element of a larger ecosystem and has successfully implemented several steps (outlined below) to harness the power of crowdsourcing. Despite its name, MapGive did not begin with a map, but with a multi-year effort to establish the legal, policy, and technical framework for sharing commercial satellite imagery, purchased by the U.S.

Government with volunteers [*Campbell*, 2015]. HIU developed a geographic computing infrastructure built from open source software to publish updated satellite imagery as web services that can be quickly and easily accessed via the Internet, allowing volunteers to trace the imagery to extract visible features such as roads and buildings. HIU also reached out to existing organizations to help organize crowdsourcing efforts and has built a significant relationship with HOT to increase the number of volunteers by providing outreach, education, and training materials. Finally, MapGive is accompanied by a thoughtful communications strategy to give maximum visibility to their initiative and garner the maximum amount of volunteers possible when needed. When taken in sum, these sets have established a repeatable, sustainable mechanism for the U.S. Government to help catalyze and direct volunteer mapping efforts [Ibid].

MapGive has played an active role in crowdsourcing geographic information for: refugee camp mapping in the Horn of Africa; risk mapping and strengthening community resilience in Uganda; disaster risk reduction Kathmandu, Nepal; disaster response to Typhoon Haiyan in the Philippines; and humanitarian planning in the Democratic Republic of Congo. It is cited as a model for governmental use of crowdsourcing [*Crowley*, 2013] and is estimated to have leveraged between $1.5 and 2 million dollars worth of imagery to crowdsourcing efforts [*Campbell*, 2015].

Data Processing for the U.S. Agency for International Development (USAID)

Similarly, USAID began piloting crowdsourcing initiatives in 2012 to test the sustainability of using online volunteers to process data regarding international development and to investigate the overall quality of the resultant data. A dataset regarding loans made as part of USAID's Development Credit Authority (DCA) was identified as a potential target for crowdsourcing. This was an ideal way to test the viability of crowdsourcing for a variety of development and humanitarian actions in a non-crisis environment. The DCA database was originally structured to capture information regarding the amount, sector, and purpose of each loan as per the guarantee agreement and paid less attention to the geographic specificity of each loan. Users who entered data were given a single field marked “City/Region” and all geographic information was stored as free-form text in a single column in the database. Typically, databases have detailed geographic information collected in separate fields that are machine-readable. The DCA database, on the other hand, did not originally envision a demand for mapping its data and did not did not separate these fields. Moreover there was no standardization given for how to enter various pieces of information (e.g., spelling of place names, abbreviations to use, separation of discreet pieces of information by commas). This unstructured, non-standard input translated into a column of information containing only partial geographic information that could not be automated for mapping.

Working with the private companies Socrata and ESRI, USAID created a web site that allowed volunteers to ‘check out’ loan records and mine them for clues to the appropriate administrative unit, such as a county or municipality, to which the loan record should be geo-referenced. Because of incomplete data, not all records could be processed and it was important to allow volunteers to flag such records as “bad data.” Working with GISCorps and the Standby Task Force, both of whom are highly visible VTC, USAID broke new ground by engaging the public, for the first time, in processing to map and make USAID data publicly available. The project attracted the attention of more than 300 volunteers worldwide, 145 of whom far exceeded all expectation by processing almost 10 thousand records in roughly 16 hours: less than one-third of the time anticipated for this task. Of the records processed, 7,085 contained useful enough information to derive the needed geographic information. An accuracy assessment, using a separate group of expert volunteers, found that the selected subset of 322 records has been processed at 85% accuracy: after adjusting for a common transcription error, the accuracy level reached 90% [*Roberts et al*., 2012].

As with MapGive, the USAID project required that I spend amount of significant time on policy issues; establishing an appropriate technological environment; building strong relationships with organizations that would ensure a "core" group of volunteers around which a wider crowd could coalesce; and developing robust communication strategy to ensure transparency and visibility for all stakeholders. Indeed, the accuracy assessment was conceived as a necessary step to dispel persistent myths that crowdsourcing is not a viable method for quality data processing. It is notable that relatively few official USAID maps contain any form or accuracy assessment.

Together, these studies show that the productive cooperation between formal organizations – in this case governmental – and the crowd is not only possible, but can improve data and the methods by which they are collected and processed if enough consideration is given to the entire process. The advantages of crowdsourcing also extended well beyond the defined tasks: DCA saw a 20% increase in Twitter followers and increased Facebook "friends" by 15%, thus ensuring that their work was more widely known and supported by the public and the project is widely considered a success by other experts in the field.

Floods and ECG: the case of Boulder Flood Relief

The case of Boulder Flood Relief differs somewhat from the previous cases in that it is an ECG and was never presented as a crowdsourced project. The activities of the organization, however, do fit the definition of crowdsourcing in that they engaged in participatory online activity in which an individuals and groups of individuals of varying knowledge voluntarily undertook given tasks. While the organization began by collecting various forms of operational data for their own response needs, over time they engaged in a wide range of data collection and management practices aimed at better coordination among responders and activities for long-term recovery.

Boulder Flood Relief (BFR) is an ECG that provided organizational infrastructure to quickly mobilize volunteers for community disaster relief during the 2013 Colorado Floods. [*Doyle*, 2015] describes how official communications channels meant to direct or manage volunteer efforts were often not sufficient and official web sites such as the state of Colorado's http://helpcoloradonow.org were overwhelmed and unavailable during the floods as "the demand for information became greater than the technology could supply." Using social media and a variety of tools associated with crowdsourcing to formulate community-based response, BFR functioned at the nexus of technology and volunteerism by filling gaps in situational information and acting as a convening point for volunteerism that found little direction or support through official channels.

As exponentially increasing number of community volunteers outstripped BFR's initial data management solutions, the ECG reversed the top-down approach of official channels, choosing instead to share data as openly as possible within the shifting roster of volunteer office staff. Using freely available collaborative tools such as Google Docs enabled a more open form of knowledge production: as volunteers rotated hourly or daily through the office, open data sharing was paramount in order to compensate for the lack of centralized updating mechanisms. Methods of project development and logistics remained highly flexible dependent on the number of volunteers available, homeowner requests, jurisdictional restrictions, and onsite leadership.

Information sharing was the best solution to all of these issues and was relied upon to the point that the act of knowledge production became its own form of update, with the use of sharing technology allowing volunteer dispatchers and office staff to collaborate effectively as events unfolded.

The contrast between "top-down" and open source modes of knowledge production is a regular feature in the conceptual landscape where ad-hoc volunteerism abuts highly regimented governmental procedures and is often a source of concern for those wishing for a more tightly controlled flow of information. However, consistent research has shown that open source modes of production can, in fact, produce widely useful results [*Gouveia and Fonseca*, 2008; *Goodchild and Glennon*, 2010; *Haklay et al*., 2010]. This approach has long been trusted for open-source software development. In describing this process [*Raymond*, 2001] likens the top-down processes to that of building a cathedral: guarded, structured, and integrated, whereas the open source approach resembled a bazaar: chaotic, rapid, and iterative. Raymond describes how the inclusion of collaborative volunteers, connected via the Internet, produces better software because the code can be reviewed and corrected by a wider audience at a greater speed than with a top-down process.

BFR used this approach to successfully share situational information and try to match volunteers to specific tasks: dispatching over 1,300 volunteers to meet more than 300 requests for assistance. However, Doyle [2015] points out that, although flexible, this mode of working presented other challenges such as ensuring adequate privacy, which were dealt with via peer oversight to the best of the organizations ability. BFR also used a "bottom-up" approach for sharing information externally by leveraging social media to deploy emerging terms the public was using to search for information. By watching these terms emerge, and adapting to them, BFR promoted rapid diffusion of the information they had on hand. BFR also became adept at structuring "packaged tasks", or well-defined needs with requests for specific types of help that could be distributed via social media. This combination of internal and external information management was well suited to the self-organized nature of BFR and the pace at which the general response was moving: it was simply "Impractical to wait for updates from a centralized location."

BFR serves as an important example that the technique of crowdsourcing may already be in practice without explicitly being stated or advertised as such. Indeed, the flexibility of ECG's suggests that, when available, they will take advantage of ICT to help achieve their goals. Unlike crowdsourcing efforts that direct a global pool of remote volunteers to collect or process data to support decision makers, which may be in headquartered on an entirely different continent from where the disaster is happening, groups like BFR are collecting situational information specifically to make decisions in their community. They may represent the affected population, real-time data collection, and a valuable resource for disaster response in situ all at once.

Harnessing the Power of the Crowd

Whatever your interest in crowdsourcing you will need to devote some time to defining how it can be beneficial to your organization and developing the appropriate resources and relationships to accomplish this. While not necessarily requiring additional financial resources, engaging with crowdsourcing will likely require time in the form of staff who can interface with volunteer groups or technical analysts who can process the multiple types of data coming from the crowd. We list here several recommendations that we have directly experienced as being critical for effective crowdsourcing.

Technology

Because crowdsourcing is facilitated through ICT, either as a tool for organizing and communicating tasks to the crowd or as a method of data collection, crowdsourcing is often conflated with ICT and other technological terms, such as "social media" and "big data." It is critical to understand these as distinct elements if one is to have a clear picture of how crowdsourcing operates and the role of technology within that.

Crowley [2013] separates crowdsourcing into several distinct elements, including social media channels and the suite of hardware and software tools that enable the completion of crowdsourced tasks. The term social media refers to the various channels through which an individual – volunteer or otherwise – may provide data or information during a disaster. These include short text messages such as Twitter, websites for sharing photographs and video, or online platforms that combine multiple forms of media, such as Facebook: they may be a channel through which social media data are collected (see *Cobb et al*., 2014; *Herfort et al*., 2014 for examples). Social media channels may also be used to communicate with the crowd and to help organize specific actions (see *Roberts et al*., 2012; *Doyle*, 2015 for examples).

Furthermore, crowdsourcing efforts generally use a suite of hardware and software tools to perform a given function such as using OSM for mapping road networks. Some tools have been explicitly built with crowdsourcing in mind, such as the open-source software Ushahidi (https://www.ushahidi.com) that allows users to collect reports from affected communities via a range of social media channels or directly through the software itself. The use of open-source software and tools – those for which the original computer code is freely available and may be redistributed and modified without licensing restrictions – allows one to continually refine and adapt them and further invites volunteers to improve on the design of the tool itself. However, many ECG or VTC use a wide array of freely accessible ICT such as Google Docs (https://www.google.com/docs/about) and develop practices to align with the capabilities and constraints of the technology they are using [*Liu*, 2014].

It is also important to distinguish the companies or nonprofit organizations that develop these tools from organizations that organize crowdsourcing efforts or respond to natural disasters. As Crowley [2013] notes, these organizations may donate their time to provide support in specific instances, but they are not disaster response organizations and their mission is to build the ecosystem around the software that drives social value, a revenue model (profit or nonprofit), or both.

When considering technological issues, it is critical to coordinate with ECG or VTC to understand the technology that they have found most useful and how it may interact with the technology being used by other stakeholders. Engaging with volunteers over the method by which data exchange will take place can foster greater trust among stakeholders and is another critical piece of successful crowdsourcing. The digital infrastructure used to collect and manage data should not be seen as separate from, but complementary to, the act of crowdsourcing since the crowd may both contribute improvements concerning how to collect or manage data, but they may also wish to access and use the data they have helped create. The increasingly blurred line between those who collect data, those who manage it, and those who use it suggests the need for new approaches to data exchange [*Budhathoki et al*., 2008], which can harness the use of ICT to promote effective collaboration as well as data collection [*Gouveia and Fonseca*, 2008]

While ICT undoubtedly facilitates aspects of crowdsourcing it also excludes those who may not have equal access to it. And while there is potential for crowdsourcing to foster greater participation and equity among stakeholders, the manner in which it is carried out can also be exclusionary. The rate of Internet penetration and the geographical distribution of digital data reflect a 'digital divide' and the uneven development levels of our world [*Sui et al*., 2013] and critical reflection about the social and technological processes surrounding crowdsourcing is an important part of understanding which social and political interactions are supported and promoted through it [*Elwood, 2008b*].

Interoperability

Because technology is a fundamental aspect of crowdsourcing, it is vital for an organization to ensure that its information systems can work together within and across organizational boundaries to consume, share, and disseminate information. Many VTC collect, analyze, and share data using open source tools composed of software that can be freely used, changed, and shared (in modified or unmodified form) by anyone and publish their data in open standards. Understanding the way that data coming into your organization must be structured and how this may differ from the standards in use by volunteer groups or the crowd is an important starting point. It is possible that your organization may want to process data itself: however, most government and public service entities do not possess the computing power necessary to process the massive amount of data that can be generated by a large crowd. In this way, partnering with VTC or volunteer groups who can help process and clean data can be very valuable.

The use of open-source tools and compliance with open data standards can greatly improve interoperability in cases where an organization would like a free flow of information between volunteer organizations or "the crowd." In the United States, some government data standards are controlled by an ecosystem of vendors, whose platforms may not support open data standards [*Crowley*, 2013]. Organizations that contract the development of information management technology should include clear language in the terms or reference or other legal documents that ensure tools will be built with open standards in mind. The U.S. Department of State, which has implemented an open-source and open-data approach to crowdsourced mapping has built strong institutional relationships with volunteer organizations and has reaped the rewards of crowdsourcing to create large amounts of open data [see *Liu*, 2014; *Campbell*, 2015].

Data: Share and Share Alike

Most formal responses to a natural disaster begin with data to help prioritize and guide response [*National Research Council*, 2007; *Verjee*, 2007; *Campbell*, 2015]. Data such as known human settlements, elevation models, and critical infrastructure serve as a baseline to understand the possible scope of a disaster and the resources that exist to respond to it. Incoming data from damage assessments, surveys, and eyewitness reports can be combined with these baseline data to continually update situational awareness. Although VGI is often viewed as a singular data source, it does show value as a helpful validator when combined with other data *[Herfort et al*., 2014] and a variety of cases support crowdsourcing as a way to supplement data in a natural disaster [*Goodchild and Glennon*, 2010; *Horita et al*., 2013; *Liu*, 2014].

Ensuring your organization publishes open data – data that can be freely used, re-used and redistributed – is an excellent way to avoid duplication of effort, such as collecting data that are already acquired, and to identify gaps in data or areas that need to be validated. For data to serve decision makers across a society, data need to be fully open. This means that data must be:

- Technically Open: Many organizational datasets are published in formats that can only be read by proprietary software (and sometimes hardware, like obsolete magnetic tape backup drives). The data must be released in ways that allow any device or software can read.
- Legally Open: Be licensed in such a way that they may be used and shared widely.

Beyond data analysis: simply understanding how certain administration information must be structured, such as a request for assistance, can present a challenge for ECT, VTC, or individuals trying to share information. As traditional humanitarian organizations each maintain their own data management systems, it can be difficult for grassroots organizations to not only engage in information sharing, but for them to establish baseline data to work from. BFR found that multiple agencies responded to the same areas: individuals affected by the disaster had multiple damage assessments performed without knowing who or when anyone would come to their aid. Though data were collected in iterative streams, it was impossible to tell where records became duplicative between agencies. Residents requesting assistance accepted whatever assistance arrived first, including the mass deployment of disaster response groups into neighborhoods. As a result, some residents were the subject of scams, and the overall response was scattered and non-comprehensive. When grassroots and faith-based groups began sharing their information across a single platform, in an agreed upon format, the information from these informal responders was used to create a much more comprehensive picture of the damage and ensure that resources were more effectively deployed to those in need.

By refusing to share data or even collaborate on common information structures, traditional humanitarian organizations will perpetuate a narrow field of disaster relief that is clearly limited by organizational capacity, information sources, and mutable notions of authority. While most ECG begin as ad hoc efforts, the very learning process that they go through can be of benefit to traditional responders. ECG are not only gathering data, but also refining their methods for using them and streamlining their own interface with crowdsourcing. By engaging with and using the volunteer nature of these crowds, traditional responders can help foster innovation, flexibility, and learning in these social groups that will enhance the data that they provide as well as preventing the 'ritualistic behavior' of bureaucratic response [*Majchrzak, Jarvenpaa, Hollingshead* 2007]. Choosing to increase interoperability, and share information structures can motivate volunteer and grassroots responders to protect, verify, and aggregate their data streams; enhance direct relief processes within communities; and increase community participation in the long-term recovery process. In recognition of this, open-data created via crowdsourcing or as part ECG efforts plays an increasing role in disaster risk reduction programming [*Crowley*, 2014; *Soden et al*., 2014] and crisis response more generally [*Campbell*, 2015].

Read the Fine Print: understand policy implications for crowdsourcing

A wide variety of actions must be sequenced to formulate and implement a response to floods or other natural disaster. These actions are held together by an intricate web of rules and policies that govern the process that is rooted in legal regimes at a variety of scales (city, state, federal, international) and political decisions that are esoteric or even unknown to a large portion of the public. It is, perhaps, for this reason that the policy implications do not garner as much attention as they deserve. Although they have been the subjects of some study [*Crowley*, 2013; *Liu*, 2014; *Campbell*, 2015] they are far outstripped by literature relating to the technological aspect of crowdsourced data. Policy specifics will change according to the actors involved and a complete review of all possible policy issues is beyond the scope of this chapter. However, we find that they can be broadly thought of in two categories: policies about people that govern relationships and policies about information that define what types of information can be shared.

Many policies exist to govern sharing and dissemination of information. These may include: non-disclosure agreements that limit how much information volunteers can share; the management of sensitive or personally identifiable information; or rules that hold final data to a certain standard of quality. Other times, policies may limit how organizational data may be shared. In order to distribute satellite imagery for MapGive, the U.S. Department of State invested considerable time to help establish the legal frameworks for how this would be accomplished, which in turn defined the technological and operational parameters necessary to implement the sharing of imagery [*Campbell*, 2015]

Because a complete and detailed view of all policies of a given organization is unlikely even by those working without that organization, many advocates of crowdsourcing within governmental organization cite the importance of finding a legal advocate within the organization itself to help accomplish what needs to be done within the bounds of existing law and create new precedents [*Crowley*, 2013].

4.5 Build Relationships with the Crowd

As we have shown, crowdsourcing as an approach to data collection or analysis involves individual human beings organized to accomplish a shared goal. Whether creating an open call to gather real-time information from the ground, organizing online volunteers to help process data, or asking for local assistance in debris removal, the most effective crowdsourcing efforts will be those that are part of longer-term strategy of inclusiveness. Maintaining emphasis on the individual nature of crowd members is the most effective way to increase organizational and response capacity through crowdsourcing: this opens the door to innovative problem solving through the individual skill sets and unique backgrounds of your crowd members while also increasing the effectiveness and level of participation in shared workflows.

The crowd is a resource and crowdsourcing should be understood as a project that requires adequate time dedicated to management and a considerable amount of communication among partners to ensure a mutually beneficial experience and positive outcomes. Any organization planning to engage with crowdsourcing should build this management capacity into their organization. VTC, ECG, or other groups that help direct this work should be viewed in the same light as a business partner. In our experience, all parties are working toward a shared goal with, generally, limited resources and under stressful timelines so clear communication is paramount. Volunteer coordinators must fully understand the task, workflow, and potential pitfalls that volunteers may encounter to help resolve problems during the project. In our work harnessing VTC and various formulations of "the crowd" we found that time spent in advance to refine workflow, communications, and test applications was vital to the success of our effort [*Roberts et al*., 2012]. The case of BFR shows that open calls for assistance can be highly productive when tasks are clearly defined and packaged with specific requests to directly maximize the efficiency of a volunteer's time [*Doyle*, 2015]. Questions of appropriate technology, interoperability, open data, and policies can all be used as starting points for discussions with the crowd, whether through VTC or ECG. Having a shared understanding of the technological and organizational environment you are working in will greatly facilitate working with the crowd and help build a trusting relationship.

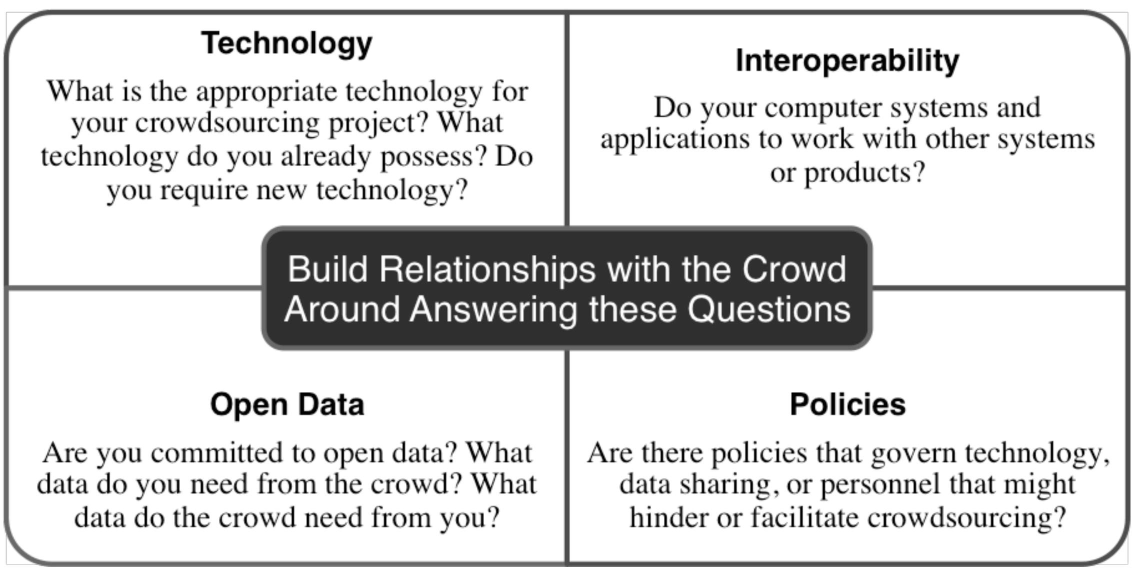

Figure 6.1: *Four primary components to a crowdsourcing project that offer important convening points for VTC or ECG.*

Beyond communicating for the sake of efficiency, remember that people volunteer to make a difference and that connecting with others often becomes a profoundly important aspect of the volunteer experience. In all of our projects we have found that fostering these connections can create a sense of community that helps improve outcomes during the course of an effort. BFR found that residents who were assisted during initial relief efforts became themselves some of the longest lasting and motivated participants in volunteer activities once their own situation was secure. Many volunteers also developed relationships with the people they were helping, and began self-deploying to assist their new community rather than relying on an external organization for project creation. After building strong, visible, partnerships for its first crowdsourcing effort, USAID found that volunteers would suggest better ways of working or make introductions to individuals who had important information to share or who could facilitate both data collection and dissemination throughout a community. Volunteers came forward with these suggestions because they felt that they were truly contributing to a social good and that they were valued as a partner in the process. In short, they felt invested. BFR found that this form of data brokerage can be very specific to different community contexts and will change over time and finding and maintaining relationship with those who understand how to appropriately collect and share data throughout a community can be critical.

Communication is also important to better understand the desires of the crowd or the volunteers who are helping to manage it. We have found that decision makers often see crowdsourcing as a way to harvest data, specifically for "situational awareness." While the advent of portable and personal technology now allows for "citizens as sensors" to capture and disseminate a wide range of geographic information [*Goodchild*, 2007] it is a mistake to focus solely on harvesting data from individuals or groups in a one-way flow of information. During a flood or other disaster, the affected population may also be your data provider: alienating them by lack of engagement means losing access to the data they collect and reducing their participation in their own recovery. As much as possible, use the crowd as a way to disseminate information about the response itself as part of a two-way communications strategy. [Doyle, 2015] found that when flood response activities were shared broadly on social media, via local radio, and disseminated through volunteers, they inspired greater community participation and helped identify new opportunities for partnerships. Conversely, Doyle notes that a lack of updated official information or official information that contradicted the lived experience of the affected population created more impetus for communities to seek out knowledge and support for themselves versus complying with official directives.

Finally, building relationships with the crowd or volunteer organizations can significantly increase public support for or interest in those entities leading the formal response. Improved public relations can help promote your work, build political capital, and help align your organization with the needs of those for whom it stands to serve. By investing in open dialogue with the crowd and VTC, USAID's Development Credit Authority (DCA) saw a significant increase in social media followers during the crowdsourcing effort: boosting Twitter followers by 20% and increasing Facebook "friends" by 15%, thus ensuring that their work was more widely known and supported by the public.

5 Summary

Contemporary technology facilitates the organization of volunteers to collect or transmit their observations about natural disasters and to synthesize them into a variety of outputs to support traditional humanitarian response. And although crowdsourcing is a relatively new phenomenon, it is best understood in the larger context of volunteer efforts that spring up in times of disaster. The fundamental question raised by this chapter is: How can one best engage volunteers – in any number of social groupings – to provide effective assistance to traditional humanitarian responders?

We situate crowdsourcing along a continuum of volunteerism in disasters and advocate for it as an avenue for greater inclusivity during the act of data collection and decision-making. As our experience and the studies presented here show, crowdsourcing geographic data can be an effective method for increasing efficiency and gaining new insight if appropriately implemented under a philosophy of greater inclusion. We find several technological and data-related elements can increase productivity and relative quality of crowdsourced data, including: the quality of existing baseline data; clearly defined tasks; and regular communication with volunteers. We also find that crowdsourcing may not be effective for certain forms of subjective categorization – such as categorizing damage from satellite images – but that it may also provide insider or highly specialized knowledge. On the basis of our experience and the studies presented, we advocate for appropriate technology to be adopted in conjunction with the crowd; greater inter-operability; and open data to maximize transparency and coordination in order to produce the most appropriate forms of data for responders. Finally, we see crowdsourcing as an opportunity to foster inclusivity into the decision making process around natural disasters. When seen as a space of exchange, the process of crowdsourcing can support greater participation, particularly in reinforcing the transparency and responsiveness of disaster response.

CHAPTER 6

MODES OF PRODUCTION FOR GEOGRAPHIC INFORMATION IN THE INTERNATIONAL AID INDUSTRY: CONCLUSIONS AND CONSIDERATIONS

In 2007 before I had begun my doctoral studies, a prominent remote sensor told me that, considering the high-cost of VHR satellite imagery, it was "really unlikely that a student could get enough data to work with" and discouraged my proposed topic of population estimates in refugee camps. Just a few short years later, as I was beginning my doctoral program, a leading remote sensor working for the UN proposed the idea that a UN fieldworker should be able to use her mobile phone to request, via a system then being developed by the UN, an imagery-based map that would guide her decision making about where to plan humanitarian interventions [*Bjorgo and Retiere*, 2009]. The difference between these two years illustrates how far technology can come, even while our assumptions about it can hinder how we envision its use.

We Do Not Have an Algorithm Problem

The idea that availability, cost, and timeliness of data would all be serious impediments to the use of remote sensing data [*Bjorgo*, 2002] are understandable, but underscore the lack of vision that practitioners and researchers showed in a field where the use of home-spun remote sensing data collection using kites [*Sklaver et al.*, 2006] – a precursor to drones – and Google Earth [*Pezanowski et al.*, 2007] would soon become matters of everyday discussion. The idea does, however, imply the importance of regular data collection and a repeatable workflow to create meaningful information that could be used to influence decision-making.

The type of analysis outlined in chapter 2 requires a reliable pipeline of data, computing power, and human operators if it is to be more than a one-time study. As outlined in chapters 3 and 4, the current context of geographic data production in international aid makes a reliable pipeline extremely difficult because:

- the computing infrastructure is often inadequate or designed more for the secure storage of other forms of operational data than the widespread sharing of geographic data;
- policies that govern the creation or sharing of data can present considerable roadblocks; and
- the job positions required to effectively create or manage the creation of geographic data – via crowdsourcing or otherwise – are often limited or do not exist. I have found that when geographic analysts positions do exist they often have very limited resources to support their work or are filled with individuals whose background is computer science versus geography of GIS.

These aspects of international aid are rarely, if ever, dealt with in academic literature regarding GIS or RS in international aid. There are examples of researchers to create, not only knowledge of, but functional workflows for geographic information [*Tiede et al.*, 2013] and working more closely with implementers of humanitarian activities [*Füreder et al.*, 2015] to ensure their adoption. A novel approach in some research has been to detail the data and methods for a particular study along with the decision-making entity that the research was meant to support and to whom the results were delivered [*Lang et al.*, 2015]. However, these studies are notable for their relative paucity rather than their ubiquity.

In a recent special edition of the Journal of Genocide Prevention devoted to new technology, research regarding the use of remote sensing is framed as something that can "*offer* *much potential* [emphasis added] in verifying and tracking human rights violations and mass violence" [*Connell and Young*, 2014] or something that is being created far outside of the context described previously: "the approaches articulated herein should be studied and built upon through further research that will *require the committed involvement of expertise and resources from a diverse community of entities* [emphasis added]. These actors may include academic institutions, human rights and humanitarian NGOs, international legal experts and bodies, governments, private business, and most importantly, the communities affected by mass atrocities themselves… If such research is pursued, MARS may *eventually* [emphasis added] have a place in mass atrocity investigations as its own formalized profession." [*Raymond et al.*, 2014].

There seems to be a widespread assumption that the computing environment and technical capacity available to the community of practice in international aid to utilize the methods being researched in academic journals are in place and simply lacking the requisite algorithms for processes such as feature extraction or detection. This is simply not the case. A continued focus in this direction obscures the real challenges of applying remote sensing, and other forms of geographic data, to international aid. As one colleague dryly stated after meeting with a contact who was offering extremely high resolution aerial imagery for a particular area of interest, "We had 3 meter resolution imagery in Haiti and nobody used it, so I don't really see how having a bunch of hard drives full of 8 centimeter resolution imagery is going to make much of a difference." In short, we do not have an algorithm problem: we have infrastructure, policy, and human resource problems.

Does Crowdsourcing Obviate or Replicate the Challenges of Geographic Data Production in International Aid?

Crowdsourcing as a mode of production for data in international aid as detailed in chapter 4 was conceived as one way to obviate the many infrastructure, policy, and even human resource roadblocks that are part of the field of practice. Crowdsourcing has the added benefit of fitting the current zeitgeist of data production and being perceived as a more publicly engaging method to create necessary geographic data. Writing in the proceedings of a recent USAID conference, Secretary of State John Kerry explained that, “Integrating the use of data across development, and making the information available to the public, helps programs be more effective and reach more people… We are also piloting and expanding innovative approaches to gathering data through social media, geospatial mapping and mobile phones.” [*Kerry*, 2014]

Again, certain assumptions embedded in the approach to geographic data in international aid obscure barriers to more widespread adoption and effectiveness. In retrospect, the crowdsourcing project outlined in chapter 4 is marked by a tension between the perception of the projects as “empowering” or “participatory” relative to the limited role of the participants: essentially that of a distributed workforce tasked with creating data in a highly prescribed manner and with very explicit guidance. Chapter 6 offers several cases of, and suggestions for, optimizing participation with VTC, ECG, or “the crowd” in an inclusive way but even these are centered on solving the infrastructure, policy, and human resource issues outlined elsewhere. While the process of each project – manual digitization in OSM related projects and the geocoding of development data for USAID – was a cooperative venture between the participants, the substantive nature of what data should be created, how it might be analyzed, and what interpretation might be drawn from it were not open for discussion. So while the “crowd” was free to contribute to the creation of geographic data, organizations such as USAID and the State Department maintained considerable roles as bodies of oversight. This opposes less critical views that by merely inviting the public to help produce geographic data one is being inherently transparent, inclusive, or participatory. Indeed, this may not be of primary importance to VTC or ECG or other "digital humanitarians" whose work is often undertaken with the intent to gain legitimacy with formal entities with the international aid industry [*Burns*, 2014].

It is my experience that, while many crowdsourcing projects can successfully work around the dysfunction of geographic information production in international aid, it nevertheless replicates many of the same power dynamics that mediate how data are created or used in the first place. This phenomena appears across scales: even as community based organizations and non-profits adopt open-source tools and crowdsourcing methods for geographic data production the need for an intermediary to help with the most fundamental technical aspects of the work, thereby re-creating some of the same power dynamics that these methods were assumed to solve (Brandusescu, Sieber, and Jochems 2015).

We Have a Political / Power Problem

During the course of my research I have often heard the terms "decision maker" and "decision making process" escape my lips almost as an afterthought… as though it is already understood that there is a defined, immutable, process or identified individual vested with the power to make rational decisions, based on evidence, for the good of all. But in those few words is the precise location of where many issues lie. This thinking does not address the power relations or policy issues that impede the implementation of 'good' science nor does it allow a view of complex and contested relationships within international aid about who does wield power, why, and what the outcomes of this are.

For this reason, Bjorgo's 2009 example of a UN mobile phone-based imagery request system merits a moment of contemplation: today any UN fieldworker with a smartphone and connectivity can receive instant satellite imagery via Google Earth – often with relatively recent, VHR – and detailed feature information via a wide range of spatial databases including OSM. The more important question is: does this matter?

While one may discuss how refugee camp planning can be informed by remote sensing [*Bjorgo*, 2000; *Tiede and Lang*, 2008; *Wendt et al.*, 2015], this purely technocratic view ignores: the fact that camp planning is often more a result of governmental desire to monitor and manage a foreign population far away from population centers [*Jacobsen*, 1997; *Hyndman*, 2000; *Horst*, 2006]; how these camps become spaces of discipline and governmentality via the politics of humanitarianism [*Hyndman*, 2000; *Agier*, 2008]; and the highly questionable nature of responding to the problem of displacement with camps in the first place [*Black*, 1998; *Hyndman*, 2000; *Montclos and Kagwanja*, 2000].

As demonstrated in chapter 2, and by the statements of Secretary of State Kerry earlier in this chapter, remote sensing and GIS are framed as part of international aid as a "technical" project that, when all the pieces are arranged in the right order, will arrive at a positive outcome. The notion that more data and better knowledge sharing will improve international aid are widespread in current thinking [see *Easterly*, 2006; *Ramalingam*, 2013] but ignore the more critical view that international aid is not something that "one does" rather, it is a complex process of political, social, and financial intervention that affects certain places, certain ways, at certain times, thereby presenting both opportunities and challenges that are negotiated by local populations in particular ways [*Carr*, 2011]. We may struggle to tinker with small adjustments to knowledge production in international aid, but until we begin to critically examine the underlying power disparities that allow uneven development to happen throughout our world it is unlikely that these small adjustments will affect the profound changes that decision makers often call for.

Recommendations for Future Research

This dissertation set out to describe how geographic data is created in the arena of international aid and relief and asked whether crowdsourcing is a viable option for the creation of these data. While there are a variety of methods which can create data, the findings of this research point to the fact that the life cycle of geographic data remains fragmented and often dependent on social relationships that may be illegible to others within the same organization. The three organizational environments that made up the research context all have different missions, yet they are all actors in international relief and aid that create or fund the creation of geographic data. I observed several similarities among them with regards to how geographic data are created. In every case, there is a curious – almost binary relationship – between the formal environments in which the creation of geographic data is discussed and scoped versus the highly informal practices through which the data are eventually created. In all three settings, those charged with the creation, management, or communication of geographic data spent the vast majority of their time engaged in bureaucratic and administrative activities including: formal meetings to discuss how certain types of data or analysis could resolve a specific problem; the seemingly endless process of procuring the necessary data, people, and processing power – often in terms of software licenses and adequate computing power and storage – to complete the desired analysis; attending to internal debates about how data or analysis should be disseminated – often involving a highly scripted briefing with individuals who held considerable political power. At the same time, many of my colleagues allowed considerable time for the maintenance of relationships that help to facilitate the forward movement of these factors in the face of sometimes considerable opposition from colleagues of opposing views.

To the degree that alternative modes of production such as crowdsourcing obviate barriers in the organizational context they are, indeed, a highly viable method for data creation. Indeed, current research shows that many analysts in the field of practice have come to increasingly depend on these types of data and are more focused on "*fitness for use*, rather than absolute precision" as a measure of quality [*Soden and Palen*, 2016]. When conducted appropriately, crowdsourcing also provides an opportunity for closer interaction with other stakeholders in international aid and relief projects and may, in fact, improve the way these projects are perceived.

Unfortunately, whatever contribution this dissertation might make to both academics and practitioners will surely be lost if it is viewed as a definitive work. If anything, this work should be seen as a first step toward deepening our collective understanding of geographic data in international aid. Specifically I recommend the following lines of inquiry:

- Critical or radical approaches to examining the power relations around the creation of geographic data are invaluable to improving international relief and aid. Recent calls to re-energize the GIScience and critical GIS agendas [see *Goodchild*, 2015] can act as a valuable starting point.
- Institutional ethnographies for international relief and aid: as shown in my research, the institutional context greatly affects how geography is used for relief and aid and more work is needed to better understand the multiple organizational contexts that influence how geographic data are produced to address the global challenges of relief and aid work.

- To this end I recommend the action research approach, specifically with the goal of influencing organizational policies related to the creation, use, and sharing of geographic data. There are multiple points of entry for academic researchers to influence policy. It is not merely enough to rise to a level of prominence that one can influence public debate: researchers with a critical eye must be present as policies are crafted; accounted for in the fluorescent lit meeting rooms; and prominently cited in the numerous – and often unbearable – PowerPoint presentations which are the tip of the policy creation spear.
- Techniques oriented research should always acknowledge, if not detail, the organizational context in which it occurs. It is not enough to suggest that an algorithm "may" have usefulness in the realm of international aid and relief: one should understand *how* a particular piece of technology could be applied.

There are, doubtless, other avenues through which we may better understand the production of geographic data in the realm of international relief and aid. These suggestions are rooted in the findings of this research, the steady grind of personal experience, and a continued belief that geography, and geographic data, can help to substantively improve international relief and aid interventions. There is much yet to learn and I hope that the body of work presented here may serve as a very modest contribution towards that end.

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